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VIDE.TEHNOLOĢIJA. RESURSI

XVI starptautiskās zinātniski praktiskās konferences rakstu krājums
2025. gada 19.–20. jūnijs

1. SĒJUMS

ENVIRONMENT. TECHNOLOGY. RESOURCES

Proceedings of the 16th International Scientific and Practical Conference
June 19th – 20th, 2025

VOLUME I

Rēzekne 2025

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VIDE. TEHNOLOĢIJA. RESURSI. 16. starptautiskās zinātniski praktiskās konferences materiāli. 2025.gada 19.-20. jūnijs. *1.sējums*: RTU Rēzeknes akadēmija, Rēzekne, Latvija, 2025. 636 lpp.

ENVIRONMENT. TECHNOLOGY. RESOURCES. Proceedings of the 16th International Scientific and Practical Conference on June 19-20, 2025. *Volume I*: Rezekne Academy of Riga Technical University, Rezekne, Latvia, 2025. pp. 636.

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Online **ISSN 2256-070X**

Published by **RTU PRESS, 2025**

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I
ENVIRONMENT AND RESOURCES

Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 17-21

The Effects of Digestate and Wood Ash Mixtures on the Productivity and Yield Quality of Winter Wheat

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***Abstract*—Field trials were conducted at the Study and Research Farm "Peterlauki" (56°53' N, 23°71' E) of the Latvia University of Life Sciences and Technologies. Soil characteristics: sod-stagnogley soil; granulometric composition – heavy dusty sand clay. Soil agrochemical parameters: pH KCl 6.7; organic matter content – 26 g kg^{-1}; phosphorus content – 60 mg kg^{-1} P_2O_5; and potassium content – 144 mg kg^{-1} K_2O. Winter wheat sowings were established using different variants of a fertilizer mix with cattle (from JSC "Ziedi JP") manure digestate (D) and wood ash (P) (from LLC "Gren Jelgava") in different ratios. The norms of the innovative mixed fertilizer for cattle manure digestate and wood ash were 5, 10, and 20 t ha^{-1}. Unfertilized winter wheat plots were used as control. Variants in the two-factor trial were randomized in triplicate. In the experiment, the influence of the researched factors on winter wheat grain yield, the content of starch and protein in grains, grain volumetric weight (kg hL^{-1}), and the mass of 1000 grains were determined. The aim of the study was to determine the impact of biogas fermentation by-product (digestate) and cogeneration plant and boiler house residues (wood ash) on the yield and quality of winter wheat. Depending on the study variant, the winter wheat yield varied from 4.26 to 9.03 t ha^{-1}. It was established that the average winter wheat grain yield in the control variant was 5.29 t ha^{-1}, which is significantly ($p<0.05$) lower (5.94 t ha^{-1}) than in the variants using fertilizers of digestate and wood ash mixtures. Using digestate and wood ash mixtures, sufficiently high and high-quality winter wheat yields can be obtained without the use of mineral fertilizers. The mixtures of digestate and wood ash are an innovative fertilizer way for improving the soil fertility, which is also suitable for winter wheat.**

***Keywords*—Digestate, mixtures, winter wheat, wood ash.**

I. Introduction

The anaerobic digestion of biomass for biogas production is considered as one of the most efficient ways of renewable energy production.

As a result of anaerobic fermentation processes, digestate can have higher nitrogen and other nutrient content compared to unfermented manure [1], [2], which in turn can affect fertilizer efficiency and yield. Some short-term studies have found lower nitrogen use efficiency for organic fertilizers (slurry, digestate) compared to mineral fertilizers [3], which is probably related to the risk of nitrogen losses due to leaching and ammonium emissions [4], [5]. However, long-term studies have observed a positive effect of organic fertilizer on crop yield, which depends not only on the amount of nitrogen applied to plants, but also on other aspects of organic fertilizer use related to changes in soil fertility [6]. The different results of studies on the effect of digestate on wheat yield are explained by the interaction of many factors, including dose and substrate type [7], [8]. The effect of digestate on crop yield depends on many factors, such as soil properties, climatic conditions during the growing season, chemical composition of the digestate, and application methods [9], [10]. Studies in England compared the effects of digestate and mineral fertilizers on winter wheat yield: the nitrogen rate for both types of fertilizer was N250 kg ha^{-1}. No significant differences in biomass and grain yield were found between the use variants of digestate (respectively 19.2 t ha^{-1} and 11.3 t ha^{-1}) and mineral fertilizers (respectively 19.6 t ha^{-1} and 11.6 t ha^{-1}). Also, when analyzing the protein content in grains, no significant differences were found between the use variants of digestate and mineral fertilizers (11.52% and 11.06%, respectively) [11]. In other studies, when digestate fertilizer was used, a higher protein content was found in wheat grains compared to the mineral fertilizer variant, but no significant differences in starch content were found [12]. Due to the significant increase in the cost of mineral fertilizers and their more difficult availability, it is necessary to find alternatives to the use of mineral fertilizers and improve soil fertility as soon as possible. The

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8686
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aim of the study was to determine the impact of biogas fermentation by-product (digestate) and cogeneration plant and boiler house residues (wood ash) on the yield and quality of winter wheat.

II. Materials and Methods

Field trials were conducted in the sod - stagnogley soil of the LBTU teaching research farm "Peterlauki" with a soil reaction of pHKCl 6.7, phosphorus (P_2O_5) content in the soil of 60 mg kg^{-1}, potassium (K_2O) content in the soil of 144 mg kg^{-1}, and organic matter (OM) content in the soil of 2.6%. A two-factor experiment was set up: 1) mixtures of cattle manure digestate (from JSC "Ziedi JP") (D) and wood ash (from LLC "Gren Jelgava") (P) with different component proportions (D+P 1:0; D+P 1:1; D+P 2:1; D+P 3:1; D+P 3:1 + NPK 8-20-30 200 kg ha^{-1},in autumn; D+P 3:1 + N 64 kg ha^{-1}, in spring; D+P 4:1); 2) different norms of mixtures used for fertilization (5 t ha^{-1}, 10 t ha^{-1}, 20 t ha^{-1}).The nutrient content of the digestate and wood ash mixtures are given in Table 1.

Table 1. Nutrient content of the digestate and wood ash mixtures

Nutrients	Nutrient content			
	D+P 1:0	D+P 1:1	D+P 2:1	D+P 3:1
Nitrogen in a natural sample (N), % of fresh weight	0.29	0.27	0.30	0.51
Ammonium nitrogen (N/NH4), g kg^{-1} in dry matter	1.20	0.43	0.40	0.76
Phosphorus (P), % of dry matter	0.74	0.90	0.89	0.83
Potassium (K), % of dry matter	1.70	2.90	2.92	2.73
Calcium (Ca), % of dry matter	2.41	13.44	13.55	10.48

Note: D – cattle manure digestate; P – wood ash.

Winter wheat fields fertilized only with digestate were used as control variants. Variants in the experiment were arranged randomly, in three replications. The size of each individual plot in the replications was 30 m^2. Winter wheat pre-crop – fallow. All previously prepared mixtures of cattle digestate and wood ash were spread in the plots prepared before sowing. The mixtures were incorporated into the soil with the combined soil tiller "Farmet Kompaktomat K400", which simultaneously crumbles and levels the soil while applying fertilizer. The winter wheat variety 'Zeppelin' was used for sowing; sowing rate – 500 germinating seeds per m^2. Sowing depth – 3–4 cm; row spacing – 12.5 cm. In the spring, when vegetation was restored, 200 kg ha^{-1} ammonium nitrate (N 34.4%) was incorporated into the plots of the trial variant D+P 3:1+N. Harvesting was carried out with a small-sized combine harvester "Sampo". After threshing of the experimental plots, the yield of each plot was weighed and cleaned using the "PFEUFFER SLN3" sample cleaning device. Qualitative indicators were determined at the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies (LBTU). Using the express analyzer "Infratec NOVA Foss", the moisture content of the samples, the total nitrogen and starch content in the grains (%) and the bulk density (kg hL^{-1}) were determined. Using the obtained result, the obtained yield (t ha^{-1}) was calculated at 14% standard moisture and complete (100%) sample purity. For the samples, the weight of 1000 seeds, in grams, was also determined using the standard method (LVS EN ISO 520). Data processing was performed using two-factor analysis of variance (ANOVA) in the "Microsoft Excel" computer program.

III. Results and Discussion

Depending on the study variant, the winter wheat yield varied from 4.26 to 9.03 t ha^{-1} (Fig.1). Using wood ash and digestate mixtures, it is possible to significantly ($p<0.05$) increase the grain yield of winter wheat. The winter wheat yield was significantly ($p<0.05$) affected by the fertilizer rate used, as well as the ratio of digestate to ash in the fertilizer. Significantly higher wheat yields were obtained when using a higher (20 t ha^{-1}) fertilizer rate, but lower yields were obtained when using lower (5 t ha^{-1}) fertilizer rates.

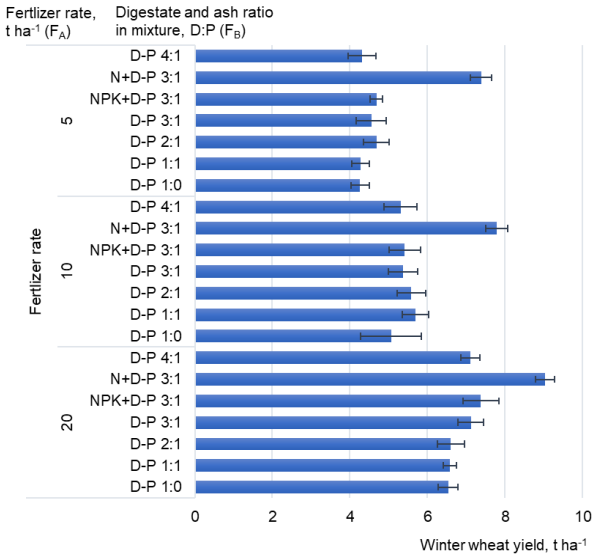

Fig. 1. Effect of digestate and wood ash mixtures on winter wheat grain yield, t ha^{-1}.

The ratio of digestate to ash in fertilizer had a significant ($p<0.05$) effect on winter wheat yield. For all fertilizer rates used (5, 10 and 20 t ha^{-1}), significantly higher wheat yields were obtained in the variant using a digestate-ash mixture in a ratio of 3:1 + N, but the lowest yields were obtained in the variant with a digestate-ash ratio of 1:0, in which ash was not used (Fig.1).

The applied fertilizer rate had a significant ($p<0.05$) effect on the following wheat quality indicators: protein content, gluten content, starch content in dry matter, Zeleny index and 1000-grain weight (Table 2, Table 3).

TABLE 2. EFFECT OF DIGESTATE AND WOOD ASH MIXTURES ON WINTER WHEAT GRAIN QUALITY INDICATORS

Fertilizer rate, t ha^{-1} (F_A)	**Digestate and wood ash ratio in mixtures (F_B)**	**Protein content, %**	**Gluten content, %**	**Starch content, %**
5	D-P 1:0	9.40	16.10	71.40
	D-P 1:1	9.50	16.27	71.37
	D-P 2:1	9.40	16.07	71.47
	D-P 3:1	9.27	15.63	71.43
	D-P 3:1+NPK	9.13	15.73	71.50
	D-P 3:1+N	10.53	18.80	71.03
	D-P 4:1	9.40	15.93	71.63
	On average	9.52	16.36	71.40
10	D-P 1:0	8.50	14.67	71.60
	D-P 1:1	9.07	15.77	71.23
	D-P 2:1	8.40	14.53	71.93
	D-P 3:1	9.17	15.47	71.30
	D-P 3:1+NPK	8.53	14.53	71.50
	D-P 3:1+N	10.77	19.53	70.87
	D-P 4:1	8.17	14.23	70.83
	On average	**8.94**	**15.53**	**71.32**
20	D-P 1:0	9.63	16.73	71.07
	D-P 1:1	10.00	17.40	71.10
	D-P 2:1	9.80	16.97	71.20
	D-P 3:1	10.33	18.10	70.80
	D-P 3:1+NPK	9.87	16.97	70.87
	D-P 3:1+N	11.23	20.70	70.07
	D-P 4:1	10.07	17.50	70.70
	On average	**10.13**	**17.77**	**70.83**
RS0.05 A (normrate)		**0.35**	**0.74**	**0.25**
RS0.05 B (ratio)		**0.54**	**1.13**	**0.39**
RS0.05 AB		0.94	1.97	0.67

Note: D – cattle manure digestate; P – wood ash.

Significantly higher protein and gluten content in dry matter was obtained by using a higher (20 t ha^{-1}) fertilizer rate, while the lowest indicators were found when using the lowest fertilizer rate (5 t ha^{-1}). Also, significantly higher Zeleny index and 1000-grain weight indicators were obtained by using a higher (20 t ha^{-1}) fertilizer rate, while the lowest indicators were found when using a lower (5 t ha^{-1}) fertilizer rate. In turn, higher starch content in dry matter was found when using lower (5 and 10 t ha^{-1}) fertilizer rates, while the lowest indicators were found when using a 20 t ha^{-1} fertilizer rate (Table 2, Table 3).

TABLE 3. EFFECT OF DIGESTATE AND WOOD ASH MIXTURES ON WINTER WHEAT GRAIN QUALITY INDICATORS

Fertilizer rate, t ha^{-1} (F_A)	**Digestate and wood ash ratio in mixtures (F_B)**	**Zeleny index, mL**	**Grain bulk density, kg hL^{-1}**	**1000-grain weight, g**
5	D-P 1:0	26.00	73.75	44.23
	D-P 1:1	26.15	74.39	45.51
	D-P 2:1	26.08	74.05	44.93
	D-P 3:1	25.94	73.84	44.90
	D-P 3:1+NPK	25.74	74.14	44.81
	D-P 3:1+N	32.80	75.34	47.62
	D-P 4:1	26.39	74.44	45.71
	On average	27.01	74.28	45.39
10	D-P 1:0	22.99	73.20	43.73
	D-P 1:1	25.04	73.64	44.38
	D-P 2:1	24.08	73.39	45.34
	D-P 3:1	24.41	73.47	43.85
	D-P 3:1+NPK	23.99	73.05	44.93
	D-P 3:1+N	35.29	75.52	47.62
	D-P 4:1	21.85	72.62	43.28
	On average	**25.38**	**73.56**	**44.73**
20	D-P 1:0	28.75	74.11	45.91
	D-P 1:1	29.50	74.90	46.54
	D-P 2:1	28.04	74.03	45.55
	D-P 3:1	31.16	74.74	46.85
	D-P 3:1+NPK	28.06	73.88	44.70
	D-P 3:1+N	37.35	74.65	46.95
	D-P 4:1	29.94	73.54	45.63
	On average	**30.40**	**74.26**	**46.02**
RS0.05 A (normrate)		**1.69**	0.68	**0.92**
RS0.05 B (ratio)		**2.58**	**1.04**	**1.40**
RS0.05 AB		4.47	1.80	2.43

Note: D – cattle manure digestate; P – wood ash.

The digestate-ash ratio in the fertilizer had a significant ($p<0.05$) effect on the following wheat quality indicators: protein content, gluten content, starch content in dry matter,

Zeleny index, bulk density and 1000-grain weight. Significantly higher protein and gluten content in dry matter was obtained in the variant that used a digestate-ash mixture in the ratio 3:1 + nitrogen. The differences in protein and gluten content between the other digestate-ash ratio variants were not significant. A tendency to form a lower protein and gluten content in dry matter was observed in the variant with a digestate-ash ratio of 3:1 + NPK. The Zeleny index, bulk density and 1000-grain weight were also significantly higher in the variant that used a digestate-ash mixture in the ratio 3:1 + nitrogen. After winter wheat harvest, the mineral residue in the soil depended on meteorological conditions and fertilizer [13], [14].

When analyzing cereal grain yields, it was found that the use of digestate can provide yields equivalent to those obtained with mineral fertilizers. For spring wheat, higher grain yields were obtained with mineral fertilizers, but no significant differences were found between different manure digestate variants [15]. One of the advantages of using fermentation residues is a higher nutrient content than in their respective raw materials. Although a significant amount of nitrogen (N) is emitted in the form of ammonium during anaerobic fermentation, and carbon (C) is released as methane and carbon dioxide, a large part of nutrients, such as N, phosphorus (P) and potassium (K), is retained [16], [17]. The content of minerals and the properties of the digestate largely depend on the properties of the substrate and the type of fermentation [18]. Digestate performs several functions, playing a beneficial role in both improving soil properties and promoting plant growth. First, digestate contains nutrients necessary for plant growth and serves as a fertilizer that improves plant productivity. Second, digestate significantly affects total soil fertility and other important soil parameters. Digestate plays a huge role in improving soil efficiency through nutrient cycling in the soil, carbon transformation, and soil structure maintenance [19]. Field application of digestate may have less short-term results due to slow mineralization rates or microbial activity [8] Nitrogen is an essential element for plant growth and soil microbial activity, and it is the nutrient most taken up by plants and is the most common limiting factor for plant growth [20]. The contribution of digestate to N availability in the soil is an important argument for its use. Digestate is particularly rich in the ammonium nitrogen (NH4-N)-N form, which is readily available to plants [21].

Digestate is a new type of waste that can be used for soil fertilization [22]. Fertilization with digestate brings an effect on crop yields increases but does not improve significantly the level of organic matter in the soil, so in longer-term it is necessary to add organic matter from other sources. [23], [24].

IV. Conclusions

The mixtures of digestate and wood ash are an innovative way for improving the soil fertility.

The results of the study showed that using digestate and wood ash mixtures, sufficiently high and high-quality winter wheat yields can be obtained without the use of mineral fertilizers. Significantly higher ($p<0.05$) winter wheat grain yield was obtained in the variant D+P 3:1 + N and D + P 3:1 + NPK.

It has been observed that to improve the quality of the winter wheat harvest, in addition to this fertilizer, it is recommended to use nitrogen mineral fertilizers. It has been found that among the studied variants, significantly higher protein and gluten content, as well as Zeleny index, were provided by the fertilizer mixture D + P 3:1 + N, regardless of the fertilizer rate.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 23-29

The Role of Management Consulting in Driving Digital Transformation for SMEs: Insights from 20 Expert Interviews

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***Abstract* - In the rapidly evolving digital era, small and medium-sized enterprises (SMEs) face increasing pressure to adopt and implement digital transformation to remain competitive. This research explores how management consulting services enable SMEs to strengthen their digital capabilities and navigate transformative change. Semi-structured qualitative expert interviews with 20 experts from the Baltic States provide valuable insights into these businesses' challenges and opportunities. The experts come from diverse professional backgrounds, including management consulting, venture capital, information technologies, finance, and professional services related to digital transformation. Qualitative comparative analysis reveals both unique perspectives and shared challenges across these groups. All experts have extensive experience working with SMEs. Key findings highlight significant barriers to digital transformation, such as limited digital skills, financial constraints, capacity issues, and insufficient know-how. Time scarcity and difficulties in maintaining strategic focus further compound these challenges. The research emphasizes the evolving role of management consulting providers, who must adapt their methodologies to meet the shifting technological landscape. The study underscores the pivotal role of management consulting in bridging the digital readiness gap for SMEs. Conclusions indicate that consultants guide businesses through complex transformation processes by offering tailored strategies, facilitating skill development, and optimizing resources. Executive insights reveal a pressing need for accessible and scalable consulting solutions to address the digital divide among smaller enterprises. This research contributes to understanding how consulting services foster digital growth in SMEs and highlights the critical need for innovative consulting approaches in the digital age, especially in the Baltic States. The findings are particularly relevant for policymakers, consultants, and SME leaders striving to enhance competitive strategy and drive digital transformation.**

Keywords — Management Consulting, Digital Transformation, Professional Services, SME.

I. Introduction

In today's rapidly evolving business environment and volatile uncertainty - digital transformation (DT) is crucial for small and medium-sized enterprises (SMEs) seeking to enhance digital capabilities and business competitiveness [1] - [3]. DT in SMEs has become a critical research area, emphasizing the need for agility, strategic adaptation, and digital capability development [4] - [5].

The research explores the role of management consulting (MC) – professional services, where experts help to improve performance, solve business problems, and develop strategies to enable SMEs to overcome barriers and strengthen their DT capabilities [6] - [7]. Other research indicates that DT, which refers to the strategic adoption and integration of digital technologies to enhance business operations [8], - plays a crucial role in enhancing the performance of the organization, and the successful implementation of operational efficiency depends on technological readiness and management commitment [9] - [10].

Research gaps identified in previous up-to-date literature reviews are still unclear about how MC services directly benefit the DT that is a part of the strategy for SMEs [7], [11] - [12]. Therefore, the authors performed targeted and semi-structured interviews, including professional service providers, to benefit the existing body of knowledge – how MC works with SMEs, what approaches are suggested, and how expertise can be used for effective DT that is integrated to strengthen competitiveness.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8644
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The research, based on results from an expert interview with 20 professionals across various fields, contributes to two aspects:

a) Research identifies SMEs' key challenges during DT, including limited skills, financial constraints, and insufficient capacity. It also examines how MC services can help with skill-building initiatives and resource optimization for SMEs.

b) Research provides actionable recommendations for SME managers and owners on effectively utilizing MC services. Additionally, it offers insights that can be used by policymakers, consultants, and SME leaders to bridge the digital divide and develop competitive strategies in the digital age.

II. Materials and Methods

A brief literature review was conducted using the Scopus database, and relevant articles were selected based on specific keywords related to DT, MC, and SMEs. A comparative analysis was then performed, discussing and contrasting the findings with existing literature to identify key trends, challenges, and research gaps.

Between November 1, 2024, and February 24, 2025, the authors designed and conducted semi-structured qualitative interviews with experts from the Baltic States. Active, direct interviews were primarily planned and conducted between December 2024 and January 2025 to capture the most recent conclusions and observations for the calendar year of 2024. However, due to natural scheduling adjustments, 4 interviews took place in late November 2024 and February 2025, still aligning with the study's intent to reflect current insights.

The study employed a three-tier expert reach pyramid framework to ensure a structured and systematic selection of expert interview participants (Fig. 1), categorizing experts based on their expertise, organizational role, public presence, thought leadership, influence, engagement, and relevance to the research focus [13].

Broad reach (top-level) – At the initial stage, 35 experts were identified based on their general influence, professional visibility, and relevance to the study's thematic area. These individuals were widely recognized for their contributions to the field but were not necessarily engaged in direct decision-making within the study's scope.

Targeted influence (middle-level) – From this broader pool, 29 experts were further qualified as relevant to the study's objectives, particularly about SMEs. These experts demonstrated specialized knowledge, industry understanding, and managerial experience. They were identified through professional networks, academic and industry publications, leadership roles, and sector affiliations. All experts at this level were contacted to ensure an inclusive and representative selection. Five did not respond, even after several channel uses and repeated attempts to reach them, and 4 declined.

Core experts (bottom-level) – ultimately, 20 participated in the semi-structured qualitative interviews. These individuals represented one of the most influential professionals with direct, hands-on experience shaping strategies for SMEs, policies, and industry practices relevant to the study. Their insights formed the foundation of qualitative data analysis.

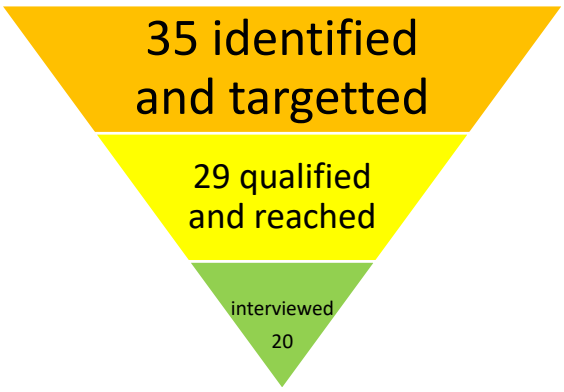

Fig. 1. The three-tier expert reach pyramid framework - based on qualitative interview data analyzed by the authors.

This hierarchical selection process ensured that the study captured both high-level industry perspectives and deep, experience-based insights, contributing to the reliability and validity of the findings. The pyramid structure facilitated a systematic narrowing of the expert pool, ensuring that only the most relevant and knowledgeable professionals were engaged in the final interviews and were willing to share their experiences, which is a common practice in social science [14].

The selection of experts for this study was based on a targeted approach to identify professionals with both practical experience in DT and MC services, specifically for the SME segment over the past 3-5 years and with overall relevancy with MC not less than 10 years (as seen in Table 1). Even if individuals share various roles in other organizations, they all work within firms offering MC, DT, or similar professional services for SMEs combined or separately during the research period. The current top executive-level positions of experts are indicated in Table 1 as the primary role in the company they are currently working for in the study's focus field: (D) directors, (P) partners, or (C) C-level executives.

A key criterion was the expert's experience and collaboration with stakeholders across the Baltic States, ensuring a diverse and regionally relevant perspective regardless of their current or former employer's size, headquarters location, or international service scope. This process ensured that the selected experts possessed deep industry expertise and hands-on experience working directly with SMEs. This enabled them to provide valuable insights into the challenges and tactics when adopting DT and to relate answers to previous findings of DT adoption [1], [15].

TABLE 1 DATA OF THE STUDY'S PARTICIPANTS

Variable	***Unit***	***Value***
Experts / Participants	Count	20
Gender	Count (M-male, F-female)	16 (M) / 4 (F)
Relevant experience in the MC field	Range in years	10-30
Primary role in the company related to MC	Count: (D) director, (P) partner, (C) C-level	8 (D) / 6 (P) / 6 (C)
Direct work with SMEs currently	Count (direct, indirect)	16 (direct) / 4 (indirect)
Area of professional expertise: - MC and professional service providers (MC-PS), - DT and IT service firms (DT-IT), - "Big Four" or similar size/recognition (BF+), -Venture capital and financial sector (VC-FS)	Count: MC-PS, DT-IT, BF+, VC-FS,	6 (MC-PS) / 6 (DT-IT) / 5 (BF+) / 3 (VC-FS)

Source: Created by authors based on expert interview data analysis.

Expert interviews were conducted through pre-scheduled 45–55-minute online video meetings to ensure a structured and systematic data collection process. Participants were informed about the research aim in advance, and all interviews were arranged via calendar invites, ensuring confirmation and accessibility through a valid online meeting link.

Before each session, technical reliability was ensured, including a private setting, stable internet connection, and functional audio-visual equipment. A digital note-taking template was prepared to facilitate real-time documentation of key insights. Responses were systematically transcribed after each interview, and the template was completed for consistency. Following professional practices and ensuring high-quality and trustful answers, the interview excludes names, projects, and companies like practice done in other research [13].

This study is based on 20 expert interviews, totaling 18 hours of direct online communication, which resulted in 68 pages of transcribed responses and quotations. The experts, as mentioned in Table 1, represent a diverse range of professional backgrounds, categorized and coded for further reference as follows:

a) 6 experts – MC and professional service providers who also offer or are connected to DT services (boutique consulting firms, specialized advisory firms) – MC-PS.

b) 6 experts – DT and information technology (IT) service firms – both recognizable and respectable in the Baltic State area and Europe (providing MC alongside technology solutions) – DT-IT.

c) 5 experts – large multinational consulting firms with branches in the Baltic States (all "Big Four" and one similar globally recognized firm) who develop competitive strategies in the digital age for all-size companies, including SMEs – BF+.

d) 3 experts – venture capital and financial sector (investment professionals, financial analysts, and strategy advisors working with SMEs) – VC-FS.

Given the overlapping nature of professional trajectories, some experts have held multiple roles across these categories. For instance, an expert previously serving as a director at a "Big Four" firm may now be a partner in a boutique consulting firm, contributing cross-sector insights into SME's DT and MC practices.

The expert selection method described above aligns with knowledge dissemination research, ensuring that insights from experienced professionals are effectively identified and shared. The semi-structured approach, due to its flexibility [16], captures broad MC, DT, and specialized knowledge trends relevant to SMEs.

The semi-structured interview comprised seven question categories, each containing 2 to 7 sub-questions (2-7q) that help trigger the focused topic of the research:

1. General understanding of DT and SMEs (3q).
2. MC for SMEs (7q).
3. DT Guidance for SMEs (5q).
4. Sector-specific insights (2q).
5. Balance of internal and external expertise (4q).
6. Competitive strategy in the digital age (3q).
7. Long-term problem-solving and focus of (6q).

All the questions were asked, and the answers were captured in the digital template based on all the information provided and addressed to the exactly related category and its fitting question during or after the interview. Interview design allowed experts in collaboration with authors-interviewers to provide in-depth insights, share specific expertise and real-world examples, and focus on areas most relevant to the research.

The collected data was then subjected to qualitative comparative and content analysis, ensuring a structured and comprehensive examination of expert perspectives.

In this article – analysis is limited to the first two question groups based on the authors' aim for this scientific research.

III. RESULTS AND DISCUSSION

The flexible semi-structured interview process ensured that discussions remained both comprehensive and aligned with the expert's domain knowledge, maximizing the value of their contributions. Two question groups that altogether included 10 sub-questions and were analyzed based on two categories:

1. General understanding of DT and SMEs (3q).

2. MC for SMEs (7q).

Thematic analysis, based on all 20 expert interviews, reveals key themes structured into four levels based on frequency, as shown in Table 2. These themes are not tied to any specific expert group, suggesting a broad consensus on the overall focus direction, and alignment with the research scope.

TABLE 2 FREQUENCY OF KEY THEMES MENTIONED IN EXPERT INTERVIEWS OF 1ST AND 2ND QUESTION CATEGORIES

Key themes in interviews	Frequency
Pressure of urgency	7
Legacy platforms	8
Digital maturity	8
Digital transformation as a buzzword	10
Business process automatization	10
Co-funding, Financial support, and grants	11
Hands-on experience	14
Priority and goal-setting	15
Trust and reputation of the consultant	16
Lack of financial resources	19
Digital transformation	20
Management consulting	20

Source: Created by authors based on expert interview data analysis.

As expected, – the most frequently mentioned topics include DT and MC (20 mentions each) and the lack of financial resources for SMEs (19). These findings highlight that while DT is a critical priority for businesses, financial constraints and the need for consulting expertise significantly impact its successful implementation. The information explored from real-life expert examples matches previous observations from literature studies [11]-[12]that SMEs face resource constraints regarding time, finances, and managerial capacity.

Another important set of factors relates to hands-on experience (14), priority and goal setting (15), and trust and reputation of the consultant (16). These elements emphasize the importance of practical knowledge, planning, and the credibility of external advisors in shaping DT and business strategies. From an expert perspective - SMEs recognize that expertise and trust in consulting services are major in guiding them, especially through complex changes.

The analysis highlights the significance of DT as a buzzword (10), suggesting that while the term is widely discussed, its practical implications may vary across businesses. Business process automatization (10) is also a key theme, indicating that companies recognize the necessity of streamlining operations to improve efficiency. Additionally, co-funding, financial support, and grants (11) emerge as crucial factors, reflecting the reliance on external funding to facilitate DT and sustain business growth. These factors collectively emphasize the need for conceptual clarity and practical resources in the digitalization journey.

Finally, some underlying constraints emerge, such as the pressure of urgency for SMEs to act (7), legacy platforms (8), and digital maturity (8). While these aspects are mentioned less frequently than financial and strategic concerns, they still influence the pace and effectiveness of DT initiatives. Businesses face challenges in balancing the urgency of transformation with their existing technological infrastructure and overall readiness for change.

In performing comparative analysis - experts broadly agree that DT is essential for SMEs to remain competitive, with key drivers including process automation, operational efficiency, and access to new markets. However, SMEs often face significant barriers to adoption, such as financial constraints, lack of knowledge, and uncertainty regarding DT project timelines. The expert insights from the four groups - MC and professional service providers (MC-PS), DT and IT experts (DT-IT), "Big Four" and similar firm (BF+), and venture capital and financial sector (VC-FS) reveal both shared perspectives and notable differences regarding following question categories that are further analyzed in:

A. General understanding of DT and SMEs

All groups emphasize that DT is essential for SMEs, not only for efficiency and competitiveness but also as a necessary adaptation for survival in the digital age. There is consensus that the maturity level of an SME significantly influences its approach to DT - companies with a higher digital maturity level tend to integrate data-driven decision-making, automation, and customer experience improvements, whereas those with a low maturity level struggle with strategic planning, implementation, and investment decisions.

A common challenge identified by all groups is the lack of resources - financial capacity, talent, or strategic vision - which hinders SMEs' ability to fully embrace DT. Furthermore, all groups recognize the role of government grants and external funding in enabling digital adoption that matches other research data as a common problem of SMEs while adopting DT [17]. However, concerns about inefficient allocation or reliance on funding without clear strategic planning are raised.

Additionally, all groups acknowledge the importance of change management - SMEs often resist digital change due to fear of disruption, lack of understanding, or the complexity of new systems. This is further complicated by decision-making being concentrated in a few key individuals (especially in majority-stake owner-led SMEs that often are limited to their digital literacy [11], [18]), limiting the speed and scope of transformation. SMEs contribute significantly to economic growth and employment, and often major challenge is ensuring SMEs' long-term sustainability and performance – especially in family businesses where generation transition happens [19].

MC-PS, VC-FS and BF+ approach DT strategically, emphasizing its role in redefining business models and enabling expansion into new markets. They caution that

SMEs often underestimate the importance of strategic planning and project management, which can result in a reactive rather than proactive approach to digitalization. In contrast, DT-IT group experts prioritize the operational aspects of DT, such as process automation, data analytics, and IT infrastructure improvements. They stress the necessity of clear implementation steps and realistic assessments of return on investment (ROI) to ensure SMEs can effectively navigate the transformation.

The perceived barriers to DT vary among different perspectives. MC-PS and BF+ identify organizational resistance, leadership buy-in, and knowledge gaps as key challenges, advocating for education, advisory services, and structured DT roadmaps, which are also advised by researchers to be implemented in the strategies of SMEs [4], [10]. DT-IT, however, emphasizes technological complexity and cost concerns more, arguing that SMEs often lack awareness of DT's financial implications and potential benefits. They also warn that DT is sometimes overhyped and can incorrectly affect the overall perception of SMEs, leading to unrealistic expectations. Meanwhile, VC-FS highlights financial strength and scalability as crucial factors influencing DT adoption, noting that well-funded SMEs are more likely to succeed. At the same time, smaller businesses may struggle without external investment or strategic partnerships.

Regarding external support and funding, MC-PS and VC-FS see venture capital and external funding as essential drivers of DT, enabling SMEs to scale their operations and expand their digital capabilities. In contrast, BF+ and DT-IT take a more cautious stance, emphasizing that financial assistance alone does not guarantee successful digitalization, which is underscored in several studies [4], [20]. Experts point out that SMEs often lack strategic clarity when applying for digitalization grants, leading to misallocated investments in technology that fail to address core business needs.

Although primarily discussed in the fourth question category, “Sector-specific insights,” which is beyond the scope of this article, industry-specific challenges are also mentioned in the first two question groups, highlighting their influence on DT adoption. MC-PS and BF+ note that industries like e-commerce and finance are naturally more inclined toward digitalization, whereas traditional sectors such as manufacturing and services face greater resistance due to legacy systems. DT-IT emphasizes the varying levels of automation and artificial intelligence adoption among SMEs, pointing out that some overestimate their capabilities while others completely avoid digitalization. Additionally, VC-FS highlights that SMEs in consumer-driven markets (e.g., retail and fintech) must adopt DT more rapidly than B2B sectors, where DT progresses more gradually.

The definition and scope of DT differ depending on the perspective. MC-PS and BF+ view DT as a continuous, strategic shift that reshapes business models and operations, requiring a fundamental rethinking of processes beyond merely adopting new technology. In contrast, DT-IT and VC-FS take a more pragmatic stance, considering DT as a tool for efficiency, automation, and cost savings rather than a goal itself. DT-IT experts especially criticize the overuse of DT as a buzzword, arguing that SMEs should prioritize practical improvements over large-scale transformations that may not align with their business realities.

B. Management Consulting for SMEs

The comparative analysis of expert responses from the biggest expert number groups, MC-PS and DT-IT, highlights both shared perspectives and key differences in their understanding of MC for SMEs.

Both groups recognize the importance of external expertise in guiding SMEs through strategic and operational challenges. They agree that MC acts as a bridge between different business areas, offering valuable insights that SMEs might lack internally. Trust and relationship-building emerge as crucial factors in consulting effectiveness, with both groups stressing the need for consultants to align with the client's culture and decision-making style. Additionally, both acknowledge financial constraints as a limiting factor for SMEs when engaging in high-level consulting services, emphasizing the role of funding programs in facilitating access to expert advice. It goes together with studies that underscore manager and employee capabilities and digital know-how that play a dual role in driving DT - acting as both enablers and barriers due to skill gaps, resistance to change, outdated systems, resource constraints, and cultural resistance [5], [21].

However, the MC-PS group emphasizes process-driven strategic consulting, viewing SMEs as distinct from larger enterprises, requiring tailored approaches rather than traditional corporate methodologies. They stress that SMEs often lack structured budgeting and long-term strategic planning, leading to a reliance on practical, hands-on consulting rather than theoretical frameworks. The DT-IT group, in contrast, focuses more on technological integration and business model innovation, positioning consultants as facilitators of DT. They highlight the need for hands-on execution rather than mere advisory roles, warning against "empty advice" without clear implementation strategies.

Another key difference lies in their perspective on consulting value. MC-PS experts stress the role of consultants as external team members who must deeply understand SMEs' realities and provide ongoing, action-oriented guidance. In contrast, the DT-IT group highlights the consultant’s role in overcoming "tunnel vision", bringing external perspectives to help SMEs explore new technological opportunities. They emphasize the importance of structured methodologies, goal setting, measurement of results, and competitive analysis to ensure measurable consulting outcomes, which is also advised in theoretical studies [4].

The perspectives from two smaller groups, BF+ and VC-FS, provide added analysis of MC’s role for SMEs,

complementing and contrasting the views of MC-PS and DT-IT.

BF+ and VC-FS emphasize the lack of awareness and appreciation for MC among SMEs, particularly in the Baltic States. The BF+ group highlights that SMEs often overestimate their own knowledge, demonstrating reluctance to pay for strategic consulting services. Similarly, VC-FS experts note that SME owners often serve as CEOs and may lack time and interest in engaging external consultants, seeing it as an unnecessary expense unless specifically required.

Another shared theme is the critical role of financial and strategic guidance in helping SMEs navigate growth. The BF+ group highlights how consulting becomes essential when external funding (e.g., venture capital, co-funding projects, or grants) requires structured strategy and execution. Likewise, VC-FS experts stress that consulting is most valuable when companies face unfamiliar challenges, particularly in scaling or securing investment. Both groups acknowledge that larger companies are more likely to seek and value consulting services as they have more complex structures and external accountability (e.g., shareholders and investors).

Both groups also highlight the importance of execution and project management as hands-on approaches, echoing a sentiment from the MC-PS group. BF+ experts criticize the lack of a consulting culture in the region that appreciates implementation, whereas VC-FS experts suggest that companies engaging consultants should expect clear, actionable steps to ensure execution, particularly in due diligence and operational improvements to justify the ROI.

While BF+ and VC-FS recognize the strategic gap in SMEs, their focal points differ. BF+ experts discuss broader business misconceptions and cultural resistance - SMEs' unwillingness to pay for consulting, lack of strategic thinking, and misjudgment of consulting value. They highlight the need for trust and long-term relationships, aligning with the MC-PS and DT-IT perspective that SME maturity and trust in consultants influence success.

VC-FS argues that generic MC often lacks justification unless tied to tangible financial returns. This aligns somewhat with the DT-IT perspective, which emphasizes consulting's role in driving DT with clear key performance indicators. VC-FS experts highlight the need for specialized consulting, especially in high-value sectors, linking their views to expert platforms to find the right expertise.

The BF+ group's observations on SMEs' strategic immaturity align with the MC-PS perspective that many SMEs do not engage in structured business planning. However, BF+ experts are more critical of SMEs' unwillingness to pay for consulting services, seeing cultural skepticism as a major barrier. This contrasts with MC-PS experts, who focus more on the value consultants bring in bridging knowledge gaps and guiding SMEs through structured frameworks.

Future research should explore SME perception of consulting through surveys or interviews to understand their decision-making factors, investigate industry-specific consulting needs in high-growth and tech-driven sectors, analyze cost versus value impact on consulting adoption rates to identify attractive pricing models, assess the long-term effects of consulting engagements on SME performance, and examine alternative consulting models (such as fractional executives, on-demand expertise platforms, and digital advisory tools based on MC-PS answers) to explore more accessible and scalable solutions for SMEs. Additional future research literature exploration can include dynamic capabilities and related theories about knowledge-based perspective, which as a direction, is indicated as valuable and practical [8], [22].

IV. Conclusions

The collective insights from the four expert groups highlight a broad agreement on the necessity of DT for SMEs, with differences in focus, perceived barriers, and strategic approaches. While some view DT as a fundamental business transformation, others emphasize its role in operational efficiency. The maturity level, industry context, financial resources, and leadership mindset influence DT adoption. The findings suggest that successful DT implementation requires technology adoption, strong leadership, strategic planning, and a clear understanding of ROI.

In defining the role of MC services for SMEs – all four expert groups recognize the value of MC for SMEs; MC-PS and BF+ focus on relationship-driven, strategic business consulting, whereas DT-IT prioritizes technological enablement and execution-focused consulting. Their differences reflect their respective areas of expertise - MC-PS and BF+ consulting rooted in business strategy and process efficiency and DT-IT in DT and operational scalability. Across all four groups, the role of MC in SMEs is recognized, but perspectives differ on its value, challenges, and execution. BF+ experts highlight cultural and strategic barriers, while VC-FS experts take a stronger stance on the necessity of financial justification for consulting engagement and ROI – that aligns closely with DT-IT experts, who stress that consulting must deliver practical, measurable value rather than theoretical insights.

MC-PS and BF+ experts emphasize the need for trust and relationship-driven consulting, whereas DT-IT experts stress the necessity of execution-focused consulting with clear goals and result measurements. The findings also suggest that while financial and strategic aspects remain the primary concerns, hands-on experience, trust and reputation of the consultant, and technological preparedness also play crucial roles in shaping DT efforts. Addressing these factors holistically can enhance business resilience and long-term competitiveness – especially if MC is used for tailored strategies for SMEs.

Ultimately, successful consulting for SMEs requires a blend of strategic alignment, financial feasibility, and

execution-focused engagement, ensuring that consulting services are insightful but also actionable and results-driven. For MC to gain wider adoption in the Baltic States, consultants must emphasize tangible results, financial justification, and long-term relationship-building to overcome cultural resistance and demonstrate value.

Further research should explore all remaining question categories from original and full-scale interview content - by exploring competitive strategy, problem-solving aspects, appropriate balance on external expertise use, guidelines for choosing the right consulting service and relevance to the industry.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference.2025. Volume I, 31-43

Through the Green Work Commitment, a Literature Review Examines the Relationship between Green HRM and Environmental Sustainability

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***Abstract*—This literature review explores Green Human Resource Management (Green HRM) initiatives aimed at nurturing employees' commitment towards eco-friendly work output and environmental sustainability in organisations. Green HRM is a strategy that integrates an organisation's environmental values into its human resource strategy and practices. This review reflects on the interplay between Green HRM practices and employees' green commitment, that is, the degree to which they feel psychologically bonded to environmental goals and pursue them. Moreover, it focuses on how green commitment contributes to achieving specific organisational environmental sustainability outcomes, including waste reduction, energy saving, and improved corporate social responsibility. Drawing on empirical research, the review outlines specific mechanisms by which Green HRM practices (e.g., green training programs and green performance appraisal) influence employees' sustainability-related attitudes and behaviours. It also addresses barriers to adopting Green HRM and developing green dedication, such as inadequate resources, a lack of management interest, and resistance within the company. The review findings are concluded with suggestions for future research direction, requesting the need for cross-sector studies and the examination of the long-term implications of Green HRM implementations on environmental sustainability. Through qualitative methodology, the study establishes a link between the main variables involving environmental sustainability, employees' green behavior, and GHRM (Green HRM). Future research can examine more closely how industry-specific elements affect workers' green commitment and how digital technologies like artificial intelligence and big data might assist businesses in meeting their sustainability goals. Further investigation into the cultural factors that can account for variations in green commitment among various geographic areas will also yield a more comprehensive comprehension of this idea. The impact of employee green commitment on organizational sustainability performance requires longitudinal studies to understand organizational practice better. Finally, future research topics must look into the barriers to Green HRM practices to promote their successful impact.**

Keywords*— *Green Human Resource Management, Environmental Sustainability, Green Work Engagement, Employee Green Behaviour, Organizational Performance, Resource-Based View, and Sustainable Management.

I. INTRODUCTION

The past few decades have seen sustainable development as a significant concern for developed and developing countries. The urgency with which climate change and its worldwide effects must be addressed, companies in every part of the world feel increasing pressure to adopt "green policies" in their business operations. Implementing these practices has become very important, not only to be less harmful to the environment but also to comply with international environmental management standards. According to Sharma, R. and N. Gupta, the examples reflect a common purpose: to address sustainable development and indicate the need for corporate accountability in the fight against climate change and to stand for environmental sustainability [1].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8635
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A researcher emphasize, companies must safeguard their long-term reputation and moral compass. Responsible decision-making that balances the pursuit of competitive advantage with the sustainability of capital and resources creates an environment that benefits all stakeholders, including regulators and employees, building trust and long-term sustainable performance [2]. While another researcher point out green HRM activities have recently received attention from researchers; they have been promoted as vital factors that impact employee green attachment and green behaviour and indirectly contribute to improving firms' environmental performance [3]. Not only does meeting these expectations keep stakeholders, including regulators and employees, happy, but it also helps create advantages of competition.

According to Guerci, M., A. Longoni, and D. Luzzini, green HRM activities have recently received attention from researchers; they have been promoted as vital factors that impact employee green attachment and green behaviour and indirectly contribute to improving firms' environmental performance Guerci, et al. [3]. Previous studies have shown that green HRM practices impact employee loyalty and eco-efficiency. Such actions increase employee participation in sustainability initiatives and are essential to improving an organization's environmental impact. The best possible implementation of a wide range of Green HRM techniques will go a long way in creating a workforce that can work towards larger sustainability goals contributing to building a natural- friendly, socially accountable, and normally responsible corporate ecosystem [4].

Environmental issues increasingly affect social, economic, political, and global systems, making corporate environmental responsibility a critical focus in contemporary research. In this context, manufacturing enterprises globally are increasingly evaluating and enhancing their green core initiatives to achieve sustainability objectives. What's more, developing and sharing green ideas has become essential for organizations looking to stay relevant. There are benefits to trying to learn from a variety of environmental organizations in the global marketplace, capitalizing on these ideas for developing more potent environmental strategies and gaining the comparative advantage in an increasingly competitive market [5]. This means harnessing innovation, working towards sustainable goals, and implementing practices aligned with the planet's and market's expectations. Maintaining relevance and achieving long-term success requires responding to these changes [6, 7].

Environmental sustainability is part of overall sustainability, and the same goes for Green Human Resource Management (Green HRM), which is essential for conducting green business. Green HRM includes actions to make the workplace greener and employees more responsible corporate citizens. Organizations have to tread a path of change to ensure their verdant sustainability goals of realigning themselves in integration with green initiatives are aligned in a holistic kind of perspective encompassing the employee's beliefs and attitudes and behaviour change. Green HRM practices are crucial in this transition and can determine how committed and engaged employees are in facilitating the desired environmental impact [8]. Today, handling the most precious asset of an organization, those employees, is at the heart of modern HRM. It is an accepted fact that HRM decisions and practices can have a major bearing on organizational effectiveness and are key to tackling major challenges. In time, long-term sustainability also started gaining prominence as a guiding principle for the spectrum of HRM. Similarly, GHRM is a decisive factor in achieving sustainability goals. This ensures that organizations can act as responsible members of society while maintaining and improving their processes and capabilities to deliver value [9] and comply with environmental objectives by aligning HR practices.

Organizational Green HRM Practices and Employee Green Commitment (EGC), nurtured by Green HRM practices, is an essential catalyst for promoting organizational environmental sustainability. Commitment provides a generalized positive outcome in terms of engagement to participate in sustainability programs [10], and endorsements of green initiatives and practices within the overall level of work [11]. Moreover, those employees who express stronger green commitment are also more inclined towards voluntary (pro-environmental) behaviours, i.e. advocating corporate green practices among peers and participating in CSR activities.

Green recruitment, a facet of Green HRM, means recruiting people possessing knowledge, skills, attitudes and approaches conforming to the organization's environmental management systems. Green recruiting is about attracting and hiring qualified candidates who are committed to sustainability. Hiring professionals with a green mindset means that these organizations can quickly onboard individuals who already understand sustainable practices and the importance of reuse, conservation, and waste minimization. Green recruitment can also aid environmental sustainability via promoting environmental sustainability such as green employment, using paperless recruitment, and facilitating recycling and waste reduction activities [12]. In Green HRM practices, employee compensation must be linked with environmental achievements in terms of pay and promotions. By linking pay to eco-sensitive outcomes, a variable pay system integrates the objectives of the employees with the elements of sustainability, as the employees are now encouraged to act against the aims of the organization related to sustainability. Incentivizing the development and application of high-level green skills in this way not only encourages employees but also can impact the long-term viability of sustainable practices. Such compensation strategies are profound and serve to reinforce environmental performance as a primary priority of the organization [13].

A key component of Green HRM is green training, which aims to increase staff members' awareness and understanding of environmental sustainability. Employees

are given the knowledge and abilities they need to create and discuss sustainable workplace practices thanks to the content. Green training guarantees that employees are prepared to support the business's sustainability goals and to match their actions with its dedication to environmental stewardship by fostering environmental "literacy" across the entire organization [14]. As state, A well-established training plan is crucial to developing environmentally conscious behaviour in the work environment. Based on social exchange theory, environmental training programs have a great potential to affect employee green performance at work. Organizations must evaluate this knowledge and establish a relationship between training and environmental initiatives to maximize impact. These activities empower employees to actively pursue the organization's environmental objective by providing them with the required skills and information for sustainable performance [15]. Green compensation plays an important role in Green HRM which encourages employees to work towards environmental objectives. The green pay system provides a combination of financial and non-financial benefits to encourage employees toward the sustainability objectives of the company. It needs a strategic approach as it links the environmental priorities with the tangible incentive system of the organization providing a reward system. Recognition and praise, for example, can be even more effective in strengthening employees' commitment to green practices than financial incentives, it is worth noting [16].

Recruiting employees who value social responsibility and environmental sustainability is a key strategy for increasing engagement and participation. These employees can synergize financial, human, and natural capital, creating additional value for the company's products or services that were previously overlooked. Also, environmental management (EM) teams are innovative employees who minimize waste by harnessing expertise through labour-intensive processes and resource management. They also allow for maintaining good oversight of complex processes while giving an enormous amount of pride/ownership/involvement to the employees, thus connecting them to the organization and its sustainability initiatives [17]. Employee green behaviour is defined as employees acting in a manner that has a positive impact on the environment. These actions align with organizational sustainability goals as well as reduce the carbon footprint from workplace activities [18].

These are called green actions which are eco-friendly practices that are performed to complete tasks in a sustainable and environment-friendly way. While organizations employ various interventions to promote sustainable environmental performance and long-term sustainability, stimulating green behaviour is at the forefront of the related interventions. Consequently, emotions play an integral role in shaping subjective actions, such as pro-environment behaviour according to research [18]. Research shows a link between employee satisfaction and participation in environmental projects, highlighting the significance of a strong workplace culture in encouraging greening behaviour [19]. Therefore, our study focuses on the relationship between organizational environmental sustainability and the main features of Green HRM, including training, recruitment, involvement, and remuneration. It also seeks to examine how green employee behaviour helps to the construction of more environmentally friendly and sustainable work environments.

In today's world, creating a stable and sustainable working environment has become a necessity. A lack of green workplace practices can lead to detrimental effects on the broader environment over time. As highlighted by Jerónimo and Henriques, organizations must prioritize the development of eco-friendly work environments to mitigate their environmental impact and support global sustainability efforts. Jerónimo, et al. [13] demonstrated that the lack of the vision and mission of the organization including the green HR practices statement of the company represents an important obstacle in the way of the company to fulfil its environmental sustainability obligations. To achieve meaningful progress on sustainability goals, organizations must embed these practices of integration and collaboration into their core strategic objectives [20]. Employees are the critical force that determines a company’s environmental sustainability; their commitment to green behaviour directly impacts such factors as sustainable innovation and environmental performance. Nevertheless, while most employees show engagement with their work, engagement in specific green initiatives or activities is usually minimal. Such a disconnect not only diminishes employee performance but also has adverse effects on the overall productivity of the business and the successful delivery of sustainability targets.

Previous research mostly was silent on the role of employee behaviour and green engagement towards environmental sustainability and GHRM. Green Environment Training Effects: This has created a workplace challenge that without assistance, employees cannot implement eco-friendly practices because of their inability to cultivate this nature in their workplace, resulting in environmental unsustainability. Importantly, there has been no prior research focusing on the framework being studied here [20].

By examining employee green behaviour as a mediator between employee involvement and Green HRM, this study will address this knowledge gap [11]. There are significant gaps in the literature identified by the review, including a lack of knowledge of the relationship between GHRM and environmental sustainability, a lack of an integrated approach to investigating these issues, and a scarcity of studies from Pakistan and Uzbekistan. We anticipate that this study will fill in these gaps and give much-needed evidence of the link between sustainability and green identity, as well as the mediation between GHRM and employee green involvement [21].

This study also presents best practices to assist HR practitioners and managers increase the efficiency of Green

HRM practices. It offers a policy formulation framework that focuses on environmentally significant behaviours. The results also provide insights on emerging trends in addition to which direction HRM will evolve in the 21st century, making it an important guide for how to shape HR policies according to market trends and compliance requirements.

However, organizations need to take these steps to ensure sustainable development goals and in line with Vision 2030. Furthermore, the study will prove helpful for HR managers, emphasizing how to be proactive in building a green organization by providing actionable solutions for overcoming obstacles to cultivating a green organization.

This research filling such a gap will help state-owned enterprise managers to contrivance Green HRM operations and for improving environmental sustainability. This research provides organizations with insights that allow them to make changes in line with Vision 2030's environmental agenda. In addition, the findings of the study provide a theoretical base for conducting future empirical investigations on Green HRM contributing to an enhanced understanding and implementation of sustainable HR practices.

This study reports a significant vacuum in the literature on Green HRM by examining its relationship with environmental sustainability in Pakistan, Uzbekistan, and Latvia. Unlike previous investigations, which were often limited to a single country or context, the research presents a comparative perspective across these regions. Previous studies have explored Green HRM, employee green commitment, and environmental sustainability; however, this study incorporates these concepts to offer a more comprehensive understanding. This review aims to contribute to the existing body of knowledge by highlighting the significance of Green HRM practices in nurturing employee green commitment and achieving sustainability goals. It also identifies research gaps and offers insights into how organizations can better integrate HRM strategies with their environmental sustainability efforts.

This study fills a critical theoretical gap by including employee green behaviour as a moderator in the association between Green HRM practices (such as green compensation, green hiring, green involvement, and green training), employee green commitment, and environmental sustainability. The primary purpose is to examine how Green HRM practices assist firms achieve environmental sustainability, as well as how employee green behaviour can transform workplace environments into more sustainable and eco-friendly settings.

This qualitative study establishes the connection between Green HRM and environmental sustainability and emphasizes the significance of employee behaviour in achieving green corporate goals. This advances our knowledge of the impacts of Green HRM and establishes the foundation for future research and practical application in diverse global contexts.

A. Research Questions

i. What is Green Human Resource Management (Green HRM)?

ii. What role did Green HRM practices and employee green behaviour play in achieving environmental sustainability?

B. Research Objectives

i. To formally review the link between Green Human Resource Management (GHRM) and environmental sustainability.

ii. To review the relationship between green HRM practices and employee green commitment

iii. To review the relationship between employee green commitment and environmental practices

The following section outlines the steps you need to take to conduct a literature review. The investigator took a methodical approach to finding relevant research, which included developing selection criteria for the literature, bibliometric evaluation using VOS Viewer, the definition of "hot topics" based on keyword analysis, and identification of scientific debates on theoretical approaches, methodologies, and influencing factors on scientific debates. The sources were selected using search terms such as "GHRM," "sustainability," and/or "green involvement," from Web of Science (via Clarivate Analytics)," resulting in a preliminary collection of 535 papers. The selection was modified to include only "Articles" (excluding proceeding papers, book chapters, editorial remarks, and newspaper articles), yielding 308 entries.

1) HRM and Environmental Sustainability

The concept of green HRM refers to the adoption of human resources policies, practices, and systems that reduce the ecological impact of the organization and encourage the sustainable use of resources. It is known as HR practices that support the environment. The importance of Green HRM is that it promotes an approach to corporate operations that integrates economic, social, and environmental considerations, addressing the so-called "triple bottom line". This method not only supports environmental sustainability, but it also aligns with the overall goals of corporate social responsibility.

Green HRM is a relative newcomer, with considerable focus on its use in a broad context of strategic HRM in recent times by practitioners and academics. Its increasing importance has emerged as an answer to the prevailing challenges of environmental degradation and its related threats, thus placing Green Human Resource Management as a vital mechanism to achieve sustainability and reduce environmental hazards [21].

Green HRM integrates typical HR functions with environmental concerns. HR business partnering entails connecting future HR activities, such as recruitment, training, performance management, and employee engagement, with the company's sustainability objectives

[22]. The ultimate purpose of green human resource management is to incorporate environmental responsibility and support long-term sustainability projects by "integrating environmental priorities into policies and practices" [23].

"The use of HRM practices to support environmentally sustainable initiatives and to increase employee commitment to environmental sustainability is known as green human resource management, or GHRM." To better ensure that employees contribute to the organization's sustainability goals, GHRM integrates green policies with HR operations such as hiring, training, performance reviews, and employee rewards [24]. This strategy improves the alignment between business goals and sustainable development priorities, in addition to promoting an environmentally conscious culture [25]. "Green HRM provides firms with environmentally conscientious, committed, and knowledgeable employees who help to lower the company's carbon footprint. Green HRM promotes sustainable practices that match with the organization's environmental goals while optimizing resource use by efficiently and effectively leveraging existing resources such as telecommunications technology, restricted paper printing, work-sharing systems, and video conferencing."

Furthermore, to achieve sustainability goals, businesses must actively seek out employment candidates who demonstrate pro-environmental habits and sensitivities. These professionals play a critical role in promoting and implementing environmentally friendly practices, ensuring that the organization's sustainability goals are properly supported and met [8]. Such “green-collar recruitment,” [14]. In other words, aligning the values of employees and employers with a shared commitment to environmental preservation fosters a sense of purpose, enhances employee morale, and increases active participation in sustainability initiatives [17]. In the highly competitive "war for talent," attracting a high-quality workforce has become a top priority for HR. Organizations that align with their values are becoming increasingly attractive to job seekers especially those that prioritize environmental sustainability. In a time of changing climate, environmental reputation and eco-friendly company practices are becoming a vital part of successful recruitment campaigns, or at least a means of enhancing value proposition in organisations to attract environmentally concision candidates [14]. As organizations recognize the need to leverage their human resource to succeed, the "battle for talent" is far from over, particularly in attracting and retaining high-quality professionals [14]. Green recruitment is the hiring of employees with the relevant skills, qualities, and attitudes that fit in with the values and goals of the organization regarding the environment. This method incorporates all decisions regarding environmental considerations into the recruitment scheme, thereby making sustainability a principle of the organization and a loop for the organization to circle to the issue of commitment to productivity and eco-friendliness [26].

Green compensation refers to a specific aspect of Green HRM aimed at offering incentives and rewards to employees for their environmental efforts and success. This approach for compensating employees would serve as a tool for building sustainable practices, recognizing environmental achievements, and incentivizing the completion of green training programs to reinforce a culture of sustainability. (e.g., [27-30]. Renwick, et al. [14], Govindarajulu and Daily [28], Bangwal and Tiwari [30] stated that Green practice-related compensation and rewards can be in different forms depending on the different motivations of employees. These are in the form of money, such as premiums, cash bonuses, or subsidies for buying environmentally friendly products, such as hybrid cars or bicycles. Non-monetary rewards can also include sabbaticals, extra time off, or gift cards. An example of recognition-based rewards would be awards for environmental excellence, annual awards, or even daily confirmation of eco-positive efforts. Additionally, organizations may use promotional opportunities or negative reinforcement strategies to encourage green behavior, further embedding sustainability into workplace culture (such as criticisms).

The employment of a system that combines monetary and non-monetary incentives to identify and motivate staff members who have demonstrated a potential to assist environmental management projects is known as "green rewards." This strategy encourages employees to adopt sustainable behaviors while also reaffirming the company's commitment to environmental sustainability [31]. Compensation is an effective incentive, and the same principle applies to environmental management. To effectively encourage and reward environmentally sensitive behavior and performance, the payment mechanism must be carefully organized. In essence, employees' contributions to environmental projects should have a substantial impact on their evaluation and compensation. Previous studies have demonstrated that incentives play a critical role in persuading employees to actively participate in eco-friendly behaviors, validating the organization's sustainability goals [21].

Green training is an effective tool for supporting sustainable development initiatives. Its effectiveness relies on its capacity to meet a variety of goals at several levels, including (1) informing employees about the organization's green policies, projects, and creative practices, as well as its mission and vision statements. [32]; (2) raising ecological awareness [33] Educating employees on eco-friendly best practices such as recycling, waste management, energy efficiency, resource selection, and carbon footprint reduction, as suggested by Ahmad [14]; and (3) motivating personnel by improving their ability to identify environmental challenges and understand their consequences [28].

The purpose of green training, sometimes called environmental training, is to educate employees about the policies, procedures, and attitudes of an organization

regarding its environmental practices [31]. Environmental obligations, participation in environmental activities, and compliance with firm environmental policy are all taken into account when measuring green performance. However, organizations commonly have challenges in analyzing environmental performance across industries and acquiring actionable insights into their employees' environmental contributions [31].

Sustainability is generally defined as it is the ability to meet current needs without compromising those of future generations [19, 34]. Environmental literature underlines that green management has many definitions that can help facilitate sustainable development that encompasses economic growth, so that capital can be created and environmental sustainability. This means the present generation will make it possible for future generations to live in harmony [15]. Similarly, sustainability is described as an organization's ability to pursue long-term activities that benefit the socioeconomic environment while also creating jobs and generating economic gain [35].

Researchers asserts that for sustainability to be achieved at the macro level, we must begin with our actions in the workplace," suggesting that individual environmental performance can influence organizational environmental outcomes both directly and indirectly [36, 37]. Furthermore, perceptions of environmental performance vary depending on whether the organization prioritizes operations or other variables. Researcher contend that focusing on employees' perceptions of their company's environmental performance provides a more accurate picture of corporate environmental sustainability [38]. This attention to the firm's associates' and employees' perspectives may provide important insights into the overall corporate environmental performance [39]. The research goes deeper into the relationships between various aspects, such as the link between environmental sustainability and Green Human Resource Management (GHRM) [18, 40-42]. Notably, green recruiting practices are linked to environmental sustainability, emphasizing the crucial importance of hiring environmentally conscious employees in enabling sustainable organizational growth [16].

2) Green Involvement and Sustainability

Environmental management stakeholders can take eco-friendly action, which encourages them to participate in pollution control and environmental protection [14]. By minimizing waste and emissions in offices while making sure that every available resource is being used at its most effective, green participation plays a critical role in enhancing energy and resource efficiency [43]. Researchers identified several strategies for motivating employees to be environmentally conscious. Following Renwick, et al. [14], the researcher identified five essential areas for evaluating green engagement (GI): green participation, green learning, the use of varied Promoting "clear green views" through media channels, and green actions." These concepts and symbols promote environmental conservation and actively engage employees in environmental concerns [14, 43].

Similarly, Jamal and Zahid stated that employee participation in green initiatives inspires and drives them to actively reduce waste and pollution. A review of many studies concludes that developing employee green involvement is critical; GI enhances company performance by using less waste, pollution, and resources. To maintain green practices, companies must actively encourage and empower their employees to participate in ecologically friendly projects [6, 44]. This can be accomplished by giving employees more autonomy and authority to take ownership of environmental projects.

Employees become more dedicated and concentrated on carrying out their environmental responsibilities, the more involved and passionate they are about environmental protection [44]. Employee involvement in green projects results in the establishment of email lists, green problem-solving teams, and collaborative squads, which improve the company's environmental efforts and introduce new information and practices to the workforce [45]. Green involvement (GI) aims to provide a strong, development-oriented vision of environmental management while also developing a collaborative learning environment that promotes environmentally responsible behavior. It also enables the establishment of both formal and informal communication pathways, promoting an organizational culture of ecologically sustainable cooperation [46].

Furthermore, GI enhances value creation and problem-solving abilities about environmental concerns by raising an understanding of how environmental groups function and promoting the development of a society that values conservation [12, 45]. Uddin and Islam [19] emphasizes that "individual action at the workplace is the first step towards sustainability at the macro level," meaning that individual environmental performance can influence organizational environmental results both directly and indirectly [37].

Over the past century, environmental performance has gained increasing importance in planning and economic analysis due to the rapid depletion of natural resources in industrialized nations and the growing emphasis on workplace social accountability to achieve a competitive edge [47]. Researchers and practitioners are encouraged to examine why companies respond to environmental challenges, as incorporating environmental performance initiatives into business processes is shown to improve overall organizational performance [48]. Furthermore, the relationship between green involvement and environmental sustainability has been thoroughly researched, demonstrating its substantial significance in improving organizational performance [14, 44, 47].

3) Green HRM and Employee Green Behavior

Human resource management (HRM) and environmental factors are closely related according to GHRM, which defines its design, development,

implementation, and influence [16]. According to scholars, in addition to communicating environmental strategies and relevant information to employees, GHRM techniques include educating employees about modern environmental practices, encouraging employee participation in environmental initiatives, and rewarding environmentally conscious behaviors [49]. Similarly, according to the GHRM definition, "HRM practices and strategies ensure long-term financial, social, and ecological goals are achieved while minimizing unintended side effects and negative feedback both inside and outside the enterprise" [50].

Environment-friendly conduct, often known as pro-environmental behavior, refers to "green" techniques that are closely related to environmental friendliness [50-52]. Employee green commitment (EGC) refers to the psychological attachment and willingness of employees to engage in environmentally responsible behaviors in the workplace. This commitment is critical for promoting environmental sustainability, which is the long-term maintenance of environmental health by minimizing ecological damage [53, 54]. Researchers emphasize the growing importance of encouraging green habits in the workplace. We see organizational green practices as recycling initiatives, adhering to environmental laws, reducing waste, reusing materials, implementing energy-saving technology, aiming to reduce water consumption and energy consumption, lowering carbon dioxide emissions, and assessing the lifecycle of products [54].

In order to participate in ecologically beneficial efforts outside of their regular job responsibilities, people need to adopt optimistic green behaviors [18, 55]. Recent research, particularly highlighted the importance of employee green behavior in attaining environmental sustainability, emphasizing its vital relationship with an organization's overall sustainability initiatives [55].

4) Role of Employee Green Commitment and Environmental Sustainability

Employee green commitment (EGC) is defined as the psychological commitment of employees toward engagement in environment-friendly corporate behaviours. This pledge is vital in raising environmental sustainability, defined as the ability to maintain the productivity of ecological systems over the long term through minimizing environmental impacts on the ecosystem. The environmental problems we face, including climate change and resource depletion, have raised interest in sustainability at the organizational level, with a central role belonging to employees [56]. Existing studies on employee green commitment have focused on its outcome variables related to the organizational effort toward environmental sustainability; however, the perspective on its antecedent variables is limited and lacks of appraising literature overview with recent developments [56].

Employees can commit to green in both effective and behavioural ways. Affective commitment describes an emotional bond to pro-environmental objectives, whereas behavioural commitment is reflected in actual green behaviour, such as recycling or conserving energy [10]. Scholars have found that employee green commitment is predicted not only by organizational factors, like corporate environmental policies, but also by personal values, social norms, and external pressures [57].

Multiple factors are more likely to lead to the employee's green commitment. Organizational culture and leadership significantly influence employees' environmental attitudes and behaviours [58]. When top management is committed to sustainability and when clear environmental policies exist, this can create a work environment that supports and fosters green behaviours [16]. Employee values and individual environmental awareness play major roles in influencing employee green commitment [7].

Organizational environmental sustainability outcomes have been positively influenced by employee green commitment. Highly committed green employees tend to consistently exhibit pro-environmental behaviours that facilitate resource conservation, waste reduction, and sustainability objectives [59, 60]. Additionally, studies show that workers intensely engaged in an organization´s environmental objectives tend to encourage sustainability processes, favouring the organization´s performance in the management of energy and waste [61].

There are many strategies that organizations may use to support employee green commitment. These practices range from green training to rewarding sustainable behaviours to inviting employees to take part in the decision-making process regarding environmental practices [62]. Moreover, setting up an open line of communication, even more so highlighting sustainability and how each employee can do their part, is vital. 9.2. Corporate social responsibility (CSR) foundations have found that green employee involvement exemplifies the company's engagement in environmental preservation initiatives [21].

Although employee green commitment is crucial for reaching sustainability objectives, creating such a type of commitment is not without hurdles. Employees' green commitment can be hampered by the lack of adequate training in their roles, ambiguity in communication about environmental policies, and inadequate support from management [63]. This could be due to external constraints like pressures that come from the shrinking market and people leading a lifestyle that is not green [58].

Previously emphasized that green behavior in a workplace can be grouped into two main classes based on different attributes. One distinction is between direct behaviors [64] e.g., Individual activities like recycling and indirect behaviors like joining an environmental petition can influence others. The emergence of new ideas in how we manage the environment is the second contrast between localized effects, like turning off lights in the workplace, and global consequences [65].

The research emphasizes correlations between variables in numerous studies. For instance, there is a strong connection between green HRM and environmental sustainability [38, 40] and green engagement and sustainability go hand in hand [44, 48]. Researchers have extensively investigated employees' environmentally conscious behavior. However, no single study has examined the impact of employee green behavior. This study emphasizes that green employee behavior is a significant mediator between green compensation and environmental sustainability, providing new insights into these connections [65, 66].

II. Materials and Methods

The researcher includes a comprehensive technique to conduct a systematic literature review (SLR), building on previously published SLRs, Tranfield's foundational work (2003), and Justine Paul's earlier guideline publications. The systematic approach was performed for the SLR, which is described in the following stages:

A. Formulating Research Questions

Preparing inclusion and exclusion criteria for the screening of included logic models. The research process started with the formulation of specific research questions that guided the scope and focus of the review. This list of questions helped rationalize the meta-analytic process and drive relevant studies. Since this research aims at analysing and interpreting GHRM and to help in developing GHRM, it was very important to create focused questions that will channel our investigation into mining meaningful insights.

B. Search Strategy Development

A systematic and focused literature review, the researcher constructed a strong search procedure that operated by the common SLR standards and guidelines. This included appropriate databases, specific search keywords, and inclusion and exclusion criteria. Green HRM, employee green behaviour, environmental sustainability, and green engagement were among the most popular searches. Scopus, Google Scholar, ScienceDirect, and Emerald Insight were employed as search databases to ensure relevant and excellent academic literature.

C. Study Selection

The studies retrieved were systematically organized by their relevance to the research questions. A systematic method was used to identify and select studies that aimed to meet the goals of the review. The relevance of titles, abstracts, and full texts was evaluated. The review considered a variety of sources, including research articles. The collection consists of books, working papers, conference proceedings, scientific journals, doctoral and master's dissertations, and other written works.

D. Data Extraction

A standardized data withdrawal form was used to collect relevant data from the included studies in a systematic manner. This process extracted specific data elements concerning study characteristics, methodologies, sample sizes, and primary outcomes. Data extraction was performed through a consistent procedure to categorize the extracted information in an organized form, allowing for a detailed analysis and interpretation of information.

E. Quality Assessment

Established assessment tools were used to evaluate the reliability and quality of the included studies. This ensured that the review was not only well supported by the best evidence but also that each study was evaluated according to its own methodological strength, validity, and overall quality. Following an exhaustive assessment of each of the studies that contributed to this particular review, those which did not satisfy the quality thresholds were discarded.

F. Data Synthesis

Ten important papers were mentioned for data synthesis, and 160 publications in all were chosen for final analysis from the 261 studies that were first examined. Finding recurring themes, patterns, and trends within the examined research required a thorough and methodical methodology. The process's outcomes successfully summed up the data, enabling the deduction of insightful conclusions and useful recommendations that were closely tied to the study's goals.

G. Reporting and Documentation

Finally, Justine Paul's SLR framework and Tranfield et al.'s journal reporting requirements guided the reporting and documentation process.
Results: The systematic literature review (SLR) was presented in a clear and systematic manner using tables, figures, and descriptive analysis. Moreover, presenting results from each literature separately allowed us to provide a comprehensive and transparent picture of the findings, giving a complete overview of the insights gained from the reviewed literature.

III. Results and Discussion

This article investigates Efforts to sustain organizational environmental sustainability through Green HRM, namely remuneration, hiring, involvement, and training. It also investigates the significance of green commitment in promoting an environmentally friendly workplace. This qualitative study analyses and synthesizes major themes from the literature.

The findings indicate a significant relationship between green training and environmental sustainability. The conclusion is that strengthening green recruitment practices can significantly increase a company's environmental sustainability. Raising green remuneration also increases the value of environmental sustainability, as previous research has shown [13, 23, 60]. Similarly, there is a strong correlation between Green HRM and environmental sustainability, meaning that implementing

Green HRM practices can increase sustainability in a wide range of business settings. Effective human resource management using sustainable ways benefits the environment while also bringing value to consumers and employees. This is consistent with research findings in the literature [56, 67].

Among the most dynamic areas of research and practice is the intersection of green human resource management, employee green commitment, and environmental sustainability. Green HRM has emerged as a strategic business function that can align human resource practices with wider environmental goals as organizations increasingly recognize the need for sustainable development. An existing literature review has brought out some emerging themes and insight into Green HRM, emphasizing employee green commitment and Organizational sustainability

One of the prominent conclusions from the literature is the positive effect that green HRM practices can have on augmenting employees' green commitment. By enhancing green HRM techniques, green recruiting, green training, green performance evaluation, and green incentive systems, organizations can persuade their employees to adopt sustainable practices and engage in the process of eco-friendly behaviour [42]. These initiatives can take the form of performance reviews that measure how well employees adhere to the company's green policies or green training programs that equip employees with the knowledge and skills to maintain a sustainable lifestyle [4]. Such practices cause employees to have a stronger psychological bond with the organizational environmental goal, and thus improve their green commitment when employees are actively supported [16].

There are some ways through which a positive association between Green HRM and employee green commitment can be explained. First, Green HRM practices offer explicit expectations and rewards for employees' sustainability-related behaviours, thus amplifying their intrinsic motivation to engage in environmental efforts [21]. Furthermore, internalization of sustainability through HRM practices embeds a common understanding of the benefits of green initiatives and cultivates a collective commitment towards sustainability from an employee perspective [6]. Alignment of organizational values with sustainable practices boosts the probability of engaging employees in resource conservation, waste minimization and promotion of sustainability initiatives, both at work and outside it.

Green compensation is shown to have a strong and significant association with environmental sustainability. Thus, increasing green remuneration can advance sustainability across all industries. More environmentally friendly compensation policies enhance both consumer and employee value for organizations. Therefore, promoting green compensation is an effective way to boost environmental sustainability, as corroborated by previous studies [29, 59, 68, 69].

Similarly, green hiring is closely associated with environmental sustainability. Enhancing green hiring practices positively impacts sustainability across industries. By implementing environmentally friendly recruitment strategies, organizations can nurture consumer and employee value while contributing to sustainability.

A strong association was also found between green training and environmental sustainability in the study. Comparable research in the literature indicates that strengthening green training programs is a promising way to improve sustainability [29, 59, 68, 69]. Furthermore, it has been demonstrated that environmental sustainability is significantly influenced by green involvement. According to a linked study, increasing green participation has a favourable impact on sustainability [56].

The study concludes that improving EBG and environmental sustainability can assist organizations in enhancing green compensation. Literature supports this link [38, 39]. Furthermore, increasing environmental sustainability can broaden green hiring efforts, with green employee behaviour serving as a bridge. Similarly, boosting environmental sustainability enhances Training and involvement in green issues, with green employee behaviour as an intermediate step, according to the research [40, 60].

The study acknowledges that the current environment faces significant challenges due to the effects of global warming and pollution in today's fast-paced lifestyle. Green HRM and green branding have emerged as essential topics, as nations grapple with increasing environmental concerns. Consumers are adopting environmentally conscious behaviours to safeguard their well-being and protect nature. This study introduces a new paradigm to the literature, offering organizations actionable strategies to enhance Green HRM practices.

Sustainable environmental practices are still an urgent concern in the age of global warming, and this study highlights their significance while offering workable solutions. The relationship between Green HRM and environmental sustainability has already been the subject of numerous research [40, 60, 67]. The importance of EBG and Green HRM in improving our kingdom's green environment is emphasized by this study.

The present study advocates the significant acts of employees in the situation of Green HRM, which plays an indispensable role in bringing environmental sustainability to our country. This contributes new insights regarding Green HRM, signalling its mediating position on the pathway between employee green commitment and ecological/organizational performance.

The current study helps employees to align their actions with organizational strategic goals by adopting green commitment, which is one of its primary contributions. Modern HRM tools and practices are particularly useful for the manufacturing industry. This study also provides a new avenue for employers to connect with their employees by creating an operating model of a

sustainable organization through better engagement. It is particularly useful for people working at the managerial level, as it shares the tools that will help in dealing with employee concerns while fulfilling sustainability objectives.

Shifting towards the concept of the need for green has pushed HR managers to incline towards green practices. The steps to shifting to green products and processes may initially appear pricey, but they are indeed eco-friendly and in the long run cost-effective as well. The finding of this research highlights the need for integrating green HRM practices at the organisational level to improve the manufacturing sector through the guidance of organizations to move towards green.

Factors such as increased consumer awareness of environmental issues have influenced consumer behaviour and steered the market toward the production of ecologically friendly goods and services. The increasing need for distinctive customers has had an impact on successful human resource management. HR managers have quickly embraced the "need for green," recognizing that hiring sustainability-minded employees can improve the environmental quality of products and services. Organizations can have a long-term positive impact by developing policies and processes that promote environmental preservation.

In this study, green HRM practices like green reimbursement, green recruiting, green training, and green involvement demonstrate effective indicators of employee sustainability and green behaviour. It highlights that selecting people with a positive attitude toward the natural world results in eco-friendly organizational practices and environmentally sustainable products.

This study focuses on national-level organizations that operate in the nations under consideration, drawing on literature published between 2000 and 2025. However, it is worth noting that the study does not show a time-sequenced relationship between the factors. Nonetheless, the findings provide practical insights for HRM practitioners and managers, supporting the implementation of green practices to create a sustainable future.

There is an increasing body of literature; however, there are additional areas that warrant further examination. Future studies could further investigate the role of industry-specific factors that influence employee green commitment and the potential for digital forms of technology (AI, big data) to be harnessed to help organizations achieve their sustainability objectives. Moreover, research exploring the cultural variables that can explain differences in green commitment across different geographical regions will also provide a more robust understanding of this concept [70]. Longitudinal researches on the influence of employee green commitment on organizational sustainability performance are needed to address the organizational practice more clearly.

This would indicate a gap in the literature on Green HRM practices that explores the intersection of these SCM practices in different HR functions. Gaps can indicate the absence of comprehensive models that explore synergies between key HRM practices, such as how green recruitment relates to green training or where performance management systems might further align with sustainability objectives. Moreover, research investigating how leadership behaviour better impacts the effectiveness of Green HRM practices while ensuring employee green commitment would lend more specificity on how (or through which routes) these Green HR practices predict sustainable outcomes.

Lastly, investigating the obstacles to Green HRM practices to promote their effective impact will be essential for future research agendas. This might include exploring how companies can alleviate resource constraints, build awareness of environmental issues, and develop a top-down approach to sustainability.

IV. Conclusion

The findings from the literature review reveal a strong relationship between green training and environmental sustainability. Improving green recruitment practices can play an important role in reaching a company's environmental sustainability objectives. Moreover, green compensation practices raise the environmental sustainability profile in organizations.

This study reaffirms the value of Green HRM for environmental sustainability. Green HRM acts as an enabler by providing a green-friendly administrative climate. Against this backdrop, greener compensation, greener hiring, greener involvement, and employee green commitment are key components of Green HRM that impact the shaping and analytics of environmental need states.

This ultimately leads to environmental sustainability as green HRM ensures the adoption of green commitment by employees. For companies looking to improve their environmental impact, integrating green HRM into their strategic vision will create a sustainable culture and empower employees to make a meaningful contribution to environmentally friendly activities.

The employee green commitment plays a significant role in advancing environmental sustainability within organizations. By fostering a culture of green commitments through leadership, training, and organizational support, companies can enhance their sustainability outcomes. However, addressing the challenges that hinder employee engagement in sustainability initiatives is crucial for the long-term success of these efforts.

Finally, this literature review emphasizes the critical link between Green Human Resource Management (Green HRM) practices and environmental sustainability, with a specific emphasis on the significance of Green Work Commitment. According to the findings, Green HRM activities, including eco-friendly recruitment, training, and

performance management, are critical in increasing employees' green commitment. As a result, organizations are better able to meet their environmental sustainability goals. However, more empirical study is required to explore the practical applications and long-term implications of Green HRM on employee engagement and organizational sustainability.

ACKNOWLEDGMENTS

Acknowledgments are the most important part of any research because it is a systematic process, and it is difficult to make it complete without any help. We wish to extend our gratitude to the researchers and practitioners whose work has greatly enhanced our understanding of the Green HRM domain. So, I would like to thank my PhD Scientific Supervisors for their kind help throughout my whole study. Special thanks to my friends, family, and colleagues for their collaboration, as well as everyone who has come here for research work guidelines and other support. I also appreciate the participation of everyone in this project.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 45-51

Building Culture – Is it Possible in EU-Funded Projects?

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***Abstract* - The focus of the study is on the environment, which is an essential part of the history, culture and economy of each country. The surrounding environment also serves as an important means of artistic expression, creating a sense of belonging, identity and tomorrow's heritage. The impact of the environment on society is crucial in ensuring and improving the quality of life. The surrounding environment is influenced by social and political factors, economic development and culture affect the surrounding environment. At the same time, these factors are also influenced by the environment itself, creating continuous and mutual interaction. Economic interests drive the development of construction in a market environment, but the quality of construction works, and the quality of the environment associated with it are public goods, the improvement of which may not be a business goal. Construction policy determines the priorities and strategic goals of the government. In this way, the state protects the public good. Every human activity aimed at creating, preserving or transforming the surrounding environment includes the aspect of creating culture, cultural identity and diversity. Construction culture requires not only the preservation of existing buildings with cultural and historical significance, but also the responsible creation of new public spaces. The novelty of this research lies in its examination of how construction culture principles are integrated into the implementation of European Union (EU) Cohesion Policy Fund projects—an aspect that has not been systematically analyzed before. This study bridges the gap between construction policy, cultural identity, and sustainable urban development by assessing whether EU-funded projects uphold the values of construction culture. The aim of the study is to determine whether the principles of construction culture can be observed in the implementation of European Union (EU) Cohesion Policy Fund projects. To achieve this goal, the following research tasks have been set: to analyze the concept of construction culture; to identify the main principles of culture formation and to provide recommendations for observing these principles when implementing EU Cohesion Policy Fund projects. The monographic and descriptive method and the logically constructive method are used. The results have developed the main components necessary for ensuring construction culture. Main conclusions and recommendations: considering the significant investments of EU funds in infrastructure and their impact on the economy and welfare of the Member States, the construction sector with all its sub-sectors should be given much greater attention. Investments in research and development of this sector should be increased in order to respond to the changing and growing demands of society, ensuring the competitiveness of the sector both in the EU and globally.**

Keywords – building culture, EU-funded projects.

I. INTRODUCTION

Europe is characterised by a rich and diverse architecture that has evolved and developed over time. Considering the varying climatic, political, geographical, social, and economic conditions that have shaped different regions, Europe can take pride in a wide range of distinctive architectural styles and landscapes. Recently, concerns about economic stability in Europe have been growing significantly influenced by migration, the COVID-19 pandemic, and the Russian Federation's full-scale invasion of Ukraine. Several regions are experiencing economic stagnation or significant contraction. Political extremism and populism are becoming more prevalent due to the increasing social and economic polarization. The European Union's (EU) cohesion policy plays a crucial role in addressing these challenges. It serves as the primary instrument to tackle these issues and counteract the resulting problems.

Addressing these challenges and responding to global trends also impacts the development and preservation of buildings and landscapes. The EU incorporates issues such as eradicating poverty and inequality, ensuring economic prosperity and security, and optimizing energy consumption - focusing on sustainable and inclusive

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8695
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environments - into many of its strategies, programs, and projects. The European Union establishes cultural requirements for modern planning and construction. The EU has emphasised the importance of high-quality built and restored environments, articulated in at least two Council of the European Union resolutions [1], [2]. Both resolutions call for improving architectural quality while taking urban sustainability into account, emphasizing a careful and respectful approach to cultural heritage. The environment must provide good, safe, and healthy living conditions that promote social cohesion.

Buildings serve technical and economic purposes while also meeting artistic, aesthetic, cultural, and social needs. The goal of construction is to ensure that buildings are fit for purposes, durable, safe, and comfortable while bringing people together, fostering a sense of well-being, and promoting social cohesion. Construction creates spaces where people meet and interact. Attractive, diverse, and inclusive cities, towns, and landscapes emerge only when construction is carried out with a commitment to high quality.

Culture is defined as "…the totality of spiritual, material, intellectual, and emotional features of a society… in addition to art and literature, it includes lifestyles, collaboration, value systems, traditions, and beliefs…" [3]. Culture shape's human identity and defines their heritage. Without culture, there can be no humanity, rationality, critical thinking, or moral commitment [4]. Culture forms the foundation of intellectual, emotional, moral, and spiritual existence. Buildings themselves are a form of culture, creating spaces for cultural expression. Building culture represents a skilled and sustainable approach to preserving and developing significant buildings and urban spaces. It encompasses every human activity that transforms the surrounding environment. Culture is a transformative force that fosters community renewal. This is evidenced by the 30-year success of the "European Capital of Culture" initiative and cultural infrastructure projects funded by the European Structural and Investment Funds. The "European Year" initiative places particular emphasis on the cross-cutting contributions of cultural heritage to European society and the economy [5].

II. Materials and methods

To achieve the research objective, the following methods were used: Monographic and descriptive method: This method was employed to provide a detailed description of the principles of building culture and their significance in the implementation of European Union (EU) funded projects. Logically constructive method: This approach was used to develop recommendations that would enable the effective application of building culture principles in EU-funded projects.

The materials used included: Scientific articles: These analysed the significance and impact of building culture on the economy and cultural development. EU official documents: These highlighted the importance and impact of building culture on society. Project data: This allowed for conclusions to be drawn about the implementation and outcomes of various projects.

III. Results And Discussion

As a component of cultural identity and diversity, building culture encompasses all human endeavours aimed at creating, preserving, or transforming the surrounding environment. Building culture calls not only for the preservation of existing buildings with cultural and historical significance but also for the creation of responsible new public spaces. "Baukultur" is particularly well-known in German-speaking countries, where it is increasingly used. The French term "culture du bâti" and the Italian term "cultura della costruzione" are direct translations from German. Thus, it can be concluded that the concept of "building culture" in Latvian has also come from the German language. This concept is quite challenging to translate into English in a way that conveys its full meaning. The German language is famous for its compound words, and "Baukultur" is no exception, as it combines the verb "to build" (Bau-) and the noun for culture or civilization (Kultur), thus giving it a simultaneous, societally significant meaning: "culture of construction." "The foundation of building culture is the tradition provided by the local architect, thorough and detailed research and analysis of heritage, onto which... functionality and technology are layered" [6]. Building culture is an active approach to shaping the environment, prioritizing cultural values over short-term economic gains, thus assembling not only functional, technical, and economic requirements but also addressing people's social and psychological needs. The way we use, maintain, and protect our cultural heritage today will be crucial for the development of high-quality construction in the future [7]. The concept of building culture in English (The Culture of Building) has been extensively studied by Howard Davis in his comprehensive book of the same title, where he describes building culture as "a coordinated system of knowledge, rules, and procedures that is common to people who participate in construction activities and that determines the form of buildings and cities" [8]. In the author's view, this explanation unjustifiably excludes all others, leaving only those who work at a professional level in construction, as the individual is the product of their living environment. Therefore, building culture applies to everyone. Regardless of whether they are merely present or actively shaping their surroundings, people influence their environment. Everyone is responsible for the active creation of their living environment. Building culture as a code of morality, ethics, and expertise in architecture, environmental culture, and construction art is nothing new. It is a modern extension of the principle of firmitas, utilitas, venustas (strength, utility, beauty – in Latin) formulated by Vitruvius, a contemporary of Christ [9]. Building culture encompasses all People shape their living environment in all its diversity, a phenomenon known as building culture. It also includes landscapes – both built and natural. Thus, building culture connects the past and the future.

In her publication on the LSM (Latvian Public Media) portal, Evita Ruka describes the significance of building culture in our lives: "The concept of culture has a wide

range of definitions, but all of them emphasize that it is not innate but develops as a result of upbringing and interaction with society. Buildings share a common nature. Human hands create them, shaping them through upbringing and societal demands. Buildings and their complexes are just like people – cultural and not so much, harmonious and destructive, outwardly brilliant and internally unstable, inviting and rejecting, joyful and gloomy, loudly striking and quietly serene. There are buildings and urban environments where a person instinctively feels good and wants to stay longer, but there are construction objects that cause stress, unpleasant feelings, and make you want to walk around them. Of course – each to their own, but building culture is the sensible and aesthetic foundation that creates pleasant places" [10]. Undoubtedly, a significant role in shaping Latvian society's understanding of architecture was played by journalist and architectural critic Mārtiņš Ķibilds (1973–2019), who created and hosted the program "Adrese," offering direct analysis and valuable recommendations. The programme emphasised that architecture is the shared living space of society, making it particularly important to study and analyse both successful and unsuccessful, or even glaringly poor, examples of architectural and environmental design [11]. The first organisations operating in the field of building culture were architecture museums, such as the Museum of Finnish Architecture, established in 1954. Since the 1970s, the number of organizations both in Europe and globally that promote architectural and construction culture has steadily increased, highlighting the significant role these fields play in people's lives. State or municipal financial resources fully or partially fund most of these organizations, with only a small proportion relying on private funding and donations. While the scope of these organisations and their understanding of the concept of building culture may vary, their main goal is to provide information and create opportunities for discussion [12]. In 2000, the German Federal Ministry of Construction launched the Architecture and Baukultur Initiative to promote and focus public discussion on construction planning and quality in Germany. In December 2006, the German federal government approved a law for the establishment of the Federal Baukultur Fund. Founded in Potsdam, the fund serves as an independent and active platform for all matters related to architecture and building culture. In April 2007, during Germany's presidency of the European Union, the European Architecture Policy Forum was held in Hamburg [13].

The concept of Baukultur gained global prominence in early 2018, when, on the eve of the World Economic Forum in Davos, European ministers responsible for culture and spatial and regional planning signed the Davos Declaration on the central role of culture in the built environment and the implementation of the Baukultur concept in construction [7]. This concept encompasses all activities within the built environment related to existing buildings and cultural heritage elements, as well as the planning, design, and construction of modern buildings, infrastructure, public spaces, and landscapes. It includes construction methods, skills, and innovative approaches. The Architects' Council of Europe [14] emphasised the critical importance of high-quality Baukultur in its 2018 annual report, urging the European Commission to take actions to implement the Davos Declaration. The significance of Baukultur was also highlighted in the organization's 2023 annual report [15].

The Davos Declaration tries to connect the past and the present by providing a broad idea that includes both protecting cultural heritage and making new environments. This idea defines Baukultur as a single entity [16]. The concept of Baukultur refers to the activities and processes that influence the spatial environment. Meanwhile, the term "high-quality Baukultur" refers to an enhanced and superior spatial environment. This concept is used to describe high-quality construction work, ensuring that Baukultur, with its values, is placed at the centre, preserving or creating an environment that meets cultural and social needs [17].

The goal of high-quality Baukultur is to create and maintain a high-quality environment. This quality fosters essential societal values such as quality of life, well-being, social cohesion, and social integration. High-quality Baukultur ensures adequate housing, including the surrounding neighbourhood, and creates conditions for the growth of economic added value. With its vision that encompasses the entire built environment and focuses on the common good, the concept of high-quality Baukultur adds value to any environment. High-quality Baukultur enhances the sense of "place," allowing people to identify with their living or working environment, thus promoting the formation of inclusive and cohesive communities. It protects the environment by supporting sustainable transportation, increasing urban green spaces, and promoting biodiversity. Baukultur represents the power and responsibility to shape the environment in which we want to live [18]. High-quality Baukultur ensures the common good for all of society. Only a conscious approach to the task, involving collaboration between the state, local governments, and the private sector, can achieve this. A crucial aspect is the shared responsibility that all these sectors must bear. The state and local government sectors should set an example for the private sector by recognising and promoting the importance of Baukultur. All sectors are equally responsible for ensuring that Baukultur becomes our heritage, which we will pass on to future generations. High-quality Baukultur can be achieved by clearly expressing and consistently implementing the desire to reach it, meaning Baukultur should be incorporated as a fundamental goal in the planning, design, and construction phases. Undoubtedly, an essential factor in this process is a fair procurement procedure, i.e., the decision about who will carry out the planned work on the site. Technical and/or economic interests must not override the principles of Baukultur in the decision-making process.

As mentioned in the Davos Declaration [7], there are several references to how the architectural environment, including materials, influences human health and psychological well-being. The declaration emphasises that intentional efforts to create a high-quality

architectural environment, one that supports human well-being, should be a priority over short-term economic gains. Many of the anticipated benefits of such quality construction include greater social cohesion, better health, and enhanced biodiversity. According to the Davos Declaration [7], Latvia needs to implement high-quality Baukultur – a new, culture-based, and sustainable approach to shaping the built environment. The preservation of cultural heritage today plays a crucial role in shaping the future development of Baukultur. There is no direct action required by the Davos Declaration [18] regarding projects funded by European Union funds. However, it is a great way to make sure that big financial investments are in line with Baukultur principles. The European Commission launched the New European Bauhaus initiative in 2021, and Latvia is actively participating in it. It promotes sustainable solutions for transforming the built environment and lifestyle during the green transition. The New European Bauhaus is a strategic, creative, interdisciplinary initiative focused on the environment, economy, and culture. It connects design, sustainability, accessibility, and investment to achieve the goals of the European Green Deal. Ursula von der Leyen, the President of the European Commission, announced the initiative in 2020 [19]. Although we can compare the concept of Baukultur to the principles of Bauhaus, this research does not focus on Bauhaus itself.

High-quality Baukultur adds economic value by creating more durable and sustainable assets. Thus, in the author's view, the concept of Baukultur is closely linked to the concept of sustainability, as the core idea of sustainability is to preserve resources for future generations, while the core idea of Baukultur is to build with respect for the past, ensuring a high quality of life for future generations. Since 2021, the Davos Baukultur Quality System has been the only way to judge high-quality Baukultur. It does this by putting social, cultural, and emotional factors on the same level as more common technical, economic, and environmental factors. Eight criteria have been defined — diversity, governance, economics, functionality, environment, context, beauty, and sense of place — which form the principles of Baukultur [20]. Baukultur is essential for creating an environment where it is and will be worth living. Similar to sustainability, which rests on three pillars - social, environmental, and economic - and incorporates an ethical aspect, Baukultur also encompasses social, environmental, and economic dimensions, along with ethical and aesthetic dimensions. Mastering, creating, and utilising Baukultur is a social process based on a broad understanding not only of quantitative indicators but also of qualitative values and objectives. Engagement in Baukultur makes wisdom from the viewpoint of many stakeholders. Private house owners can generate circumstances for the long-term care and improvement of their funds. Through their projects, public organisations can donate to the individuality of our cities and thus fortify local and national individualities. Politicians can address potential discontent and direct it into productive channels, thus gaining broad approval for development and change. Baukultur is the main way to generate equally social and profitable additional prices. It is an investment in upcoming living spaces.

Only a genuine effort to uphold sustainability can ensure it, just as discussing Baukultur requires an understanding of the old, preservable elements and the ambition to create new structures that meet the quality standards dictated by contemporary times. The role of the client is particularly important in this context. The construction industry is increasingly playing a key role in mitigating climate change and ensuring environmental, social, and economic sustainability. The sector is increasingly focusing on these issues and conducting substantial explanatory work. Industry professionals are working to create innovative solutions, breaking down the perceived boundaries between construction and sustainability. It is common for every project's failure to have an excuse - lack of money, insufficient time, poor-quality materials, subpar work, unforeseen tasks, lack of will or desire from the client or other stakeholders, lack of experience, and so on. Sometimes, the situation is even more complicated, as the issue could be that the project is being implemented at the wrong time, place, or with the wrong function for the space or environment. Often, the bureaucratic requirements of funding are cited as one of the main reasons, but it's not always clear what additional bureaucracy is involved in implementing funded projects compared to self-funded ones. Unfortunately, situations are still observed where funding projects are implemented not because there is a specific need but simply because there is available funding. That is, instead of defining the problem first and then solving it, the approach often becomes: we see there's money available and then find a problem to match it. The biggest challenge is preserving cultural and historical heritage - whether to preserve the old in its original form or to find a new method that combines it with the new. There are often debates about this, especially when the process of restoration involves very expensive efforts, such as using authentic and high-quality materials, techniques, methods, and labor. People may not understand why the costs are so high. Ultimately, they might perceive the expenditure as invisible - everything could seem excessively costly. This means that when implementing such projects, it is crucial to also focus on explanatory work. Society needs to be told and shown what exactly has been done, what has been preserved, what has been restored, and what has been newly built. Only in environments where people expect it can Baukultur thrive. It exists when all stakeholders are involved in the construction process and society at large has a clear understanding and ambition for it. The greatest understanding and ambition must come from the client. Certainly, indifference has not led to the creation of so many masterpieces in the world. An important guiding principle of built culture is investment in the living space of the future. During the 2013–2020 programming period of the EU funds, one of the mandatory elements of the publicity campaign was the slogan "An investment in your future!" Is there not an obvious similarity? Let’s not ignore it!

IV. CONCLUSIONS

There is promising evidence that favourable environmental impacts can lead to positive changes in human behaviour and physiological states. For example, various elements of building design can promote a sense of social identity and the development of social capital. Built culture balances cultural, social, economic, planning, design, construction, adaptive reuse, environmental, and technical aspects. The quality of landscape and architecture shapes urban space, which is also a significant factor not only in tourism development but also in attracting qualified and creative workers to a specific locality. Therefore, it is crucial to increase the interaction between planning, architecture, and construction sectors to create or restore attractive, user-orientated areas that adhere to the principles of built culture. The state, regions, local municipalities, residents, and businesses must collectively address the important task of creating and revitalizing functional and well-designed urban environments. Municipalities need sufficient room for action to responsibly plan, implement, and control environmental development measures, ensuring long-term stability. Given that a significant portion of municipal financial resources invested in infrastructure development or renovation come from European Union funds and initiatives, it is especially important to use these funds in line with the principles of built culture. Undoubtedly, national-level responsible bodies, such as the Ministry of Economics, which oversees the construction sector in Latvia, must also be involved in addressing this issue and supporting municipalities. Only interdisciplinary discussion and cooperation can ensure the preservation of built culture. It is essential to ensure integrated collaboration, not conflict, among the responsible parties. Systematic and structured exchange of experience and knowledge must take place to create sustainable inhabited areas. Europe needs cities and regions where living is comfortable. To make sure that the EU's sustainable development strategy, the Lisbon strategy, the European employment strategy, and the Davos Declaration are all followed, there needs to be a European-level platform for developing and coordinating good practices, statistics, and evaluative research. This platform should also include and coordinate how these issues are updated and dealt with at all levels and sectors.

The EU Cohesion Policy is a significant source of funding for regional development and shapes the geographic and thematic distribution of local regional policy funding over a seven-year planning period. It forms a substantial part of the overall national capital expenditures and funding for national economic development. To ensure that these significant financial resources are invested in line with the principles of built culture, several key aspects need to be considered, as listed below. When preparing the project application, built culture should be established as one of the principles to be adhered to throughout the project's implementation. It is essential to clearly understand the status of the building and/or location where the project's activities will take place, including its value and other critical factors. The project's target group, the local community, and the neighborhood residents should be informed about the planned activities, as they will be the primary consumers of the project's outcomes. In the author’s view, it is not correct to invest in infrastructure or implement project activities solely with the aim of developing a tourism product and increasing tourist flows. The primary environmental consumers are the local community. When considering new functions, they must be compatible with the existing environment, meet the community's needs, and be sustainable. An analysis of existing built culture models can also provide inspiration for how to preserve and build. The quality outcome of any project largely depends on the human resources involved, the methods applied, and the relationships between all stakeholders. To ensure compliance with the requirements for effectiveness and quality, it is essential that all project participants are adequately involved in every stage of the project. Establishing effective communication channels with all parties involved in the project implementation ensures both planned communication and the ability to promptly address issues. The project implementation plan and management structure must be clearly defined and aligned, allowing for adjustments to planned activities and the efficient use of resources. It is crucial to anticipate unforeseen circumstances as much as possible. Funds should be allocated for additional research, material testing, or other unplanned activities. We must fully document, archive, and make available for future use the entire project implementation process.

The system of technical regulations is the foundation of building culture. This system defines the mandatory requirements for all participants in the design and construction process, establishing effective control mechanisms for evaluating compliance with these requirements. To ensure building culture, at least the following three key components are necessary:

- A highly effective system of technical regulations.
- Safe and high-quality materials and technical resources.
- Highly qualified personnel.

The eternal dilemma - the headache of all project managers - faster or better? In the case of EU project implementation, the allotted time often cannot be extended, or can only be extended for a limited period, such as no more than six months, unless it's an exceptional case. Therefore, this limited time frame creates additional pressure for all involved and significantly impacts the quality of construction work. Therefore, it's crucial to engage in extensive and continuous planning. No optimism in procurement - a contract won't be signed in a month. It won't! If this scenario occurs, the contract won't yield any positive results. Don’t be pleased if no questions are asked during procurement - that means the bidder hasn't delved into the requirements, specifications, or construction project. These questions during procurement often help "catch" significant errors in the terms and conditions, technical specifications, or the construction project itself. Losing a

couple of weeks by carefully responding to bidders' questions helps avoid painful and expensive mistakes in the future. The project implementation schedule should also factor in this time. When developing procurement regulations for design/author supervision, construction works, and construction supervision, it is crucial to avoid vague formulations, such as "5 years of experience in similar projects." This already contains at least two contradictions: which specific five years are meant to demonstrate experience (for example, if the procurement is announced in June, does the experience gained up until June of the year of the tender submission count?), and what exactly is meant by similar experience (scope of work, type of work, type of construction, etc.). Procurement requirements, like ensuring maximum energy efficiency on the construction site, are equally debatable. However, it remains unclear whether and how these requirements will be considered when evaluating the bids, and what specific evidence the bidder needs to provide to support them. Unfortunately, there are many such examples of unclear requirements in the regulations. It is crucial for specialists drafting these regulations to maintain complete confidence in each requirement, including its necessity, the supporting documents, and the evaluation process. To ensure that price does not hold too much weight in procurement and is not the determining factor in the decision-making process, the so-called two-envelope system can be used. This system guarantees the separate evaluation of criteria unrelated to price. The goal of this procedure is to ensure neutrality and objectivity when making the decision to award the contract, prioritising quality over price. The evaluation process takes place in two stages: first, the technical proposal is evaluated. In the second stage, only the financial offers of those bidders whose technical proposals have received enough points are considered. This approach ensures a better balance between price and quality.

A crucial aspect in assessing environmental impact is the application of life-cycle cost and life-cycle analysis. By taking environmental, quality, and life-cycle factors into account in the procurement evaluation criteria, these principles make sure that society gets the most for its money.

High-quality building culture:

- It shapes identity and establishes a system in which individuals coexist while still having the chance to secure their own living space.
- The goal is to create cities and settlements that are well-planned, vibrant, and equipped to meet changing social demands while preserving their historical character.
- Encourages people's desire to identify with their city, locality, or region.
- Buildings and landscapes add value by enhancing economic efficiency and external perception.
- Supports sustainable development, playing a crucial role in ensuring prosperity and stability.
- The provision of effective solutions is crucial, as the quality of construction depends on close collaboration and discussions regarding planning, construction, and usage.
- Promotes society's ability to embrace innovation, as large-scale, high-quality projects improve the quality of life for everyone.
- It facilitates a comprehension of the process by which we construct our structures and urban areas, thereby boosting the demand for superior results.

Considering the significant investments from EU funds in infrastructure and their impact on the economies and well-being of member states, the construction sector, with all its sub-sectors, must receive much more attention. Investment in research and development within this sector needs to be increased to respond to society's evolving and growing demands, ensuring the sector's competitiveness both within the EU and globally. It is important to ensure that EU Cohesion Policy programmes are appropriately formulated and include vital issues such as urban environments, quality of life, innovative approaches to construction, and the preservation of cultural heritage, i.e., building culture.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 53-57

Possible Improvements of Saving Bonds in Latvia

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***Abstract*— In the European Union government debt issues are combined with Maastricht requirements, whom the majority of member states are not following. At the same time in the case of Latvia in the summer of 2013 the specific saving bond system were introduces and government started to attract resident investments. From authors perspective the system, where each resident can invest money in its own country is the right direction for country development. At the same time there are world wide experience of saving bond instrument and by having the best world practice, the system can be improved. As the first challenge for government is to understand the quantity of financial resources in the household accounts. That follows by the interest rates for deposits. At the end the government can offer some additional bonus programs, to support its residents from one side, and to receive their votes on next elections from other side. The main thing is the way how households are saving their money, as if there is investments in corporate debt or equity, then, by attracting money for saving bonds, government decreases economic activity. At the same time, if the money comes from deposits, it affects profit of banks and supports diversifications on residents investment portfolios.**

Keywords — Government debt, government debt securities, saving bonds

I. Introduction

The theory of government debt and savings bonds is a fundamental aspect of public finance, focusing on how governments manage their borrowing and the instruments they use to finance expenditures. Government debt is typically issued in the form of bonds, which are essentially promises to repay borrowed funds with interest. These bonds can be broadly categorized into nominal bonds and inflation-linked bonds.

Nominal bonds are fixed-income securities that pay a specified interest rate and return the principal at maturity. However, they are susceptible to inflation risk, as the real value of the interest payments and principal can erode over time due to rising prices. Inflation-linked bonds, such as Treasury Inflation-Protected Securities (TIPS) in the United States, are designed to mitigate this risk by adjusting the principal and interest payments based on changes in the inflation rate[1].

The optimal management of government debt involves balancing the issuance of nominal and inflation-linked bonds. Nominal bonds provide flexibility in terms of monetary policy, as governments can inflate away the debt, reducing its real burden. However, this can lead to higher inflation expectations and increased borrowing costs. On the other hand, inflation-linked bonds offer a commitment to maintaining the real value of the debt, which can help stabilize inflation expectations and reduce the inflation risk premium.[2]

In practice, the share of inflation-linked bonds in a government's debt portfolio is often small. For example, TIPS account for a relatively minor portion of the total U.S. government debt. This is partly due to the liquidity penalty associated with these bonds, as they are less liquid than nominal bonds and may require higher yields to attract investors. Despite this, inflation-linked bonds play a crucial role in providing a hedge against inflation and can be particularly valuable during periods of rising inflation.[3]

The interplay between fiscal and monetary policy is also critical in the context of government debt management. Governments must carefully consider the impact of their debt issuance strategies on inflation and interest rates. By issuing a mix of nominal and inflation-linked bonds, governments can achieve a more balanced approach to debt management, addressing both short-term financing needs and long-term inflation risks.

The theory of government debt also encompasses the concept of intergenerational equity. This principle suggests that the burden of government debt should be distributed fairly across different generations. By issuing long-term bonds, governments can spread the cost of current expenditures over time, ensuring that future generations who benefit from these expenditures also share in their cost.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8654
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However, excessive reliance on debt can lead to higher future tax burdens and reduced fiscal flexibility.

Inflation-linked bonds, such as TIPS, are particularly relevant in this context. They provide a mechanism for governments to commit to maintaining the real value of their debt, thereby protecting future generations from the eroding effects of inflation. This commitment can help build trust in government finances and support long-term economic stability[1].

Moreover, the issuance of inflation-linked bonds can influence investor behaviour and market dynamics. These bonds attract investors seeking protection against inflation, which can help diversify the investor base and stabilize demand for government securities. Additionally, the presence of inflation-linked bonds in the market can provide valuable information about inflation expectations, aiding policymakers in their decision-making processes.

In the European Union, the practice of issuing inflation-linked bonds has been adopted by several member states as part of their debt management strategies. Countries like France, Italy, and Germany have been issuing inflation-linked bonds to diversify their debt portfolios and provide a hedge against inflation. These bonds are typically linked to the Harmonized Index of Consumer Prices (HICP), which is a measure of inflation used across the EU.[4]

France, for example, has been issuing inflation-linked bonds since 1998. These bonds, known as Obligations Assimilables du Trésor (OATi), are linked to the French CPI excluding tobacco. The issuance of OATi has allowed France to attract a diverse investor base, including pension funds and insurance companies, which seek to match their liabilities with inflation-protected assets. Similarly, Italy issues Buoni del Tesoro Poliennali Indicizzati all'Inflazione Europea (BTP€i), which are linked to the European HICP. These bonds have helped Italy manage its debt more effectively by reducing the inflation risk premium and stabilizing borrowing costs.[5]

Germany, known for its conservative fiscal policies, also issues inflation-linked bonds called Bundesobligationen (Bobl€i). These bonds are linked to the European HICP and have been part of Germany's debt management strategy since 2006. The issuance of Bobl€i has provided Germany with a tool to manage inflation expectations and maintain investor confidence in its debt sustainability.

The European Union's approach to inflation-linked bonds highlights the importance of these instruments in achieving a balanced and sustainable debt management strategy. By issuing a mix of nominal and inflation-linked bonds, EU member states can address both short-term financing needs and long-term inflation risks. This approach not only helps stabilize inflation expectations but also supports the broader goals of economic stability and fiscal sustainability.[6]

Saving bonds are popular in the EU for several reasons. Firstly, they are considered safe investments due to the relatively low risk of default, making them attractive to risk-averse investors looking for stable returns. Recent increases in interest rates have made euro area sovereign debt more appealing by offering higher yields compared to other low-risk investments, drawing in both domestic and foreign investors. The resilience of the euro area economy, along with enhancements in the European institutional framework, such as the European Commission's Next Generation EU package, has boosted investor confidence. Additionally, the integration of EU bond markets provides a more unified and stable financial environment, making it easier for investors to diversify their portfolios within the euro area. Bonds are also accessible to a wide range of investors, including households and corporates, providing a relatively safe and attractive option for investing savings.

The popularity of inflation-linked bonds in the EU could increase due to several factors. Firstly, rising inflation expectations make these bonds more attractive as they provide protection against inflation by adjusting the principal and interest payments based on changes in the inflation rate. This ensures that the real value of the investment is maintained, which is particularly appealing during periods of high inflation.

Secondly, the economic policies of the European Central Bank (ECB) and other EU institutions can influence the demand for inflation-linked bonds. For instance, if the ECB adopts policies that lead to higher inflation or if there is increased uncertainty about future inflation, investors may seek out inflation-linked bonds as a hedge.

Additionally, the diversification benefits of inflation-linked bonds can attract investors. These bonds typically have a low correlation with other asset classes, providing a means to diversify investment portfolios and reduce overall risk. This is especially important for institutional investors like pension funds and insurance companies that need to match their liabilities with inflation-protected assets.

Lastly, the growing awareness and understanding of inflation-linked bonds among investors can also contribute to their increased popularity. As more investors become educated about the benefits and mechanics of these bonds, the demand for them is likely to rise.

II. MATERIALS AND METHODS

Measurement of Savings bond system in any country is a challenge, and from theoretical perspective it could be done in comparison to GDP or to other countries. In the case of Latvia the main comparison is made to neighbor countries Lithuania and Estonia, but in this case it is impossible, as in Estonia there is no saving bond system, but in Lithuania the system is based on Defence approach. That means that the money received from the bonds goes to defence direction. In none of three countries saving bond system helps people overcome the fear that their money will be lost due to inflation and United States TIPS approach is not common.

The Euribor 12 month data together with data from Monetary financial institutions account stock are analyzed to understand the situation at the time of analyses. The next thing is to understand the situation with the credit amounts

taken by the households, and if the money in the account decreases and credits are decreasing too, that meant that some money goes to lower dependance from credits.

The main issue is to assess the amount invested in the Saving bonds. As till the end of 2021 the invested money was not impressing, the need for such system could be under discussion from liquidation perspective, like it was done in the case of Lithuania. At the same time changes in the interest rate leads to need for Saving bond systems.

III. RESULTS AND DISCUSSION

Saving bonds system in Latvia is governed by the Treasury of Latvia since 2013. In 2013 it was the way of new approach to investors, who could invest their money, but the interest rates were too low. As the low EURIBOR interest rates lead to lower interest rates for debt securities and saving bonds.

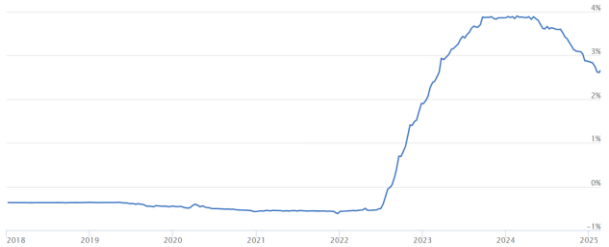

FIG 1. 12 month Euribor from 2018 till 2024 [7]

That leads to the fact, that there is need for commercial banks to follow interest rate changes, and offer higher deposit rates. It can be effective if the price of money is higher via saving bonds them by bank deposits.

TABLE 1 AMMOUNT HELD BY HOUSEHOLD IN ACCOUNTS OF MONETARY FINANCIAL INSTITUTION MIO EUR [8]

Year	Total	Difference to previous year	Euro	Foreign currency
2018	6,926	-	6,343	583
2019	7,442	517	6,918	524
2020	8,395	953	7,865	530
2021	9,671	1,275	9,114	557
2022	10,172	501	9,650	522
2023	10,070	-102	9,626	444
2024	10,978	908	10,513	465

From data in the table we can see, that the amount hold on accounts increased during all the years except 2023, when it was decreased. At the same time the interest rate of Euribor was higher in 2023 than any year before or after.

If there is no connection to increase of Euribor and amount of money on the accounts, there should be another explanation.

From authors perspective there could be explanation from two direction:

Decrease of credit liabilities of households;

Alternative investment options.

From decrease of credit liabilities perspective the data from National Credit register can be used to make assessment of it.

TABLE 2 TOTAL CREDIT AMMOUNT BY HOUSEHOLD IN CREDIT REGISTER REPORTED BY BANKS MIO EUR [9]

Year	Ammount outstanding mio EUR	Difference to previous year	Euro	Foreign currency
2018	5'660	-	5'464	195
2019	5'559	-100	5'388	171
2020	5'413	-147	5'280	133
2021	5'774	361	5'644	130
2022	5'950	175	5'836	113
2023	5'994	45	5'922	72
2024	6'334	339	6'267	66

From the Credit perspective it is understandable that the increase in credit amounts during 2023 was much lower than year before and after. From authors perspective the main reason was high interest rates. The differences during 2019 and 2020 from analyses perspective are hard to assess due to the fact, that when a bank stops its work, they are excluded also from Ammount outstanding. As one of the Latvian biggest bank at that time ended its banking business [15] the difference appeared. At the same time increase on Ammount outstanding in 2021 shows that the PNB bank under liquidation credit takers were attracted by other banks and increased in accordance to linear regression.

Another investment option from safety perspective is saving bonds, as it is issued by the Treasury of Latvia and is paid back in the same way as government debt securities.

One of the factors that is important for investors is Maturity period, as the longer you choose to give the money for government, the less you can use it.

Usually one of the aspects is interest rate, but for saving bonds the previous interest rates are not published or kept in open data, that leads to the fact, that authors can not do analyses of linkage between maturity period, increase of amount outstanding and investors decision in connection to interest rate offered by the governments.

TABLE 3 INVESTMENT PERIOD TILL MATURITY AS OF DECEMBER 2024 [10]

Maturity perod	Ammount of securities in mio EUR	Percentage from total
6 month	10	3.1
12 month	237	73.6
3 years	30	9.3
5 years	19	5.9
7 years	3	0.9
10 years	23	7.1
Total	322	100

Saving bonds by the investment period shows that the majority of investors has made investment for one year, and in such case they need to reinvest after the end of the period. At the same time if the profit will decrease as EURIBOR rate can decrease, the saving bonds can become not as

attractive to the investors as they were during high interest rate periods.

From analyses of the quantity of different investors and total amount borrowed, it is understandable, that the increase in both of the values starts as of 2022, and the biggest increase was during 2023.

At this point in time we can understand, that the popularity of this investment type is the highest possible, but when there were lower interest rates, the investors made their decisions in favor of other investment options.

TABLE 4 SAVING BONDS BY THE AMMOUNT OUTSTANDING [11]; [12]

Year	Ammount outstanding mio EUR	Difference to previous year	Investors
2018	5.5	-	-
2019	5.5	0	-
2020	5.5	0	-
2021	5.5	0	-
2022	14.7	9	>1000
2023	253	238	7200
2024	322	69	7900

From data in the table we can see, that till 2022 the interest in saving bonds was low. There were small investor group, who made some investments.

As of 2023, the investors are 7'200 and in end 2024 7'900, at the same time total population of residents 2023 were 1,883 mio and 2024 just 1,872 mio [13], it leads to the fact that investors from total population were:

*a) End 2023; 7200/1,883*1mio = 0,38%*

*b) End 2024; 7900/1,872*1mio = 0,42%*

From one perspective we can see that the investors could be more, but the increase shows the financial literacy of residents of Latvia and that with good offer from the government perspective, the money for investments will follow it.

TABLE 5 INFLATION IN LATVIA [14]

Year	Inflation during one year	Inflation to year 2018
2018	2.6	2.6
2019	2.3	4.9
2020	-0.5	4.4
2021	7.9	12.6
2022	20.8	36.1
2023	0.6	39.6
2024	3.3	41.4

As an alternative approach toward saving bond attraction can be not to give good interest rates, but to give social or political or economical reason for households to do the investments.

In the case of Lithuania, the saving bond system existed from 1999 till 2021. As the resident willingness to invest in saving bonds was too low, the system was closed as of 01.01.2022. At that point in time the international financial markets offered more attractive coupon rate that the government of Lithuania to their residents.

At the same time, one of possible usage of saving bond system, is to attract the money for certain goal. That led to the fact that on 07.08.2023 the saving bond system was reopened. The main difference was political, as there was no more possibilities just to invest in government, but the investment were directly linked to defence goals of the country. [16]

IV. CONCLUSIONS

Results:

1) In accordance to Table 4., during year 2023 and 2024 the saving bonds in the case of Latvia were bought by resident households more than ever before. The number of total amount attracted by the government increased dramatically, and the number of investors also increased.

2) In accordance to Figure 1., during year 2023 and 2024 the Euribor rate increased extra high, and that led to increase of saving bond coupon rates.

3) It is not possible to make assessment on the connection to price of saving bonds, as such data are not published by the government and no data portals provide it.

4) In the case of Lithuania, the saving bond system was closed from 01.01.2022 till 07.08.2023. At the same time it is much easier to reopen system that was some years ago, than to start development of new system. From theoretical point of view it is better to have system, as in the case of urgent need for debt, the money should be able for lower interest rate, than the system were not at all.

5) In the case of Lithuania new direction of saving bonds were implemented – defence saving bonds. It shows, that not always the interest is important, but sometimes the goal of money usages is over the coupon.

6) In accordance to Table 2 and description below it, usage of data from credit register is complicated, from one side we can assess that the total amount outstanding of credits from banks to households increases. At the same time if the bank looses its license, the total amount can decrease for some period, as it is no longer banks credit, but in certain time (one to two years) households are refinancing the credit from other bank and the statistics of credit shows it again.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 59-67

Enhancing National Innovation Frameworks Through Open Innovation: a Theoretical Approach to Integrating Open Innovation Principles into the European Innovation Scoreboard

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***Abstract*- Despite the growing prominence of Open Innovation (OI) in business and policy, National Innovation Metrics (NIM) remain largely rooted in traditional, firm-centric models, failing to capture ecosystem-wide collaboration and knowledge exchange This study critically examines how OI is integrated - or overlooked - within major Innovation Measurement Frameworks (IMF), particularly the European Innovation Scoreboard (EIS), Global Innovation Index (GII), and Bloomberg Innovation Index (BII). Findings reveal that existing innovation scoreboards prioritize input-output indicators (e.g., R&D expenditure, patenting) while neglecting systemic, network-driven innovation dynamics. The continued absence of OI-specific metrics reinforces a "black box" effect, where national innovation success is assessed without visibility into knowledge flows and collaborative innovation mechanisms. This study contributes to rethinking NIM by advocating for a shift from closed-system assessments to dynamic, network-based measurement models. By bridging innovation policy, measurement theory, and OI research, it provides a foundation for future empirical studies on integrating OI indicators into national benchmarking frameworks, ensuring more accurate assessments of Innovation Ecosystem (IE) performance.**

Keywords- European innovation scoreboard; innovation ecosystems; national innovation metrics; open innovation measurement

I. INTRODUCTION

In today's interconnected global economy, fostering innovation-driven growth has become a key priority for governments and policymakers [1], [2], [3], [4]. Innovation is widely recognized as a catalyst for regional economic resilience and competitiveness, playing a fundamental role in shaping industries, advancing technological progress, and addressing global challenges [5], [6], [7], [8]. The rapid advancement of digital transformation is increasingly being recognized as a crucial driver of OI, enabling more dynamic knowledge flows and collaboration between ecosystem actors. To capture these dynamics, countries develop National Innovation Frameworks (NIF) [9], [10], [11], [12]. which define policies, funding mechanisms, and institutional structures that support innovation activities at the national level. These frameworks aim to translate investments in R&D, education, and technological infrastructure into tangible economic and societal benefits [13], [14].

Despite their importance, NIF remains largely opaque in terms of how they function and deliver innovation outcomes. Many such frameworks continue to operate as "black boxes", see figure 1., a concept introduced by Ashby [9] in cybernetics, which describes systems where inputs (such as R&D funding, collaboration incentives, skilled talent, or regulatory policies) and outputs (such as patents, startups, exports, or productivity growth) are visible, but the internal mechanisms driving these transformations

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8625
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remain unclear. This lack of transparency hinders policymakers' ability to optimize national innovation strategies, leading to inefficiencies in how resources are allocated and how innovation policies are designed.

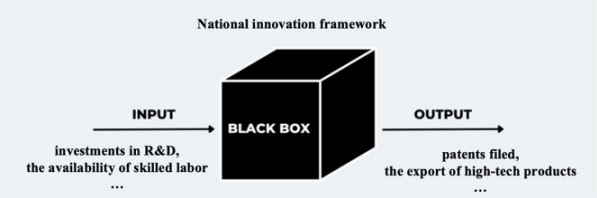

Fig. 1. The black box representation of the National Innovation Framework (NIF) in the European Innovation Scoreboard (EIS). Author created.

One of the key challenges in understanding NIF is their reliance on traditional innovation metrics. Existing national and regional innovation benchmarking tools, such as the EIS, primarily evaluate innovation performance based on input-output indicators like R&D intensity, patent activity, and high-tech employment rates [5]. While these metrics provide valuable insights, they fail to account for the increasingly open, collaborative, and ecosystem-driven nature of modern innovation [4].

A. Role of OI *in transforming NIM*

A significant body of research has shown that innovation is no longer confined within individual firms or research institutions but is instead driven by collaborative networks, knowledge exchange, and open platforms [1], [8]. This shift is encapsulated in the OI paradigm, which emphasizes the importance of external knowledge flows, co-creation, and ecosystem-wide innovation processes [15].

Despite its growing prominence, OI remains underrepresented in how national innovation performance is measured. Current NIM does not adequately reflect:

- Collaboration intensity – the extent to which businesses, universities, and governments engage in co-creation and cross-sector partnerships.
- Knowledge exchange effectiveness – the degree to which knowledge flows across organizational, regional, and national boundaries.
- Systemic Innovation Outcomes – the broader impact of collaborative innovation on long-term economic growth, technological diffusion, and societal well-being.

This paper argues that enhancing NIM through OI is essential to improving how countries perform in the EIS. As IEs become more interconnected and cross-disciplinary, it is imperative that measurement frameworks evolve beyond traditional firm-centric and R&D-based indicators. The growing complexity of national innovation strategies calls for a more holistic, transparent, and dynamic approach to assessing innovation performance, particularly in the context of the EIS.

B. Bridging the gap between OI and NIM.

The European Union's Smart Specialization Strategy (RIS3) has made significant progress in aligning regional innovation policies with localized strengths, emphasizing the need for place-based innovation strategies [11]. While RIS3 has provided a framework for regional innovation-driven development, disparities persist in how different types of regions—Leader, Moderate, and Modest Innovation Regions—capitalize on OI principles [5]. These disparities suggest that a more refined set of OI indicators is needed to assess how different NIF contribute to innovation performance at the European level.

This paper, therefore, sets the stage for a deeper exploration of how OI can transform NIM, making them more reflective of the real drivers of innovation success. By doing so, this study lays the foundation for further author research, which will focus on the specific methodologies and tools required to measure OI's impact more effectively.

It is important to emphasize explicitly that this article constitutes the initial, conceptual groundwork intended to identify theoretical gaps and provide foundational insights for improving innovation measurement frameworks. Therefore, specific practical recommendations, empirical validation, and concrete methodological approaches, while recognized as highly relevant, are deliberately not covered here but are currently being addressed comprehensively in a subsequent empirical study by the authors, which is already underway.

By bridging the gap between policy-level innovation measurement and OI research, this study aims to contribute to the development of more transparent, evidence-based national innovation policies that support both ecosystem resilience and European competitiveness.

II. MATERIALS AND METHODS

Given the interdisciplinary nature of this research, this study employs a systematic literature review (SLR) methodology, as outlined by Tranfield, Denyer, and Smart [16], to ensure a transparent, replicable, and comprehensive analysis.

To structure the review effectively, this study synthesizes existing academic contributions on three key themes:

- IMF – evolution of innovation metrics from linear models to systemic and networked approaches.
- The OI paradigm – theoretical underpinnings and empirical findings on OI's role in enhancing knowledge flows and innovation outcomes.

- IEs –networked and multi-actor nature of innovation, emphasizing collaboration and interdependencies.

This review follows a four-stage process:

Selection of sources – peer-reviewed journal articles, books, and policy reports were sourced from Scopus, Web of Science, and Google Scholar, alongside policy documents from the European Commission and OECD.

- Search strategy – Boolean search queries used terms such as "OI measurement," "innovation ecosystems," "regional innovation indicators," and "collaborative knowledge flows."
- Thematic categorization – studies were classified based on their conceptual, empirical, and methodological contributions.
- Comparative analysis – findings were critically analyzed for commonalities, divergences, and methodological gaps.

By following this structured approach, this section establishes a comprehensive and well-argued foundation for the need to improve IMF by integrating OI principles.

A. IMF: From linear to systemic models

Early IMF were rooted in linear models, where innovation followed a sequential path from R&D investment to commercial output [17]. This perspective is reflected in traditional indicators such as patents, R&D expenditures, and technology diffusion rates [18], [19].

Critiques of the linear model emerged as innovation processes became more complex, interactive, and network-driven. Scholars such as Lundvall [7] and Edquist [20] argued that national innovation systems (NIS) must be understood as networks of interacting actors, rather than simple input-output relationships. This systemic perspective was later extended by OECD's Oslo Manual [17], which emphasized knowledge flows, institutional interactions, and collaborative dynamics as key drivers of innovation.

Despite these advancements, most national and regional innovation frameworks still prioritize traditional R&D and firm-centric indicators, which do not sufficiently capture the role of external knowledge-sharing and cross-organizational collaboration—fundamental principles of OI [1], [2].

Thus, while systemic models acknowledge the importance of interaction, they still lack metrics that specifically assess OI processes such as knowledge co-creation, external collaboration, and ecosystem-wide value generation [8]. This gap suggests a need to extend current measurement frameworks by incorporating OI-specific dimensions.

B. OI paradigm: From firm-level strategy to ecosystem thinking

OI was first conceptualized by Chesbrough [1] as a model in which firms rely on both internal R&D and external knowledge sources to drive innovation. This approach challenged the closed innovation model, which assumed that firms should internally develop and control the entire innovation process [1].

Scholars such as West & Bogers [8] and Radziwon & Bogers [12] later expanded the OI model by analyzing its applicability beyond firm-level strategy, emphasizing collaboration networks, inter-organizational knowledge exchange, and open-source innovation. Their research demonstrated that firms engaged in OI achieve higher innovation performance due to their ability to access external expertise, markets, and funding opportunities.

There are several opposing views that exist:

- Laursen & Salter [22] argue that while OI enhances innovation speed, it may also lead to increased complexity and knowledge leakage risks.
- Dahlander & Gann [4] suggest that firms engaging in OI must carefully balance inbound and outbound innovation activities, as excessive openness may dilute competitive advantage.
- Cheng & Huizingh [28] provide empirical evidence that OI's effectiveness varies significantly across industries, with technology-intensive sectors benefiting more than low-tech industries.

Despite these debates, there is strong agreement in the literature that OI provides a fundamental shift in innovation theory, requiring new measurement approaches that extend beyond traditional firm-level indicators [2]. The challenge remains: how can we systematically measure OI's impact at the regional and ecosystem levels?

C. IEs: A multi-actor perspective on OI

The concept of IEs builds upon the networked nature of innovation, emphasizing how diverse actors co-create value in a shared environment [10], [21]. Unlike firm-centric models, ecosystem theory focuses on interdependencies among businesses, academia, government, and users [7].

Key contributions to this field include:

- Adner [10] – introduced the concept of ecosystem orchestration, where firms must coordinate resources beyond their own boundaries.
- Gawer & Cusumano [22] – studied platform ecosystems, showing how digital platforms facilitate OI through ecosystem-wide knowledge sharing.
- Jacobides et al. [21] – developed a theoretical framework for ecosystem dynamics, emphasizing organized interdependencies and strategic alignment.

While case studies provide rich insights, they do not enable comparative analysis across regions, limiting their usefulness for policy development and benchmarking alone[2].

Thus, while the ecosystem theory has significantly advanced our understanding of innovation networks, its integration with OI measurement frameworks remains underdeveloped.

D. Identifying the research gap: Towards a measurement framework for OI in IE

Despite extensive research on innovation measurement, OI, and IEs, a significant gap remains in understanding:

- How can OI's impact be systematically measured beyond the firm and other IE stakeholders' level?
- Which specific dimensions of OI should be integrated into innovation benchmarking frameworks?
- What existing measurement tools (e.g., EIS) can be adapted to capture OI's role in ecosystem-wide innovation success.

Although previous scholars have examined OI at the firm level, few studies have developed quantifiable indicators that link OI to regional innovation performance [2]. Moreover, while ecosystem theory provides insights into collaborative innovation, it lacks standardized assessment models that allow policymakers to measure and compare OI across different regions [21].

This research aims to bridge these gaps by establishing a conceptual framework that identifies what aspects of OI should be measured in IEs.

III. Results and Discussion

A. Research design

This research is structured as a qualitative, conceptual study, employing an SLR and comparative analysis to examine how OI is integrated into IEs and measured through global innovation scoreboards. This study represents the first stage of a broader research agenda, focusing on theoretical foundations and comparative metric analysis rather than conducting an in-depth evaluation of National Innovation KPIs or EU policy frameworks.

This research follows a two-pronged approach:

- SLR – to synthesize existing academic perspectives on IEs, OI, and innovation measurement methods.
- Comparative analysis of innovation scoreboards (EIS, GII, Bloomberg Index) – to evaluate how different frameworks measure innovation performance and assess whether OI principles are adequately represented.

By combining these methods, the study provides a structured theoretical foundation that will guide future research in developing more comprehensive OI measurement frameworks.

A.1. SLR

SLR was conducted following the approach of Tranfield, Denyer, and Smart [16] to ensure a structured, transparent, and replicable research process. The literature review focuses on:

- IEs – understanding their structure, key actors, and interdependencies [10], [21].
- OI – examining its theoretical foundations and role in driving ecosystem-wide innovation [1], [2].
- Innovation measurement methods – reviewing past research on how innovation is quantified and assessed across different contexts [18].

SLR Process

Databases selected (Scopus, Web of Science, and Google Scholar) were specifically chosen due to their broad coverage, authoritative reputation, and extensive indexing of high-quality, peer-reviewed sources. Priority was given to articles published in highly cited academic journals, frequently referenced policy reports from reputable institutions, and influential foundational works essential for understanding the historical and theoretical context of innovation measurement.

- Database selection – peer-reviewed journal articles, books, and reports were sourced from Scopus, Web of Science, and Google Scholar.
- Search strategy – Boolean search queries were used with keywords: *"OI measurement," "innovation ecosystems," "innovation scoreboards," "European Innovation Scoreboard,"* and *"innovation policy assessment."*
- Inclusion criteria – literature published in high-impact academic journals and policy reports from the European Commission, OECD, and World Economic Forum.
- Thematic categorization – sources were categorized based on their contribution to:
    - Conceptual models of IEs
    - Empirical evidence on OI's role in national frameworks
    - Comparative analyses of IMF

This structured approach ensures a rigorous synthesis of existing research while identifying gaps in current innovation measurement methods.

A.2. Comparative analysis of global innovation scoreboards

To understand how OI is currently represented in global innovation assessment frameworks, a comparative analysis of the following three scoreboards was conducted:

- European Innovation Scoreboard (EIS) –EU's primary benchmarking tool for innovation performance.
- Global Innovation Index (GII) – worldwide ranking system that evaluates innovation capacity across multiple dimensions.
- Bloomberg Innovation Index – business-focused ranking system that emphasizes technological advancement and economic competitiveness.

Comparative Analysis Process

1. Metric identification – key indicators from each scoreboard were categorized based on:
    a. Innovation inputs (e.g., R&D expenditure, human capital, education).
    b. Innovation outputs (e.g., patents, new business formation).
    c. Collaboration & knowledge-sharing indicators (to assess the inclusion of OI dimensions).
2. Gap analysis – frameworks were compared to evaluate:
    a. The extent to which OI principles are incorporated.
    b. Differences in how IEs are measured across frameworks.
    c. Limitations in existing metrics, particularly in capturing cross-sector collaboration and knowledge exchange.

This comparative analysis identifies gaps in how OI is quantified and benchmarked at national and regional levels, reinforcing the need for rethinking NIM to integrate OI principles.

B. Scope and limitations

This research represents the first phase of a broader investigation into OI measurement. At this stage research covers:

- Theoretical and comparative analysis, rather than empirical testing of specific KPIs.
- National Innovation KPIs and EU policy analyses are beyond the immediate scope but will be explored in future research stages.
- Limitation to secondary data sources, primarily academic literature and official reports, rather than conducting new data collection at this stage.

Despite these limitations, the study provides a robust foundation for rethinking how NIF can be adapted to better measure OI's impact on ecosystem performance. Empirical validation, practical examples, and concrete methodological approaches are planned for the next phase of this research, currently underway

C. Results

C.1. OI and its limited integration in NIF

SLR highlights a growing recognition of OI as a key driver of IE success. Research by Chesbrough [1], Bogers et al. [2], and West and Bogers [8] emphasize that OI fosters knowledge sharing, cross-sector collaboration, and ecosystem-wide technological development. Despite this, NIF continues to rely predominantly on traditional input-output models, such as R&D intensity, patent filings, and high-tech employment, as primary indicators of innovation performance [17].

A key limitation identified in the literature is the lack of systemic integration of OI principles within national policy frameworks. While firms increasingly adopt OI strategies, national innovation measurement models remain largely firm-centric, failing to account for inter-organizational knowledge flows and open collaboration mechanisms [23]. This disconnect suggests that while OI is widely acknowledged as a transformative approach, it is not yet reflected in the core metrics used by national innovation policymakers.

Moreover, the literature confirms the "black box" problem in NIS. Innovation policies often focus on tangible inputs and outputs without systematically capturing how knowledge is created, transferred, and utilized within national ecosystems [24]. This opacity hinders the ability of policymakers to understand the true impact of OI strategies and makes it difficult to optimize innovation governance structures.

In addition to theoretical limitations, empirical research on OI's role in national innovation performance remains scarce. While certain regional strategies, such as the EU's Research and Innovation Strategies for RIS3, acknowledge the importance of open and collaborative innovation [9], no standardized NIF exists for measuring the extent to which OI influences macroeconomic innovation performance. This gap highlights the need for a re-evaluation of NIM to better reflect the realities of modern, networked innovation systems.

C.2. Comparative analysis of innovation scoreboards

A comparative analysis of three major innovation benchmarking tools—the EIS, GII, and the BII —reveals significant variations in how innovation is assessed at the national and regional levels. While these frameworks offer structured methodologies for evaluating innovation capacity and performance, their alignment with OI principles remains limited.

The EIS , the EU's primary tool for assessing regional innovation performance, places a strong emphasis on firm-level outputs, such as R&D expenditure, SME innovation activity, and patent intensity [3]. On other hand, EIS includes only a limited number of indicators related to knowledge exchange and collaboration, meaning that OI's systemic effects remain underrepresented.

GII incorporates a broader set of indicators, including knowledge creation, business sophistication, and institutional support for innovation [6]. Compared to EIS, GII offers a more comprehensive assessment of

collaborative innovation, capturing cross-border knowledge flows and the role of university-industry partnerships. Despite this, GII still relies heavily on macro-level innovation inputs and outputs, rather than evaluating ecosystem-wide OI processes.

TABLE 1 COMPARATIVE SUMMARY OF INNOVATION SCOREBOARDS. AUTHOR CREATED

Indicator category	*EIS*	GII	*BII*	*OI representation*
Firm-level R&D & patents	High	High	Very High	Minimal
Knowledge collaboration	Low	Moderate	Low	Limited
Ecosystem-level innovation	Limited	Moderate	Low	Lacking
OI practices	Not included	Some metrics	Not included	Underrepresented

The BII adopts a more technology-driven approach, ranking economies based on high-tech density, R&D intensity, and patent activity [25]. While useful for tracking technological progress, this framework largely ignores collaborative and ecosystem-driven innovation. The absence of OI-specific metrics suggests that Bloomberg's methodology remains rooted in closed innovation models, failing to reflect the increasing importance of external knowledge exchange in national innovation success.

A comparative synthesis of these three scoreboards confirms that none of the major IMF fully capture OI's systemic impact. While some indicators related to collaboration and knowledge transfer exist, they remain peripheral rather than central to innovation assessment methodologies.

C.3. Gaps in measuring OI within NIF

The findings from both the literature review and comparative analysis highlight three major gaps in how OI is currently measured at the national level [26]. First, NIM continues to prioritize traditional firm-centric indicators rather than systemic, network-based measures of innovation success [7]. Metrics such as R&D intensity and patent filings, while useful, fail to capture how knowledge flows between ecosystem actors, how firms co-create innovations, or how open collaboration enhances national [8].

Second, current measurement frameworks lack transparency in tracking the effects of OI policies. The "black box" problem persists in both national and regional innovation assessments, as policymakers struggle to measure the causal links between investment in OI strategies and long-term innovation outcomes [9]. Without clearer methodologies, it remains difficult to determine how OI practices translate into national innovation success or to compare countries based on their ability to leverage OI principles [12].

Finally, OI remains an underdeveloped concept in major global innovation scoreboards. Although frameworks such as the GII partially integrate collaboration-based indicators, neither the EIS nor Bloomberg Index fully reflects the role of OI in shaping regional and national innovation competitiveness. This gap underscores the need for rethinking NIM, integrating ecosystem-wide indicators that go beyond traditional R&D-driven assessments.

D. Discussion

D.1. Rethinking NIM

The results of this study reveal a persistent misalignment between NIM and the realities of OI [27]. While existing measurement frameworks continue to emphasize firm-centric, input-output models [17], [26] author in this research challenges the assumption that national innovation success can be adequately assessed through R&D intensity, patent counts, and firm-level technological outputs alone. This study highlights the systemic and collaborative nature of modern innovation, arguing that NIF must evolve to capture ecosystem-wide knowledge flows, co-creation mechanisms, and open collaboration models [1], [8].

This research contributes to the field by offering a conceptual rethinking of how OI should be integrated into national and regional IMF. Rather than accepting the traditional indicators as given, this study critically examines how these indicators fail to account for new forms of value creation in open and digital IEs. In doing so, it opens new pathways for developing measurement methodologies that reflect contemporary innovation practices, setting the stage for future empirical validation.

A central argument presented in this study is that NIM currently functions as "black boxes," where policymakers can observe innovation inputs and outputs but lack visibility into the knowledge dynamics that drive innovation success [9], [24], [29]. This conceptual limitation has serious policy implications: it distorts national innovation assessments, obscures the impact of OI practices, and limits the effectiveness of government intervention strategies. By bringing this issue to light, this research provides a new framework for understanding the missing dimensions in innovation measurement, reinforcing the urgency of rethinking NIM at both theoretical and policy levels.

D.2. Addressing the gaps in IMF

The comparative analysis of innovation scoreboards (EIS, GII, Bloomberg Index) underscores the inadequacy of existing measurement tools in capturing OI dynamics. While frameworks like the GII partially incorporate indicators related to knowledge sharing and collaboration, others, such as the EIS and Bloomberg Innovation Index, remain largely focused on traditional firm-centric measures [6], [25].

This study contributes to the field by systematically mapping where and how these frameworks fail to measure OI adequately. The results indicate that:

- Current national and regional scoreboards lack standardized indicators for tracking OI-driven collaboration, knowledge mobility, and co-creation dynamics.
- IEs rely increasingly on digital platforms, cross-sector partnerships, and open knowledge-sharing models, yet these are not reflected in major benchmarking tools.
- The EIS does not systematically assess how OI influences national innovation rankings, despite EU-level policies actively promoting OI principles (e.g., RIS3, Horizon Europe).

By making these gaps explicit, this study provides a foundation for rethinking how national and regional innovation frameworks should evolve, moving beyond static indicators toward more dynamic, relational, and network-based measurement methodologies [30], [31].

D.3. Need for a conceptual shift in national innovation policy

From a policy perspective, the findings suggest that the current approach to national innovation assessment is fundamentally outdated. Many national governments continue to rely on rigid, linear models of innovation measurement, assuming that increasing R&D spending or patent activity will automatically translate into broader economic and technological success [14], [31], [32], [33]. Yet, OI research has demonstrated that innovation is increasingly driven by external knowledge flows, inter-organizational collaboration, and digital ecosystems [2].

This study makes an original contribution by conceptually bridging the gap between OI theory and national innovation policy, proposing that:

- Innovation policies should prioritize openness and connectivity, rather than just internal firm capabilities.
- National innovation rankings should shift from closed-system assessments toward measuring how effectively countries leverage external knowledge and collaboration networks.
- Governments should incentivize open R&D partnerships, platform-based IEs, and transnational knowledge-sharing models.

By presenting these arguments, this research challenges the prevailing assumptions that underpin national innovation governance. It provides a new theoretical foundation for future policy-oriented studies that can further refine how OI is embedded in national and regional innovation policies.

IV. Conclusions

Innovation has long been considered the foundation of economic growth and technological advancement, yet the methods used to measure its success remain deeply rooted in traditional paradigms. This study critically examined the discrepancies between OI and NIM, highlighting the persistent reliance on firm-centric, input-output models that fail to capture the complex, networked, and knowledge-driven nature of modern IEs. The findings underscore that, despite the increasing importance of collaboration, external knowledge absorption, and digital ecosystem interactions, NIF and global innovation benchmarking tools still lack standardized mechanisms to assess these dynamics.

Through an extensive review of literature and a comparative analysis of three major innovation scoreboards—EIS, GII, and BII —this study identifies significant gaps in how OI is incorporated into national and regional assessments of innovation performance. While some frameworks, such as the GII, integrate elements of knowledge mobility and ecosystem connectivity, the prevailing methodologies continue to prioritize traditional indicators such as R&D expenditure, patent activity, and high-tech employment, leaving OI largely invisible within the dominant measurement frameworks.

These findings point to a fundamental challenge in national innovation governance. If innovation policies continue to rely on outdated indicators, they risk misrepresenting the actual drivers of competitiveness and technological progress. Countries that excel in fostering collaborative innovation, cross-sector knowledge flows, and open business models may not see these strengths reflected in their innovation rankings, leading to potential misallocation of resources and misguided policy interventions. The issue is not simply one of measurement but of policy relevance—an inability to assess OI accurately translates into an inability to govern it effectively.

A key contribution of this research is the conceptual reframing of NIM in light of OI theory. By drawing from both theoretical insights and empirical shortcomings in existing innovation scoreboards, this study argues that innovation should no longer be assessed solely within the boundaries of firms or national economies but as a product of dynamic, interdependent networks of actors engaging in collaborative knowledge creation. This perspective challenges the dominant innovation assessment models, calling for a fundamental restructuring of how innovation success is conceptualized, measured, and benchmarked at both national and regional levels.

Analysis also raises broader questions about the role of transparency and adaptability in innovation measurement. The continued reliance on static, linear models of innovation evaluation fails to account for the fluidity and openness that characterize contemporary IEs. Without rethinking these assessment tools, innovation measurement risks becoming a black box, where inputs

and outputs are visible, but the actual mechanisms of innovation—how knowledge moves, how networks evolve, how collaborations drive technological advancement—remain obscured. The study, therefore, calls for a shift towards more transparent, ecosystem-based measurement frameworks that not only track innovation outputs but also the conditions and interactions that enable them.

Despite these contributions, the study acknowledges several limitations. Given its conceptual nature, this research does not empirically validate new OI indicators or propose a quantitative model for measuring OI's impact on national innovation performance. Instead, it serves as a foundational step in establishing the theoretical and methodological groundwork for future empirical research. Furthermore, while the comparative analysis of innovation scoreboards provides valuable insights, a deeper investigation into the specific methodologies used by national governments to assess innovation performance would offer further clarity on the policy implications of this study's findings. These limitations, however, also indicate pathways for future research. As IEs continue to evolve, developing new OI measurement methodologies will be essential to ensuring that national and regional policies remain relevant and effective. The challenge ahead lies not only in rethinking what is measured but also in determining how best to capture the evolving nature of innovation in a way that is both empirically rigorous and policy-actionable. This research has laid the groundwork for such an endeavor, setting the stage for further inquiry into how OI can be systematically incorporated into NIM and the EIS.

As the global economy becomes increasingly knowledge-driven, the ability to measure and govern OI effectively will become a defining factor in national and regional competitiveness. Countries that succeed in integrating ecosystem-wide innovation indicators, collaboration metrics, and open knowledge flows into their policy frameworks will likely emerge as leaders in innovation performance. For this to happen, measurement frameworks must evolve in tandem with the innovation systems they seek to assess, ensuring that policy decisions are based on a complete and accurate understanding of what drives sustainable innovation in the 21st century. By incorporating OI principles, these frameworks can better reflect the interconnected nature of modern IEs and strengthen the NIS. This alignment ensures that innovation policies not only track performance but also actively support systemic collaboration, knowledge flows, and long-term competitiveness.

This study has contributed to shaping the discourse on innovation measurement by challenging the assumptions embedded in existing frameworks and advocating for a more holistic, OI-driven approach. While much remains to be done, the findings presented here reinforce the urgency of rethinking how we define, assess, and ultimately enable innovation at the national and global levels. The next phase of this research will focus on developing concrete methodologies for measuring OI's impact on NIF, ensuring that future innovation policy is informed by the realities of contemporary IEs rather than outdated economic models.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 69-74

The Potential of Supervision in Restoring Work Capacity in Individuals with Chronic Back Pain Conditions

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***Abstract*-Chronic back pain is a prevalent issue that significantly affects individuals' work capacity, general well-being, and economic productivity. Supervision, defined as a structured consultative support system, has been shown to play a crucial role in improving workforce reintegration by addressing psychosocial factors, motivation, and adaptation to workplace conditions. This study examines the necessity and impact of supervision in the rehabilitation process for individuals with chronic back pain, analysing its effectiveness in reducing psychological barriers, enhancing resilience, and improving work ability. The findings indicate that lower self-assessed health status correlates with increased demand for professional supervision, while satisfaction with rehabilitation services reduces the necessity for such support. The results suggest that supervision should be integrated as an essential component of rehabilitation programs for individuals with chronic conditions. Future research should further explore how supervision can enhance workforce reintegration, particularly by aligning rehabilitation strategies with economic development goals and the adoption of new eco-technologies in the workplace. Investigating the role of sustainable work environments and innovative technological solutions in supporting long-term employability could provide valuable insights for optimizing interdisciplinary rehabilitation approaches.**

Keywords- supervision, chronic back pain, rehabilitation, work capacity, employee well-being, workplace adaptation

I. Introduction

Chronic back pain is among the most prevalent health conditions on a global scale, contributing to significant economic and social burdens. Many affected individuals experience prolonged periods of incapacity from work, reduced productivity, and impaired quality of life [1], [2]. Conventional medical interventions primarily focus on physical symptoms, often neglecting psychological and emotional aspects that are critical for successful rehabilitation [3]. The biopsychosocial model of health posits that chronic pain is influenced not only by biological factors but also by psychological and social determinants [4]. This holistic perspective underscores the necessity of integrating physical, mental, and social support mechanisms in rehabilitation to ensure sustainable recovery [5]. Supervision, as a structured professional support system, plays a crucial role in addressing these multifaceted challenges. It provides guidance, emotional support, and practical strategies that help individuals navigate workplace challenges, regain motivation, and restore functional capacity [6]. Research has demonstrated that supervision can facilitate coping strategies for individuals experiencing pain-related distress, reduce workplace anxiety, and improve self-efficacy in returning to professional duties [7]. Furthermore, evidence suggests that individuals with greater psychosocial support exhibit higher adherence to rehabilitation protocols and report better health outcomes compared to those without such support systems [8].

Latvia, like many other countries, faces increasing challenges in managing chronic musculoskeletal disorders. According to national health statistics, musculoskeletal conditions, including chronic back pain, are among the leading causes of long-term work incapacity [9]. Despite the availability of rehabilitation services, patient satisfaction with these services varies, and many individuals report difficulty reintegrating into the workforce due to unresolved psychological and social concerns [10]. The traditional biomedical approach in Latvian healthcare often prioritizes symptomatic treatment, overlooking the psychological distress and work-related anxieties experienced by patients with chronic pain conditions [11]. This gap in care highlights the need for

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8681
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more comprehensive rehabilitation strategies that incorporate supervision and psychosocial support.

One of the key barriers to returning to work for individuals with chronic back pain is fear-avoidance behavior, which contributes to prolonged inactivity and exacerbates disability. Studies indicate that individuals with heightened fear of movement or work-related tasks are at greater risk of developing chronic disability and psychological distress [12]. Supervision provides a structured space where individuals can address these fears, receive constructive feedback, and develop strategies to gradually reintegrate into their professional roles. Additionally, workplace-based supervision can foster a supportive organizational culture, reducing stigma around chronic pain conditions and encouraging open communication between employees and employers [13]. A crucial aspect of work reintegration is employer involvement. Research highlights those employees who receive workplace support, including flexible work arrangements, ergonomic adjustments, and regular supervision, report higher job satisfaction and lower rates of absenteeism [14]. In Latvia, employer engagement in rehabilitation remains limited, with many organizations lacking formal return-to-work programs. Encouraging a culture of support and supervision in the workplace could significantly improve long-term rehabilitation outcomes and prevent work disability [15].

The aim of the study is to investigate the need for professional counselling support (supervision) in the rehabilitation process of people with chronic back disorders in order to provide suggestions for activities in the process of recovery.

II. MATERIALS AND METHODS

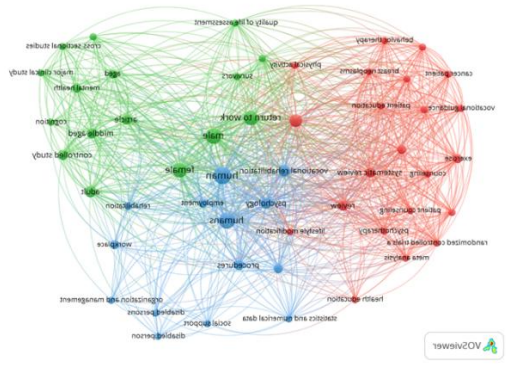

Fig.1 Network visualization of key terms.

Figure 1. Shows the network visualization of key terms related to “rehabilitation,” “work capacity,” “psychosocial support,” “economic development,” and “workplace reintegration” in analyzed studies (2015–2025, Europe). The red cluster represents psychological and behavioral aspects, the green cluster focuses on demographic and health-related factors, and the blue cluster highlights statistical, procedural, and organizational elements. The central term “return to work” indicates strong interdisciplinary connections. Developed by the authors using VOSviewer (based on 23 documents). This network analysis demonstrates a close correlation between the concepts of rehabilitation, recovery and psychosocial support, and a range of medical, behavioural and organisational factors. This emphasises the necessity for a multidisciplinary approach to workforce reintegration and economic development.

The present study employs a cross-sectional quantitative design to investigate the relationship between supervision and work capacity restoration. The survey was distributed electronically from 11 November 2024 to 2 January 2025 via online platforms and anonymity was ensured to reduce the influence of social desirability on the responses. Permission was obtained from the Ethics Committee of the Latvian Association of Physiotherapists before the survey was distributed. The survey was also published on the website of the Latvian Association of Physiotherapists. The research sample comprises individuals aged 18 to 64, categorised as working age, who had previously experienced back pain during the preceding year. Data were collected through standardised health-related quality of life surveys (EQ-5D) [16] and fear-avoidance belief questionnaires (FABQ) [12]. Statistical analyses included Spearman's correlation and regression modelling to identify significant associations between supervision needs and variables such as self-assessed health status, fear of physical activity, fear of workplace reintegration, and satisfaction with rehabilitation services.

Self-assessed health status exhibited a Cronbach's alpha of 0.79, Fear of pain at work - 0,80, Fear of pain during physical activities - 0,85, Satisfaction with rehabilitation services – 0,76, indicating good internal consistency.

III. RESULTS AND DISCUSION

A total of 85 respondents were accepted to participate in the study. The demographic data of the respondents is summarised in Table 1. Furthermore, an examination of the geographical distribution of respondents indicates that the Riga region (43,5%) accounts for the largest proportion of participants, followed by the Vidzeme region (19,2%), which exhibits a notable representation. In contrast, respondents from Kurzeme, Zemgale and Latgale are present, though in smaller numbers. An analysis of the respondents' educational attainment reveals a preponderance of higher education (77%) among the study's participants. The distribution of respondents indicates that the majority of survey participants (80%) have incomes in excess of €1001 per month.

TABLE 1 DESCRIPTIVE STATISTICS ON DEMOGRAPHIC DATA

Indicator	Data
Gender	Male 24,7%
	Female 75,3%
Age	Mean 45,2
	Median 46 SD 9,93
Employment	Employment 62,4%
	Self-employed 21,2%
	Unemployed 1,2%
	Student in employment 9,4%
	Retired and in employment 5,9%

The EQ-5D is a widely used standardized instrument for measuring health-related quality of life, assessing five key dimensions: mobility (MO), self-care (SC), usual activities (UA), pain/discomfort (PD), and anxiety/depression (AD). The Visual Analogue Scale (VAS) enables respondents to rate their overall health from providing a quantitative measure of subjective well-being. It provides both a descriptive health profile and an index value derived from population-based preference weights, enabling comparisons across different health conditions and interventions.

As illustrated in Table 2, the EQ-5D demonstrates that pain and discomfort, as well as anxiety or depression, are the most significant factors in this population. Forty-six per cent of respondents indicated that they experience moderate pain, while 40% of respondents rated their emotional state as average. A further 10% of respondents rated their emotional state as poor, indicating emotional challenges. Finally, 7% of respondents reported very low emotional well-being, indicating a need for more intensive emotional or psychological support.

TABLE 2 EQ-5D DESCRIPTIVE

Descriptive	MO	SC	UA	PD	AD	Index	VAS
Mean	1,67	1,33	1,65	2,47	2,35	0,0119	6,62
Median	1	1	1	2	2	0,0	7
Mode	1	1	1	2	2	0,0	6
SD	0,79	0,68	0,8	0,77	0,84	0,109	1,5
Min	1	1	1	1	1	0	3
Max	4	4	4	5	5	1	10

The findings suggest that the majority of respondents (65%) had previously undergone a rehabilitation programme incorporating physiotherapy. This observation underscores the significance and extensive accessibility of physiotherapy in such treatment and recovery processes.

TABLE 3 RELATIONSHIP BETWEEN PAIN FEAR OF PHYSICAL ACTIVITY AND NEED FOR PROFESSIONAL COUNSELLING SUPPORT

Factor	Seamans's rho	Need for professional counselling support
Self-assessment of health	Correlation Coefficient	-0,3**
	Sig. (2-tailed)	0,005
Pain fear of physical activity	Correlation Coefficient	0,4**
	Sig. (2-tailed)	0,00
Fear of pain at work	Correlation Coefficient	0,3*
	Sig. (2-tailed)	0,015
Absenteeism	Correlation Coefficient	0,44**
	Sig. (2-tailed)	0,00

However, for a smaller group, physiotherapy rehabilitation was not available or utilised, which could be indicative of access constraints or individual decisions not to engage in such programmes. Notably, 57% of respondents expressed that their rehabilitation experience had been beneficial and had contributed to an improvement in their condition.

The results, summarised in Table 3, indicate that there is a statistically significant association between self-rated health and the need for professional counselling support. The negative correlation coefficient indicates that individuals who rate their health more highly are less likely to feel the need for professional counselling support. This correlation, although statistically significant, is relatively weak, indicating that there are other factors that may influence the need for professional support. The results of the study demonstrate a statistically significant and moderately positive association between pain fear of physical activity and the necessity for professional counselling support. This finding suggests that individuals who experience greater fear of physical activity are more likely to seek or recognise the need for professional counselling support. These results indicate a potential necessity to focus on the psychological and emotional aspects of physical activity in order to provide appropriate support. The findings of the study demonstrate a statistically significant, albeit weak, positive correlation between fear of pain in the workplace and the necessity for professional counselling support. This observation suggests that individuals who experience heightened pain fears in the workplace are more likely to require professional counselling support. Furthermore, the results indicate that those who have missed work more frequently due to back problems are also more likely to require professional counselling support.

TABLE 4 RELATIONSHIP BETWEEN SATISFACTION WITH THE REBABILITATION SERVICES AND NEED FOR PROFESSIONAL COUNSELLING SUPPORT

Factor	Seamans's rho	Satisfaction with the rehabilitation service
Need for professional counselling support	Correlation Coefficient	- 0,32**
	Sig. (2-tailed)	0,00

As demonstrated in Table 4, the data indicate a negative weak-to-moderate relationship between satisfaction with rehabilitation services and the need for professional counselling support. The negative correlation suggests that as satisfaction with rehabilitation services increases, the need for professional counselling support decreases. This indicates that satisfaction with rehabilitation services is a significant factor that is inversely related to the need for professional counselling support. Conversely, as satisfaction with rehabilitation services decreases, the need for professional counselling support increases.

As demonstrated in Table 5, the regression analysis reveals a statistically significant relationship between the necessity for professional counselling support and several

independent variables, including pain, fear of work, pain fear of physical activity, satisfaction with rehabilitation services, and self-rated health status.

TABLE 5 PARAMETER ANALYSIS OF THE LINEAR REGRESSION MODEL

	Model parameter values		**Standardised model parameters**	**t**	**Sig.**
	B	**Standard error**	**Beta**		
Self-assessment of health	-0,993	0,405	-0,26	-2,45	0,02
Pain fear of physical activity	0,355	0,241	0,2	1,47	0,14
Fear of pain at work	0,064	0,218	0,04	0,29	0,77
Satisfaction with the rehabilitation service	-0,421	0,165	-0,25	-2,55	0,001

The findings indicate that satisfaction with rehabilitation services and self-rated health are statistically significant factors influencing the demand for professional counselling support. The negative Beta coefficient in both cases indicates that lower levels of satisfaction and lower self-rated health are associated with a greater need for support.

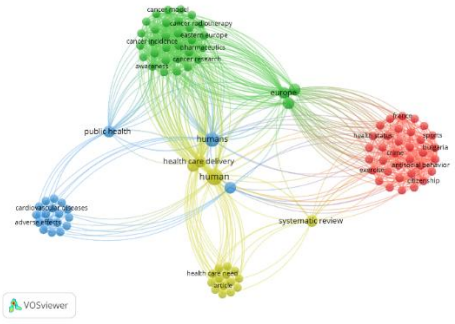

Fig.2. Network visualization of key terms for future research.

As demonstrated in Figure 2, the network visualisation methodically illustrates the pivotal interdisciplinary connections in research related to the acquisition of novel eco technologies, economic development, psychosocial support, rehabilitation, and work capacity within the European context (2015–2025). The grouping of significant terms indicates numerous possibilities for future research, particularly in the development of integrated, evidence-based strategies that enhance rehabilitation and workforce sustainability.

Advancing Public Health and Workplace Well-being: The robust associations evident within the blue cluster, particularly those between cardiovascular diseases, public health, and rehabilitation, underscore the mounting imperative for research endeavours focused on the development of preventative healthcare strategies that foster long-term employability. Future studies should focus on how early interventions and lifestyle modifications can improve work capacity, especially for individuals with chronic health conditions.

Innovative Approaches to Economic and Environmental Sustainability: The green cluster, which emphasises cancer research, healthcare services and environmental factors, indicates an opportunity to investigate how ecological innovations and healthcare advancements can contribute to economic sustainability. Future research could explore the role of green technologies in workplace reintegration and how eco-friendly work environments might support rehabilitation efforts.

Context-Specific Policy Development: The red cluster, associated with regional and social factors, highlights the need for localized and adaptable rehabilitation policies. Future research should focus on developing country-specific or industry-specific rehabilitation frameworks that align with economic development strategies and labor market demands.

The Enhancing Systematic Healthcare Approaches study is a seminal piece of research which has significantly advanced the field of systematic healthcare approaches. The yellow cluster, with its focus on healthcare delivery and systematic reviews, underscores the importance of evidence-based policymaking. Future studies should explore the long-term impact of psychosocial support programs, evaluating their effectiveness in improving work capacity and quality of life. Additionally, research on integrating digital health solutions and artificial intelligence in rehabilitation services could provide new avenues for personalised treatment approaches.

Addressing these research gaps is therefore imperative for future studies to contribute to more holistic, data-driven approaches to rehabilitation, ensuring that economic growth and workforce reintegration align with evolving healthcare and environmental priorities.

IV. CONCLUSIONS

The study's findings underscore the pivotal function of supervision as a professional consultative support mechanism in the rehabilitation of individuals grappling with chronic back pain. The results of the study suggest a correlation between a diminished self-rated health status and an augmented demand for professional supervision, thereby emphasising the necessity for targeted interventions that address both the physical and psychological dimensions of rehabilitation. Furthermore, individuals who expressed a higher degree of fear regarding physical activity and workplace reintegration demonstrated a greater necessity for professional counselling support, thereby reinforcing the importance of addressing emotional and psychological barriers to recovery.

Additionally, the study identified a negative correlation between satisfaction with rehabilitation

services and the demand for professional supervision, suggesting that well-structured and effective rehabilitation programmes may reduce the necessity for additional counselling support. This emphasises the significance of integrating supervision as a complementary component of rehabilitation, ensuring a holistic approach that enhances work capacity restoration. The results support the development of structured supervision programmes within rehabilitation frameworks, focusing on emotional resilience, workplace reintegration strategies, and psychological support.

To enhance work capacity restoration, rehabilitation programs should:

1. Incorporate supervision as a structured intervention, particularly for individuals with high levels of fear-avoidance behavior.
2. Address psychological barriers by integrating cognitive-behavioral strategies and workplace reintegration programs.
3. Improve rehabilitation service quality, ensuring that individuals receive holistic care that meets both physical and psychological needs.
4. Monitor self-perceived health status to identify individuals at risk of long-term work incapacity, providing early intervention strategies.

These findings provide a strong justification for integrating supervision as a key support mechanism in rehabilitation frameworks, ensuring effective work reintegration and improved well-being for individuals with chronic musculoskeletal conditions.

Future research should explore the long-term impact of supervision on work capacity restoration and patient well-being, as well as the optimisation of interdisciplinary approaches to ensure a comprehensive and sustainable rehabilitation process. This includes investigating how preventive healthcare strategies and psychosocial support interventions influence long-term employability, assessing the role of eco-technologies in workplace adaptation, and developing context-sensitive rehabilitation models tailored to specific industries and regional needs. Additionally, research should evaluate the integration of digital health solutions and AI-driven tools in supervision frameworks to enhance personalised rehabilitation strategies and improve overall patient outcomes.

V. Acknowledgments

I.Ž. conducted the literature review and provided scientific references. I.Ž. and L.B. collected and analyzed the research data. D.A. provided supervision and methodological guidance. L.B. drafted the manuscript. All authors contributed to the interpretation of the findings and approved the final version of the manuscript.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 75-79

Effect of Hydrogen Peroxide on Pigment Composition and Chlorophyll Fluorescence in Basil (Ocimum Basilicum L.) Leaves

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Abstract **- Basil is one of the most famous herbs, widely used fresh, and for therapeutic and pharmaceutical purposes. Basil has recently been shown to rank first among spices and herb crops regarding xanthophyll-carotenoids, which are associated with a reduced risk of cancer and age-related eye diseases. Given the widespread use of the herb basil in nutrition and herbal medicine, the contents of its leaves are of obvious interest. However, some studies say that water enriched with hydrogen peroxide helps more effectively saturate plant cells with oxygen molecules, activates the growth processes of all parts of seedlings, and increases the resistance of seedlings to various unfavorable factors, including dangerous fungal and bacterial diseases (late blight, downy mildew, root rot, powdery mildew, bacteriosis). However, in high concentrations, hydrogen peroxide also can have a phytotoxic effect on plants. The research goal for the current study was to determine the application of hydrogen peroxide (H_2O_2) on photosynthetic processes (the content of photosynthetic pigments, the parameters of the chlorophyll a fluorescence) in sweet basil (*Ocimum basilicum* L. cv. "Genovese"). The experiment was carried out under controlled conditions with three replications. Four treatments of H_2O_2 were tested: 0.0, 0.1, 0.5, 1.0 and 3.0%. Both photosynthetic pigments and parameters of the chlorophyll a fluorescence in basil leaves were quantified and compared with the control. The plants were cultivated in an environmental climatic chamber with conditions close to real natural conditions (temperature: 24-30°C, humidity: 70 – 80%, photoperiodism: day/night (8/16), illumination: 10 000 lux). The present results revealed the changes in chlorophyll fluorescence parameters in basil under different concentrations of H_2O_2 (0.1, 0.5, 1.0 3.0%). In addition, changes in photosynthetic pigment composition have also been noticed depending on the concentrations of H_2O_2 in the water before watering the plants. However, it is necessary to continue studying the effect of H_2O_2 on the whole plant in future research**

Keywords - basil, carotenoids, chlorophylls, hydrogen peroxide (H_2O_2), Ocimum basilicum L

I. INTRODUCTION

Basil (*Ocimum basilicum* L.) is one of the world's most popular aromatic, medicinal, and spice plants of the *Lamiaceae* family. Basil grows in tropical and subtropical regions from Central Africa to temperate Southeast Asia and is considered an annual plant [3]. Basil is a plant rich in various biologically active compounds such as flavonoids, phenolic acids, carotenoids, and chlorophylls. Various phenolic acids have been identified in basil leaves: rosmarinic, gallic, caffeic, chlorogenic, hydroxybenzoic, vanillic, ferulic, and transcinnamic [29] with strong antioxidant activities. In the group of flavonoids, rutin, naringin, naringenin, and quercetin were found [6]. Green and purple basil leaves contain a lot of pigments such as chlorophylls, protective carotenoids, and anthocyanins that are active in the process of

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8647
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photosynthesis [9]. Basil leaves contain many essential oils that are used to treat some ailments, such as headaches and colds, as well as severe diseases like diarrhea and kidney failure, as well as some of the aromatic herbs already studied [4], [23], [28]. The most important compounds of the essential oils are eucalyptol, linalool, and methyl chavicol. Minor compounds are neral, 1,8-cineol, and myrcene [13]. Such a high concentration of various active substances gives basil phenomenal medicinal, pharmaceutical, and health properties, including anti-inflammatory, antioxidant, and antibacterial activities. The active substances of this plant are used to treat flatulence, strengthen the digestive system, and relieve pain and fatigue [23]. Studies have also revealed other medicinal properties of basil, such as lowering blood pressure and fever, lowering blood glucose and cholesterol levels, suppressing muscle spasms and inflammation, and enhancing the body's natural activity [7]. Depending on the basil variety, environmental conditions, and harvest time, the exact concentration and composition of these active compounds may vary.

Hydrogen peroxide (H_2O_2) at high concentrations causes cellular damage, whereas, at low or moderate concentrations, it acts as a second messenger in intracellular signalling cascades, triggering various metabolic reactions and enhancing the ability of plants to withstand adverse conditions [2], [12]. However, since H_2O_2 is considered a reactive oxygen species (ROS), its improper use can cause negative effects and damage cell membranes, leading to oxidative damage and programmed cell death [24].

II. MATERIALS AND METHODS

A. Plant material and growth conditions

Sweet basil (*Ocimum basilicum* L. cv. "Genovese") was evaluated for leaf tissue carotenoid and chlorophyll pigments. Basil seeds (country of origin: Latvia) were cultivated in an environmental climatic chamber (MLR-351H, Versatile Environmental test Chamber, Sanyo, Japan) close to real natural conditions (temperature: 24-30°C, humidity: 70 – 80%, photoperiodism: day/night (8/16), illumination: 10 000 lx). Four treatments of H_2O_2 (Chempur Hydrogen Peroxide 30% pure p.a., Poland) were tested: 0.1, 0.5, 1.0, and 3.0% and control (absence of H_2O_2). Seeds were watered to maintain the required humidity of the growing medium.

B. Pot preparation and soil of the experiment

Basil seeds (cv. "Genovese") were planted in polyvinyl chloride (PVC) pots with a diameter of 11 cm, a height of 12 cm, and a soil volume of 1 L. Each pot was filled with commercial substrate (Versatile flower and vegetable substrate: Garden Guru, Latvia). The physical and chemical characteristics of the potting soil: pH_{KCl} 5.5-6.5, electrical conductivity (EC): 0.1-0.6 mS/cm, calcium (Ca) – 1.1%, magnesium (Mg) – 0.07%, moisture – max. 60%, substrate fraction 0-20 mm. Three seeds preselected by size and quality were planted at a depth of 2 cm in each pot, and after the seedlings' germination and establishment, one plant was left in each pot, and the rest were thinned out. When the basil plants grew to 15 cm after 4 weeks, they were used for experimental purposes. For experimental purposes, only basil leaves were used

C. Determination of photosynthetic pigments

The quantification of chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*), and carotenoids (Car) content were evaluated through solvent extraction (80% acetone), according to the methodology [20]. 200 mg sample of examined plant material was extracted with cold 80% acetone (-20°C) in a pre-chilled mortar, and then, magnesium carbonate was added. After complete extraction, samples were centrifuged twice (7000 rpm, 4°C, 10 min), and the volume was brought to 10 mL with cold acetone. The samples were thoroughly mixed and the absorbance of the test samples was measured at the following wavelengths: 663 nm, 646 nm, and 470 nm (the spectrophotometer was calibrated using cold 80% acetone). The values obtained were used to calculate the results, and these were expressed in (mg/L) of pigment in fresh leaf tissue

D. Chlorophyll fluorescence measurements

Chlorophyll fluorescence measurements were carried out at room temperature (20 ± 1°C) using a modulated OS- 30 Chlorophyll fluorimeter (Opti Sciences, US) with a clip-on holder for plant leaves. The dark-adapted basil plants were used for the measurement of minimal (F_0) and maximal (F_m) chlorophyll fluorescence. The basil plant was exposed to bright light for 60 seconds (fluorescent light was used as the light source: photosynthetically active photon flux: 150 µmol m^{-2} s^{-1}, luminance: 12 400 Lx. For the dark-adapted F_v/F_m test, the following sampling intervals were used: 30 min; 60 min; 90 min; 120 min, and 24 h after bright light exposure for each concentration as recovery period [21]. The PS2 photochemical efficiency or the ratio of variable to maximum fluorescence (F_v/F_m) of dark-adapted plants was calculated automatically according to F_o and F_m and measured by the formula: [$F_v/F_m = (F_m-F_o)/F_m$].

D. Statistical analysis

The results obtained were statistically evaluated using Microsoft Excel Ver. 14.0.7214.5000 software. Each experiment was done in three replicates ± standard error (SE).

III. RESULTS AND DISCUSSION

The chlorophylls (Chl) and carotenoids (Car) are integral components of thylakoid membranes and act as accessory pigments in light trapping as photoprotective agents, dissipating rapidly absorbed excess light [17]. Measured Chl *a* and Chl *b* concentrations in basil ranged from 21.94 to 24.33 mg/L FW and 6.70 to 8.29 mg/L FW, respectively, as depicted in (Fig. 1).

Compared to Car pigments, basil had a much higher concentration of Chl pigments in leaf tissues. In leaves of

basil seedlings Chl *a* and Chl *b* concentrations were enchased by applying H_2O_2 treatment. In plants treated with H_2O_2 (0.1%), there was an increase in Chl *a* concentration (24.33 mg/L FW), compared to the control (22.49 mg/L) and to plants treated with 1% and 3% H_2O_2 (23.32 and 24.07 mg/L FW). However, in plants treated with H_2O_2 (0.5%), there was a decline in Chl *a* content (21.94 mg/L FW). The obtained results showed that Chl *b* measured in plants treated with 0.1%, 1% and 3% H_2O_2 was 7.91, 7.63, and 8.29 mg/L FW, whereas, plants treated with 0.5% H_2O_2 Chl $_b$ was 6.70 mg/L FW. The values of the concentrations of photosynthetic pigments of the examined plant varied greatly depending on the applied treatment.

By analysing the obtained results for the concentration of photosynthetic pigments treatment with H_2O_2 had a slight increasing impact. This increase can be partly explained by the role of H2O2 in protecting the chloroplast ultrastructure and thus increasing the efficiency of the photosynthetic apparatus [23]. Some authors associate the signalling role of H_2O_2 with the protective function related to maintaining the ultrastructure of chloroplasts. Previous studies have observed a significant increase in Chl concentration in plants treated with H_2O_2 [15], [25]. On the other hand, Mani et al. demonstrated that applying H_2O_2 at a low concentration (20mM) decreased Chl content in *Solanum tuberosum* L. [16].

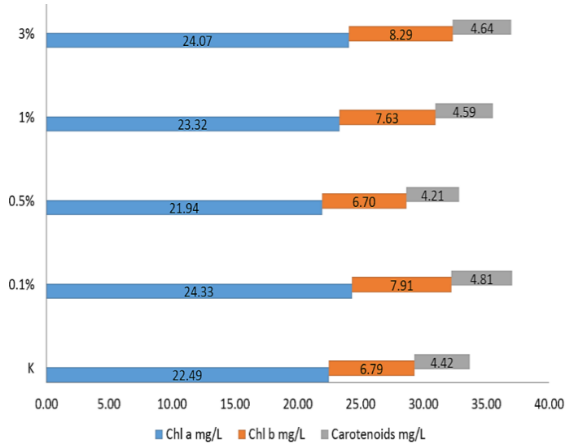

Fig. 1. Chlorophyll *a*, Chlorophyll *b*, and carotenoids content changes in leaves of sweet basil (*Ocimum basilicum* L. cv. "Genovese") under the influence of H_2O_2

Carotenoids act in the process of energy dissipation in the form of heat, reducing the deleterious effects of stress on plants [27]. The highest (4.81 mg/L FW) concentration of total carotenoids was measured after the treatment with H_2O_2 (0.1%) compared to the control treatment (Fig. 1). In the present experiment, compared to the control treatment (4.42 mg/L FW), the 1% and 3% H_2O_2 concentrations increased Car concentrations (4.59 mg/L FW and 4.64 mg/L, respectively) (Fig. 1). An increase in the concentration of carotenoids occurs as a mechanism of photoprotection of plants under stress conditions. In general, Car are compounds connected with Chl synthesis and are isoprenoids that, in addition to helping to capture light, are also directly related to the photoprotection mechanism in plants under stress conditions [25], [26].

A treatment with H_2O_2 leads to a series of physiochemical changes that modify the protoplasmic characteristics of plant cells, improving the physiological activity of embryos and future seedlings [30]. Since H_2O_2 is a multifunctional molecule, at lower concentrations it is involved in the regulation of plant growth, development, and physiological processes [8]. The application of H_2O_2 results in the maintenance of protein structure and regulation of enzymes responsible for protein synthesis [21]. Additionally, H_2O_2 has been shown to stimulate photosynthetic processes by improving gas exchange, Chl content, and protection, and scavenging ROS [19]. These facts were also confirmed by [14], [10].

The maximum photochemical efficiency or quantum yield (F_v/F_m) can be used to estimate the photosystem II (PSII) operational efficiency. It indicates the capacity of absorption of excitation energy by leaves, and it is usually decreasing thereafter because of leaf senescence and a decrease of photosynthetic assimilation [5]. In the control condition, the ratio (F_v/F_m) is generally around 0.8, and it decreases in stressful situations [1], [31]. However, high values of this ratio characterize non-stressed leaves [18].

Concerning plants treated with H_2O_2, the presented results showed that the maximum photochemical efficiency (F_v/F_m) values were similar for different treatments (Fig. 2). They ranged from 0.731 to 0.781. This ratio was high (0.781 and 0.769) when plants were treated with respectively 0.5% and 3% of H_2O_2. Notably, the lowest basil F_v/F_m values were observed treated with 0.1% and 1% of H_2O_2 (0.731 and 0.744 respectively), while the maximum basil F_v/F_m value was recorded at control plants (0.803).

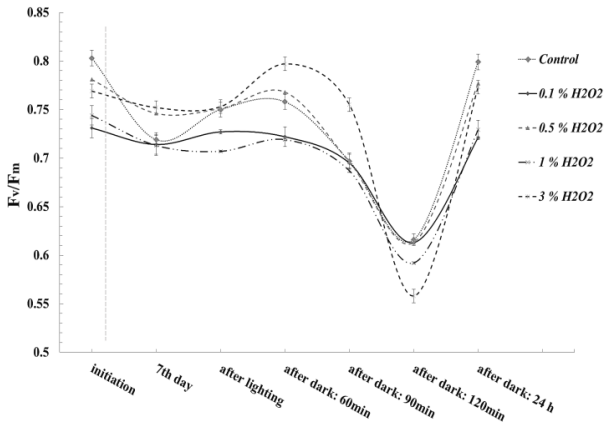

Fig. 2. F_v/F_m parameter changes in sweet basil (*Ocimum basilicum* L. cv. "Genovese") under the different concentrations of H_2O_2.

The photosynthetic efficiency (F_v/F_m), as measured in dark-adapted leaves (after 24 h) treated with H_2O_2, expressed no significant changes in comparison to the control material except for leaves treated with 0.1% and 1% H_2O_2 (0.721 and 0.729, respectively). Thus, the

maximum photochemical efficiency (F_v/F_m) of leaves of plants treated with H_2O_2 depends on the used concentrations. The reduced value of this ratio (F_v/F_m) measured in plants treated with H_2O_2 may be related to the conformational changes in the reaction centre of PSII [11], [22].

IV. CONCLUSIONS

The study demonstrated that hydrogen peroxide (H_2O_2) plays a significant role in the universal regulatory and signalling mechanisms of plant cells. Its impact on plant physiology is clearly evident, particularly under stress conditions. By optimizing environmental parameters, it is possible to modulate the intensity of metabolic processes, enhance nutrient uptake and transport, strengthen immune responses, and improve stress tolerance - ultimately contributing to increased crop productivity.

The data obtained provide a foundation for further investigation into the fundamental properties of H_2O_2 and its functional role in plant development and adaptation. A deeper understanding of the mechanisms by which various factors influence plant cells enables targeted regulation of physiological processes and offers new strategies for enhancing agricultural productivity.

Based on the study's findings, it can be concluded that hydrogen peroxide may act as a signalling molecule, triggering the activation of cellular defense responses - such as the synthesis of antioxidant enzymes - when plants are exposed to adverse environmental conditions.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 81-87

Ecological and Human Rights Aspects of National and Local Decision-Making

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Abstract- **Climate change, such as rising temperatures and changing weather patterns, has certain consequences associated with the loss of individuals' favorable physical and mental health or productivity. The authors mention some important factors such as extreme heat waves, air mass movement, changed precipitation patterns, and global warming, and their impact on the health status of Europe's population, namely increases in cardiovascular, respiratory and some infectious diseases. Consequences like worsening of food security, economic inequality and the situation of vulnerable groups have also been addressed. The article discusses the interconnectedness of environmental degradation and human rights violations as well as the international and European legal framework of the interrelationship between human rights and the environment. Emphasizing a rights-based focus, the article highlights the core position of national and local authorities in fostering environmental accountability while defending human rights. The article also touches upon the general social implications of climate change, i.e., how it is disproportionately impacting children, the elderly, and vulnerable groups. It examines how national and subnational governments can address these impacts through innovative policy, legal reform, and multi-level governance approaches. Examples include the Climate City Contract 2030 in Stockholm and throughout Europe, demonstrating the promise of cooperative and adaptive governance approaches to addressing sustainable development challenges. The relationship between the environment and human rights protection within the European Convention for the Protection of Human Rights and Fundamental Freedoms as a relevant part of international law is discussed, as an attempt to contribute to the improvement of environmental protection on the national and local fronts. This study aims to holistically examine the interface between environmental law and protection of human rights based on an integration of historical, rational and comparative methods and analysis of statistical data. Leaning on national and international law regimes, the study aims to provide support in designing strategies to address the environmental and human rights challenges brought about by climate change. This approach centers on the requirement for a shared vision that unites sustainability and justice, equity and human dignity.**

Keywords- climate change, ECtHR case-law, human rights, national and local decision-making.

I. INTRODUCTION

The crossroads of environmental protection and human rights has been a focal point of study, particularly with the exacerbation of climate change and its everlasting implications. The environmental crisis of the present times underscores the imperatives of effective legal regimes synthesizing ecological sustainability and protection of essential rights. National and local policy formulation are crucial here towards addressing issues of climate change while upholding human rights. Recognition of environmental rights as part of the 'third generation of human rights' is evidence of growing appreciation of the truth that there exists a connection between a clean environment and the practice of

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8650
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fundamental human rights like the right to life, health, and well-being. Path-breaking cases, i.e., *Verein KlimaSeniorinnen Schweiz v. Switzerland* [1] and *Duarte Agostinho and Others v. Portugal and 32 Others* [2], illustrate the way in which international human rights law has developed to respond to climate change and the social aspects of it. The cases make it essential that environmental interests be incorporated within human rights law to achieve just and sustainable options for current and future generations.

II. Materials and Methods

The present article aims critically to analyze the interrelation between the environment and the human rights protection. The issue still needs further attention and research, especially after the 2024 ECtHR judgment in *Verein KlimaSeniorinnen Schweiz and Others v. Switzerland*. Due to the sensitive nature of the issue, a complex methodology has been used, combining several approaches and including logical-analytical, teleological, historical and comparative methods. To achieve the goals of the research, the article also uses some statistical data collected from the official websites of European and national institutions, the observation and analysis of which allows the authors to reach scientifically based conclusions. The relationship between the environment and the protection of human rights under the European Convention for the Protection of Human Rights and Fundamental Freedoms as a relevant part of international law is discussed, as an attempt to contribute to strengthening environmental protection at the national and local levels.

III. Results and Discussion

A. Climate change

Climate change is affecting people's health in Europe primarily through recorded temperature increases and changing weather patterns. More frequent or intense natural disasters, as well as changes in air, water, food (in terms of quality and quantity), ecosystems, agriculture, and infrastructure, inevitably affect the health and well-being of individuals. Health challenges will continue to increase in the future and increase existing environmental health risks [3].

Climate change is directly related to the quality of the environment in general, and also to social infrastructure.

Climate change and related natural disasters affect the security of society. Security in the 21st century depends on a set of interdependent determinants such as economic development and food security, cultural dimensions, migration and mobility, armed conflict and geopolitical rivalry [4]. Some authors have even found a direct causal relationship and pathways between climate change and violent conflicts. Historical examples of collapses of empires, political upheavals and wars in connection with large-scale climate disturbances are pointed out [5], [6].

It should be borne in mind that critical factors known to contribute to armed conflicts within countries, such as low incomes and social inequality, are particularly sensitive to climate change. Conflict and its impacts and consequences (such as damage to infrastructure and institutions, loss of natural and human resources, migration, and reduced opportunities) are generally exacerbated by climate change [4].

The Intergovernmental Panel on Climate Change proposes that poverty reduction strategies include climate change risks to ensure progress in health and access to safe water and sanitation, as well as other indicators of social and environmental status. In its 2014 report, the Panel concluded that "*the continuation of greenhouse gas emissions will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of widespread severe and irreversible impacts on people and ecosystems. Limiting climate change would require substantial and sustainable reductions in greenhouse gas emissions that could limit climate change risks*" [7].

In the announcement published in August 2021 of the Working Group of the Intergovernmental Panel on Climate Change, it is stated that greenhouse gas emissions from human activities correspond to approximately 1.1 ℃ of warming between 1850 and 1900, and on average over the next 20 years, global temperatures are expected to reach or exceed 1.5 °C of warming. At 1.5 °C of global warming, there will be more frequent heat waves, longer warm seasons and shorter cold seasons. However, at 2 °C of global warming, thermal extremes would more often exceed critical thresholds for agriculture and health [8]. Globally, according to the WHO forecast, climate change in the period 2030 - 2050 can cause mortality of about 250 thousand people per year due to malnutrition, malaria, diarrhea and heat stress [9].

Vulnerability to weather and climate change depends on the broader social and environmental context and level of exposure of populations, as well as their access to resources. Older people, children, outdoor workers and migrants, for example, are particularly vulnerable populations. Older people are the focus of a growing number of studies: their vulnerability stems from a complex mix of factors such as multiple chronic diseases, poverty, isolation, lack of access to transport and other mobility-related issues [10]. Children, in turn, are particularly vulnerable because of their physiological and cognitive immaturity and a greater likelihood of being exposed to climate change for a longer period. Extreme weather events can pose a threat to all stages of a child's development: as a fetus in the mother's body, as newborns, minors, adolescents [11].

The increase in global temperature by around 4 °C compared to the levels of the late twentieth century, combined with increasing demand for food, increases the likelihood of food insecurity on a regional and global scale [12]. In this sense, the number of malnourished children is expected to reach 138 million, including 3.7 million in Europe. While cereal yields may increase in some areas of the WHO European Region, more frequent extreme events such as droughts and floods in certain

areas may lead to a decrease in food production and an increase in malnutrition of vulnerable populations.

Southern Europe is likely to experience significant losses in food production (up to 25 % in the event of a temperature increase of up to 5.4 °C), while food production in some areas of northern Europe is likely to increase due to an extension of the growing season. Food safety and climate change need to be addressed in the context of sustainable development of agriculture and be included in national adaptation plans [13].

In a possible climate change scenario of an increase of 2.0-5.4 °C by 2050, agriculture is expected to be negatively affected by the changes. Crop yields will fall, production will be affected, food and meat prices will increase, and cereal consumption will decrease, leading to reduced calorie intake and malnutrition of children [14]. For this reason, the Second International Conference on Nutrition recognized the need to address the impacts of climate change on food security and nutrition – in particular on the quantity, quality and variety of food produced, taking appropriate action to address the negative effects [15].

B. Human rights and a broader legal context

Climate change should also be taken into account in the context of human rights. It is obvious that, in the context of natural disasters, it is hardly possible to speak of full respect for all human rights, but it is nevertheless then that respect for such rights as the right to life and the right to health become particularly important.

Nowadays, the environment is protected under international law through various treaties that govern specific environmental issues, such as climate change, pollution, loss of biodiversity, etc. Nevertheless, the first human rights documents—namely, the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, and the International Covenant on Economic, Social and Cultural Rights—do not refer to the environment, as it was not part of the international agenda at the time. The same is true for the European Convention for the Protection of Human Rights and Fundamental Freedoms and the European Social Charter, as they were also drafted well before the environmental issues became the concern of the international community [16].

Today it is commonly accepted that environmental rights belong to a so-called 'third generation of human rights' and that the environmental issues and human rights are interdependent [17], [18]. It should also be noted that the more recent regional human rights instruments, such as the African Charter on Human and Peoples' Rights and the Arab Charter on Human Rights, do formulate a specific human right to a healthy environment. Moreover, nowadays it is quite obvious that rights relating to the environment have an inter-generational character [19].

It should be pointed out that the Paris Agreement, adopted on 12 December 2015, was the first international environmental treaty that in its Preamble explicitly underlines the interrelation between climate change and human rights, stating that "*the parties should, when taking action to address **climate change**, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations … and intergenerational equity*" [16].

In 2017, the Inter-American Court of Human Rights highlighted in its Advisory Opinion ''*the existence of an undeniable relationship between the protection of the environment and the realization of other human rights, in that environmental degradation and the adverse effects of **climate change** affect* the real enjoyment of human rights" [20].

Tracing the development of the human rights concept over the decades—from the protection of individual rights to the protection of the rights of vulnerable groups—it should also be borne in mind that, among universal international instruments, only the Convention on the Rights of Persons with Disabilities contains a direct reference to natural disasters. Article 11 of the Convention states that "*States Parties shall undertake, in accordance with their obligations under international law, including international humanitarian law and international human rights law, all necessary measures to ensure the protection and safety of persons with disabilities in risky situations, including military conflict, humanitarian and **natural disasters***" (authors' emphasis) [21].

C. Recent judgements of the European Court of Human Rights (ECtHR)

As environmental concerns have become more important for the international community, national states and local authorities in the second half of the 20th century, the ECtHR case-law has gradually reflected the idea that human rights law and environmental law are mutually interrelated. An illustration of that is the contemporary situation where the Strasbourg Court's case-law shows a wide range of environmental factors that may have an impact on individual rights. This development is in accordance with the Court's insistence that the Convention is 'a living instrument' [16]. Therefore, the interpretation of the rights and freedoms is not fixed but can take account of the social context and changes in society. The Court has systematically linked its case-law to the main international environmental law standards and principles.

As it was mentioned before, the European Convention on Human Rights was not designed to provide a general protection of the environment as such and do not expressly guarantee a right to a safe, clean, healthy and sustainable environment [16]. Protection of environmental issues has been granted with the evolving ECtHR jurisprudence. However, the Strasbourg case-law slightly differs from a multitude of cases heard by various national and international jurisdictions. It should be noted

that the first court ruling in Europe was the Dutch 'Urgenda judgment' where the Supreme Court found that the Dutch State was liable for the dangerous consequences of climate change [22]. The reasoning of the judgment was based on Articles 2 and 8 ECHR.

Two recent cases reveal the Strasbourg Court's vision towards the climate change issues. The first one is *Verein KlimaSeniorinnen Schweiz and Others v. Switzerland,* where the Court discussed whether the ECHR applies to climate change issues [1]. On 9 April 2024, the European Court of Human Rights ruled for the first time whether governments have an obligation to combat the effects of dangerous climate change. According to the Court national governments have to take proper measures under Article 8 ECHR in order to achieve sustainable climate goals and to prevent the harmful pressure of climate change. It confirmed that inadequate national climate policies can violate the human rights as guaranteed in Articles 2 and 8 of the ECHR.

The Court noted that Switzerland has not adopted an adequate national legislation in regards to the limitation on CO_2 emissions, despite the fact that it has been encouraged to do so [23]. Although the Court stressed that the choice of climate policy measures falls within the wide margin of appreciation of the State, finally it concluded that the absence of any relevant domestic measure on behalf of Swiss authorities represents a breach of Article 8 ECHR. By a majority of 16 votes in the Grand Chamber, the Court ruled that the inaction of Swiss authorities had violated Article 8 ECHR [24]. However, there are voices from both academic and political circles that the decision could be even counterproductive while "*inventing new obligations on member states in relation to climate change*...". [25]. In his dissenting opinion judge Eicke describes that the majority has "*tried to run before it could walk*". [26]

In the other climate case *Duarte Agostinho and Others v. Portugal and 32 Others* [2], the applicants put forward that the respondents (33 States) had not taken sufficient action on climate change and invoke the intergenerational issue. The six applicants are young Portuguese, aged between 10 and 23. They argue that the existing and future impacts of climate change are attributable to the respondent States and that, in particular, the effects of heat waves, wildfires and smoke from wildfires affect their lives, well-being and mental health, as well as the amenities of their homes [24]. In addition, the applicants argue that global warming primarily affects their generation and that, in view of their age, the potential infringement of their rights would be greater than it is for older generations. The applicants insisted that there was no adequate domestic remedy available to them, and this represents an exemption under Article 35 ECHR which requires all remedies under national law to be used.

The other important issue that the Court has discussed was about the extraterritorial principle. Since the claimants were Portuguese citizens, the capacity of Portugal as a defendant is not in doubt. However, with regard to the other respondent States, the Court does not consider, however, that the principle of extraterritoriality should be applied [24]. The complaint against Portugal was declared inadmissible for non-exhaustion of domestic remedies. The Court noted that the Portuguese constitution explicitly recognised the right to a healthy and ecologically balanced environment. Moreover, this right is directly applicable in front of the domestic courts, and that the Portuguese legal system provides for adequate remedies, according to the ECtHR.

With the judgment, the Court in practice has tried to strike a balance between on the one hand, the human rights protection while combating climate change and on the other hand, preventing citizens from abuse with rights related to climate issues.

D. The case of Bulgaria: embedding environmental rights in the national policy and legal framework

In Bulgaria, as in other European countries, the environment is protected through the constitution. For example, the Bulgarian Constitution provides for the right to a "*healthy and favourable environment in accordance with the established standards and norms*" (Article 55) [27]. The same article proclaims vice-versa an obligation for the citizens to protect the environment. The Bulgarian Constitution states that underground resources, national roads, coastal beach front, forests and parks of national importance, etc. constitute exclusive state property and that the state exercises the sovereign rights in developing, utilizing, protecting and managing the continental shelf and the exclusive offshore economic zone, and the biological, mineral and energy resources therein (Article 18) [27]. The land as a basic national resource shall receive special protection by the state and the society (Article 21) [27]. The Environmental Protection Act ensures that anyone who culpably inflicts pollution or environmental damage on another shall be liable to indemnify the aggrieved party (Article 170) [27].

In Bulgaria the horizontal legislation in the field of environment conservation includes the Environmental Protection Act, Liability for Prevention and Remedying of Environmental Damage Act, and the Access to Public Information Act [28]. In addition, separate legal acts have been passed in main sectors such as air quality, waste management, water quality, nature conservation, chemicals and mine waste.

E. National and local decision-making

It should be pointed out that, in accordance with the judgments of the European Court of Human Rights, the assessment of which measures are necessary to protect the environment rests entirely upon national authorities. The Court has recognized that national authorities are best placed to make decisions on environmental issues, which often have difficult social and technical aspects. Therefore, in reaching its judgments, the Court affords the national authorities in principle wide discretion in their decision-making in this sphere. This is the practical implementation of the principle of subsidiarity [29], [30]. According to it, violations of the Convention should be

prevented or remedied at the national level with the Court intervening only as a last resort after the domestic remedies have been exhausted. The principle is particularly important in the context of environmental matters due to their very nature [31].

As Europe faces economic, social, and environmental pressures, the role of local governments also becomes increasingly important. Local governance structures, closer to citizens and more adaptable than national bodies, are increasingly tasked with addressing global problems that manifest at the community level. Moreover, citizens are pressuring for more participation at all levels and are demanding to be given a voice in local government decision-making [32].

Ensuring a long-term environmental security in the era of climate change requires a milti-level strategic approach. National and local authorities' efforts are crucial when addressing social justice and environmental sustainability alongside technical solutions [33]. They have all the necessary resources through local policies and action plans that enhance safety and equity and at the same time introduce digital and artificial intelligence solutions. Municipalities also play an important role in preserving ecosystems and biodiversity, through public investment, urban planning and infrastructure. A good example is Stockholm's Climate City Contract 2030 that exemplifies a multi-level governance approach uniting the efforts of cities, businesses, academia, and civil society [34]. This aligns with the principle of subsidiarity, ensuring that decisions are made at the most local level feasible [35].

IV. CONCLUSIONS

The intersection of environmental law and human rights has emerged as a frontline aspect of contemporary legal and policy discourse, especially in the context of climate change. The present study has examined on how changing new legal tools and jurisprudence are shaping the interaction between these disciplines, and with particular focus on the pivotal role of national and subnational decision-making in addressing environmental issues. Landmark cases, like *Verein KlimaSeniorinnen Schweiz v. Switzerland*, demonstrate how international human rights law is increasingly acknowledging the urgent necessity to incorporate environmental considerations into its framework. These trends reflect a growing agreement on the intergenerational and cross-border nature of environmental rights, confirming their importance for safeguarding human dignity and well-being [36]. As reflected in the study, climate change threatens society in many ways, from its effects on health to food shortages and exacerbating existing inequalities. Such effects weigh heaviest among vulnerable populations such as older persons, children, and economically disadvantaged persons and thereby point to the need for specifically designed legal and policy interventions [37]. National governments and local authorities are crucial in this context, as they are ideally situated to implement adaptive strategies and uphold the principles of justice and equity. By utilizing multi-level governance frameworks, integrating digital and artificial intelligence solutions, and encouraging collaboration across different sectors, governments can tackle these challenges while advancing sustainable development [36], [38]. The study also underscores the necessity of making human rights standards part of environmental policy. Global conventions, such as the Paris Agreement, and regional mechanisms, such as the European Convention on Human Rights, offer invaluable frameworks for balancing natural sustainability with protection of inherent rights. Success here relies primarily on the will and ability of national governments to balance their policies in accordance with global commitments. For instance, Stockholm's Climate City Contract 2030 shows the power of new, multi-stakeholder approaches to provide long-term environmental security [34]. Looking into the future, the interface between human rights and environmental law must be strengthened to address the increasing complexity of global issues. This involves not only strengthening legal regimes but also informing the public and increasing public involvement in decision-making [39]. The prominent elements of this program are environmental education, public involvement, and fair access to resources so that all segments of society can enjoy and contribute towards sustainable solutions [40]. Overall, a combination of human rights and conservation of nature sets a good ground for reconciling climate change survival needs [41], [42], [43]. Through cooperation, justice-informed policy, and collective alignment, national and subnational governments can strengthen resilience, safeguard vulnerable groups, and secure conservation of ecological and human systems for the future. This research calls for reaffirmation of commitment to aligning legal and policy interventions with the pillars of sustainability, justice, and human rights in the knowledge that environmental protection is inherently encompassed in the mission of providing a safe and just future for all.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 89-95

The Human Resources - a Factor for a Sustainable Agricultural Sector

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***Abstract*— The topicality of the topic: *The agricultural sector is vital to the national economy. A key factor in maintaining the well-being of the population is the human resource to specific activities in the sector, in the context of the common European agricultural policy union*. The research *aims* to assess the human factor as a tool for achieving sustainability in the agricultural sector of the economy. In terms of *methods* – in the study are used statistical methods, including arithmetic mean (arithmetic average) value, median, fashion. The development focuses on finding new income opportunities in the agricultural sector and tracking the digital skills of the population - with an emphasis on the Human Development Index - The Digital Economy and Society Index (DESI). *The main results* of the study of the achievements of human capital development are reduced to the identified need for new knowledge, respectively the growing need to acquire and maintain modern skills. This applies as a matter of priority to the managers of agricultural and livestock farms without completed education in the field of agriculture. This requires permanent qualification and retraining of employees in the agricultural sector. In conclusion, there is an opinion that the development of human potential requires training adequate to current technologies. The limited land as a resource for production requires the search for new opportunities for income in the agricultural sector. Regarding the research novelty on the developed issues - digital skills are perceived as a major factor in determining human capital, from this position the achievements in the individual member states of the European Union are followed. Study limitation - access to current public data. The development of a sustainable national agricultural sector is a guarantee of food security and independence, vibrant rural areas and employment of the local population.**

Keywords*— *Agricultural Sector, Human Development Index, Digital Skills.

I. Introduction

The agricultural sector is vital to the national economy. A key factor in maintaining the well-being of the population is the human resource to specific activities in the sector, in the context of the common European agricultural policy union.

The purpose of the study sets the stages of the study, ie. action plan. The research aims to objectively evaluate the human factor as a tool for achieving sustainability in the agricultural sector. The current study aims to reveal the state of the agricultural sector in terms of its ability to achieve sustainability for the development of individual and human capital as a whole. The agricultural sector is the primary sector of production. This proves its resilience in an indisputable way, on the one hand. On the other hand, the scarcity of land as a resource, the consolidation of farms and their specialization [1] justify the search for new opportunities for income in the agricultural sector.

In this regard, the research focuses on solving several conceptual problems, namely:

- Conduct a relevant review of the current state of the agro-industrial sector;
- Reflect trends in the development of human capital in crop production and animal husbandry;
- Identify employment priorities and the age structure of farm managers, including gender composition;
- Characterize the existing digital skills of the population of rural settlements, focusing on the Human Development Index (DESI).

The main results of the study of the achievements of human capital development are reduced to the identified need for new knowledge, respectively the growing need to acquire and maintain modern skills.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8687
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Sustainable development characterized as a long-term development approach, including sustainability of results, «protection of the environment and natural resources, social and economic balance» [2].

The presented study reveals the state of the agricultural sector and proves its ability to achieve sustainability for the development of individual and human capital as a whole. The labor market feels the need to continuously improve the skills and retraining of workers in the industry. M. Petrova [3] points out that 98% of Bulgarian farmers do not have the necessary education; therefore, it is necessary to optimize the indicators of qualification and competence of the human capital of agricultural enterprises. Nevertheless, the intercalation of the competence approach into the human capital of agro-industrial enterprises is quite controversial [4]. Several researchers, scientists, and practitioners associate the development of the agricultural market and, accordingly, human capital with the introduction of environmental standards [5].

The concept of carbon farming was first mentioned in the strategy «From farm to fork», which aims to reduce the use of chemical pesticides by 50% and fertilizers by 20% by 2030. Carbon farming will in fact build on the Common Agricultural Program, which will enter effective from 2023. It is expected to contribute to the storage of 42 million tons of CO_2 in natural carbon sinks (Kodzhaivanova A (2022) [6].

The idea has both supporters and opponents. Critics say carbon offsets are basically a way for corporations and big business to shirk responsibility for the pollution they pay for by paying for it instead of actually reducing their emissions. There is also no mechanism to ensure that carbon storage in the soil is long-term.

An increasing number of studies highlight the potential of agrovoltaics (APVs) as an alternative in the fight against climate change. The idea of producing solar energy and growing crops on the same area originated in Germany in the early 1980s [7].

We are of the opinion, that the energy and transport, as pollutants, followed by agriculture (24-28%), are the reason for looking for ways to reduce damage to nature and climate change [6]. We consider it right, at European level, to seek new opportunities for a green business model - for example, carbon farming, in which the earth absorbs carbon dioxide from the atmosphere and stores it in the soil. The European Commission (European Union, 2021) [2] is about to regulate trade in emissions (so-called low- carbon agriculture) caught and stored in soils through Agri-environmental practices. The idea, presented as an opportunity for a new source of income for certified farmers, is still in its infancy. Legislation for reporting and certification is pending by the end of the year.

To protect the landscape and biodiversity is need further development and improvement of agro voltaic systems. This is an opportunity for sustainable policies in the energy, agriculture and rural development sectors.

II. Materials and methods

At national level, according to data from the Ministry of Agriculture [8], information on the number of agricultural holdings for the period 2003-2020 presented in Table 1. Their census was conducted in 2003, 2010 and 2020. Data for 2020 are preliminary. An intermediate review carried out in 2005, 2007, 2013 and 2016 respectively.

Table 1 Crop farms (number) in Bulgaria for the period 2003-2020

Year	Holdings (number)	Change (%) * compared to 2020 **
2003	665.500	-80
2005	534.600	-75
2007	493.100	-73
2010	370.200	-64
2013	254.100	-48
2016	201.000	-34
2020 *	132.400	-

Source: Compiled by the author.
Note: * Values are rounded.
** Presented data are preliminary.

Based on the presented information, the steady trend for the reduced number of plant farms is visible (Figure 1). In 2010 there were 371.100 farms. The decrease compared to the number of farms in 2003 was 44% and 64 % - 2020 compared to 2010. The decrease is maintained especially in recent years - by 2020 it is 80%.

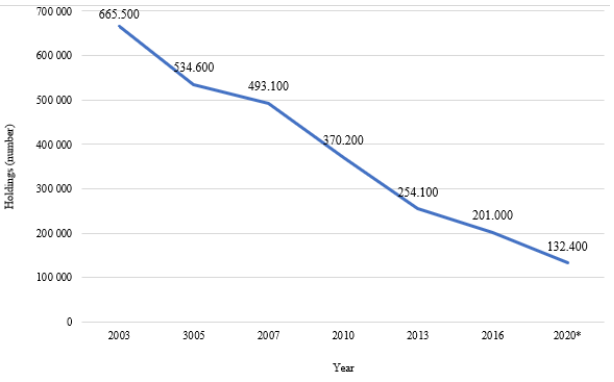

Fig. 1. Graphic presentation of the crop farms (number) in Bulgaria for the period 2003-2020.

Source: Compiled by the author.

The factors for the significant reduction are:

- The increased amount of utilized agricultural area - at average values cultivated by farms, amounting to 3.957 thousand ha. The positive trend is an increase of 9% compared to 2010 and 36% compared to 2003;

- Increased (average) number of holdings - Table 2, keeping animals, birds and bee colonies [9].

TABLE 2 BULGARIAN LIVESTOCK FARMS (NUMBER) FOR THE PERIOD 2003-2020 *

Year	Holdings (number)	Change (%) * compared to 2020 **
2003	600.815	-53%
2010	279.717	-74%
2020 *	71.693	-

Source: Compiled by the author.
Note: * Values are rounded.
** Presented data are preliminary.

The significant changes registered in the Livestock sector are presented in Figure 2.

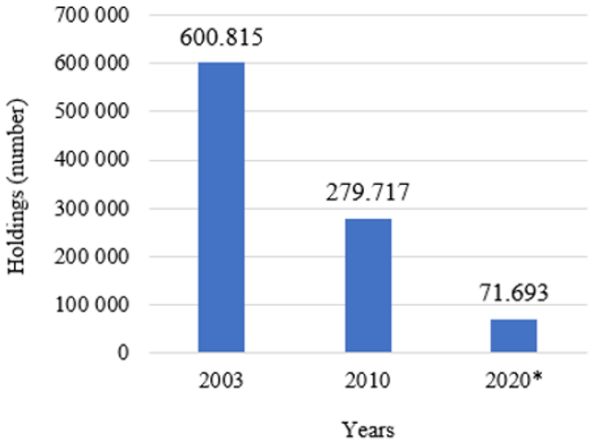

Fig. 2. Graphic presentation of livestock farms (number) in Bulgaria for the period 2003-2020.

Source: Compiled by the author.

As a structural determinant for the economy of our country, it is claimed that the agricultural sector provides employment to about 1,4 million people (permanently or seasonally employed). Data on the age structure of farm managers in the agricultural sector for the period 2003-2020 are presented in Table 3:

«The relative share of women farm managers in 2020 is 28% (compared to 5% as of 2010) [10].

Women in Europe make up 42% of the population labor in the agricultural sector**.** Three out of ten agricultural enterprises are run by women. With equal access to resources for women and men, it is claimed that agricultural production could increase by 30% (including 4% in developing countries), allowing another 150 million people to be fed» [10].

In recent years, there has been a change in the identified negative trend - Figure 3.

TABLE 3 AGE STRUCTURE OF BULGARIAN FARM MANAGERS FOR THE PERIOD 2003-2020

Years / Age	Relative share (%) by years		
	2003	***2010***	***2020****
Under 24	1	1	1
25-34	4	6	8
35-44	11	12	16
45-54	18	18	21
55-64	26	25	24
Over 65	40	37	31
Total:	100	99 **	101 **

Source: Compiled by the author.
Note: * Presented data are preliminary.
** Some inaccuracies in the published data have been found.

The development of a modern agricultural sector requires leadership to promote sustainability and diversity of the workforce.

The data presented in Table 4 are an opportunity for their deepening and further development.

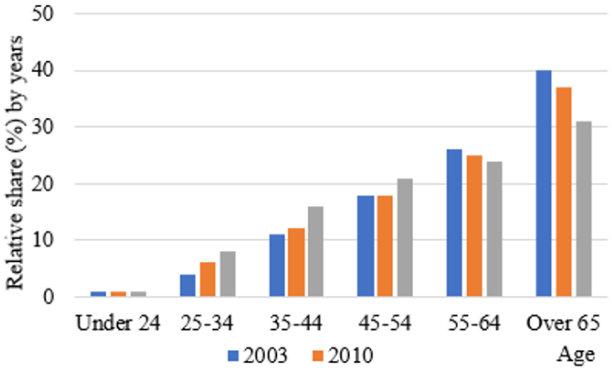

Fig. 3. Graphic presentation of the age structure of the managers of agricultural holdings for the period 2003-2020.

Source: Compiled by the author.

Attention is focused on the interest on publicly available ideas, respectively in niches for agribusiness [4].

- Cultivation of daffodils in mountainous areas - a special type of daffodils grown in adverse conditions above 300 m above sea level, containing *Narcissus pseudonarcissus*, used in drugs to treat dementia and Alzheimer's.
- Year-round food delivery - mediation for others companies to plan individual food supply products [11] one year earlier.

TABLE 4 IDEAS FOR OWN BUSINESS IN THE AGRICULTURAL SECTOR

Year	Holdings (number)	Change (%) * compared to 2020 **
Cultivated cultivation of daffodils in mountainous areas	over 10.000	7.241
Year-round food delivery - mediation for other companies to plan their food deliveries	501-1.000	8.338
Production of fruit wines	over 1.000	9.254
Construction of phytowalls	5.000-10.000	9.940
Paulownia cultivation plantation	1.001-5.000	20.217
Germination machine and ponies	1.001-5.000	25.882
Combined cultivation of hazelnuts and truffles	101-500	31.275

Source: Compiled by the author.

- Construction of phytowalls (plantwall, green wall) – Phytowalls are special walls planted with live plants, which are located in offices, hotels, public buildings, private homes, etc.
- Production of fruit wines from berry crops - raspberries, blackberries, blueberries, chokeberry, blackcurrants, tayberry.
- Combined cultivation of hazelnuts and truffles - The roots of hazelnut saplings are one of the best hosts of the expensive and highly sought-after truffle mushroom.
- Plantations for growing Paulownia - Fast-growing tree, grown for timber and biomass. The idea is to use the uncultivated areas, especially in the semi-mountainous and southern regions of Bulgaria.
- Machine for germination of seeds and ponies of sprouts at home. It is possible to make money by selling sprouts to a retailer.

Descriptive statistics methods were used for analysis of the collected data - arithmetic mean (arithmetic mean), median, mode). Thus, the research used (1) a set of methods based on the analysis of numerical indicators statistics of human capital in rural settlements; (2) multidimensional statistical analysis of human capital to substantiate the objectivity of the data; and (3) analysis of functions (processes) and time series of the human capital of the agro-industrial sector in recent years. Besides, we used statistical methods for agro-industrial objects with non-numerical characteristics to prove the priority of human capital development. To measure the result of the presented ideas for obtaining a typical, pronounced main trend, we will calculate the average point in the distribution of participants' assessments, namely:

- We will use the arithmetic mean (arithmetic average) value to present participants' interest. In the specific case 16.021. There is considerable interest in the ideas for: Paulownia plantation, germination machine and ponies, combined cultivation of hazelnuts and truffles.
- Median - gives an idea of the center of the numbers in the group, that is half the numbers are bigger and half the numbers are smaller than it. For example, building phytowalls.
- Fashion - the most common numbers in the group are used. Defined as the elementary indicator for calculating a central trend, we will use fashion when considering the amount of investment. In this case - Paulownia plantations and germination machines and ponies, in the range of 1.001 EUR.

Presented information we can summarize, with some conditionality, that: the greatest interest, with the least possible funds, is in the combined cultivation of hazelnuts and truffles.

III. RESULTS AND DISCUSSION

Doing business requires more than ever updating the knowledge and skills of those employed in the agricultural sector.

In Bulgaria 98% of farmers do not have the necessary education. Many small farms do not know what digital agriculture is [3].

At European level, the Index of Digital Entry into the Economy and Society (DESI) is used to measure Member States' progress in the field of digital technologies - Table 5 [12].

The presented indicator is a set of selected significant factors. The following are considered to be the most important for digitalization:

1. human capital connectivity;

2. connectivity;

3. integration of digital technologies;

4. digital public services [13].

Individual achievements by Member State and averages at European Union level are presented in Table 6.

In rural areas, the coverage of very high capacity networks is only 1% (EU average: 28%). In addition, Bulgaria ranks very low in the overall distribution of broadband internet access, with only 59% (an increase of 1 percentage point compared to 2019) of households having a subscription (EU average: 77%) [12].

Despite the actions taken, Bulgaria ranks last in the EU according to the index for the penetration of digital technologies in the economy and society (DESI) for 2020. It is well below the EU average in all measured values [14].

TABLE 5 «DIGITAL ECONOMY AND SOCIETY INDEX (DESI)» 2021 RANKING

Indicator	Rank	Score
EU	**-**	**50.7**
1. Bulgaria	26	36.8
2. Austria	10	56.9
3. Belgium	12	53.7
4. Croatia	19	46.0
5. Cyprus	21	43.5
6. Czech Republic	18	47.4
7. Denmark	1	70.1
8. Estonia	7	59.4
9. Finland	2	67.1
10. France	15	50.6
11. Germany	11	54.1
12. Greece	25	37.3
13. Hungary	23	41.2
14. Ireland	5	60.3
15. Italy	20	45.5
16. Latvia	17	49.5
17. Lithuania	14	51.8
18. Luxembourg	8	59.0
19. Malta	6	59.6
20. Netherlands	4	65.1
21. Poland	24	41.0
22. Portugal	16	49.8
23. Romania	27	32.9
24. Slovakia	22	43.2
25. Slovenia	13	52.8
26. Spain	9	57.4
27. Sweden	3	66.1

Source: The Digital Economy and Society Index – Countries` performance in digitization (2022)» [12]. Compiled by the author on the basis of publicly available information.

«Following the approval of the National Recovery and Sustainability Plan by the European Commission, in 2022 the agricultural sector will be able to benefit from additional financial resources for investment. They will support activities to ensure the protection of environmental components and mitigation of the effects of climate change, introducing innovative production and digital technologies, electronic processes in the industry and communication between administration and business» [5].

With regard to the current state of farms in the agricultural sector, their declining number is visible.

Crop farms are significantly ahead of livestock farms - Tables 1 and 2.

Recent years have reflected a positive age management profile – Table 3. The trend continues with regard to the participation of women farm managers.

Significant efforts are needed to increase the digital skills of the population - with special emphasis on increasing the indicators for measuring the degree of digitalization not only at the national level – Table 5 and 6, but also in the agricultural sector in particular.

Human resources will soon be a limiting factor for the development of the national agricultural sector. The presented results support this statement – Table 6. The low educational level of its employees is indicative in the field of mechanization, animal husbandry, viticulture, fruit growing and vegetable production. We believe that this fact will have a negative effect on the development of modern agriculture and the introduction of innovations in the industry, respectively its competitiveness.

IV. CONCLUSIONS

The analysis on the topic, made within the discussed issues, examined the main trends in the agricultural sector, including the factors that have the greatest impact on trends in the context of the country's priorities.

The methodology used, which is based on a three-step deductive method - an overview of the general picture, reflecting current attitudes in the sector and recommendations for future action in specific areas, includes analysis of data from national and international statistical and information sources.

Theoretical conclusions:

1. In recent years, Bulgarian agriculture has taken shape as monocultural agriculture.

Commodity agricultural production, carried out in the current and even more so in the future market conditions, requires *adequate conditions for the development of human potential in the agricultural sector*.

2. Today, Bulgarian agriculture is becoming increasingly dependent on climate change.

Efforts are also needed for *the sustainable management of soil and water resources*.

TABLE 6 «INDICATORS FOR MEASURING THE DEGREE OF DIGITIZATION IN THE MEMBER STATES OF THE EUROPEAN UNION»

Indicator	Human capital		Connectivity		Integration of digital technology		Digital public services	
	Rank	***Score***	***Rank***	***Score***	***Rank***	***Score***	***Rank***	***Score***
EU	**-**	**47.1**	**-**	**50.2**	**-**	**37.6**	**-**	**68.1**
1. Bulgaria	27	32.7	26	38.1	27	20.5	21	56.0
2. Austria	9	53.3	11	53.0	11	41.3	9	79.8
3. Belgium	10	50.8	16	48.4	6	498	17	65.8
4. Croatia	16	46.7	20	45.4	13	40.0	24	52.0
5. Cyprus	23	39.7	24	41.8	20	30.5	19	61.8
6. Czech Republic	15	47.2	22	44.6	15	39.1	20	58.6
7. Denmark	4	61.2	1	74.0	2	57.9	2	87.1
8. Estonia	5	57.9	18	46.6	9	41.5	1	91.8
9. Finland	1	71.1	13	51.3	1	59.5	3	86.7
10. France	14	47.4	17	47.4	19	34.8	13	73.0
11. Germany	7	55.2	6	58.0	18	35.5	16	67.5
12. Greece	21	41.0	27	37.7	22	28.5	26	41.9
13. Hungary	22	40.5	12	52.0	26	23.3	25	49.2
14. Ireland	8	54.1	7	56.4	7	48.9	6	82.6
15. Italy	25	35.1	23	42.4	10	41.4	18	63.2
16. Latvia	20	41.1	14	50.4	23	26.8	10	79.6
17.Lithuania	17	46.1	25	41.7	12	41.2	12	78.0
18. Luxembourg	6	56.2	4	61.0	14	39.4	11	79.4
19. Malta	11	49.1	8	54.1	4	50.8	4	84.2
20. Netherlands	3	61.5	2	68.4	5	50.7	8	79.9
21. Poland	24	37.7	21	45.3	24	25.9	22	55.1
22. Portugal	18	45.6	15	48.5	17	36.6	14	68.5
23. Romania	26	33.1	10	53.2	25	23.8	27	21.5
24. Slovakia	19	43.8	19	46.3	21	29.1	23	53.7
25. Slovenia	13	47.8	9	53.2	8	42.3	15	68.0
26. Spain	12	48.3	3	62.0	16	38.8	7	80.7
27. Sweden	2	64.6	5	59.6	3	56.3	5	83.9

Source: The Digital Economy and Society Index – Countries` performance in digitization (2022)» [12]. Compiled by the author on the basis of publicly available information.

Practical conclusions:

1. The development of a sustainable agricultural sector depends to a large extent on the subsidies paid in the context of the European Union's Common Agricultural Policy. The financing indisputably guarantees the income support of large farmers. *A digital platform is needed to monitor the sector*.

2. The development of human potential requires *training adequate to modern technologies* - a prerequisite for the development of the individual and human capital in general.

The preconditions for economic development of the country fail to realize their potential. For this reason, it is not necessary to mechanically list specific activities, but *real indicators for measuring and evaluating specific measures*.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 97-102

The Integration of the Digital Economy and the Green Transition – Opportunities for Small and Medium-sized Enterprises

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***Abstract*—Small and medium-sized enterprises (SMEs) play an important role in the development of national economies. The specificity of digital transformation in the conditions of green transition requires the disclosure of the problems and opportunities arising in their practice. Based on a conceptual framework of the digital transformation of SMEs in the context of the green transition, this study outlines some of these issues and opportunities through in-depth interviews with expert managers managing SMEs. The analysis of the results shows: the specificity of the problems of SMEs working in the field of production of organic food and bio products; the role of digitization of activities in the management of SMEs to support the transition to productions with minimal impact on the environment; the need to inform customers about the benefits of consuming products that do not endanger the environment; the need to explore the application of artificial intelligence in the field of ecological production. On the basis of these conclusions, a quantitative study of the problems and challenges faced by SMEs in the digitalization of their activities in the conditions of the green transition can be planned.**

Keywords*—SMEs, digital economy, green transition, in-depth interview

I. Introduction

The application of digital technologies, as well as the reduction of the harmful impact of human activity on the environment, is a current topic of the modern economy.Digital skills and competences have an important role in increasing the possibilities of adaptation of human capital to the changing requirements of jobs and the labor market in the conditions of Industry 4.0. [1]. Globalization, changing economic and social conditions, the introduction of innovative digital technologies are some of the factors requiring the need for changes and restructuring of labor markets. Flexicurity is a holistic approach to labor market policy that provides workers with secure jobs the opportunity to quickly find new ones. Flexibility implies a smooth transition of workers to rapidly changing working conditions. Flexibility and security go hand in hand. [2]. In the exceptional difficult conditions in which modern business is to function, Industry 4.0 has become ubiquitous in the following economic areas, characterized by enhanced digital connectivity and mobility of people of active working age, whose existence has become part of the large digital community: [3]

- information and communication technologies;
- cyber-physical systems;
- storage and processing of large-scale data sets (so-called cloud systems);
- systems for modeling, simulating and virtual presentation of information;
- tools for interaction between humans and computing machines.

On the other hand, the role of small and medium-sized enterprises (SMEs) is very important for the development of national economies – within the European Union, SMEs provide employment to more than 100 million people and produce more than half of the GDP in Europe.Micro, small and medium-sized enterprises (SMEs) make up 99% of companies in the EU [4].They provide two-thirds of jobs in the private sector and contribute to more than half of the total added value created by businesses in the EU.In Bulgaria, small and medium-sized enterprises contribute to 75.7% of total employment and to 65.3% of the added value in the

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8657
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economy in 2018. The combination of digitalization policies and orientation towards ecological sustainability of the economy in the context of the specifics of small/mediumenterprises can lead to a synergistic effect and deserves in-depth study and application of the results in practice.In the current development, a study is planned using the method of in-depth interviews with experts, in order to outline the opportunities and challenges for SMEs in the integration of digital and "green" solutions in their practice.

II.Materials and Methods

A. The integration of the digital economy and the green transition

The development of modern economies and societies focuses on two issues: the potential of information and communication technologies (ICT) and the challenge of environmental sustainability."Digital economy" is a relatively new concept in policy development, replacing terms such as "information economy" (1970), "knowledge economy" and "e-economy" (1980), "new economy" (1990) or "network economy" and "Internet economy" (2000s).Although there is no single definition of the digital economy, there is general agreement on some basic principles [5].Digital transformation and in particular the use of information and communication technologies (ICT) is a comprehensive and long-term process that includes: the development of new technologies to improve production processes, which may include cloud computing, big data analysis, IoT (internet ofthings);improvement of business processes, including use of business decision support systems;improving customer service, including improving marketing solutions;building an organizational culture oriented towards digitalization-related changes.It can be said that the implementation of ICT fundamentally changes the way a business works in order to be more flexibly managed and bring more benefits to customers - digital transformation creates a new organizational culture oriented towards innovation and continuous process improvement.In the context of considering digitalization, we cannot ignore the entry of artificial intelligence into all spheres of production and business management.

There is no universally accepted definition of artificial intelligence (AI), but the term generally refers to a manifestation of digital transformation that involves the use of algorithms and machine learning to automate tasks that traditionally require human intelligence.This can include tasks such as speech recognition, text generation, image recognition and creation, and more.AI technologies can be used to automate routine tasks such as data entry or customer service inquiries, freeing up time and human resources for more complex and creative tasks.Automation is a broader category that includes any technology or process that reduces or eliminates the need for human labor in a task or process.Digital transformation, AI and automation are related concepts, but each has different goals and use cases.By understanding these specifics, managers can make informed decisions about which technologies to implement in the production and management of the company and how to use them to achieve maximum effect.The focus of numerous publications by contemporary authors is the impact of digitalization on sustainable development, part of which is the transition to a green economy and the reduction of the impact of human activity on the environment.

B. Specificity and challenges for SMEs in the context of the digital transformation of SMEs in the conditions of the green transition

There are significant structural differences between SMEs and large enterprises.They become evident in the exploitation of resources, policy-making procedures and the structure of organizations [6].Due to the size of large enterprises (250+ employees), they tend to be bureaucratic, possibly specialized, highly standardized and formalized [7].SMEs, in contrast, tend to have informal procedures that extend to the loss of working relationships and lack of standardization [8].Bureaucratic structures would be less effective for SMEs due to their turbulent environment, which is oriented towards quick results, innovation and flexibility to adapt to new situations [9].Large organizations have several levels of management, resulting in top management being far from the point of delivery.In SMEs, hierarchies are flat and top management is visible to other employees, effective communication is facilitated and it is easier for managers to lead by example [8].The flexible work environment of SMEs, which is associated with flat hierarchies, allows top management to develop strong personal relationships with their employees [7], [8].However, it can also increase the potential for interpersonal conflict.Large organizations have a range of management styles, such as direct, participative or paternalistic.Employees are often evaluated based on their performance, leaving less room for personal relationships [6].The culture of a large organization is usually diversified and inert due to the number of employees, departments and business functions, while the culture of an SME tends to be more unified and fluid [7], [9].Due to limited financial resources and the lack of qualified specialists, SMEs have limited opportunities for staff training and development.Large organizations, on the other hand, plan their staff training on a budget and implement it on a large scale [6].Overall, this leads to a defining difference between the two forms of organizations.

Although large companies are system-oriented, they are also less innovative and responsive to changes in customer demand; take longer to respond to environmental changes, and experience a high degree of resistance to change [9].SMEs, in contrast, are people-

oriented, can more easily respond to market needs, adapt to change, and use their innovative capabilities to meet customer demand [8], emphasizing everything that ensures their competitiveness.Sustainable development is also a serious precondition for achieving high quality. By adopting the principles of sustainable development, enterprises can not only gain a competitive advantage in the market but also promote a positive reputation and increased public prestige [11], p. 383.

One of the challenges for SMEs is the identification and subsequent legal protection of intellectual property objects, which can also create a competitive advantage.These issues are extensively discussed in the available literature. [12], [13], [14], [15].

According to the literature review, the challenges facing SMEs are reflected in the following aspects: (1) Manpower constraints in small businesses, each employee has a key role, sometimes several, resulting in few free resources [16].Allocating employees to a project will leave them with less time for their actual work, a reason why management often views employee training as a waste of time and why a small workforce is considered a critical failure factor for SMEs [8].Smaller firms tend to allocate more of their internal resources to administrative functions than larger firms.(2) Financial constraints The lack of financial resources of SMEs implies that companies cannot afford large investments in technology, sufficient infrastructure and staff training, although these are considered critical for reducing the time to implement continuous improvement methodsand ultimately lead to savings and reduced labor costs [8].(3).SMEs are more dependent on the administrative environment, economic shocks and market contingencies (e.g. the health crisis caused by COVID 19).

The conceptual framework of the digital transformation of SMEs in the conditions of sustainable development, of which the green transition is a part (Figure 1), was presented in a previous publication and was considered in the context of the threats and opportunities determined by the specifics of the functioning of SMEs in the country [17].

In the research area thus delineated, the questions are posed to highlight the main issues and challenges faced by SMEs in this context.To outline these problems and challenges, qualitative studies are suitable, which do not lead to the collection of representative data, but are the basis for revealing possible answers to the questions posed in the researched area.For the purposes of the present study, the method of in-depth interviews with experts from practice was chosen.

C. Research methodology

The in-depth interview method is widely used in the field of marketing research as part of the collection of formative data.This research method belongs to the qualitative methods, which means that the aim is not to collect representative data and a representative sample is not necessary.The aims here are to uncover personal opinions, motivations and attitudes that can be valuable in planning quantitative research and in particular in generating research hypotheses about the main research questions.

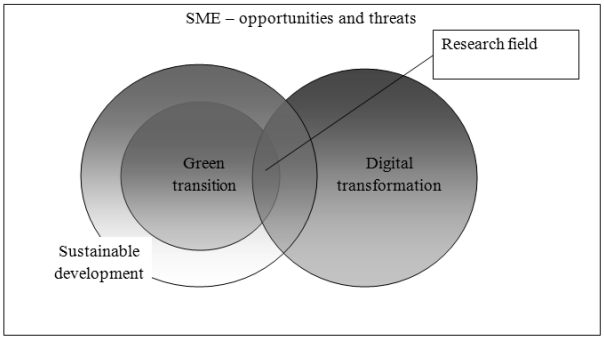

Fig.1. Conceptual framework of the digital transformation of SMEs in the conditions of sustainable development, part of which is the green transition

Advantages of in-depth interviewing:

• The main advantages of qualitative methods – they are creative and can lead to valuable discoveries;give greater freedom to the researcher and do not require a representative sample.

• Advantages of personal contact – interviewers can create a sense of trust in interviewees, resulting in honest responses.

• Interviewers have the opportunity to clarify the meaning of the questions, to deepen the conversation based on the answers already received, as well as to return to already discussed questions to clarify more fully the opinions, motives and attitudes of the interviewees.

• Interviewers can also receive non-verbal information by observing the displayed emotions and characteristic speech of the interviewees, including by observing "body language".

• Possible distractions and deviations from the issues discussed during focus group discussions are avoided.

• They are suitable for researching the opinion of experts in a given field, in this case – managers of small and medium enterprises.

The purpose of the conducted in-depth interviews is to outline the main challenges facing SMEs and the directions in which they achieve results in the field of digitization of their activities in the conditions of the green transition.For this purpose, surveys were conducted using the in-depth interview method with several leading managers of SMEs.The results will be used to plan a quantitative survey among SMEs in certain regions of Bulgaria.

Questions included in the interview:

- *What are the characteristics of SMEs in Bulgarian conditions - advantages and disadvantages? What are the advantages of large companies in the implementation of ICT?*
- *are the advantages of large companies in the introduction of green technologies?*
- *Are there negative impacts due to the physical development of productions as a result of the use of ICT (eg pollution and energy consumption for production and for disposal, etc.)?*
- *What Are there positive impacts due to the opportunities created by the application of ICT to optimize unsustainable pollutant/water consumption processes (ie energy saved by using consumed ICT in applications)?*
- *Are there impacts as a result of replacing some activities with digital task performance, for example avoiding travel?*
- *Are there any impacts on the company, especially on marketing decisions? Is AI being used to improve the site and customer contact?*
- *What are ICTs mostly used for - to improve production processes, to optimize management decisions or to improve customer contacts?*

III. Results and Discussion

A. Analysis of the results of the conducted interviews

Some small companies, whose representatives were interviewed within the framework of the present study, have started their activities in the field of production of organic food and other biological products.One of these managers pointed out that the company operates with a **completelycarbon neutral footprint**, and by digitizing production processes, the impact of production on the environment is taken into account at all times.A medium-sized company points to experience in the digitization of production processes, which leads to a significant environmental effect - **recycling production machines** (including those of competing companies) with 3D printed parts and achieving less production waste.In some industries, waste is recycled into 3D printing material instead of being thrown away and polluting the environment.SMEs in Bulgarian conditions are more flexible and there are no particular restrictions on their activities.A limitation is that they have a smaller financial resource and cannot take advantage of a ready-made development by purchasing it in the form of a patent or license, and own developments require additional investment.

Difficulties in legalizing innovative materials, for example materials from sugarcane and bio plastics, and especially materials intended for use in construction, are an obstacle for both large, medium and small companies.There are also problems to be solved at national and European level - for example the introduction of a digital passport of the material - based on tracking how it was before and after recycling.As a rule, there are no negative influences due to the physical development of productions as a result of the use of ICT.Sometimes there is a need to expend energy to recycle the materials, but these additional needs are offset by renewable sources.The benefit of recycling is greater because it **reduces the use of plastic**, reduces the use of water and energy to produce it, and ultimately makes production cheaper.

The search for ways to avoid environmental pollution and the introduction of waste-free technologies leads to directing the thinking of managers in the direction of greening production processes and minimizing the footprint on the environment.Some of the interviewees indicated that they faced bureaucratic and corruption obstacles in financing.There are also legal and regulatory barriers to the import and production of organic foods.

The lack of consumers preferences towards ecological products, in particular – packaging, is often pointed out.

The low level of consumer awareness of the offer of organic products and products produced using ecological technologies, as well as the insufficient efforts of companies in the field of offering these products has been detected. Some activities are replaced by digital performance of tasks - they rely on online trade, advertising and make contacts with foreign partners and end customers.ICT is used to a large extent to **improve production processes** and to **establish contacts with customers**, relying mainly on online sales.Some of the interviewees have a vision of **using artificial intelligence (AI)** in the field of company management.This can be done in at least two ways:

• **Improving company's site management** and customer service: With the help of AI capabilities, the preferences and rhythm of submitting requests from current customers, as well as trends in the searches of potential customers can be studied.Customers can be assisted in the form of consultation and answering questions through artificial intelligence-based software. The growing number of online customers leads to the need to implement more and more automatic business solutions - these solutions can be in the field of predictive models, optimization methods, language models, etc.;

• **Cyber security management** - regardless of the specifics of their activity, all companies are potentially at risk of breaches in the security of this data, at least through their contacts with various partners.AI-based

software can detect threats to company data, for example by detecting unusual Internet activity.The summarized results of the conducted interviews can be presented schematically, finding the opinions expressed more than once by SMEs, manufactured organic products and SMEs from other industries - table 1.

Table 1. Summary results of the conducted interviews

SMEs	**Digitization of the activity**	**Digitization contributing to greener production**	**A vision for using artificial intelligence**
SME producers of organic products	Digitization of production processes and customer service	Achieving zero impact on the environment through digitization of production processes	-
SMEs in other industries	Digitization of production processes and customer service	Recycling of details and materials	To improve customer service; To manage cyber security

B. Discussion

The results obtained outline certain issues and opportunities that should be addressed further, including quantitative research.One of the problems facing SMEs is the low level of awareness in the markets about the benefits of products, firstly aimed at improving the quality of life of end users (organic food and organic products) and secondly - those whose productionand consumption does not harm the environment.It is necessary to determine how **campaigns to inform consumers about the benefits of these products** affect consumer attitudes and sales volumes.Special attention should be paid to the **market of organic foods and nutritional supplements** and the market results of companies specializing in their production.Such firms should be represented by a **separate quota in the sample in quantitative research.**

As found from the answers of the interviewees, **technologies for material recycling** are entering the practice.It is necessary to investigate the attitude of managers regarding the introduction of waste-free technologies and technologies for recycling materials used in production.This research should take into account, firstly, **the immediate benefits** of the introduction of technologies and secondly, **the impact of this process on the company image.**

Problems and opportunities are also determined by the use of artificial intelligence for the purposes of company management.In the in-depth interviews conducted, some of the respondents indicated that they use the capabilities of artificial intelligence tools that are not specialized for their specific company goals.The experience of large companies shows that it is possible to develop and use specially developed and company-oriented AI systems.However, this requires resources that SMEs generally do not have.Therefore, SMEs need their **own strategy for using a combination of AI tools** to optimize their results while using limited resources.

AI tools can be used to create digital images of the "ideal customer" and "problem customer" to serve as a basis for segmenting markets and optimizing customer service.

The obtained results are the basis for planning a quantitative study that will discover the most common problems and opportunities facing SMEs in the digitalization of production and management processes in the conditions of transition to a green economy.The questions through which quantitative data will be collected should follow the logic of the questions asked in the in-depth interviews and the possible answers that emerged as a result of them.

IV. CONCLUSIONS

The results of the conducted in-depth interviews show, **first of all,** that SMEs working in the field of bio-food and bio-products production should be considered separately and in more depth, as they have a certain specificity - their very activity is aimed at minimizing harmful effects on consumers and the environment.

Second, the digitization of SME management activities can support the transition to production with minimal (or even zero) environmental impact.

Third, attention must be paid to the challenges in the area of informing customers and the public about the benefits of using products (including packaging) that do not endanger the environment.

Fourth, the application of artificial intelligence in the field of ecological production, which is yet to be developed, should be explored. The outlined main challenges for SMEs in the field of digitization of their activity in the conditions of the green transition will serve to plan a quantitative study in this area.

AKNOWLEDGMENTS

This paper was funded by a project on the topic: Development and testing of a methodology for implementing and evaluating innovation strategies in business organizations by Technical University of Gabrovo, Bulgaria.

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Legal Aspects and Practical Solutions to Environmental Problems in the Construction of New Nuclear Power Plants in the Republic of Bulgaria

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***Abstract* — Nuclear technologies are emerging as one of the best ways to produce clean energy and ensure sufficient power for base load. At the global and national level, nuclear power plants are becoming a key resource that can guarantee national energy security, independence and affordable electricity prices. The issues related to project financing, lengthy and expensive licensing procedures, still unresolved issues with nuclear waste management and public opinion in assessing the impact of the project on the environment are being discussed. In view of the historical and regulatory analysis of the experience gained in the Republic of Bulgaria in building new nuclear power plants, conclusions have been formulated and trends for practical solutions to environmental and technological problems in nuclear energy have been outlined.**

Keywords*— *environment, licensing, nuclear legislation, nuclear power plant.

I. INTRODUCTION

The Republic of Bulgaria has many years of experience in using nuclear technologies for the production of electricity. The beginning was made in the 1960s at the site in the town of Kozloduy, where four nuclear reactors of the VVER-440/B-230 type and two nuclear reactors of the VVER-1000/B-320 type were gradually built and put into operation.

The VVER-440/B230 reactors were designed in the late 1960s and their design was found to be inconsistent with modern safety requirements. Therefore, a number of improvements were implemented in the 1980s and 1990s to implement an acceptable level of safety. Nevertheless, due to the country's accession to the European Union, the operation of the four nuclear reactors was terminated before the expiration of their design life. Units 1 and 2 were finally shut down for decommissioning at the end of 2002, and units 3 and 4 at the end of 2006.

The design of the VVER-1000/B-320 reactors (units 5 and 6 of the Kozloduy NPP) generally complies with internationally accepted safety requirements. They have a hermetic containment, triple redundancy of safety systems. They were put into operation in 1987 and 1991, respectively. The basic principle of nuclear power plant safety has been applied to them - defense in depth, using several physical barriers. Based on the analysis of operating experience, comparison with similar reactors and increased international safety requirements, a modernization program has been developed and implemented to improve the safety of the units.

Over the past two decades, the topic of "nuclear energy" has once again been on the agenda, both in the Republic of Bulgaria and worldwide, attracting the attention of scientists and politicians regarding the benefits of nuclear energy. Its role in combating climate change and carbon dioxide pollution is emphasized [1];[2]. It is gradually becoming an effective and economical alternative to electricity produced from fossil fuels. The expectations are that the European Union Commission will propose that nuclear energy be included as a "green" or "transitional" technology within the European Union's taxonomy for sustainable finance.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8636
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On 2 February 2022, the European Commission approved in principle a Supplementary Delegated Act on Climate under the Taxonomy Regulation, relating to climate change mitigation and adaptation and covering certain activities related to natural gas and nuclear energy.

Two years later, on 6 February 2024, the European Parliament and the Council reached a political agreement on the proposal for the Net Zero Emissions Industrial Act. The European Union finally adopted the Net Zero Emissions Industrial Act on 28.05.2024.

This legislation is expected to attract investment and create better conditions and market access for clean technologies in the European Union. The aim is to increase the Union's overall strategic capacity for the production of net-zero emission technologies to at least 40% of annual deployment needs by 2030. This will accelerate progress towards the Union's 2030 climate and energy targets and the transition to climate neutrality by 2050. It also simplifies the regulatory framework for the production of clean technologies. This will help to increase the competitiveness of the net-zero emission technology industry in Europe, as well as to improve the capacity to store CO2 emissions.

The legislative act identifies technologies that will make a significant contribution to decarbonization. The production of nuclear reactors and components for the operation of nuclear power plants is given priority support and incentives, including faster permitting procedures. Nuclear technologies are emerging as one of the best ways to produce clean energy and ensure sufficient baseload power. Nuclear power plants are emerging as a key resource that can guarantee national energy security, independence and affordable electricity. Currently, the Member States of the Union are working on plans to build about 21 new nuclear reactors - both conventional and small modular reactors.

II. Materials and methods

The article analyzes international and national legislation, including strategic and guiding documents of state bodies.

In Bulgaria, scientific publications on the topic are scarce, and changes in state policy and regulations are frequent and inconsistent. A combination of different scientific research methods was used to obtain a more complete and objective picture of the problem under study, among which the following stand out: historical-chronological, comparative and systematic analysis.

III. Results and discussion

A. National nuclear characteristics of the Republic of Bulgaria

Nuclear energy is of great importance for the Republic of Bulgaria. In the national energy mix, it accounts for 33% of the total amount of energy produced. The Council of Ministers manages the country's energy sector in accordance with the strategy adopted by the National Assembly and the current Integrated Plan for Energy and Climate of the Republic of Bulgaria. With the changes in the geostrategic and political plan and the escalation of the conflict in Ukraine, the public discussion of the Draft Energy Strategy until 2030 with a horizon of 2050 scheduled for September 2020 has been postponed. Thus, as of 2020, the country has not had an effective, approved strategy for energy development that has been adopted by the National Assembly.

In January 2023, the Council of Ministers adopted a Strategic Vision for the Development of the Electricity Sector of the Republic of Bulgaria 2023 – 2053. Despite being adopted by a collective body of the executive power within its competence, the strategic vision does not have the features of an individual, general or normative act. It can be defined as a political framework, a document of a programmatic nature, formulating the policy, priorities, strategies.

According to the Strategic Vision for the Development of the Electricity Sector of the Republic of Bulgaria 2023 - 2053, the necessary investments for the nuclear energy, renewable energy and hydroelectric power sub-sectors for the period amount to 46,350 million euros.

It is planned that 1 billion euros or 23% of the total amount will be state participation. Investments in nuclear energy for 2023 - 2053 are planned for two projects with an estimated value of 22,000 million euros. International financial institutions and strategic investors are indicated as sources of financing.

In order to preserve the energy independence of the Republic of Bulgaria and its role as a net exporter of electricity and a balancer for the region, Part VIII of the document presents the prospects for electricity development for the period 2023-2053, including a set of options for achieving full decarbonization in 2050, while at the same time complying with the European "Fit for 55" package in 2030.

The reform of the EU's emissions trading system, as part of the "Fit for 55" energy package, is projected to lead to higher emissions prices. This in turn will lead to a 58% reduction in coal-fired power generation by 2030. In the model, most of the emissions reduction occurs by 2035, when lignite production declines significantly and is replaced by new nuclear generation.

The country's energy policy is carried out by the Minister of Energy. The Council of Ministers approves the Integrated Energy and Climate Plan of the Republic of Bulgaria and updates to the plan upon proposal of the Minister of Energy and the Minister of Environment and Water.

The National Integrated Energy and Climate Plan of the Republic of Bulgaria 2021-2030 was prepared in implementation of Regulation (EU) 2018/1999. It was submitted to the European Commission in March 2020 and approved in October of the same year. The plan is currently being updated. Given the current situation and trends in the

development of electricity price levels on energy markets, it appears that the envisaged reform regarding the decarbonization of the Bulgarian energy sector by 2026 in the Recovery and Sustainability Plan is unrealistic and difficult to achieve.

Including energy production from new nuclear capacity in the national energy mix after 2030 is part of the main assumptions in the draft updated plan.

B. Brief description of the nuclear projects for new nuclear capacities under construction in the Republic of Bulgaria

Nuclear power plants, as well as the approved sites for their construction, are sites of national importance.

According to the Act on the Safe Use of Nuclear Energy, a nuclear power plant is built by a decision of the Council of Ministers. The proposal for the construction of a nuclear power plant is submitted by the relevant minister. He organizes a discussion of the proposal for the construction of a nuclear power plant, in which state bodies and local government bodies, representatives of public organizations and interested individuals and legal entities participate. The assessment of the results of the discussion, including the environmental impact, is applied to the proposal. The use of a power unit of a nuclear power plant in accordance with its main purpose begins after the entry into force of an operating license issued in accordance with the law and in the presence of an effective license for the production of electricity and/or heat, issued in accordance with the Energy Act.

In 2005, by decisions of the Council of Ministers, the Belene site intended for a new nuclear power plant was designated as a site of national importance. The proposal of the relevant minister was approved and a consent in principle was given for the construction of the nuclear power plant after obtaining licenses and permits.

Seven years later, the Council of Ministers revoked its decisions, and the National Assembly, for its part, supported its actions and on 29.03.2012, adopted a decision terminating the construction of a nuclear power plant at the Belene site. The same decision assigned the relevant minister to carry out the necessary work to build a new nuclear power plant at the Kozloduy NPP site, using the equipment paid for by the Republic of Bulgaria. In addition, on 11.04.2012, the Council of Ministers adopted a decision giving its consent in principle to the construction of a new nuclear power plant at the Kozloduy NPP site. The decision assigned the relevant Minister to submit to the Council of Ministers a report with a view to making a decision on the substance and a report on the legal and organizational form for the implementation of the project.

The experience of the Republic of Bulgaria with the development of new nuclear projects and the licensing process for the construction of new nuclear power plants is long-standing, and at certain stages it is contradictory and inconsistent. In addition to the various factors that contribute to hesitant progress, there is also a lack of a clear vision for monitoring procedures and processes aimed at ensuring a safer and more secure environment for citizens [3]. Furthermore, there is a pressing need to update the availability of both collective and individual anti-chemical and anti-radiation protection measures for the population [4].

In order to obtain information about the characteristics of the projects for new nuclear power plants in the country in terms of the application of eco-innovative technologies and the solution of environmental problems, the implementation of investment intentions in this direction was monitored over the last ten to fifteen years. The study of the established organization for licensing and commissioning the implementation of the project established the following:

The main objective of the state-owned company "Kozloduy NPP - New Builds" PLC is to organize and implement a feasibility study, design, construction and commissioning of power units of a nuclear power plant.

The site selection studies aim to assess the proposed four potential sites for new nuclear capacity. The sites are adjacent to the existing nuclear power plant – "Kozloduy NPP", which is in accordance with the requirements of national and international regulatory documents, including the recommendations of the International Atomic Energy Agency. These studies were contracted out to an external contractor and were carried out in the period 2012-2014.

In accordance with the requirements of the Environmental Protection Act, in May 2012, a procedure for assessing the environmental impact of an investment proposal was initiated. The assessment was also commissioned to an external contractor to conduct an independent analysis of the possible causes, sources, and degrees of impact during the project's implementation on environmental components and to determine the potential risks to the environment and human health during construction, normal operation, and possible design and beyond-design accidents at the plant.

An Environmental Impact Assessment Report was prepared, which was submitted to the Ministry of Environment and Water, as the competent authority for assessing the quality of the report, in August 2013, regarding the degree of impact of the investment proposal on protected areas, in accordance with the provisions of Article 34, paragraph 1 of the Ordinance on the terms and procedure for conducting an assessment of the compatibility of plans, programs, projects, and investment proposals with the subject and objectives of protecting protected areas.

The Ministry of Environment and Water gave a positive assessment of the report. In general, the results of the analysis reflected in the Environmental Impact Assessment Report are summarized in the following conclusions:

- No non-radiation impact on environmental components and factors is expected;

- No radiation impacts on water, land and soil, geological environment, subsoil, land use, mineral diversity, biological diversity, ecology, and cultural resources are1 expected; areas inhabited by protected, important, and sensitive species of flora and fauna; scenic areas; sites and objects of historical and cultural significance, objects protected by international or national law, as well as on human health;

- No negative impact from radioactive waste is expected, provided that the nuclear facility's decommissioning plans and all applicable Bulgarian and international legal requirements and practices are followed;

- The contribution of the new facility to the radiation background in the vicinity of Kozloduy from external radiation exposure is negligible, even in accumulation with the existing nuclear facilities at the Kozloduy NPP site. The cumulative impact in radiation terms on the environment is assessed as insignificant, and no cumulative impact in non-radiation terms is expected;

- No transboundary impact is expected on the territories of neighboring countries.

In August 2013, the Nuclear Regulatory Agency issued a permit for determining the location (site selection) of the nuclear facility. On the recommendation of the agency, the Bulgarian Academy of Sciences was assigned to carry out an independent verification of the results obtained during the studies carried out at the stage of the feasibility study. The subject of independent verification are the developments related to site selection in the areas of: Seismics, Meteorology, Engineering Geology. The independent verification confirms the studies carried out - the proposed site is suitable for the deployment of both the equipment ordered for the Belene NPP and the equipment under the project for a completely new technology III or III+.

In early 2014, negotiations began for the structuring of the project and its financing with Toshiba Corporation, Japan, as a strategic investor and Westinghouse Electric Company, USA, as the owner of the technology "Pressurized Water Reactor (PWR) - AP1000 of Generation III+". A few months later, in June 2014, Westinghouse Electric Company LLC replaced Toshiba Corporation as a strategic investor in the negotiations for the construction of a new nuclear capacity at Kozloduy NPP. During the negotiations, a proposal was made to change the strategic investor, which necessitated the Council of Ministers' decision to authorize the conclusion of an annex to the Strategic Investor Agreement.

In January 2015, the Environmental Impact Assessment procedure was completed with Decision No. 1-1/2015 of the Minister of Environment and Water, by which the competent authority approved the implementation of the investment proposal for the construction of a new nuclear power unit at the Kozloduy NPP site.

The administrative act was appealed before the Supreme Administrative Court, and the administrative case continued during the period 2016-2019.

With Decision No. 4904 of April 2, 2019, under administrative case No. 12369/2018, a five-member panel – Second Chamber of the Supreme Administrative Court overturned Decision No. 6524 of May 17, 2018, of the Supreme Administrative Court, rendered under administrative case No. 3947/2015, which had overturned Environmental Impact Assessment Decision No. 1-1/2015.

Along with overturning the decision of the lower court, the cassation instance also ruled to dismiss all appeals against the Environmental Impact Assessment Decision. Decision No. 4904 of April 2, 2019, is final (Article 223 of the Administrative Procedure Code), as with its issuance, the regular means of judicial review of the issued administrative act are exhausted. In accordance with Art. 90, para. 1 of the Administrative Procedure Code, the resolution of the dispute by the relevant judicial authority leads to the removal of the regulatory prohibition on the execution of the administrative act, in view of which, it should be considered that the contested Environmental Impact Assessment Decision has entered into force. In accordance with the requirements of the Nuclear Regulatory Agency and the applicable regulatory framework, with the entry into force of the Environmental Impact Assessment Decision, all necessary prerequisites for the issuance of an Order by the Chairman of the Nuclear Regulatory Agency for the approval of the selected site for the construction of a nuclear facility have been met.

• The National Assembly made a decision in June 2018 to resume activities to explore opportunities for the construction of Belene Nuclear Power Plant. With its decision, the National Assembly recommended to the Council of Ministers to take action to repeal its decision No. 250 of 29.03.2012, in order to conduct negotiations with potential investors and equipment manufacturers. This repeal became a fact with the adoption of the Council of Ministers decision No. 447 of 29.06.2018. The adopted decision of the Council of Ministers and the possible restart of the construction of the Belene NPP (by repealing decision No. 250/29.03.2012) does not imply the termination of the activities of Kozloduy NPP - New Builds PLC. The specified acts of the legislative and executive authorities relate only to the Belene NPP project, and have no legal effect with regard to the project for the construction of a new nuclear capacity at the Kozloduy NPP site. The establishment of the Company is the result of a valid decision of the sole owner of the capital - "Kozloduy NPP EAD", which has received prior consent from Bulgarian Energy Holding EAD, in accordance with the articles of association of both companies. The specified actions were taken in implementation of a decision of the Council of Ministers under item 1 of Protocol No. 14 of April 11, 2012, which gives consent in principle for the construction of a new nuclear capacity of the latest generation at Kozloduy NPP and which is not affected by the repeal of the decision of the Council of Ministers No. 250/29 March 2012. Along with this, the decision of the

National Assembly from 2012, which has also not been repealed, should also be taken into account, and by which the Minister of Economy, Energy and Tourism is assigned activities for the construction of a new nuclear power plant at the Kozloduy NPP site.

Working meetings were held with representatives of the Ministry of Environment and Water and in May 2019, specific actions were determined in accordance with the effective Decision No. 1-1/2015 of the Minister of Environment and Water, which approved the investment proposal for the construction of a new nuclear power plant of the latest generation at the Kozloduy NPP, concerning:

- Development of a Plan for measures to prevent, reduce or eliminate significant harmful impacts on the environment (Monitoring Program) in accordance with the requirements of the Decision;

- Assessment of the need to prepare an environmental assessment of the developed Plan/Program;

- The transboundary nature of the investment proposal - the need to notify the affected parties in the Environmental Impact Assessment procedure of the effective Decision;

- Development of the above-described Monitoring Plan/Program and preparation of the necessary documentation for its submission to the Ministry of Environment and Water and the Regional Inspectorate for Environment and Water - City of Vratsa.

In order to fulfill the imperative obligations, conditions and measures set out in the Decision on Environmental Impact Assessment, it is necessary to carry out constant monitoring and periodic control of the parameters of the processes and phenomena of natural and technogenic origin, concerning the site area, by building monitoring systems in a radiation and non-radiation aspect. A working group has been formed, with experts from Kozloduy NPP and "Kozloduy NPP – New Builds" PLC, which has developed a Program for constant monitoring of site No. 2, approved for the deployment of a new nuclear facility – a nuclear power plant, containing activities, methods and requirements necessary to ensure the construction and implementation of a monitoring network in volume and content, in accordance with national and international requirements.

In accordance with the requirements described in the terms of the Decision on Environmental Impact Assessment, the Program has been sent for coordination with the Executive Agency for Environment, the Ministry of Health and the Nuclear Regulatory Agency.

The Executive Agency for the Environment has no comments on it. The Ministry of Health has noted the need to add clarifying information, which will not significantly change the content of the Program.

The main objectives of the monitoring are resource provision, use of sensors and interfaces suitable for the implementation of the objectives and application of the principles of autonomy, redundancy and diversity.

• At its meeting on October 14, 2020, in the context of achieving the European Union's goals for climate neutrality by 2050 and diversification of energy resources, the Council of Ministers decided to take preparatory actions and study the possibilities for building a new nuclear power plant at Site No. 2 at Kozloduy NPP, approved by order of the Chairman of the Nuclear Regulatory Agency.

The relevant Minister has been assigned to take the necessary actions and authorize Bulgarian Energy Holding EAD to enter into negotiations with companies from the United States of America developing new nuclear technologies for peaceful purposes, including small modular reactors, in order to study the possibilities for building a new nuclear power plant at the approved site at Kozloduy NPP.

• The Bulgarian Minister of Energy and the US Assistant Secretary of State for International Security signed a Memorandum of Understanding on future nuclear cooperation in October 2020. In the context of the Memorandum of Understanding, on December 4, 2020, the U.S. Ambassador and her team visited the Kozloduy NPP to explore the possibility of a partnership in developing a solution for the future energy needs of the Republic of Bulgaria.

• Based on a meeting between the Prime Minister of the Republic of Bulgaria and the Executive Director of Kozloduy NPP on January 20, 2021, a report by the Minister of Energy on the actions and results of the study of opportunities for the construction of a new nuclear power plant at the approved site in Kozloduy NPP was adopted at a meeting of the Council of Ministers. At the meeting, the Minister of Energy specified that talks had been held and correspondence had been exchanged, including with Westinghouse, as three technologies were approved under the Environmental Impact Assessment. One technology is the American AP1000 reactor technology, the other two are Russian technologies, which are the reactors for Belene NPP. The experts' report notes that the implementation of Unit 7 of Kozloduy NPP with the available equipment from the Belene NPP project is supported. The executive director of Kozloduy NPP EAD expressed the opinion that with good organization, a new unit could be launched within ten years.

• "Kozloduy NPP - New Builds" PLC concluded a contract with Westinghouse Energy Systems LLC - Bulgaria Branch in March 2023 for the provision of initial engineering and design services. Within the framework of the contract, the advantages of the site at "Kozloduy NPP" for the deployment of two nuclear units of type AP1000, related to the available infrastructure, should be assessed, as well as the opportunities of the Bulgarian industry for participation in the project should be analyzed. After completion of the activities under the contract, it is expected to provide engineering services related to the design, project management and engineering development of the site for the deployment of two new nuclear units of

III + generation type AP 1000. In June 2023. The implementation of the concluded contract began, and a year and a half later, on October 23, 2024, an additional agreement was signed between the parties to extend the term and scope of the contract for preliminary engineering activities.

• Kozloduy NPP - New Builds PLC published an announcement in January 2024 on its official website for the expression of interest in the construction of a new nuclear unit. The purpose of the procedure is to determine the so-called "shortlist" of potential construction companies for engineering, construction, delivery and commissioning of a nuclear power plant at the approved site in Kozloduy, with AP1000 technology. This is the initial stage of the selection of a contractor. It is expected that Westinghouse will be the supplier of equipment, but not the project implementer.

Companies that have expressed interest in the construction of a new nuclear unit must provide financial data on the state of the companies they represent for the last five years, and financial statements must have a net profit and turnover exceeding an average of 6 billion US dollars for this period. An important element is proof of experience in the nuclear field, and such experience acquired in the last 15 years, as a lead designer under contract/s for the construction and commissioning of at least two nuclear units.

The announced procedure is limited to pre-qualification of candidates and selection, during which the requested information submitted by interested candidates is checked for compliance with the eligibility criteria and pre-qualification on a "pass/fail" basis. Approved candidates who meet the pre-qualification criteria have the opportunity to submit their offers in a separate new procedure. A separate new procedure will be launched for the purposes of detailed negotiations with those selected in the shortlist.

Meanwhile, on February 12, 2024, the U.S. Assistant Secretary of Energy for International Affairs and the Bulgarian Minister of Energy signed an Intergovernmental Agreement for Cooperation on the Development of the Civil Nuclear Energy Program of the Republic of Bulgaria and Potential Other Forms of Clean Energy Cooperation as the United States and Bulgaria may determine. The agreement will establish a working group to support the Bulgarian government's plans to design, build, and commission a new reactor with an installed capacity of at least 1,000 megawatts at the Kozloduy NPP.

The procedure announced by the project company "Kozloduy NPP - New Builds" for expressing interest from a potential general contractor of the project to enter a consortium with the American "Westinghouse", whose AP1000 technology will be used to build the reactors, ended on February 2. Five companies submitted expressions of interest. Fluor B.V., Bechtel Nuclear Power Company Limited, Hyundai Engineering & Construction Co., Ltd., a consortium led by China National Nuclear Corporation Overseas Ltd. and partner China Energy Engineering Group Tianjin Electric Power Construction Co., Ltd., as well as China Energy Engineering Corporation Limited. Of the five candidates, only Hyundai (Hyundai Engineering & Construction Co.,Ltd.) meets the requirements. The Korean company must submit its binding offer for the construction of the two reactors, have it accepted by the Bulgarian company, and the construction company itself must be approved by Westinghouse, with which they must create a consortium for the construction of the new nuclear power plants.

When presenting their vision for the 7th and 8th units of the Kozloduy NPP, the Korean investors from the Hyundai company, elected by the parliament, in a television interview for NOVA on 25.06.2024, claimed that their construction would be completed by 2032, that is, in 8 years, with an average duration of 10 years for such projects. Also, 70% of the construction costs will not come from the state, but from loans, some of which from the Korean Development Bank. Their intention is for the 7th and 8th reactors in our country to be ready by 2032, with the planned capacity of just one reactor being over 1,000 megawatts. The company claims that the construction will require 10,000 people to work directly at the Kozloduy NPP site. Before that, Hyundai and Westinghouse will create a consortium in which they will invite Bulgarian companies with their experts to participate. In January 2024, they conducted a study of the Bulgarian market and met with about 40 companies. Their calculations indicate that within the framework of this process they will include over 150 Bulgarian companies that will participate in the implementation of the project. However, before this happens, the acting Minister of Energy explains, a detailed project plan must be developed.

• Pursuant to Art. 95, para. 1 of the Environmental Protection Act and Art. 4, para. 1 of the Ordinance on the terms and procedure for conducting an environmental impact assessment, in February 2024 "Kozloduy NPP - New Builds" announced an investment proposal for the construction of Unit 8 at Kozloduy NPP. A notification of the investment proposal for the construction of Unit 8 of Kozloduy NPP has been sent to the Minister of Environment and Water.

• It should be clarified that at the present moment, the national public procurement procedures and the selection of contractors under them are carried out by Kozloduy NPP in accordance with the Public Procurement Act and the Regulations for the Implementation of the Act. The company is a sector contracting entity under the law with its main activity in electricity. The project company "Kozloduy NPP - New Builds" PLC, which is engaged in the construction of a new nuclear power plant (units 7 and 8) at the "Kozloduy NPP" site, is not a contracting authority within the meaning of the Public Procurement Act. It conducts the procedures for selecting a contractor in accordance with the Procurement Rules (an internal company document adopted and registered in accordance with the established procedure in the company). Invitations to interested parties who wish to participate in the procedures are announced on the company's website. All

necessary documents for applying for the procedure are attached there as a link.

• The Ministry of Energy officially announced in November 2024 that Kozloduy NPP – "New Builds" PLC and the Westinghouse HD&C consortium have signed a contract for the engineering of Units 7 and 8 at Kozloduy NPP. As a result of signing the contract, within the next 12 months the ministry will have a clear commitment to the schedule and financing of the new power plants. According to the announcement, the signing of the contract is a key stage in the work on the implementation of the project for the construction of a new nuclear power plant in the Republic of Bulgaria. The joint work of the two global companies - "Westinghouse" and "Hyundai" - to provide an integrated service in Bulgaria will guarantee the implementation of the project within the previously set deadlines and budget.

IV. CONCLUSIONS

The article presents the perspectives of nuclear energy in the national energy policy of the Republic of Bulgaria, based on eco-innovative technologies, the experience gained in the development of new nuclear projects and the established organization for licensing and commissioning the implementation of these projects. An important emphasis is placed on environmental legislation, the licensing process, technical standards and international cooperation.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 111-117

Small Modular Reactors in the Nuclear Energy Sector of the Republic of Bulgaria – Advantages in Implementation and Challenges in their Licensing

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***Abstract*— Over the past four to five years, intensive development has been observed in Central and Eastern Europe of the American nuclear company NuScale - a world leader in the design of small modular reactors. Initiatives to expand the use of nuclear energy and the advancement of technologies in this production are supported and led by the United States of America government. In the article, the author analyzes the prospects of small modular reactors as an eco-innovative technology in nuclear energy, which allows the construction of reliable, clean, safe and economically advantageous energy sources for future generations. Their place in the national energy policy of the Republic of Bulgaria is examined and to what extent the country is interested in their implementation. When compared, the progress in countries such as Romania and Poland is tangible and can be useful to the country. At this stage, the implementation of NuScale's small modular reactors technology in our country is still being studied and evaluated within the framework of the Memorandum of Understanding signed in 2020. It is known that nuclear projects are associated with radiation and environmental risks and the process of their licensing by the national nuclear regulatory authority - the Nuclear Energy Agency is complex and lengthy. The main points of licensing according to the Bulgarian nuclear legislation are presented and the changes that need to be made to the current licensing regimes in order to facilitate the introduction of small modular reactors into operation. The possibilities of international cooperation are also examined to help the process of their licensing.**

Keywords*— licensing, nuclear legislation, nuclear regulatory authorities, small modular reactors

I. Introduction

A small modular reactor (SMR) is a class of small nuclear fission reactors designed to be built in a factory, shipped to operational sites for installation, and then used to power buildings or other commercial operations. The term SMR refers to the size, capacity, and modular design. The reactor type and nuclear processes can vary. Of the many SMR designs, the pressurized water reactor (PWR) is the most common. However, recently proposed SMR designs include: Generation IV, thermal neutron reactors, fast neutron reactors, molten salt, and gas-cooled reactor designs.

After the Fukushima accident [1], the last ten years have seen increased interest in this class of nuclear reactors as an eco-innovative technology in energy production.

Modular reactors are expected to reduce on-site construction and increase containment efficiency. These reactors are also expected to improve safety by employing passive safety features that do not require human intervention, although this is not specific to SMRs, but rather a feature of most modern reactor designs. SMRs are also claimed to have lower plant personnel costs because their operation is relatively simple and they are claimed to have the ability to circumvent the financial and safety barriers that hinder the construction of conventional reactors.

Maximum safety [2] is one of the main characteristics of small modular reactors. They are fail-safe and self-sufficient with the passive mode of operation of the safety systems. They are protected from external influences by a

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8637
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strong hermetic core enclosure. They are designed to withstand extreme external influences. Defense in depth is provided by multiple levels of protection to reduce the impact of accidents. They are designed to shut down the reactor and maintain it in a safe state without any operator action, without the need for backup power or the operation of electric pumps.

They are easy to build. Many reactors with such technology are already in commercial operation or are in the process of being built. The modular design is simplified modular. The operation of those already in operation is reliable with shortened planned shutdowns for repairs and refueling with nuclear fuel. The target operational life of the reactors is over 80 years.

II. MATERIALS AND METHODS

The article analyzes international [3], [4] and national legislation, including strategic and guiding documents of state bodies.

In Bulgaria, scientific publications on the topic are scarce, and changes in state policy and regulations are frequent and inconsistent. A combination of different scientific research methods was used to obtain a more complete and objective picture of the problem under study, among which the following stand out: historical-chronological, comparative and systematic analysis.

III. RESULTS AND DISCUSSION

A. Opportunities for building small nuclear fission reactors in the Republic of Bulgaria

In the context of achieving the European Union's goals for climate neutrality by 2050 and diversification of energy resources, on October 14, 2020, the Council of Ministers of the Republic of Bulgaria decided to undertake preparatory actions and study the possibilities for building a new nuclear power plant on the site at Kozloduy NPP approved by order of the Chairman of the Nuclear Regulatory Agency. According to point two of this decision, the relevant Minister is assigned to take the necessary actions and authorize Bulgarian Energy Holding EAD to enter into negotiations with companies from the United States of America developing new nuclear technologies for peaceful purposes, including small modular reactors, in order to study the possibilities for building a new nuclear power plant on Site No. 2 at Kozloduy NPP.

An information release on the website of "Kozloduy NPP - New Builds" PLC regarding the meeting draws attention to the fact that the small modular reactors in question would have advantages in liberalized markets such as the European one, due to their ability to follow the load of the grid and support its sustainability, especially after the widespread penetration of unpredictable alternative energy sources.

The above expresses interest at the government level in the implementation of this new eco-innovative technology for our energy sector. It is known that in implementation of the decision taken, actions have been taken in an operational plan and at the end of 2020 a Memorandum of Understanding was signed to study the possibility of implementing nuclear technology based on small modular reactors in the Republic of Bulgaria between "Kozloduy NPP - New Builds" PLC and NuScale Power, LLC. This Memorandum strengthens bilateral strategic relations, while at the same time deepening cooperation in the field of energy security. Through the document, both parties are committed to the responsible use of nuclear energy and technologies with an emphasis on human capital and labor development, education, training, in order to maintain the highest standards and practices in the field of nuclear safety and security.

In the context of the Memorandum of Understanding, on December 4, 2020, the US Ambassador and her team visited Kozloduy NPP. The purpose of the visit was to familiarize themselves with the activities of Kozloduy NPP and its project company in order to explore the possibility of a partnership in developing a solution for the future energy needs of the Republic of Bulgaria. The Ambassador and the management of Kozloduy NPP discussed how Kozloduy NPP is leveraging its infrastructure and human capital advantages to make it the center of Bulgarian nuclear energy for generations to come.

In a February 17, 2021, statement, NuScale said that under the agreement it would support Kozloduy in conducting studies and analyses, including the development of a feasibility study schedule, project-specific cost estimates, and design, planning, and licensing activities. NuScale was created based on research funded by the United States Department of Energy (DOE) and conducted by a team of nuclear scientists at Oregon State University and Idaho National Laboratory. In the early 2000s, DOE funded the research from 2000 to 2003.

NuScale was founded in 2007, and certification with the US Nuclear Regulatory Commission (NRC) began in February 2008.

In 2020, the U.S. Nuclear Regulatory Commission (NRC) approved the design of a new type of reactor known as a small modular reactor (SMR). The design, by Portland, Oregon-based NuScale Power, aims to speed up construction, reduce costs, and improve safety compared to traditional nuclear reactors, which are typically many times larger. SMR proponents have long touted them as a way to help revive the nation’s nuclear industry and expand the reach of low-carbon electricity. But some experts have raised concerns about the potential costs and remaining safety issues the industry will need to address before such reactors are actually built.

B. Prospects for the construction of small nuclear fission reactors in the regions of Central and Eastern Europe

In March 2019, NuScale and Nuclearelectrica signed a Memorandum of Understanding covering the exchange of

business and technical information regarding NuScale's nuclear technology, with the aim of evaluating the development, licensing and construction of a NuScale SMR in Romania. Nuclearelectrica is the operator of Romania's only nuclear power plant, Cerna Voda, which currently provides approximately one-fifth of the country's electricity.

In November 2021, following a meeting between US Special Presidential Envoy for Climate John Kerry and Romanian President Klaus Iohannis at the Glasgow Climate Conference, NuScale announced its intention to build its first small modular reactor in Romania by 2028 with the Romanian national nuclear company Nuclearelectrica. The six-module nuclear power plant will have a gross installed capacity of 462 MWe and will make Romania the second country in the world after the United States to deploy NuScale's SMR technology.

Nuclearelectrica's participation in the project is carried out through the project company RoPower Nuclear, of which it owns 50%.

In January 2021, Nuclearelectrica received a non-repayable grant of 1.28 million USD from the United States Trade and Development Agency for use in identifying potential sites in Romania to host SMRs. The grant will be used to finance the costs of services required in connection with the provision of technical assistance for the preliminary assessment of new potential SMR-compatible nuclear sites in Romania, excluding the existing Cerna Voda site. The funds will also be used in the development of a roadmap for SMR licensing.

In January 2023, RoPower Nuclear received a $14 million grant from the U.S. Trade and Development Agency to build an SMR plant in Romania. RoPower and NuScale are currently conducting Phase 1 of the FEED Study, which consists of a series of engineering and design activities and surveys, a technical analysis of the preferred site, which is the former Doicesti power plant, a schedule and cost estimate.

The Small Modular Reactor (SMR) power plant project to be developed in Romania has received key approval from the National Nuclear Control Commission (CNCAN) in 2023, according to a statement from Romanian nuclear company Nuclearelectrica.

"The approval of the Licensing Base Document (LBD) represents a key milestone in the small modular reactor project, which will facilitate the implementation of the licensing process for all stages of the NuScale power plant in Romania," Nuclearelectrica said in a filing to the Bucharest Stock Exchange.

The LBD establishes the licensing requirements for the six-module power plant project, the applicable national and international regulatory documents, codes and standards, as well as the design characteristics that ensure the fulfillment of nuclear safety requirements and criteria.

In addition to Romania, NuScale and Polish mining conglomerate KGHM also announced a contract to build an SMR in Poland in February 2022.

The final commercial agreement with mining and processing company KGHM Polska Miedź SA is for the deployment of a VOYGR power plant with a capacity of up to 924 MWe as early as 2029 to support KGHM's copper and silver production in Poland.

The agreement, signed on February 14, 2022 in the presence of US and Polish government officials, will begin the preparation of the entire investment project, including site selection.

The deal adds another major perspective to NuScale's development of small modular reactors (SMRs) in Central and Eastern Europe, a region that has quickly become a hotspot for advanced nuclear projects due to a combination of factors. But it is also particularly noteworthy because it represents a deal with a large industrial energy user, a key decentralized energy market that could benefit from smaller baseload, flexible power plants. KGHM is the second largest industrial energy user in Poland.

This confirms the attractiveness of SMRs for large industry.

The commercial agreement follows a memorandum of understanding that the two companies and Poland-based business engineering consultancy Piela Business Engineering signed in September 2021 to collaborate on the development, licensing and construction of NuScale VOYGR in Poland. Under this memorandum of understanding, the companies worked to study the implementation of NuScale's SMR technology as a coal diversion/repurposing solution for existing coal-fired power plants as well as for energy to support industrial operations in Poland. The study included an analysis of technical, economic, legal, regulatory, financial and organizational factors.

NuScale's VOYGR SMR technology, first introduced in 2000 as a concept at Oregon State University, has evolved into a modular light water reactor (LWR) design that can deliver energy for power generation, district heating, desalination, hydrogen production, and other process heat applications. With flexibility as a key attribute, NuScale currently offers VOYGR power plants in scalable sizes, including as twelve 77-MWe modules and as four- and six-module facilities.

For KGHM, which owns Europe's largest copper ore deposit (located in southwestern Poland), the prospect offers a new path to decarbonizing its mining operations, as well as potential cost savings. SMR technology is expected to increase the company's cost efficiency and transform the Polish energy sector. SMRs can be used not only to generate power – they can be used to generate heat and also to produce hydrogen for various operations.

Poland has the largest coal reserves in Europe, generating 70% of its energy from coal in 2020. In November 2021, it committed to phasing out its coal-fired

power plants. It aims to do so by 2040. The country is steadily increasing its shares of gas and renewables to meet the European Union's strict climate targets and reach climate neutrality by 2050.

However, Poland has no nuclear power plants. Although this will require detailed planning, including the creation of a related regulatory framework, Poland's revised energy policy until 2040, adopted in February 2021, envisages commissioning its first nuclear power reactor in 2033, followed by subsequent units. The plan envisages an investment of PLN 140 billion (about $40 billion) in new facilities. The deployment of GE-Hitachi Nuclear Energy's BWRX-300 SMRs is also being explored.

NuScale is preparing for a major expansion in Poland. It is considering a 2027 delivery schedule for its first commercial offering, VOYGR, with the timing dependent on Poland's regulatory requirements. NuScale is preparing to meet the regulatory requirements of global customers like Poland. NuScale Power says its modular light water reactor can deliver "reliable and abundant" carbon-free nuclear power for power generation, district heating, desalination and other process heat applications. NuScale's SMR design includes a fully fabricated NuScale Power Module capable of generating 77 MWe using a "safer, smaller, scalable version" of pressurized water reactor technology.

C. Rules for licensing activities related to the use of nuclear energy in the Republic of Bulgaria

State regulation of the safe use of nuclear energy and ionizing radiation and of the safe management of radioactive waste and spent fuel in the Republic of Bulgaria is carried out by the Chairman of the Nuclear Regulatory Agency, which is an independent specialized body of the executive branch and has competence defined by the Act on the Safe Use of Nuclear Energy.

A significant part of the nuclear legislation and specifically in the Act on the Safe Use of Nuclear Energy is devoted to the regulation of activities, respectively, obtaining a permit or license to carry them out. In Chapter Three of the act entitled "Regulation of Activities", the legislator has provided for three sections, which set out the general conditions, fees and nuclear facilities for which the Chairman of the NRA issues permits or licenses, and in general terms present the requirements and the procedure for their issuance.

The issues relating to the procedure for issuing licenses and permits, the issuance procedure, the scope and content of licenses and permits, the conditions for their amendment, renewal, termination, revocation and control are regulated in detail in the Regulation on the Procedure for Issuing Licenses and Permits for the Safe Use of Nuclear Energy. The structure of the regulation is tailored to the specifics of the types of nuclear facilities and activities.

Nuclear power plants, as well as the approved sites for their construction, are objects of national importance [5]. According to the Act on the Safe Use of Nuclear Energy, a nuclear power plant is built by a decision of the Council of Ministers. The proposal for the construction of a nuclear power plant is submitted by the relevant minister. He organizes a discussion of the proposal for the construction of a nuclear power plant, in which state bodies and local government bodies, representatives of public organizations and interested individuals and legal entities participate. The use of a power unit of a nuclear power plant in accordance with its main purpose begins after the entry into force of an operating license issued in accordance with the law and in the presence of an effective license for the production of electricity and/or heat, issued in accordance with the Energy Act.

In accordance with the requirements of the Environmental Protection Act, actions should be taken to carry out a procedure for assessing the environmental impact of an investment proposal for the construction of a new nuclear power plant and obtaining an environmental license [6], [7].

A procedure for notifying the local population through the mass media is launched and, after receiving instructions from the Ministry of Environment and Water, a task for the scope and content of the Environmental Impact Assessment is developed. A report on the Assessment is prepared and submitted to the Ministry of Environment and Water, as the competent authority for assessing the quality of the report and the degree of impact of the investment proposal on the protected areas.

The activities related to the ongoing Environmental Impact Assessment procedure include responses to questions received in connection with the Assessment report from the competent authorities and the interested public. The Assessment procedure ends with a Decision of the Minister of Environment and Water, by which the competent authority approves the implementation of the investment proposal for the construction of a new nuclear power plant.

According to Section III of the Law on the Safe Use of Nuclear Energy, the licensing procedure for a new nuclear power plant includes the issuance by the Chairman of the Nuclear Regulatory Agency of individual administrative acts, through which compliance with the safety requirements of the nuclear facility is controlled.

After the Council of Ministers has taken a decision in principle to build a new nuclear power plant, the relevant Minister is given a mandate to submit a report under Art. 45, para. 2 of the Safe Use of Nuclear Energy Act for a decision on the merits. When implementing the investment proposal, the two-stage approach indicated by the International Atomic Energy Agency is followed, in which first a site assessment is carried out to identify possible locations for future NPPs (carried out by a ministry or national authority) and secondly - the licensee carries out the assessment of the proposed site.

Analyses and development of documents - annexes to the Minister's report follow. Preparations begin for the implementation of the first stage of the licensing regime for nuclear facilities - the so-called pre-project stage, in which, if the requirements of the Regulation on the procedure for issuing licenses and permits for the safe use of nuclear energy are met, the Chairman of the Nuclear Regulatory Agency issues a permit for site selection and subsequently an order for approval of the selected site. A process for licensing the new nuclear capacity is initiated. An application is submitted to the Nuclear Regulatory Agency for the issuance of a permit for determining the location of a new nuclear facility (site selection) within the meaning of Art. 15, para. 4, item 1 of the Act on the Safe Use of Nuclear Energy.

After issuing a permit for determining the location of a new nuclear facility (site selection) by the Nuclear Regulatory Agency, the activities related to "Investigation and determination of the location of the preferred site for the construction of a new nuclear power plant" have been finalized, an independent verification of the submitted project documents is carried out and a Preliminary Report for the analysis of the safety of the nuclear facility is developed. In connection with the preparation for construction, a Technical Terms of Reference for the design of a detailed development plan with a supporting plan included therein is developed, in accordance with Art. 125 of the Spatial Planning Act. The Technical Terms of Reference are coordinated with the Ministry of Environment and Water.

Then, documents are prepared and submitted to the Nuclear Regulatory Agency for issuing an Order for Approval of the Preferred Site by the Chairman of the Agency within the meaning of Article 33, Paragraph 4 of the Safe Use of Nuclear Energy Act.

The second stage of the permitting regime concerns the so-called Engineering. Design is carried out and, accordingly, preparation and submission to the Nuclear Regulatory Agency of the necessary documents for issuing a design permit, within the meaning of Art. 15, para. 4, item 2 of the Act on the Safe Use of Nuclear Energy. This is followed by a procedure for selecting a designer, preparation of a technical design and issuance of an order for approval of the technical design by the Chairman of the Nuclear Regulatory Agency. With the order for approval of the technical design, the Engineering stage is considered completed.

The third stage of the permitting regime under the Safe Use of Nuclear Energy Act – concerns Construction and commissioning and includes a Permit for the construction of a nuclear facility, within the meaning of Art. 15, para. 4, item 3 of the Act and a Permit for the commissioning of a nuclear facility, within the meaning of Art. 15, para. 4, item 4 of the Act. The same are issued before the license for the operation of the nuclear facility. For the issuance of both permits, the applicant must be a legal entity registered in the Republic of Bulgaria (Art. 33, para. 2) and must have financial, technical, material, human resources and an organizational structure to fulfill its obligations to ensure the requirements, norms and rules for nuclear safety, radiation protection and physical protection.

The application for a license to operate a nuclear facility shall be submitted after the conditions of the permit for commissioning the nuclear facility have been met. The compliance with the conditions of the permit for commissioning shall be established by a commission of inspectors of the Nuclear Regulatory Agency, appointed by order of the Chairman of the Agency, which shall verify the documents submitted by the applicant and carry out an on-site inspection.

D. Challenges in licensing small modular reactors and the role of regulatory authorities and international cooperation in this process

Small Modular Reactors business models require them to be manufactured in large numbers with the same design licensed in several countries without significant changes. As a result, regulators are encouraged by suppliers, licensees and some governments to increase the harmonisation of their regulatory requirements, streamline their licensing processes and promote mutual recognition of safety reviews carried out by their partners to facilitate the national licensing process for these designs [8].

The International Atomic Energy Agency plays a key role in international cooperation related to the use of nuclear energy [9]. It is an organization within the framework of the United Nations, without being a specialized agency within the meaning of Art. 57 of the Charter of the United Nations. Its statute was approved on 26 October 1956 in the form of a treaty that entered into force on 29 June 1957. It is a classic intergovernmental organization with a global focus on scientific and technical cooperation in the field of peaceful uses of nuclear technologies [10], [11].

During the period 2021-2022, the Chairman of the Nuclear Regulatory Agency of the Republic of Bulgaria and representatives of the agency took an active part, respectively, in the 65th and 66th regular sessions of the General Conference of the International Atomic Energy Agency.

During the sessions, the Chairman of the Nuclear Regulatory Agency, as the head of the Bulgarian delegation, exchanged information with the Deputy Director General of the International Atomic Energy Agency on the review of safety and security standards in relation to the proposed new technologies in the nuclear field, including small modular reactors. The events accompanying the General Conference included a forum for discussing the new platform on small modular reactors and a workshop dedicated to the challenges in their licensing, in which representatives of the Nuclear Regulatory Agency participated. Outside the plenary sessions, the Chairman of the Agency held bilateral meetings with high-ranking representatives of the International Atomic Energy Agency, the European Commission and similar regulatory bodies from other

countries. At the meeting with the Executive Director for Operations of the US Nuclear Regulatory Commission, among other issues, the American experience in the licensing process for small modular reactors was discussed.

The Chairman of the Nuclear Regulatory Agency also participated in the meetings of the Bulgarian delegation with the US Deputy Assistant Secretary of State for Non-Proliferation of Nuclear Weapons, with representatives of the US industry, led by the US Deputy Assistant Secretary of State for Commerce, with the Deputy Minister of Industry and Trade of the Czech Republic and with representatives of the French company EDF. At the meetings, the Bulgarian Deputy Minister of Energy presented the current status of the nuclear program of the Republic of Bulgaria, as well as the existing plans for its development at this stage. Issues related to the technologies for small modular reactors being developed by the US and French sides were also discussed, and with the US representatives, issues related to the diversification of nuclear fuel supplies.

The Spring Workshop of the Western European Nuclear Regulators Association (WENRA) was held in Helsinki, Finland on 5 and 6 April 2023. The Bulgarian Nuclear Regulatory Agency was represented by its Chairman.

During the meeting, WENRA issued a statement on the development of small modular reactors and innovative reactors, stating that more and more countries are supporting the development of small and innovative reactors to meet their decarbonized energy needs in the context of climate change, with a strong expectation from stakeholders that national licensing processes will be completed quickly.

Such processes allow each national regulator to gain an understanding of the acceptability of the plant safety case and, where applicable, the validity of the assessment already carried out by its counterparts. In particular, the assessment of site-specific aspects of the projects will remain the responsibility of the national regulatory authority.

WENRA members confirm their willingness to promote mutual cooperation in the safety assessment of reactor projects in this regard. To this end, they encourage their respective governments to provide the regulatory authorities with a mandate, if necessary, and sufficient resources.

On June 27, 2023, the Chairman of the Bulgarian Nuclear Regulatory Agency participated in the second plenary meeting of the Nuclear Harmonization and Standardization Initiative. The meeting is taking place in Vienna, Austria.

The Initiative was established by the Director General of the International Atomic Energy Agency, Raffaello Grossi, to support the harmonization and standardization of regulatory and industrial approaches to facilitate the safe and successful deployment of small modular reactors worldwide. This process brings together nuclear regulatory authorities and companies from the nuclear sector from around the world, as well as international organizations and industry associations. The second plenary meeting took stock of the work already done on the Initiative, and reported on the progress, as well as the difficulties in its implementation, discussed the outstanding issues and planned future actions, where necessary. The Republic of Bulgaria is an active participant in the Initiative, as a representative of the Nuclear Regulatory Agency is included in the working group for the "Pre-licensing Regulatory Review of Small Modular Reactors".

IV. CONCLUSIONS

Small modular reactors, as an eco-innovative technology in nuclear energy, allow for the construction of reliable, clean, safe and economically advantageous energy sources in the national energy policy of the Republic of Bulgaria.

With the Memorandum of Understanding signed at the end of 2020 to study the possibility of implementing nuclear technology based on small modular reactors in the Republic of Bulgaria between "Kozloduy NPP - New Builds" PLC and NuScale Power, LLC, both parties are committed to the responsible use of nuclear energy and technologies with an emphasis on human capital and labor development, education, training, in order to maintain the highest standards and practices in the field of nuclear safety and security.

The Memorandum of Understanding is a proven commercial practice through which the parties lay the foundations for the implementation of projects of mutual interest, while at the same time not requiring the assumption of a commitment to a future investment decision or the incurrence of related financial costs and to what extent the party is interested in their implementation. The comparison made for the implementation of similar projects in countries in Central and Eastern Europe and specifically in Romania and Poland shows that their experience can be studied and used in Bulgaria.

It should be noted that our country has well-established nuclear legislation and a well-structured national regulatory authority, which is a necessary starting point for licensing new nuclear capacities, but combined with the practical problems of a lack of information internationally regarding the appropriate method for licensing small modular reactors, this creates inconsistencies and deficiencies in the legal framework for their licensing.

Questions arise as to whether the current licensing regimes are appropriate? What changes should be made? Could increased international cooperation help speed up the licensing process and does this threaten national sovereignty?

These objective factors determine the need for legislative intervention to harmonize the legal framework for licensing small nuclear reactors.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 119-123

Assessment of Sustainable Economic Development in Estonia and Latvia

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***Abstract*— Current trend in global development is to manage national economies sustainably, but significant challenge is measuring progress. There is a need for studies that can help to monitor if national economy develops sustainably or not. The aim of this study is to assess the main trends in sustainable economic development in Estonian and Latvian economies. Literature review, regression and correlation analysis are applied for data analysis in this research. The results allow to conclude that Estonia and Latvia have not reached the turning point in sustainable development when larger GDP is produced with using fewer amounts of natural resources and generating less waste (falling Footprint). Both countries have similar sustainable development trends, excluding temp of increase in the number of population.**

Keywords*— Estonia, Latvia, sustainable economic development.

I. Introduction

Current problem in global development is to manage national economies sustainably, but huge challenge is to measure its progress. There is an urgent necessity for studies that can help to monitor if national economy develops sustainably or not, because resolving problems and planning activities are impossible without the accurate evaluation of actual conditions (see more 1]. Sustainable development is crucial for creating a balance between economic growth, environmental protection and social well-being because the results of business activity of humans have led to global warming and climate change [see more 2, 3, 4]. The United Nations believes that the urgent action is needed to stop current negative changes in the world to preserve our resources, including biodiversity. In 2015 all member states of the United Nations accepted *the 2030 Agenda for Sustainable Development* [5]. This sustainability framework consists of 17 goals and 169 targets.

Analysis of scientific literature shows that there are different approaches in measuring sustainable economic development at national level because 17 Sustainable Development Goals are very complex in assessment and implementation improving all goals simultaneously, as well as countries have different development problems and priorities [see more 6, 7]. It is not clear nowadays if universal method exists in measuring sustainable development [8]. Considering these facts, the aim of this study is to assess the main trends in sustainable economic development in Estonia and Latvia. This study continues the efforts of authors to apply Latvian approach in evaluating sustainable development using indicators of sustainable development defined in the Sustainable Development Strategy in Latvia until 2030 [9]. Previous study was devoted in measuring sustainable development in Latvia [10]. But this study extends application of selected indicators to comparative analysis between Estonia and Latvia. Latvia and Estonia share similarities as small, open economies in the Baltic region, but they also have distinct economic trajectories, making them great subjects for comparative research. It is useful to compare Latvia with Estonia because Estonia has conducted development processes more successfully that can be seen in the higher well-being represented by the Human Development Index ranking [11].

Two tasks are carried out to reach the aim. Firstly, to identify and compare existing indicators for the evaluation of sustainable economic development. Secondly, to choose an appropriate set of indicators to evaluate historical and nearest perspectives of sustainable economic development in Estonia and Latvia. The research methods applied in this study are the literature review and regression and correlation analysis, which help to assess Estonian and Latvian progress in sustainable economic development.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8651
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II. Materials and Methods

Measurement of sustainable economic development is significant in any country in the world because all member states of the UN accepted *the 2030 Agenda for Sustainable Development*. The United Nations' SDGs provide a comprehensive framework for measuring progress towards sustainable development. They include goals related to economic growth, social inclusion and environmental protection. But the 17 Sustainable Development Goals are not the only approach measuring sustainable development in countries. Firstly, other method is Environmental Performance Index (EPI) It ranks countries based on their environmental performance and ecosystem vitality [12]. EPI includes indicators such as air quality, water resources and biodiversity. One other indicator is Carbon Footprint that measures the total greenhouse gas emissions caused by economic activities helping assess the environmental impact of growth. Thirdly, Ecological Footprint measures the amount of natural resources consumed and the waste generated by economic activities. It helps to determine whether a country's growth is within the planet's ecological limits. Fourthly, there are also different other approaches to sustainable development that are set in strategic development plans in different countries. In Latvia sustainable development targets are set in the Sustainable Development Strategy in Latvia until 2030. Sustainable development is measured by set of indicators in the Sustainable Development Strategy in Latvia until 2030, including GDP per capita and Ecological Footprint. The following abbreviations are used further in this paper: Number of inhabitants – POPUL; Gini coefficient – GINI; GDP per inhabitant (per capita) per year (EUR, according to purchasing power parity) – GDPCAP; Ecological footprint (ha per inhabitant)- FOOTPRINT; Human Development Index (place in the world) - HDI. The sources of data are EUROSTAT and the United Nations Development Program (UNDP).

III. Results and Duscussions

Sustainable economic development in Estonia and Latvia is assessed taking five indictors applied in the Sustainable Development Strategy in Latvia until 2030 and based on availability of data for both countries studied in this research. The fallowing indicators are analysed:

1) Number of inhabitants;

2) Gini coefficient;

3) GDP per inhabitant per year (EUR, according to purchasing power parity)

4) Ecological footprint (ha per inhabitant);

5) Human Development Index (place in the world).

Data of the indicators are compared in pairs. It allows, firstly, to find individual trends and secondly, to compare their differences between the two selected countries.

The graph in Fig. 1 shows the changes in HDI over time for both countries. It can be observed that the curves essentially copy each other, and their trend can be well described using a quadratic trend line.

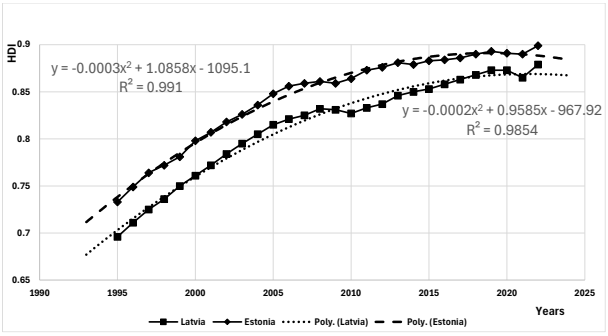

Fig.1. HDI changes over time in Latvia and Estonia

Now it is possible to measure the relationship between development trends for HDI. We will graphically depict the relationship between the indicators and measure it using the correlation coefficient R. If both countries have the same trends in the changes in the indicators, then their mutual dependence is reflected as a straight-line relationship. The correlation coefficient also directly measures how well the relationship is described by a straight-line equation. In this case, we have the following graphical relationship in Fig. 2. An almost perfect linear relationship is visible, with a correlation coefficient of R=0.97. As can be seen from the graph, the corresponding coefficient of determination R^2 is 0.99 equivalent, and 99% of the changes in the indicators are determined by the same factors.

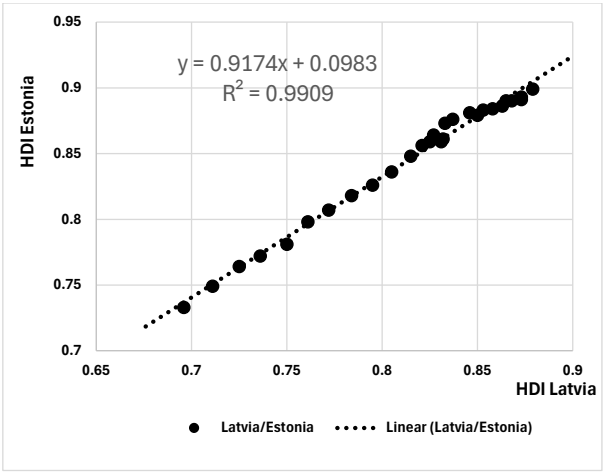

Fig.2. Correlation graph of changes in Humand Development Index (HDI) in Latvia and Estonia.

Analyzing the Fig. 3., the footprint trend for both countries is basically the same, only for Estonia it is significantly larger. Latvia has no peculiarities with FOOTPRINT, and it is slowly growing linearly. This is indicated by the coefficient of determination R2 = 0.86. For Estonia it is fluctuating around the linear trend line and the linear trend can explain only 41% of the variation. Other study should be carried out to investigate why there are such differences between countries.

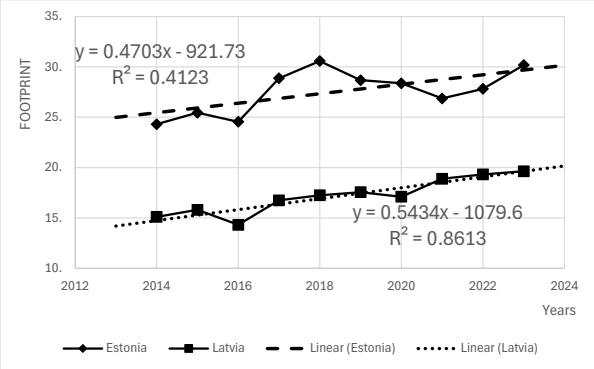

Fig.3. Footprint changes over time in Latvia and Estonia.

Taking look at Fig. 4., the correlation between the variables is determined by the coefficient R= 0.68 and the corresponding coefficient of determination R^2 = 0.46 determines that 46% is determined by the same factors. And here, however, there is a difference between the countries, although it cannot be said that the trends are too different. One thing can be said that Estonia uses and exploits resources more intensively.

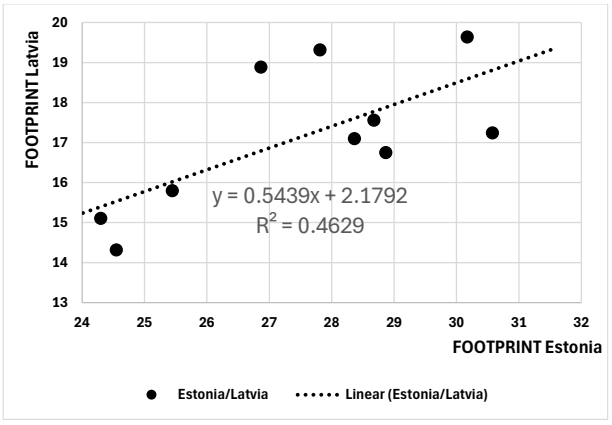

Fig.4. Correlation graph of changes Footprint in Latvia and Estonia.

An important component of sustainable development is GDP or GDP per capita. In the case of this paper, it is GDP per capita. The curves for both countries are shown in Fig. 5.

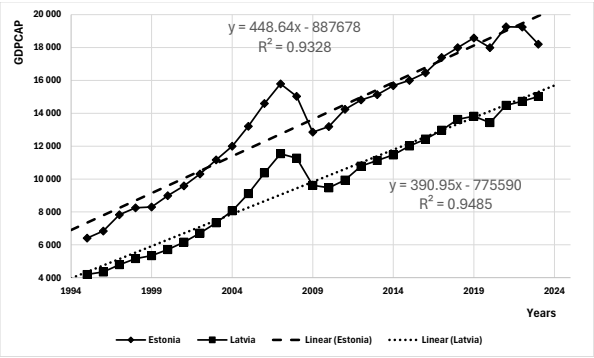

Fig.5. GDP per capita changes over time in Latvia and Estonia.

It could be said that the trends here are very well described by a linear relationship (if we do not consider the crisis and the impact of Covid 19). If we compare the trends using the correlation coefficient for their relationship in Fig.6, it is 0.99. Although Estonia has a higher income per capita, the development trends of the two countries are almost completely the same.

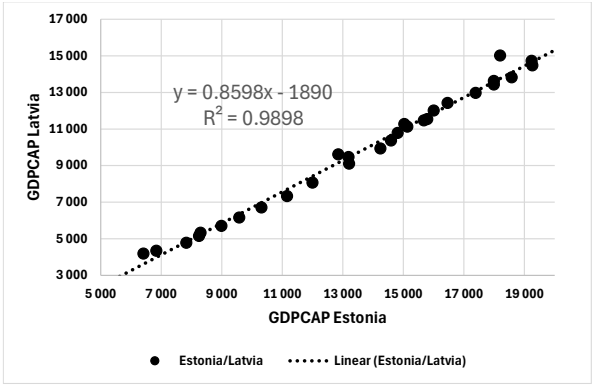

Fig.6. Correlation graph of changes GDP per capita in Latvia and Estonia.

The coefficient of determination of 0.99 indicates that GDP per capita in both countries develops based on the same economic mechanism.

The differences in trends are in the dynamics of the population. To make it easier to see the differences, let's depict them in the form of growth rates.

The calculation temp of increase for base year 2014 is as follows:

$$T_{base} = \frac{X_m - X_{base}}{X_{base}} \%; \quad (1)$$

Where:
X_m current value of indicator,
$X_{base} = X_{2014}$ value of indicator in the base year 2014

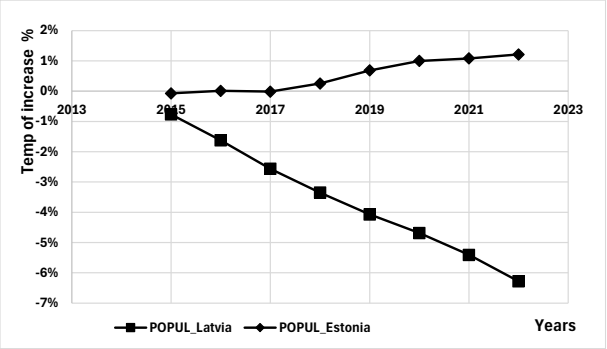

Fig.7. Temp of increase of population in Latvia and Estonia.

If 2014 is chosen as the base year, then in 2022 the population of Latvia decreased by 6.28%, while that of Estonia increased by 1.28%. If we calculate the correlation coefficient for the population of Latvia and Estonia, it is -0.93. So, there are opposite trends that are close to linear.

It is not possible to find a relationship between the Gini coefficients of the two countries in Fig. 8. For Latvia, it is slowly decreasing linearly. For Estonia, it first decreased rapidly and is now increasing. And if we look at the trends, then in both countries these indicators could equal (unfortunately, there is no data for 2024).

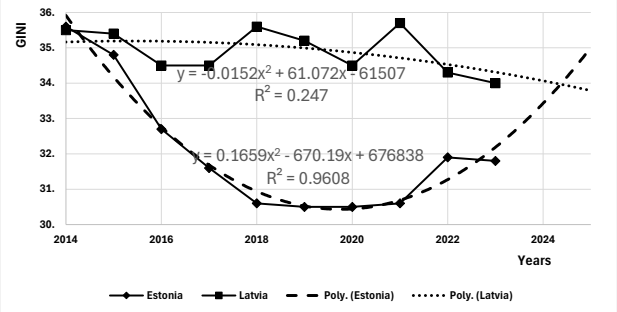

Fig.8. Gini coefficient (GINI) changes over time in Latvia and Estonia.

The correlation between all variables is presented in Table 1. The correlations in the table are located one above other to allow us to assess the structural difference.

	Country	*HDI*	*POPUL*	*GINI*	*GDPCAP*	*FOOT*
HDI	Latvia	1				
	Estonia					
POPUL	Latvia	-0.92	1			
	Estonia	0.84				
GINI	Latvia	-0.41	0.27	1		
	Estonia	-0.73	-0.62			
GDPCAP	Latvia	0.89	-0.98	-0.15	1	
	Estonia	0.91	0.87	-0.83		
FOOT	Latvia	0.79	-0.91	0.00	0.92	1
	Estonia	0.64	0.35	-0.79	0.64	

Fig.10. Correlation for set of studied indicators for Latvia and Estonia.

The most significant difference in trends between the two countries is in population dynamics, so all correlations involving this indicator are reversed. The absolute value, however, indicates the closeness of the relationship to linear.

For both countries there is a strong correlation between POPULATION and HDI and between POPULATION and GDPCAP. Latvia has a strong inverse correlation between POPULATION and FOOTPRINT, whereas Estonia has a positive and not very strong correlation. However, if we look at the correlation between POPULATION and GINI, there is an opposite trend: Estonia has the opposite well-defined trend, while Latvia has a positive trend and not a very strong one.

If we look at the HDI, both Latvia and Estonia have a strong positive relationship with both GDPCAP and FOOTPRINT. Both countries have opposite correlations with GINI. Estonia has a stronger correlation and Latvia a weaker one. If we look additionally at FOOTPRINT, both countries have a positive correlation with GDPCAP. On the other hand, Estonia has a negative correlation of Footprint with GINI whereas Latvia has no such correlation at all.

IV. Conclusions

Apart from the opposite trends in POPULATION, the sustainable economic development trends of the two countries are similar enough. Their change curves practically replicate each other, but with a certain lag.

If we assume that the structural development of countries is determined by GDP per capita, FOOTPRINT and Human Development Index, then both countries are developing similarly, although Estonia has better GDP per capita and Human Development Index. At the same time, Estonia has a higher FOOTPRINT, which is not so positive. There is no clear evidence that Estonia and Latvia have reached the turning point in sustainable development when larger GDP is produced with using fewer amounts of natural resources and generating less waste (falling Footprint). Latvia has painful problems with POPULATION, and how much it affects Latvia's positive development is a special issue to be studied.

The confusion is with GINI coefficient. Here, no unambiguous explanations for the trends can be found. To be clear, a specific study is needed for this indicator. Its measurement mechanism, accuracy, unambiguity, dependence on the region, etc.

The indicators studied in this paper are a reflection of a complex economic system. The article examines only correlations between indicators. However, the same indicator can be influenced by different factors, so a more complete understanding requires the application of more sophisticated statistical research models, such as factor analysis. This would allow the identification of complex hidden factors that determine the performance of the system as a whole.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 125-132

The Role of Green Technologies and Smart City Projects (Synergy for a Sustainable Future)

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***Abstract*— In the context of growing global challenges related to climate change, urbanization and the need for sustainable development, green technologies and smart city projects play a decisive role in the transformation of modern societies. Their potential to reduce environmental footprints, optimize resources and improve quality of life makes them an integral part of strategies for a sustainable future. The study focuses on the interaction between green technologies and smart city projects. It aims to analyze the synergies between them, highlighting their potential and contribution to sustainable development. The following objectives have to be settled for reaching the above-mentioned goal: 1. to research the main characteristics and types of green technologies; 2. to analyze the principles and best practices of smart city projects; 3. to identify the opportunities for synergies between the two concepts in the context of sustainability; 4. to assess the environmental, economic and social benefits of the integration of these approaches; 5. to formulate recommendations for enterprises and the public sector on the implementation of green technologies in smart city systems. In the course of the study shall be justified the thesis that the integration of green technologies in smart city projects not only contributes to sustainable development, but also creates innovative platforms for effective natural resource management, pollution reduction and quality of life enhancement in urban areas. The methodology includes a comprehensive literature review, structured interview, needs analysis, gap analysis and SWOT analysis. The expected results are: clarification of the relationship between green technologies and smart city projects; assessment of successful examples of synergies between these approaches; formulation of recommendations for business and public sector to support their implementation; identification of the main challenges and barriers related to the integration of the researched innovations.**

Keywords*— *green technologies, smart city projects, sustainable development, urban environment

I. INTRODUCTION

Green technologies are innovations and solutions focused on environmental protection, sustainable use of resources and reduction of harmful impacts on nature. They integrate the technological, environmental and economic aspects of the activity because they aim to create a sustainable future. Green technologies seek, on the one hand to reduce the environmental footprint and on the other to create a competitive advantage for the entity by enhancing its reputation and value in society. They are essential for the successful implementation of smart city projects that aim to create sustainable, environmentally, friendly and efficient urban areas. Smart city projects use technologies such as the Internet of Things, artificial intelligence, big data to improve quality of life. They support sustainable initiatives through transport optimization, energy loss reduction, pollution monitoring and smart resource management. Sustainable initiatives provide the strategic framework and guide efforts to implement green technologies and develop smart cities. They are based on policies and targets for carbon reduction, circular economy and social responsibility [1].

Green technologies, smart cities and sustainable initiatives are the "engine" of sustainable transformation. They have a strong interrelationship and brought together in a single study will reveal their roles in the context of the guiding principle of the 21st century – for Sustainable Development and the expectations, goals, transformation and role of an entire generation, businesses, non-financial sector enterprises, public sector organizations, etc.

II. MATERIALS AND METHODS

A. Theoretical framework of the issue

To achieve the set objectives, the team conducted an empirical study and performed an in-depth analysis. This

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8633
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research focuses on smart urban development in three key Bulgarian cities—Sofia, Plovdiv, and Varna—placing special emphasis on the role of green technologies and their synergy as a driver of a sustainable future. The methodology includes the application of z-transformation, SWOT analysis, AHP (Analytic Hierarchy Process), and GAP analysis to ensure a precise assessment of various aspects of smart development [2].

The study was conducted between July and November 2024 and is based on data collected through structured interviews with representatives of five main stakeholder groups: the public sector, citizens, businesses, educational institutions, and non-governmental organizations. The primary objective of the analysis is to assess the relative performance of the studied cities based on key smart development indicators, identify their strengths and weaknesses, explore opportunities and threats, and propose perspectives for future growth. The selection of Sofia, Plovdiv, and Varna is based on several significant factors. According to the European Smart Cities 4.0 platform research from 2015, Plovdiv and Varna were among the cities analyzed for smart development, whereas the previously considered Bulgarian cities—Ruse and Pleven—were excluded from the ranking that same year. Additionally, since 2020, Sofia has been featured in the prestigious IMD Smart City Index, making its inclusion in this study particularly relevant. Moreover, both Sofia and Varna are part of the European Commission (the largest network of European cities network), further highlighting their role in the broader European smart city landscape. [3]-[8]

The methodological framework of this study builds upon both established theoretical models and previous analyses and rankings in the field of smart cities. The authors adopt the concept that a smart city is one that effectively balances the development of six main dimensions: smart economy, smart mobility (transport), smart environment, smart education, smart living, and smart governance.

For the purposes of this research, 120 structured interviews were conducted in each of the three cities, with a total sample of 360 respondents. Instead of focusing solely on the absolute number of surveys, the analysis emphasizes the distribution of participants by percentage, providing a clearer perspective on the sample structure. The respondents were categorized as follows: 5.6% from the public sector (20 interviews), 19.4% citizens (70 interviews), 8.3% businesses (30 interviews), 4.2% educational institutions (15 interviews), and 4.2% non-governmental organizations (15 interviews). A combined approach was used to select participants. Specialists and experts from the public sector, businesses, educational institutions, and NGOs were chosen through purposive sampling to ensure a high level of expertise and credibility. Meanwhile, citizens were selected randomly to enhance representativeness and minimize selection bias. This approach is based on the principles of stratified sampling, which integrates expert opinions with broader public perspectives. The selected methods ensure a balance between analytical depth and result objectivity. Structured interviews facilitated the collection of both quantitative and qualitative data, allowing for a comprehensive SWOT analysis supported by z-transformation, AHP, and GAP analysis. Respondents evaluated various aspects of smart city development using a five-point scale, where 1 represents "poor performance" and 5 indicates "excellent performance." Additionally, respondents had the opportunity to provide open-ended feedback, which was also analyzed and incorporated into the findings [9]. This study contributes to the expansion of scientific knowledge in the field of smart urban development and provides empirically grounded recommendations for the future sustainable growth of Bulgarian cities through the integration of innovation, technology, and strategic management.

III. Results And Discussion

A. The impact of green technologies

Green technologies are related to practical problems, and needs analysis leads to real solutions. This allows us to adapt our approach to the specificities of non-financial enterprises and public sector organizations. The analysis makes the report more valuable and useful for stakeholders as it identifies real needs and opportunities for action. This analysis not only demonstrates the importance of the topic but also provides a strategic approach to the research.

We will conduct a needs analysis at the beginning of the overall study we are pursuing: ✓ *First*, to identify key needs and issues. Green technologies are diverse and widely applicable. The analysis will allow us to identify which specific needs and issues need to be addressed in the context of non-financial enterprises and public sector organizations. As a result, we will focus on the real challenges – energy efficiency, resource management, regulations, etc. ✓ *Second*, to provide a basis for strategic planning by answering two important questions – why and what will be achieved. The analysis will provide us with a clear picture of needs and gaps, which is necessary for formulating strategies and policies. This will make it easy to define concrete steps and recommendations for green technology deployment based on real needs. ✓ *Third*, support for informed decision making. Businesses and the public sector often have limited resources. The analysis will help to allocate resources efficiently to the areas with the greatest impact. This will reduce the risk of unnecessary investment and focus on the most efficient technologies. ✓ *Fourth*, assessing the potential for synergy. Green technologies and smart city projects are often treated separately. The analysis allows us to identify areas where they can work together in an inclusive and coordinated way. This will visualize how integrating different approaches can lead to better results. ✓ *Fifth*, preparing for access to finance and regulatory incentives. Many innovations in green technologies require external funding or must necessarily meet specific regulatory requirements. Analysis will reveal and demonstrate the need for investment, and thus facilitate attracting funding and/or

political support In the process of our research we have: 1) assessed the environment and stakeholders. We have analyzed the needs of businesses and public sector organizations in relation to the challenges of sustainable development. 2) identified key areas for action. We have defined specific points where green technologies can be deployed with the greatest impact. 3) established a basis for specific recommendations [10]-[11]. The analysis will help inform practical proposals for businesses and public organizations. 4) supported the argument for the importance of green technologies. Through the analysis we have shown that these technologies are not just an innovation but a necessity for the sustainable development of society. For both non-financial sector enterprises and public sector organizations, green technologies are not just an option, but a necessity for achieving sustainable development.

Needs analysis – Enterprises of non-financial sector: 1) *Need for energy efficiency* (businesses operating in the non-financial sector (manufacturing, transport, logistics) often use significant energy resources; green technologies such as energy saving systems and renewable energy sources can reduce costs and carbon footprint); 2) *Resource optimization and waste reduction* (non-financial sector needs circular economy technologies that enable recycling and reuse of materials; sustainable management of water and raw material resources is essential); 3) *Compliance with regulatory requirements* (European directives such as CSRD and sustainability reporting requirements put pressure on enterprises to integrate green practices; green technologies facilitate meeting environmental standards); 4) *Improving corporate image and attracting customers* (consumers are becoming increasingly sensitive to sustainability. Investment in green technologies improves companies' reputation and strengthens competitiveness); 5) *Access to finance and subsidies* (many green projects are co-funded by EU or national programs. Businesses need a willingness to take advantage of such opportunities); 6) *Innovation and technological development* (non-financial sector is looking for ways to implement smart systems for resource consumption monitoring, waste management and logistics through green technologies).

Needs analysis – Organizations of public sector: 1) *Improving the quality of the urban environment* (cities and municipalities need technologies to reduce air, water and soil pollution; smart solutions such as green roofs, air quality monitoring systems and sustainable waste management are therefore essential); 2) *Resource management* (public sector needs energy efficiency technologies in public buildings, street lighting and transport; water resource management through smart water irrigation systems and loss reduction is important in the context of climate change); 3) *Integration of smart city projects* (creating "smart cities" including smart transport, energy grids and digital service management platforms; need for green technologies for electrification of public transport and deployment of electric vehicle charging stations); 4) *Environmental policies and regulations* (National and European regulations require the public sector to integrate sustainable practices into urban planning and management; green technologies are a strategic tool for achieving carbon neutrality targets); 5) *Enhancing social sustainability* (public sector must respond to citizens' growing expectations for greener, healthier and environmentally friendly urban spaces; the need for solutions to improve mobility, access to green spaces and quality of life); 6) *Funding and international projects* (public sector has a need for technologies that allow access to European funds and programs for sustainable development).

While business seeks competitiveness and innovation, the public sector acts as a strategic planning and regulatory "driver". Their common interest creates synergies for a sustainable future.

B. Analysis of smart city projects

The theoretical study identified six key areas that form the basis of the research. Each of these areas encompasses different aspects of the development and functioning of modern cities, with an emphasis on the integration of innovative technologies, sustainable practices, and effective governance [12]-[14].

K1 (Smart Economy) – focuses on developing a competitive and sustainable economic environment through digital technologies, innovation, and entrepreneurship. It includes aspects such as business digitalization, startup development, production automation, and the use of artificial intelligence to optimize economic processes. The smart economy promotes investments in research and development, as well as the integration of sustainable business models. **K2** (Smart Mobility) – examines the efficiency of transportation systems and their environmental impact. It includes the development of eco-friendly transport solutions such as electric vehicles, intelligent transport systems (ITS), integrated public transport platforms, and sustainable urban planning. The primary focus is on enhancing citizens' mobility, reducing congestion, and optimizing logistics through data analysis and automation. **K3** (Smart Environment) – relates to environmental sustainability and the management of natural resources in urban areas. It includes the use of smart technologies for pollution monitoring, waste management, improving energy efficiency, and implementing renewable energy sources. The goal is to reduce the ecological footprint of urbanized areas and create a healthier, more sustainable urban environment. **K4** (Smart Governance) – refers to the application of modern technologies in public administration to improve efficiency, transparency, and accessibility of services for citizens. It includes the implementation of e-government solutions, big data analytics for informed decision-making, and the introduction of digital platforms for citizen engagement and interaction with institutions. **K5** (Smart Living) – this category examines aspects related to the quality of life in modern cities, including healthcare, culture, social services, and public safety. Smart living involves leveraging technology to enhance medical services (telemedicine, electronic health records), provide access to

cultural and social activities via digital platforms, and develop smart housing solutions. The ultimate goal is to create an urban environment that is comfortable, secure, and accessible to all citizens. **K6** (Smart Education) – focuses on the use of modern technologies to improve the learning process and access to knowledge. This includes the digitization of educational materials, the implementation of interactive learning platforms, the application of artificial intelligence for personalized education, and the development of distance learning solutions. Smart education fosters an innovative learning environment that adapts to the needs of students while promoting critical thinking and creative development.

By examining the six key areas that form a comprehensive model for studying the intelligent development of cities and society, the authors aim to conduct an in-depth analysis of smart cities in Bulgaria. The specified criteria provide an analytical framework that encompasses economic and technological aspects, as well as social and environmental dimensions [15]. The interaction between these spheres is crucial for building modern, sustainable, and efficient urban environments that address the challenges of the contemporary world. As stated, the data was collected through a structured interview conducted among representatives of the public sector, citizens, businesses, educational institutions, and non-governmental organizations in the cities of Sofia, Plovdiv, and Varna. The weighting of the criteria was determined through expert assessments, reflecting their relative significance in the context of smart urban development. The evaluations were derived from the responses (Table 1) of the participants in the structured interviews, ensuring that the collected data accurately represents the perspectives and expertise of key stakeholders involved in the urban development process (Fig. 1).

Fig. 1 clearly illustrates the contrasts between the cities and highlights the specific strengths and weaknesses of each urban center. Sofia dominates in economic and mobility aspects, Plovdiv stands out with its education, while Varna offers a high quality of life but faces challenges in governance. This visualization provides a valuable basis for future strategies aimed at balanced and sustainable development of smart cities in Bulgaria.

TABLE 1 INPUT DATA

Criterion	Weights	Expert evaluations		
		Sofia	*Plovdiv*	*Varna*
K1	0,15	4,78	2,33	1,56
K2	0,20	3,67	1,25	3,85
K3	0,15	1,39	2,88	2,99
K4	0,10	3,27	2,56	1,45
K5	0,25	3,87	2,75	4,05
K6	0,25	3,36	4,75	2,11
K1	0,15	4,78	2,33	1,56

(Source: authors' own research)

In our study, z-transformation plays a key role in analyzing the ratings obtained from expert evaluations of various criteria for smart urban development. By standardizing the data, we can compare the ratings of the three cities—Sofia, Plovdiv, and Varna—regardless of the differences in the scales of the evaluations. This allows for a more objective analysis and assessment of the performance of each city against the defined criteria (Table 2). The Z-transformation also helps identify anomalies or extreme values, and by standardizing the data, our study provides a more accurate and reliable basis for conclusions about the development of the smart city in Bulgaria. This approach enables us to formulate recommendations for improving management and sustainable development in urban environments. Consequently, the evaluations for each criterion were normalized and analyzed using z-transformation [16].

An important role in our study is played by the Analytic Hierarchy Process (AHP), which provides a structured and systematic framework for decision-making. Through AHP, we can establish priorities among the different aspects of smart urban development, which is essential for the formulation of sustainable and effective strategies, guiding us towards improving the different indicators.

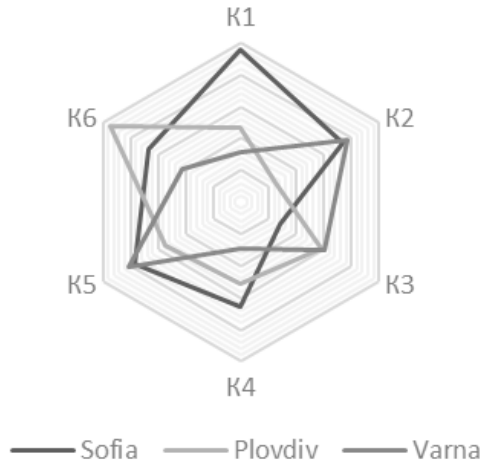

Fig. 1. Logic scheme and survey tools. (Source: authors' own research).

TABLE 2 Z-SCORES FOR THE STUDY CITIES

Criterion	Sofia	Plovdiv	Varna
K1	1,38	-0,41	-0,97
K2	0,63	-1,40	0,78
K3	-1,41	0,63	0,78
K4	1,12	0,17	-1,31
K5	0,53	-1,40	0,84
K6	-0,05	1,24	-1,20

(Source: authors' own research)

In the study, we use the AHP method to quantitatively evaluate cities according to set criteria and determine the relative importance of factors. This approach provides objectivity in the analysis of urban characteristics and identifies not only strengths and weaknesses, which helps in targeted improvements, but also indicates specific areas where targeted actions are needed. AHP is a valuable tool for informed management decisions and strategic planning.

In our study, we will use the weights previously established for each criterion to build a matrix (Table 3). This will allow us to analyze and compare the criteria related to smart urban development for more informed and effective decision-making. Furthermore, AHP allows for the integration of different perspectives and opinions in the decision-making process. By building a hierarchy and evaluating alternatives, we can ensure that the decisions made are well-founded and reflect the realities of the urban environment. The Analytic Hierarchy Process is a tool in our research that increases the reliability and validity of the results and allows us to develop more targeted and effective policies for the development of smart cities. [17]-[18]

The analysis of the normalized matrix and the priority weights, which are obtained as the average value of the rows in the normalized matrix, reveal the distribution of the relative importance of the criteria for smart urban development. The most important are the criteria K5 and K6, with priority weights of 0.227, which indicates that they play a leading role in the decision-making process. Criterion K2 also has a significant weight with a priority weight of 0.182, while K3 and K1 are of medium importance, with 0.147 and 0.134, respectively.

The lowest influence is K4 with a priority weight of 0.091, which means that its role is weaker compared to the others. These values indicate decision-making priorities and can be used to plan strategies and allocate resources.

The priority of the criteria thus determined allows us to make a more in-depth analysis of smart urban development, considering their relative importance.

TABLE 3 MATRIX FOR PAIRED COMPARISONS

Criterion	**K1**	**K2**	**K3**	**K4**	**K5**	**K6**
K1	1	0,75	1	1,50	0,60	0,60
K2	1,33	1	1,33	2	0,80	0,80
K3	1	0,75	1,5	1,5	0,60	0,60
K4	0,67	0,5	0,67	1	0,40	0,40
K5	1,67	1,25	1,64	2,5	1	1
K6	1,67	1,25	1,67	2,5	1	1
Total	7,34	5,5	7,34	11	4,4	4,4
Normalized matrix						

Criterion	**K1**	**K2**	**K3**	**K4**	**K5**	**K6**
K1	0,136	0,136	0,204	0,055	0,136	0,136
K2	0,181	0,182	0,181	0,182	0,182	0,182
K3	0,136	0,136	0,204	0,136	0,136	0,136
K4	0,091	0,091	0,091	0,091	0,091	0,091
K5	0,227	0,227	0,227	0,227	0,227	0,227
K6	0,227	0,227	0,227	0,227	0,227	0,227

(Source: authors' own research)

Based on the determined priorities of the criteria, we calculated the SWOT index (2) - a weighted sum of z-scores with AHP weights (Table 4). It allows for a comprehensive assessment of the performance of the cities [2].

$$\text{SWOT index} = \sum_{n=1}^{6} \omega_n Z_n \qquad (2)$$

where:

ω_n are the AHP weights

Z are the Z-transformed values from the already calculated Z-scores

Table 4 presents the calculated values of the SWOT index for the three analyzed cities. Sofia shows the highest value (0.37), which suggests a better performance compared to the other cities in the context of the studied criteria. At the same time, Plovdiv and Varna have negative values (-0.20 and -0.18 respectively), which points to relatively weaker results.

TABLE 4 SWOT INDEX VALUES FOR THE ANALYZED CITIES

City	**Sofia**	**Plovdiv**	**Varna**
SWOT index	0,37	-0,20	-0,18

(Source: authors' own research)

For a more in-depth analysis, we proceed to the calculation of priorities based on the weights, z-scores and the results of the paired comparisons (Table 5). These priorities will allow us to understand more precisely which aspects have the greatest impact on the development of smart cities and how they differ between individual urban environments.

Table 5 presents the priorities of each city based on the SWOT analysis and the relevant criteria. Sofia has a strong economic strength (K1/S) as a main advantage, but faces serious challenges related to socio-economic inequality (K4/W) and transport problems (K2/W). Plovdiv stands out for its high quality of education (K6/S), but experiences

difficulties in terms of transport infrastructure (K2/W) and economic diversification (K1/W). Varna relies on a high quality of life (K5/S) and the potential for development of urban infrastructure (K2/O), but faces serious threats such as a lack of qualified labor (K6/T) and inefficient resource management (K4/W).

These results clearly outline the priority areas where targeted action and strategic efforts are needed to achieve sustainable and balanced development in each of the cities under review.

Table 6 presents a comprehensive analysis of the main factors influencing the development of Sofia, Plovdiv and Varna. Each of these cities has its own specific strengths and weaknesses, as well as unique opportunities and challenges that determine their potential for future development. The analysis helps to highlight even more clearly and categorically the key aspects on which efforts should be focused.

Sofia is distinguished by its developed economy and strong business environment (K1/S), as well as a well-developed transport infrastructure (K2/S), which supports its economic growth. However, the city faces significant challenges related to congestion (K2/W), leading to mobility inefficiencies, and high levels of air pollution (K3/W), impacting public health. Socio-economic inequality (K4/W) is another concern, with disparities in income and access to services.

Opportunities for improving urban transport (K2/O) and developing sustainable technologies (K3/O) can help address these issues, though economic instability remains a potential threat (K1/T).

Taking advantage of the opportunities for sustainable development and modernization of the urban environment will be key to the future of the capital as a smart and functioning city. Plovdiv relies on its cultural and historical tourism (K3/S) and high-quality education (K6/S) as its main advantages. However, the city suffers from low economic diversification (K1/W), transport problems (K2/W) and environmental challenges (K3/W). Development opportunities include promoting innovative sectors such as IT and startups (K1/O) as well as improvements in transport infrastructure (K2/O). However, the loss of young people due to lack of economic prospects (K1/T) is a serious risk that could limit the city's long-term growth. Varna, with its status as an attractive tourist destination (K3/S) and high quality of life (K5/S), has significant development potential. The city has natural and cultural assets that attract visitors and create a favorable living environment. However, the lack of economic diversification (K1/W), poor management of urban resources (K4/W) and the shortage of skilled labor (K6/W) pose significant obstacles. Development opportunities for urban infrastructure (K2/O) can help improve conditions, but the risk of environmental problems (K3/T) and the shortage of staff (K6/T) remain key challenges for Varna.

TABLE 5 PRIORITIES CALCULATED BASED ON WEIGHTS, Z-SCORES, AND PAIRED COMPARISONS

City	Priority					
	1	*2*	*3*	*4*	*5*	*6*
Sofia	K1/ S (0,35)	K4/ W (0,25)	K3/O (0,20)	K2 / O (0,15)	K3/ W (-0,10)	K2/ W (-0,10)
Plovdiv	K6/ S (0,31)	K3/T (0,09)	K4/W (0,02)	K1/W (-0,06)	K2/W (-0,28)	K5/ T (-0,35)
Varna	K5/S (0,21)	K2/ O (0,16)	K3/ T (0,12)	K1/ W (-0,15)	K4/ W (-0,13)	K6/ T (-0,30)

(Source: authors' own research)

TABLE 6 SWOT ANALYSIS OF CITIES BASED ON KEY CRITERIA

SWOT Category	Sofia	Plovdiv	Varna
Strengths (S)	K1: Developed economy and high concentration of businesses K2: Well-developed transport infrastructure (metro, buses, trams)	K3: Developed cultural and historical tourism K6: High-quality education.	K3: Attractive tourist destination (seaside resorts, beaches) K5: High quality of life (clean air, green spaces)
Weaknesses (W)	K2: Traffic congestion issues K3: High levels of air pollution K4: Socio-economic inequality	K1: Low economic diversification K2: Lack of an efficient transport network K3: Environmental issues K4: Migration of young people	K1: Lack of economic diversification K3: Risk of environmental problems. K4: Inefficient urban resource management K6: Lack of a qualified workforce
Opportunities (O)	K2: Improvement of public transport and infrastructure K3: Development of green technologies and sustainable energy	K1: Development of innovative sectors (IT, startups) K2: Improvement of transport infrastructure	K2: Improvement of urban infrastructure
Threats (T)	K1: Risk of economic instability	K1: Loss of young people due to a lack of economic opportunities	K3: Risk of environmental problems. K6: Lack of a qualified workforce

(Source: authors' own research)

In summary, the SWOT analysis shows that each of the three cities has unique strengths and challenges that require specific development strategies [19]. Sofia needs to address transport and environmental issues, Plovdiv needs to promote economic diversity and retain young people, and Varna needs to improve resource management and ensure

the attraction of qualified personnel. These conclusions serve as a basis for further strategic planning and prioritization of actions in the context of smart urban development.

C. Identifying sustainable initiatives

The SWOT analysis highlights the main strengths, weaknesses, opportunities and threats for each city, providing a structured understanding of their urban development landscape [20]-[22]. However, to gain a deeper insight into performance gaps and areas requiring improvement, we turn to gap analysis. [9]

Table 7 compares the performance of Sofia, Plovdiv, and Varna against target values for key criteria, using GAP values to highlight deviations and areas needing improvement. Sofia shows the smallest gaps in economic development (K1) and urban infrastructure (K2) but struggles with social equality (K4) and education (K6). Plovdiv performs well in economic growth (K1) and urban transport (K2) but faces challenges in education (K6) and environmental sustainability (K3). Varna has significant gaps in economic and transport infrastructure (K1, K2) but excels in social development (K4) and education (K6).

TABLE 7 GAP VALUES

Criterion	Target value	Sofia	Plovdiv	Varna
K1	5,0	0,22	2,67	3,44
K2	4,5	0,83	3,25	0,65
K3	4,0	2,61	1,12	1,01
K4	4,5	1,23	1,94	3,05
K5	4,5	0,63	1,75	0,45
K6	5,0	1,64	0,25	2,89

(Source: authors' own research)

The data presented in Table 8 show the need for individual strategies. Sofia should focus on improving social inclusion and education, Plovdiv should strengthen the environmental and educational sectors, and Varna needs targeted investments in economic diversification and transport infrastructure. This will help to overcome imbalances and achieve sustainable growth.

D. Synergy between all three elements

The analysis of the three cities reveals that sustainable initiatives, smart projects and green technologies are key to overcoming the challenges. Each city demonstrates specific strengths and weaknesses. In Sofia, the well-developed economy and transport infrastructure (K1/S and K2/S) create a solid foundation for the implementation of smart city solutions, such as digital traffic management and optimization of public transport. However, serious problems with air pollution (K3/W) and socio-economic inequality (K4/W) require increased implementation of green technologies and sustainable policies aimed at energy efficiency and reducing carbon emissions. Plovdiv has strong positions in education (K6/S), but suffers from an underdeveloped transport network (K2/W) and limited economic opportunities for young people (K1/W). Investments in smart urban mobility and digitalization of services can help overcome these barriers. At the same time, the opportunity to improve infrastructure (K2/O) can be supported by introducing sustainable transport solutions, such as environmentally friendly vehicles and modernizing public transport. Varna, as a tourist destination, has a high quality of life (K5/S) and potential for developing a sustainable urban environment. However, environmental risks (K3/T) and insufficiently efficient management of urban resources (K4/W) pose threats to long-term development. The implementation of green technologies for waste management, water resources and energy efficiency can significantly improve the sustainability of the city.

The data from the GAP analysis (Table 7, Table 8) further highlight where the largest imbalances in urban development are located and which aspects require targeted action.

TABLE 8 GAP-SUPPLEMENTED SWOT ANALYSIS

SWOT Category	Sofia	Plovdiv	Varna
Strengths	Strong K1 GAP: 0,22	Higher K6 GAP: 0,25	Good K5 GAP: 0,45
Weaknesses	Bad K3 GAP: 2,61	Bad K2 GAP: 3,25	Bad K4 GAP: 3,05
Opportunities	Green policies	Investments in transport	Digital control
Threats	Bureaucratic barriers	Lack of fundin	Slow reforms

(Source: authors' own research)

In Sofia, the largest deviation is in air pollution (K3, GAP: 2.61), which requires immediate measures through green technologies. In Plovdiv, transport infrastructure remains a priority (K2, GAP: 3.25), while Varna needs to focus efforts on socio-economic inequalities (K4, GAP: 3.05).

Combining sustainability, smart technologies and green solutions offers an effective approach to solving the challenges: Sofia to focus on clean technologies and transport, Plovdiv - on digital solutions, and Varna - on eco-management, which will increase the quality of life and ensure sustainable growth.

IV. CONCLUSIONS

Sofia is distinguished by a developed economy and transport infrastructure, but faces serious problems such as congestion (K2/W), air pollution (K3/W) and socio-economic inequality (K4/W). It would be good to focus on

investing in sustainable transport and environmental technologies (K2/O, K3/O), as well as improving social policies to reduce inequalities. Plovdiv has an advantage in cultural tourism and education (K6/S), but suffers from a lack of transport efficiency (K2/W) and low economic diversification (K1/W). It is desirable to develop innovative economic sectors (K1/O) and modernize the transport network (K2/O) to attract investment and retain young people. Varna benefits from its tourism potential and good quality of life (K5/S), but experiences problems with urban resource management (K4/W) and the lack of qualified labor (K6/W). It is recommended to focus on improving the city's digital governance (K2/O) and promoting educational initiatives for staff qualification (K6/O). Overall, integrated strategies for transport, eco-innovation and economic development will help the three cities address the challenges and achieve sustainable growth.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 133-139

Models for Sustainable Urban Development in the EU (Good Practices and Challenges for New Member States of the EU)

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***Abstract*— The focus of the study is on sustainable urban development in the context of the European Union (EU), examining best practices and challenges related to the adaptation of successful models in the new member states of the EU. The analysis is based on the example of three leading European cities – Barcelona, Amsterdam and Copenhagen, which are known for their innovative approaches to resource management, transport, energy efficiency and social integration. The aim is to identify innovations and sustainable solutions in resource management, transport, energy efficiency and social integration. The leading thesis is that sustainable urban development in the new member states can be accelerated through strategic governance, smart technology integration and active citizen participation, supported by effective public-private partnerships and innovative financial models. The methodology used is process and strategic benchmarking, which allows for a systematic comparison of different approaches and identification of opportunities for their implementation in newer EU Member States. The results show that the successful practices in the cities examined can be adapted to the specific contexts of the new member states, provided that there is effective interaction between local government, business and civil society. The research highlights the importance of sustainable policies and management strategies that contribute to long-term socio-economic and environmental goals.**

Keywords*— *smart cities, sustainable development, smart technologies, circular economy, urban mobility, Public-Private Partnerships

I. INTRODUCTION

Sustainable urban development is a key priority in European Union policies, as part of global efforts to deal with climate change, improve quality of life and manage resources efficiently. Smart cities that combine innovation, sustainable technologies and smart governance have established themselves as a strategic model for the development of urban areas. Examples such as Barcelona, Amsterdam and Copenhagen provide successful practices in the integration of innovative solutions that combine social, economic and environmental aspects, and offer opportunities to accelerate sustainable development in other European cities

Despite the progress made in infrastructure and economic modernization, some of the major cities in the new EU member states – Bulgaria, Romania and Croatia – still lag behind in some key aspects of sustainable urban development compared to more developed Western European regions. Large cities in these countries face serious challenges in areas such as transport sustainability, energy efficiency and social integration. To catch up, it is essential to prioritize actions to integrate innovation, develop intelligent transport systems and deploy technologies to accelerate the transition to sustainable governance. A strategic focus on public-private partnerships and the active involvement of citizens in decision-making processes could make a decisive difference in closing these gaps.

Achieving sustainable development in these cities requires an in-depth analysis of leading examples and the identification of strategic priorities that can accelerate the transition to smart governance. The aim of this study is to analyse best practices in sustainable urban development through a comparative analysis of Barcelona, Amsterdam and Copenhagen using the benchmarking method. This study focuses on the key tools and solutions implemented in these cities to serve as a benchmark for the formulation of development priorities for large cities in the new EU member states.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8634
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Expected outcomes of the study include:

- Identification of successful practices and solutions to be applied in the context of smart cities;
- Analysis of the main challenges faced by cities in the new Member States;
- Formulation of strategic planning recommendations to facilitate the transformation towards sustainable development.

The relevance of the topic arises from the need to narrow the development gap between old and new EU Member States, as well as the growing need for integrated solutions to address urban and environmental challenges. This study aims, on the one hand, to identify good practices and, on the other, to propose practical guidelines for their adaptation in the context of the new Member States.

II. MATERIALS AND METHODS

A. Theoretical framework of the issue

Sustainable urban development is an integrated concept that combines social, economic and environmental aspects to ensure balanced and long-term development of urban areas. The foundations of this concept are laid in the report Our Common Future, where sustainability is defined as development that meets the needs of the present without compromising the opportunities of future generations [1]-[4].

This concept has subsequently been developed by authors such as J. Sachs, who highlights the importance of global SDGs [5]. And furthermore by D. Meadows and J. Randers, who emphasize a systems approach to urban planning and management [6].

Smart cities extend the concept of sustainable development through the integration of information and communication technologies (ICTs) that optimize resource use, improve quality of life and reduce environmental footprint. J. Morelli, L. Greenwood, K. Lockwood, and C. Portillo research how smart technologies can support sustainability [7], [8].

A. Caragliu, C. Del Bo и P. Nijkamp proposes an analytical framework for smart cities based on 6 key aspects: economics, mobility, environment, human, quality of life and governance [9], [10]. Whereas N. Komninos, H. Schaffers, P. Tsarchopoulos and R. Hollands emphasize the importance of innovation and intelligent systems in urban development [11]-[16].

The benchmarking method, widely used in strategic management, is a proven approach for identifying and adapting best practices. R. Camp и I. Bruno define benchmarking as the process of systematically comparing results and processes to identify opportunities for improvement [17]-[19]. M. Spendolini adds that the success of benchmarking depends on the ability to adapt leading practices to the specific local circumstances [20].

Within the framework of sustainable urban development, benchmarking is applied to analyse innovative solutions successfully implemented in global leaders such as Barcelona, Amsterdam and Copenhagen.

Barcelona establishes itself as a leader in the integrated management of urban services through smart technologies and green platforms [21]. Amsterdam has demonstrated success stories in sustainable mobility and the circular economy, combining innovation in transport and waste management. Copenhagen, on the other hand, stands out for its carbon-neutral development strategy and innovations in urban planning that promote the balanced use of resources [22].

At the same time, large cities in the new EU Member States face a number of challenges that hinder the implementation of sustainable and smart approaches. Lack of effective institutional coordination and limited financial mechanisms to stimulate innovation are identified. Gaps in digital connectivity and outdated infrastructure also present major obstacles.

The theoretical review shows that the success of sustainable urban development depends on the integration of leading practices and their adaptation to the local conditions.

The research, using the benchmarking method (Fig. 1), focuses on the analysis of best practices applied in Barcelona, Amsterdam and Copenhagen with the idea of proposing priority directions for the development of cities in the new EU Member States.

B. Methodology of the research

This study applies an integrative approach combining both quantitative and qualitative methods of analysis, with an emphasis on process-oriented and strategic benchmarking. This methodological approach allows a systematic comparison of sustainable and smart practices implemented in three leading European cities – Barcelona, Amsterdam and Copenhagen. Process-oriented benchmarking focuses on a detailed overview of the management practices and operations that lead to sustainable urban development, while strategic benchmarking analyses the long-term goals and vision of these cities in terms of sustainable management.

The analysis focuses on key indicators related to resource management, the transport system, energy efficiency, digitalization and citizen participation, aiming to compare results and, on this basis, to extract useful strategies and approaches that can be adapted to the context of other cities.

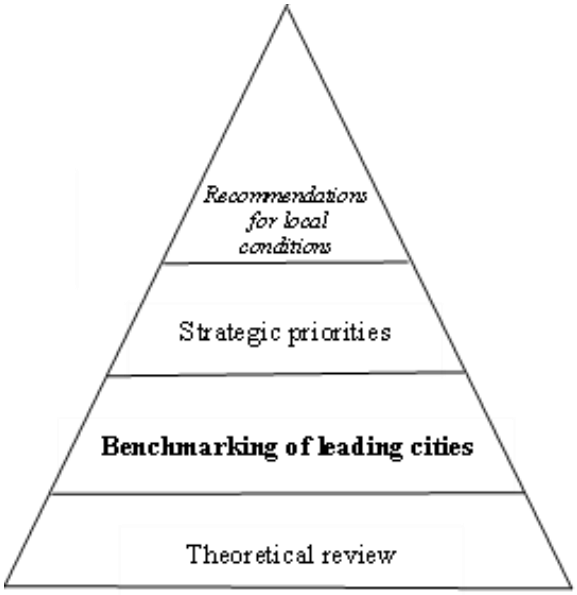

Fig. 1. Logic scheme and survey tools. (Source: authors' own research).

The analysis focuses on key indicators related to resource management, the transport system, energy efficiency, digitalization and citizen participation, aiming to compare results and, on this basis, to extract useful strategies and approaches that can be adapted to the context of other cities.

The data used in the study was taken from secondary sources including academic publications, official reports, strategic plans and statistical sources. For the cities of Barcelona, Amsterdam and Copenhagen, examples were used from well-established international initiatives that demonstrate innovative approaches to sustainable development.

The qualitative component of the study aims to identify successful approaches and innovative solutions in the cities surveyed, while the quantitative analysis is applied to compare three main sets of indicators. Using these methodological approaches provides a systematic and objective analysis that contributes to the formulation of practical guidelines and policies to accelerate sustainable development in European cities.

III. RESULTS AND DISCUSSION

A. Empirical Research

The study is based on the benchmarking method, following its methodological procedure for systematic comparison and analysis of best practices. The approach allows to identify leading innovative solutions and to adapt successful models applied in the cities under consideration – Barcelona, Amsterdam and Copenhagen. By comparing key indicators related to sustainable urban development, the study aims to provide conclusions and recommendations that can serve as a basis for strategic planning and development.

The analysis is structured around three main groups of indicators that are essential for assessing sustainability: environmental sustainability, social sustainability and quality of life, economic sustainability and innovation. They illustrate the key dimensions of sustainable development and allow for a comprehensive assessment of progress and challenges in the context of the cities surveyed.

For the purpose of the study and in view of the benchmarking analysis, three main groups of sustainable urban development criteria were identified, each including specific sub-criteria and indicators (Table 1).

Due to the limited length of the publication, the specific results obtained by the evaluation method will not be presented here. Instead, attention will be focused on the general guidelines and main conclusions that can be drawn from the analysis of sustainable urban development in the European cities under review – Amsterdam, Barcelona and Copenhagen. The study aims to identify the main characteristics of successful practices and excellence in the field of environmental, social and economic sustainability, in order to provide valuable results, insights and recommendations for other cities in the process of transformation.

On the basis of the comparison made, the significant integration of sustainable development in the strategies and policies of the leading cities is noticeable. In Copenhagen, for example, environmental sustainability is underpinned by ambitious carbon neutrality targets, with around 50% of the city's energy currently coming from renewable sources, and the aim to increase this to 70% by 2030. In Barcelona, the focus on green urban spaces and energy efficient buildings has shown significant progress, with 40% of buildings in the city center already reported to have been renovated to achieve better energy efficiency.

In the social area, we report that the cities under review are actively working to improve quality of life through access to high quality public services, safety and a healthy urban environment. Amsterdam, for example, is actively integrating smart technologies to support city management, with 60% of its residents now using mobile apps to access services and information. The city also encourages citizen participation through digital connectivity platforms that provide feedback and citizen involvement in decision-making. At the same time, Barcelona places special emphasis on social integration and cultural diversity, creating a sense of community and belonging through public initiatives that cover around 30% of the population.

Economic sustainability, on the other hand, is characterized by a strong focus on innovation, high-tech industries and cooperation between the scientific and business communities.

In Amsterdam, the success of the start-up ecosystem and the focus on the circular economy demonstrate a skillful approach to attracting investment and building a sustainable economic structure.

TABLE 1 GROUPS OF CRITERIA AND INDICATORS FOR SUSTAINABLE URBAN DEVELOPMENT

Environmental sustainability	**Social sustainability and quality of life**	**Economic sustainability and innovation**
1. Carbon dioxide emissions (tone/capita/year)	1. Access to public services (percentage of population)	1. Share of green economy (percentage of GDP)
2. Energy efficiency of buildings (kWh/sqm/year)	2. Equality and social inclusion (Gini index)	2. Investment in innovation (percentage of GDP)
3. Share of renewable energy sources (% of total energy consumption)	3. Healthy urban environment (number of parks/thousand people)	3. Support for start-ups (number of start-ups per year)
4. Waste management (percentage of waste recycled)	4. Conditions for cultural activities (number of cultural events per year/1000 inhabitants)	4. Share of high-tech companies (% of all companies)
5. Air quality (PM2.5 concentration in µg/m³)	5. Level of education (number of graduates per 1000 inhabitants)	5. Research expenditure (percentage of GDP)
6. Water resources management (percentage of reused water)	6. Transport connectivity (length of public transport/sq km)	6. Employment rates (% of working age population)
7. Urban green infrastructure (percentage of green space/urban area)	7. Sustainable urban planning (density index)	7. Share of sustainable tourism (percentage of tourism revenue)
8. Sustainability of urban mobility (percentage of electric vehicles)	8. Safety (number of crimes/1000 inhabitants per year)	8. Sustainability of the digital economy (number of IT companies per 10 000 inhabitants)
9. Green space (m² of green space per inhabitant)	9. Quality of life indicators (subjective satisfaction index)	9. Number of patents (number of patents per 1000 inhabitants per year)
10. Sustainable land use management (percentage of agricultural land)	10. Accessibility for people with disabilities (number of adapted public facilities)	10. Attractiveness for foreign investment (euro per capita/year)
11. Biodiversity (number of species/100 km²)	11. Indices of subjective well-being (work-life balance)	11. Number of public-private partnerships (number of projects/year)
12. Sustainable transport (number of cycle lanes/100 km²)	12. Promotion of citizen participation (number of public consultations per year)	12. Financial incentives for innovation (EUR/year/company)
13. Redevelopment of industrial zones (number of zones converted/year)	13. Promotion of healthy lifestyles (percentage of physically active people)	13. Competitiveness of local enterprises (% revenue growth per year)
14. Pollution control (number of inspections per year)	14. Improvement of educational infrastructure (number of schools upgraded)	14. Export potential (exports in euro per capita per year)
15. Environmental areas (percentage of protected areas)	15. Promotion of volunteering (percentage of people participating in volunteering initiatives)	15. Participation in international networks (number of partnerships per year)
16. Climate impact (% reduction in CO2 emissions over 10 years)	16. Youth development programs (number of programs per year)	16. Sustainable funding (percentage of sustainable projects of total funding)
17. Sustainable urban technologies (number of technologies deployed per year)	17. Social housing affordability (number of dwellings per 1000 inhabitants)	17. Scientific and business cooperation (number of joint projects)
18. Eco-labelling (number of certified products/services)	18. Cultural diversity indices (number of cultural events for ethnic groups)	18. Sustainable supply chains (number of chains in place)
19. Resource efficiency (percentage of recycled materials used)	19. Sustainable well-being indicators (sustainable well-being index)	19. Economic sustainability of cities (% GDP per capita growth)
20. Climate change vulnerability assessment (vulnerability index)	20. Resilience of social systems (% of population covered by social protection)	20. Number of green initiatives (number of initiatives per year)

In 2024, start-ups in Amsterdam attracted investments worth around €2 billion, with sustainable technology and healthcare among the key areas for development. Copenhagen is another impressive example with innovation in energy efficiency and leadership in developing green technologies that are even being exported to the international market, with the value of green technologies expected to reach €4,5 billion by 2025.

These observations underline the importance of a holistic approach to urban planning where the three main pillars of sustainability - ecology, society and economy - are interlinked and complementary. While environmental initiatives set the long-term direction for conservation, social policies provide the immediate impact on human well-being, and economic measures provide the resources to sustain and expand these efforts. The next section will provide a more in-depth analysis of best practices that demonstrate outstanding results in the area of sustainable urban development. Examples will be specifically selected to illustrate innovative approaches and solutions that can serve as models for adaptation in other urban contexts.

B. Strategic Approaches to Sustainable Urban Development

The comparative analysis of Barcelona, Amsterdam and Copenhagen clearly shows how leading European cities are implementing sustainable urban development and highlights the significant differences in their progress. These cities have built solid foundations for a sustainable future by integrating smart technologies and renewable energy into their urban infrastructure. On the one hand, they are investing in innovation and, on the other hand, they are actively promoting social integration and mobility, making them pioneers in sustainable development at a global level. At the same time, many large cities in the new EU Member States are facing challenges related to delayed innovation, insufficient financial resources and congested infrastructure.

As it is illustrated in Table 2, Barcelona has demonstrated impressive success in adapting smart technologies and energy efficiency, actively implementing solutions that reduce carbon emissions and lead to a cleaner and more sustainable urban environment. Amsterdam, on the other hand, exemplifies innovation in the circular economy by actively promoting recycling and waste reduction. The city is a leader in electric mobility and is creating sustainable economic models that can be adopted by other European cities. Copenhagen also provides clear examples of sustainable resource management, focusing on reducing carbon emissions and integrating sustainable technologies into the urban environment.

Many Eastern European cities still face serious challenges affecting their ability to adapt to a rapidly changing urban environment.

TABLE 2 BEST PRACTICES IN SUSTAINABLE URBAN DEVELOPMENT

Environmental sustainability	**Social sustainability**	**Economic sustainability and innovation**
Barcelona Integrating renewable energy and energy efficiency	Barcelona Opportunities for citizen participation in sustainable city management	Barcelona Integration of smart technologies in urban infrastructure, with a focus on sustainable construction and transport
Amsterdam Promoting electric mobility and reducing waste	Amsterdam Strategies for social integration and inclusive public spaces	Amsterdam Supporting innovation in electric mobility and the circular economy
Copenhagen Carbon neutrality and emissions reduction strategy	Copenhagen Investment in health and social services that meet the needs of all citizens	Copenhagen Supporting start-ups with a focus on green technologies and sustainable innovation

Lack of sufficient investment in modern transport and environmental solutions, as well as difficulties in innovating, make it difficult to accelerate the introduction of sustainable solutions in urban infrastructure. Despite the difficulties, these Eastern European cities have great potential for progress and any small effort towards sustainable development can bring significant benefits to the quality of life of citizens.

Comparative studies of Barcelona, Amsterdam and Copenhagen show that these cities are innovating in their urban environment and actively demonstrating how sustainable development can be achieved by integrating different areas of society and the economy.

Barcelona stands out as an example of energy efficiency and sustainable urban planning, where renewable energy and smart technologies create a dynamic and environmentally friendly urban environment. Strategies to reduce carbon emissions, as well as innovations in transport, show how modern technologies can change urban governance towards a sustainable future.

Amsterdam, for its part, has not only innovated in the circular economy and electric mobility, but has also established itself as an example of social sustainability by actively involving citizens in decision-making processes and creating inclusive public spaces. Strategies such as encouraging recycling and reducing waste reduce the City's environmental footprint and also offer economic and social benefits to all its residents. This combination of environmental, social and economic innovation makes Amsterdam one of the leaders in sustainable urban development.

Copenhagen demonstrates how sustainable resource management can be linked to innovation in the industrial sector and entrepreneurship. The city is steadily reducing carbon emissions while investing in social and health initiatives that improve the quality of life for all its residents. Copenhagen is a successful example of how a carbon neutral strategy can be embedded not only in energy policies but also in the economic and social development of the city.

These three examples of sustainable urban development show how integrating different aspects of sustainability – from eco-innovation to social integration and economic efficiency – can lead to significant achievements in creating smart and sustainable cities. They lay the foundations for the future of cities and show how the achievements of leading European cities can be applied and adapted in other contexts.

Recommendations to promote sustainable development of large cities in the new EU Member States. The existing lag of large cities in the new EU Member States in the context of sustainable urban development can be overcome by adopting innovative approaches and strategically applying successful practices from leading European cities such as Barcelona, Amsterdam and Copenhagen. In order to catch up with these leaders, concrete strategies need to be developed that include integrating advanced technologies, stimulating innovation, social responsibility and citizen engagement.

In Fig. 2, we present several key tools and approaches that can help large cities in the new Member States achieve sustainable development and close the gap with leading examples in Europe. The proposed measures will be analysed sequentially by their defining characteristics: tools (T), approach (A), objective (O).

a) Establishing innovation hubs and initiating public-private partnerships – innovation hubs and techno parks to support start-ups in sustainable development (T); leveraging local universities, research institutes and private investors to encourage collaboration to develop innovations in clean technology, energy efficiency and sustainable building practices (A) [23]; supporting the rapid deployment of new technologies and practices that will accelerate the development of urban infrastructure and increase the competitiveness of the economy (O).

b) Implementing smart and environmentally friendly transport solutions – expansion of low-carbon public transport networks and promotion of electric vehicles (T); constructing "green" transportation corridors and expand bike lanes. Incorporate Intelligent Transport Systems (ITS) to manage traffic and reduce congestion (A); reducing carbon dioxide emissions and improve urban mobility while reducing energy costs and increasing the efficiency of the transport network (O).

c) Supporting the circular economy and sustainable resource management – stimulating recycling and waste reduction through circular business models and technologies (T); encouraging enterprises to adopt resource reuse models through initiatives such as separate waste collection and the promotion of green entrepreneurial practices (A); reducing waste and better manage resources with a focus on renewable energy and energy efficiency in production processes (O).

d) Strengthening civic engagement and social integration – introduction of public forums, public councils and platforms for participation in urban policies (T); using digital platforms to interact with citizens and involve them in decision-making processes, encouraging socially responsible projects that improve the quality of life of vulnerable groups (A); improving social integration, promoting active citizenship and ensuring equal access to basic public services such as health and education (O).

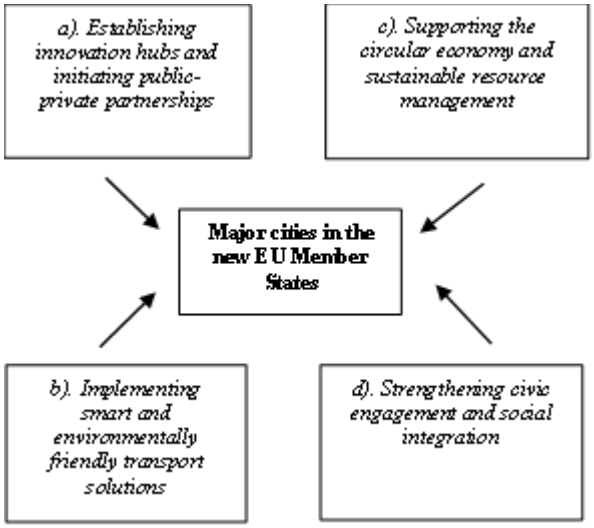

Fig. 2. Tools and approaches for urban development. (Source: authors' own research).

By following these recommendations and adopting innovations that have already proven effective in other European cities, major cities in the new EU Member States have the opportunity to accelerate the transition to sustainable development. These steps will position them not only as leaders in sustainable development, but also as innovation hubs that attract new investment and create jobs leading to a higher quality of life for their citizens.

IV. CONCLUSIONS

Large cities in the new EU Member States have the potential to catch up with the leaders in sustainable urban development if they integrate strategic innovations and best practices, such as the following:

First - Invest in innovation and technology for sustainable development to accelerate the transition to smart and green cities.

Second - Stimulate public-private partnerships that will enable effective implementation of innovation and build infrastructure for sustainable development.

Third - Active citizen participation and social responsibility to strengthen public ownership and achieve a better quality of life for all.

Overall, with a focus on innovation and engaging all stakeholders, the new members could create sustainable and competitive cities.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 141-148

Perspectives on the Application of Social Innovations in the Social Services Sector

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***Abstract*- Rapid societal changes drive the integration of social innovations into the social services sector. Demographic shifts, population aging, increasing social inequality, and ongoing challenges related to service accessibility and sustainability necessitate innovative solutions to enhance the efficiency and effectiveness of social services. The challenges of globalization further encourage a shift from traditional service delivery models. Social innovations, characterized by novel operational methods, collaborative governance models, and technological advancements, provide opportunities to improve service quality, accessibility, and long-term sustainability. These innovations not only address pressing social issues but also play a crucial role in strengthening community resilience, reducing social exclusion, and fostering inclusive development. Despite the potential of social innovations, their implementation faces numerous obstacles, including financial constraints, bureaucratic inertia, institutional barriers, and the complexities of adopting technological solutions. The aim of this study is to assess the role of social innovations in the social services sector, identify key barriers to their implementation, and propose strategies to overcome these challenges. The study employs a qualitative research methodology, utilizing interviews and content analysis to provide a comprehensive examination of social innovation practices across various social service sector contexts. The findings reveal that integrating innovative solutions not only enhances the efficiency of social services but also drives broader social transformations—strengthening local communities, reducing social inequality, and increasing the resilience of social service systems in times of crisis. The study highlights the importance of interdisciplinary collaboration, continuous professional development for social service practitioners, and the creation of a more flexible institutional environment to support the expansion of innovations.**

Keywords: Innovation, social innovation, social services sector.

I. INTRODUCTION

The social services sector is a crucial component of the social welfare system, aimed at reducing inequality, fostering the integration of vulnerable groups, and enhancing their quality of life [7], [9], [24]. However, traditional models of social service provision increasingly face significant challenges, including limited resources, rising service demand, and evolving societal structures and needs [9], [12]. In this context, social innovations have gained prominence as they enable the modernization of service delivery, optimization of resource utilization, and enhancement of service efficiency and sustainability [1], [5], [10], [14], [32].

Social innovation is a widely studied phenomenon encompassing various strategies, technologies, and governance models aimed at addressing complex social issues and generating long-term social value [1], [25], [26]. Research indicates that the successful implementation of innovations depends not only on technological advancements but also on organizational transformations and effective cross-sectoral collaboration between public, private, and non-governmental sectors [17], [31], [32].

Despite the potential of social innovations, their implementation faces numerous challenges. Financial constraints, bureaucratic inertia, organizational and cultural barriers, technological complexities, and a lack of competencies among social service providers constitute major obstacles to innovation diffusion [12], [32], [33], [34]. Moreover, disparities in infrastructure development and regional differences further hinder the implementation of innovative solutions and their impact assessment [35].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8688
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The concept of social innovation has been analyzed from various perspectives in the academic literature. Researchers [1], [5], [6], [11] argue that social innovations represent novel solutions to societal challenges, driving substantial social change and improving problem-solving efficiency. Researchers [10], [19], [21], [23] emphasize that social innovation extends beyond technological advancements, encompassing new organizational models, social enterprises, and community engagement in problem resolution.

Researchers further highlight that the success of social innovations is contingent on the political and institutional environment, which can either facilitate or constrain innovation development [13], [19], [21], [27]. Cross-sectoral collaboration is also considered a key determinant of effective innovation implementation [12], [17], [31]. Additionally, studies indicate that the integration of social innovations into the social services sector is often impeded by workforce shortages and insufficient staff training [13], [19], [33]. Consequently, the implementation of social innovations requires not only new competencies but also organizational transformations, which frequently encounter resistance from both employees and institutional leadership.

The primary aim of this study is to assess the prospects for implementing social innovations in the social services sector by analyzing their impact on sector efficiency, identifying key implementation challenges, and proposing strategies that contribute to sustainable innovation adoption. To achieve this objective, the study sets forth the following research tasks: analyze the academic literature on the impact of social innovations on the efficiency of social services and their significance in contemporary society; identify key barriers to the implementation of social innovations based on existing research and expert insights; provide recommendations for reducing implementation barriers and fostering sustainable social innovation development in the social services sector.

II. MATERIALS AND METHODS

A. Literature review

The implementation of social innovations in the social services sector is becoming increasingly important in effectively addressing issues related to social inequality, poverty, health challenges, and other societal concerns [27]. Although societies have long recognized the need to support vulnerable individuals and promote overall well-being, contemporary challenges demand innovative, creative, and efficient solutions [15], [12], [13], [24]. Social innovations enable the transformation of traditional social services, improving their quality, increasing accessibility, and promoting a sustainable, user-centered service model. The application of social innovations is based on insights from various social science disciplines. Empirical studies indicate that innovative forms of social service delivery, such as digital solutions, personalized services, and community participation, can significantly enhance service efficiency and accessibility for different societal groups. According to social innovation theories [25], [26], [28] and the collaboration paradigm the social services sector can undergo a fundamental transformation through innovations that ensure better service adaptation to the specific needs of recipients [4], [25], [27]. Moreover, innovations help reduce structural social inequalities, as modernized service models can be more effective, cost-efficient, and accessible even to the most socially vulnerable groups [1], [6], [7], [12].

Social innovations, defined as new methods, strategies, or ideas aimed at addressing social problems and creating long-term social value, have become a crucial factor in modernizing the social services sector. The application of these innovations enhances service efficiency, accessibility, and adaptability to rapidly changing societal needs [9], [11], [25], [27]. Recent studies indicate that social innovations not only improve service quality but also contribute to social integration and reduce social exclusion [29]. Social innovations play a key role in increasing the effectiveness of social services by providing systematic solutions to contemporary societal challenges. Recent research highlights that technology integration into the social services sector is a fundamental element of innovation. For example, the use of digital platforms not only optimizes service delivery but also enables service personalization based on individual needs. Studies conducted during the pandemic revealed that the expansion of remote services can improve accessibility and reduce administrative costs [3], [12], [22].

The effectiveness of social innovations is also closely linked to cross-sector collaboration. The latest literature suggests that partnerships between the public, private, and non-governmental sectors facilitate more efficient resource coordination and ensure the sustainability of innovations [31], [32]. For instance, Kolk and Lenfant [17] emphasize that such partnership models not only reduce redundancy but also strengthen service management, fostering long-term change.

Another significant aspect is the involvement of communities in innovation processes. Participatory methods, such as community budgeting, strengthen social capital and enhance public trust in institutions [23], [30]. Lim and Ong [23] note that such initiatives increase the effectiveness of social services by ensuring they are better tailored to the specific needs of communities.

The impact of social innovations on efficiency can also be explained through the lens of systems theory. This theory emphasizes that complex social problems require a multi-layered approach, with continuous adaptation and renewal at its core. In this context, social innovations act as a catalyst, connecting different systems and facilitating inter-institutional collaboration [5], [34]. Systems theory highlights that each system has its own internal dynamics, but social innovations create linkages between these

dynamics, fostering coordinated actions and synergy [28]. For example, Kwilinski et al. [18] notes that digital platforms serve as intermediaries, connecting public institutions, non-governmental organizations, and communities, thereby ensuring faster and more efficient communication and decision-making.

Systems theory also emphasizes feedback loops, which are essential for ensuring long-term effectiveness. These loops allow organizations and communities to assess the impact of social innovations, adapt strategies, and ensure continuous improvement tobulėjimą [2], [5], [26]. Ahrweiler [2] highlight that systems theory requires constant data analysis, which enables the identification of potential problems and addressing them before they escalate. In this way, social innovations not only respond to existing needs but also create preventative measures to mitigate potential risks. Despite progress, the implementation of social innovations still faces various challenges. A lack of funding is one of the biggest obstacles, especially when projects rely on temporary or limited funding. Scholars emphasize that to ensure the sustainability of innovations, it is necessary to create long-term financial mechanisms and encourage private sector investments in social projects [21].

According to scientific research, the success of social innovations in the social services sector is closely linked to the professional competencies of employees, their ability to apply innovative solutions, and continuous learning [5], [6], [8], [13]. Organizations play a crucial role in investing in employee qualification development, as this directly impacts the effectiveness of innovation implementation [7], [21]. Birdi et al. [8] argue that continuous training programs aimed at strengthening employees' skills are one of the key factors ensuring the sustainability and long-term impact of innovations in the social services sector.

Research reveals that ongoing learning and adapting to technological changes not only increase service delivery efficiency but also foster employee motivation, job satisfaction, and reduce the risk of burnout [12], [13]. It is important to note that the implementation of innovations requires not only enhancing individual employee skills but also cultivating a learning culture throughout the organization. This requires flexible learning methods, incorporating both formal (training programs, seminars, certification courses) and informal (hands-on workshops, mentoring programs, peer learning) forms of learning [14], [15], [19].

Moreover, studies show that the integration of technologies, such as e-learning platforms and technology-based training systems, can increase the accessibility of training and personalize the learning process, thus contributing to the more effective implementation of innovations [15], [19]. In this context, social service organizations should not only promote professional development among employees but also create an environment where innovations are easily applied in practice, and employees feel empowered to experiment and introduce new solutions. Only in this way can the implementation of social innovations bring real benefits not only to organizations but to society as a whole [18], [19], [20], [33], [35].

Community involvement, technology integration, and intersectoral collaboration are key components of social innovations that determine the effectiveness of the social services sector [20], [21], [29], [32]. These factors not only contribute to higher service quality but also promote long-term social changes by reducing social exclusion, strengthening social justice, and optimizing resource use. Empirical research shows that active community participation in the creation and implementation of social services ensures greater efficiency and better alignment with the real needs of users [1], [3], [6], [7], [13]. Eurich and Langer [19] emphasize that community involvement builds stronger social networks and fosters mutual aid mechanisms, which not only increase service accessibility but also reduce social isolation. Additionally, community participation raises awareness and activism within civil society, promoting long-term social capital [15], [17], [20], [21].

Intersectoral collaboration between the public, private, and non-governmental sectors has become a key catalyst for the implementation of social innovations [5], [26], [31]. Unseta et al. [34] notes that this collaboration model allows for the optimization of financial, human, and organizational resources, ensuring sustainable and innovative service delivery. Cooperation among various sector participants fosters the sharing of best practices, creates synergies between different actors, and helps ensure more effective service access [29], [30], [33].

Technology integration in the social services sector is also one of the most important factors that can enhance the sustainability and effectiveness of innovations. Digital tools, artificial intelligence, and big data analytics not only optimize service management but also provide the ability to more efficiently predict the needs of service recipients, allowing for the application of preventative models [7], [35]. Moreover, properly implemented technologies can reduce bureaucratic burdens, increase service personalization, and ensure faster and more accurate responses to social challenges.

Survey instrument.

The research was conducted using a qualitative methodology, which provides the opportunity to thoroughly analyze the impact of social innovations on the effectiveness of social services. Qualitative research allows for a deeper understanding of the participants' experiences, their perspectives, and the contextual factors that contribute to the success or failure of innovations [16]. By using this method, it is possible to analyze in detail how

the implementation of social innovations affects service accessibility, quality, and organizational work principles.

One of the primary advantages of qualitative research is its ability to provide contextually grounded information that is not easily accessible through quantitative methods [16], [36]. The chosen strategy helps to highlight not only general trends but also individual perspectives, experiences, and evaluations that may be significant for the development and effectiveness of social innovations. Qualitative research methodology allows for assessing the impact of innovations not only based on objective indicators but also through the subjective experiences of social service providers [16], [36]. According to Hennik at al. [16], qualitative research provides the opportunity to explore phenomena in their natural context, taking into account their complex and dynamic nature. In the field of social innovations, this is particularly important as their impact often depends on many interconnected factors, such as organizational culture, management models, policy directions, and service user involvement.

The qualitative study also emphasizes intersubjective knowledge, which helps understand how different social actors perceive the impact of innovations and what significant changes they notice [16], [27], [36]. The participants' experiences and their individual evaluations provide additional value when analyzing the success factors and challenges of implementing innovations. This way, it is possible to identify which factors promote the adoption of innovations and which aspects may hinder their effective implementation.

Empirical data were collected through semi-structured interviews, which allow for a balance between standardized structure and open-ended questions that encourage deeper responses. To ensure the validity of the research, the collected data were analyzed using thematic analysis, which enables the identification of key themes and patterns reflected in the participants' responses. Additionally, the triangulation principle will be considered, which helps verify the reliability of the data by comparing information from different sources [16].

To ensure a comprehensive perspective on the implementation of social innovations, nine respondents will participate in the study: three representatives from the public sector (P_1; P_2; P_3), three from the non-governmental sector (N_1; N_2; N_3), and three from the academic community (A_1; A_2; A_3). Participants will be selected through purposive sampling, allowing for the selection of individuals based on their experience in managing or analyzing social innovations. During the study, semi-structured interviews will be conducted, maintaining a balance between structured questions and flexibility, allowing participants to freely express their perspectives. The interview topics will cover the following areas: *What changes in service quality, accessibility, or user satisfaction have been observed? What difficulties did you face when implementing new solutions? Did intersectoral collaboration contribute to the success of social innovations? How did decisions change in response to feedback from service users or partners?*

Research Ethics and Confidentiality.

The study adhered to ethical standards to protect participants' rights and interests. Before the interviews, they were thoroughly informed about the study's objectives, process, and participation conditions. All collected data remained confidential, and respondents' anonymity was ensured by removing or encoding personal information, including the names of organizations and job position

Research limitations.

Due to the qualitative nature of the methodology, the findings of the study cannot be directly generalized to the wider population. The results may be influenced by subjective experiences and interpretative differences within each respondent group. During the interviews, there is a risk that representatives of different sectors may avoid critical assessments or emphasize positive aspects, improving their personal or organizational image. Despite these limitations, the study provides valuable, deeply contextualized information that reveals key aspects of the impact of social innovations and creates useful insights for further research and practical application.

III. RESULTS AND DISCUSSION

The research reveals the perspectives of three sectors—public, non-governmental, and academic—on the implementation of social innovations and their significance. The responses provided by participants highlight specific priorities, core operational principles, and challenges in each sector.

Public sector participants emphasized that innovations are often introduced in response to political changes or social issues. The following key trends emerged: The pandemic acted as a catalyst for digitization, such as the implementation of remote consultation systems that increased service accessibility. One participant stated: *"During the pandemic, we implemented a remote consultation system, which significantly increased service availability"* (P_3). Another participant added, *"Using digital platforms allows us to reach citizens quickly, especially in unfavorable circumstances"* (P_2). Innovations focused on improving the efficiency of bureaucratic procedures, reflecting the public sector's aim to reduce operational costs and improve service delivery quality. One participant noted: *"New technologies implemented in our organization have allowed us to shorten decision-making time and reduce the paperwork burden"* (P_2). Innovations are often centered around programs aimed at reducing social exclusion. Participants emphasized: *"Innovations in our sector are usually focused on targeted assistance to reduce social exclusion"* (P_3). Another participant added, *"New social programs*

help include vulnerable groups and ensure they feel part of society" (P_1).

Non-governmental sector participants emphasized flexibility and collaboration with communities as the foundation of innovations: *Experimentation and problem-solving with communities (N_1)*: Non-governmental organizations often act as innovation laboratories, seeking effective solutions to social problems. One participant stated: *"We often experiment with new programs that help communities solve their problems"* (N_1); another participant added, *"Communities are actively involved in creating solutions because only they know their real needs"* (N_3).

Changing funding models as innovation reflects strategic changes aimed at ensuring the continuity and independence of organizations' operations. Participants noted: *"By changing the funding model, we were able to attract more investors and ensure the continuity of projects"* (N_2); *"We diversified our funding sources to become less dependent on one sponsor"* (N_1). The role of volunteers shows that non-governmental organizations are able to quickly adapt and attract new ideas. One participant said, *"Volunteers bring new ideas and allow us to quickly adapt to changing needs"* (N_3); another added, *"Expanding the volunteer network allows us to operate more efficiently and implement larger-scale projects"* (N_1).

Academic community representatives indicated that their innovations are primarily related to the application of research results, as academic knowledge helps other sectors better meet the needs of target groups. Study participants stated: *"Our research data allows the public and non-governmental sectors to better understand the needs of target groups."* (A_2); *"Based on the analysis, we were able to create solutions that are more effective and better substantiated."* (A_1). The academic community develops and refines new methods that help gain a deeper understanding of social processes: *"The implementation of new methods allows us to more accurately identify trends and better respond to societal changes."* (A_2). Academic institutions help connect different sectors by acting as platforms for knowledge and idea exchange.

Public sector respondents' insights reveal that social innovation is an effective tool for increasing service accessibility and addressing the inclusion issues of disadvantaged groups: *"Electronic systems have reduced waiting times and increased citizens' satisfaction with services."* (P_3). This shows how digital technologies can not only optimize service delivery but also contribute to residents' satisfaction. Study participants highlighted that innovations allow for better addressing social exclusion issues. These insights reveal that public sector innovations, when focused on the needs of vulnerable groups, can significantly contribute to social equality and the overall improvement of service accessibility.

The emphasis on community involvement by the non-governmental sector demonstrates how this sector ensures that social innovations are tailored to the real needs of communities: *"When creating projects, we always involve local communities."* (N_1). This approach reveals a people-centered method of innovation implementation, which strengthens local residents' participation and trust in organizations. One study participant noted: *"Due to new technologies, we can respond more quickly to the needs of recipients."* (N_3). This highlights the importance of technology, allowing non-governmental organizations to operate more dynamically and efficiently. From a scientific perspective, the non-governmental sector becomes a space for creating social innovations, where the needs of the community drive innovation.

The responses provided by the academic community emphasize its contribution to the development of evidence-based and data-driven solutions: *"Our research results allow us to more accurately identify the needs of target groups."* (A_3). This statement underscores the importance of academic research in creating more targeted and effective interventions in the field of social policy. *"Some public sector decisions were based on our analysis, which allowed resources to be directed more precisely."* (A_1). This statement reveals how recommendations from the academic community can contribute to the creation and implementation of innovative, data-driven solutions.

Representatives of the public sector identified bureaucratic constraints and a lack of long-term funding as the biggest challenges: *"Innovations often get stuck due to strict regulations."* (P_1). This shows how the regulatory environment limits the public sector's ability to respond flexibly to social challenges.

Representatives of the non-governmental sector emphasized that their main challenges are related to financial and technological resources. N_1 stated: *"Sometimes we have many ideas, but we lack the funds to implement them."* This highlights the vulnerability of the non-governmental sector, which arises from its dependency on external funding.

Representatives of the academic community indicated that their influence is limited by the gap between research and practice and long approval procedures. One participant stressed: *"There is a gap between research and practice, which makes it difficult to apply the results."* (A_2). This shows that academic research often does not match the pace of real decision-making.

Intersectoral collaboration plays a crucial role in ensuring the effectiveness of innovation implementation and the sustainability of solutions. Representatives of the public sector emphasized that partnerships with other sectors help create data-driven strategies, better

understand community needs, and implement technological solutions. Participants in the study said: *"Regular discussions with non-governmental organizations help better understand community needs."* (P_3). This demonstrates how intersectoral collaboration contributes to creating targeted support and adapting services for specific groups.

Non-governmental sector representatives also emphasized that partnerships with the public, academic, and private sectors are essential for the continuity of projects and innovation financing: *"Public sector support is often crucial for the long-term sustainability of projects."* (N_2). This response highlights that non-governmental organizations are dependent on the public sector, which provides not only financial but also institutional stability. One study participant mentioned that the academic sector helps assess the impact of activities: *"We regularly collaborate with scientific institutions to evaluate the effectiveness of our programs."* (N_1). This demonstrates how research-based assessments allow non-governmental organizations not only to improve their activities but also to prove the effectiveness of innovations.

Academic community representatives identified their role as intermediaries between the public and non-governmental sectors, as well as promoters of the practical application of research results: *"We help the public and non-governmental sectors communicate and exchange ideas."* (A_2). This response reflects the academic sector's role in promoting sector collaboration and ensuring knowledge exchange. *"Collaboration with non-governmental organizations allows us to better apply research in practice."* (A_1). This reveals the academic sector's potential to contribute to solving specific social problems.

The future prospects of the social services sector are based on three main directions: technology development, closer intersectoral collaboration, and new financing models. Public sector representatives unanimously highlighted the importance of technology in optimizing service delivery: *"Digitization has the potential to reduce costs and expand service accessibility even in the most remote regions."* (P_1). This indicates that the public sector sees digital solutions as a way to reduce regional inequality and increase operational efficiency.

Non-governmental sector participants emphasized the importance of community involvement and the development of social enterprises in the future: *"By collaborating with communities, we can ensure that services are tailored to their real needs."* (N_1). This perspective highlights the importance of involving service users in innovation creation. *"A stronger practice of community involvement will allow us to better identify their needs and reduce the risk of service inefficiency."* (N_3). Participants also stressed the significance of social enterprises for increasing financial independence: *"Social enterprises can ensure that our programs won't rely solely on short-term grants."* (N_1).

Representatives of the academic community highlighted the importance of scientific research and data analysis in shaping innovations in the social services sector: *"In the future, it is important to develop data analytics solutions that allow for real-time monitoring of the impact of innovations and the adaptation of programs."* (A_1). This demonstrates the potential of technological solutions and data analysis to more effectively manage the quality and impact of social services; *"Data-driven decisions allow for more accurate identification of problems and directing resources to the areas that need them most."* (A_3). These responses show that the academic sector not only focuses on innovation creation but also seeks to strengthen the link between theory and practice, ensuring the potential for intersectoral knowledge exchange.

The findings of this study reveal that the implementation of social innovations in the social services sector depends on the collaboration between the public, non-governmental, and academic sectors. Each of these sectors operates based on distinct principles that can either facilitate or hinder the development of innovations. The public sector, guided by institutional and political decisions, shapes the direction of innovation; however, bureaucratic constraints, a lack of long-term funding, and complex regulatory mechanisms limit its flexibility. The non-governmental sector, in contrast, is community-oriented and highly adaptable but is often reliant on external funding and access to technological resources. The academic sector provides a scientific foundation for innovations, yet its impact is constrained by lengthy knowledge transfer cycles and challenges related to practical application.

The study highlights the strengths, weaknesses, opportunities, and threats associated with the implementation of social innovations. Key strengths include technological integration, community engagement, and evidence-based decision-making, all of which enhance innovation effectiveness. However, bureaucratic restrictions, limited resources in the non-governmental sector, and the slow implementation of academic research hinder the smooth introduction of new initiatives. Opportunities lie in technological advancements, the expansion of social enterprises, and the strengthening of cross-sectoral collaboration, which could facilitate the optimal utilization of resources across different sectors. Nevertheless, short-term funding models, a lack of technological competencies, and inadequate monitoring of innovation impact pose significant threats to their sustainability.

Based on this analysis, integrating social innovations can significantly enhance the efficiency and sustainability of the social services sector, provided that financial, bureaucratic, and technological challenges are addressed.

Cross-sectoral collaboration is a critical factor in leveraging the strengths of the public, non-governmental, academic, and private sectors. The development of social enterprises has the potential to serve as a financial foundation for innovative solutions, yet their growth requires a supportive legal and economic environment. Furthermore, technological advancements and research-based decision-making can ensure that social innovations are not only effective but also inclusive and accessible to the most vulnerable societal groups.

To ensure the sustainable development of the social services sector, it is essential to simplify bureaucratic processes, invest in technological capabilities, and strengthen cross-sectoral cooperation. These measures would foster an effective innovation ecosystem aimed at enhancing societal well-being and promoting social equity.

IV. CONCLUSIONS

The study revealed that the implementation of social innovations in the social services sector depends significantly on the interaction among the public, non-governmental, and academic sectors. The public sector, responsible for establishing an institutional environment and implementing policy decisions, improved accessibility and efficiency of social services through digital solutions and optimization of administrative processes. The non-governmental sector demonstrated flexibility and responsiveness to community needs, whereas the academic sector played an essential role by conducting evidence-based analyses that assess the impacts and feasibility of social innovations. Cross-sector collaboration emerged as a critical factor for the successful implementation of social innovations, enabling more effective adaptation to community needs and evidence-based decision-making. The findings confirm that social innovations considerably enhance the efficiency, accessibility, and impact of social services, especially for marginalized groups, by promoting user-oriented service models.

Although the public sector plays a pivotal role in creating conditions favorable to the implementation of social innovations, its potential is constrained by bureaucratic limitations and short-term funding strategies. The stability of the non-governmental sector is challenged by unpredictable funding and a lack of technological resources, highlighting the necessity for systematic resolution of these issues to ensure sustainable sector development. While the academic sector's analyses are comprehensive, their direct practical application in social innovation initiatives often remains limited; thus, mechanisms for applying research findings in practice must be strengthened. Collaboration between the public sector and academic institutions enables evidence-based decision-making, while partnerships with non-governmental organizations facilitate more effective tailoring of services to community needs. Non-governmental organizations, by collaborating with academia, can substantiate their impact and secure additional funding. Academic institutions serve as crucial intermediaries fostering knowledge exchange and developing innovative strategies.

ACKNOWLEDGEMENTS

The research was financed by the Research Council of Lithuania (RCL), contract registration No. S-PD-24-43.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 149-156

Legal Barriers and Policy Gaps in Industrial Symbiosis: a Pathway to Regulatory Innovation

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***Abstract*— The latest report on the Circularity gap reveals that the circularity ratio in 2022 has dropped by 21%. Simultaneously, in just the past six years alone, global consumption reached over half a trillion tonnes of materials - nearly as much as the entirety of the 20th century. This paper explores the key legal and policy facilitators and barriers that prevent businesses from fully engaging in Industrial Symbiosis, focusing on EU waste legislation and national regulatory constraints, applying methodologies such as literature review and analysis of secondary data. This research aims to analyse policy planning documents and identify key strategies for implementing Industrial Symbiosis. The paper highlights practical solutions to support the expansion of Industrial Symbiosis by addressing the legal and policy roadblocks. Overcoming these barriers will help businesses operate more sustainably, foster cross-sector collaboration, and accelerate the shift toward a circular and resource-efficient economy. In addition, the implementation of Industrial Symbiosis will also lead to the country's ability to i) account for credible and verifiable data for waste prevention, ii) increase resource productivity rate (which is currently a significant issue for countries such as Latvia), iii) increase material circularity rate. The main findings and conclusions will outline the strategies required at the policy and regulatory levels to foster industrial symbiosis. The paper provides practical recommendations to policy planners on how to apply Industrial Symbiosis for an efficient country's economy's transition to a circular economy.**

Keywords — circular economy, industrial symbiosis, material circularity rate, resource productivity.

I. INTRODUCTION

According to the Circularity Gap 2024 report, global statistics show that despite the circular economy reaching 'megatrend' status, ambitious goals are yet to translate into action and measurable impact. While the total amount of materials consumed by the global economy continues to rise: in the last six years alone, we have consumed more than half a trillion tonnes of materials – almost as much as in the entire 20th century – the global circularity rate fell from 9.1% in 2018 to 7.2% in 2023 [1]. Without bold, urgent action to move towards a circular economy, the world will not achieve its broader social and environmental goals, from reducing emissions to promoting secondary materials. However, the per capita material footprint remained stable from 2010 to 2022 and dropped by 4.5% in 2023. Raw material extraction was 14.1 tons per capita in 2023, which is considered unsustainable and above the global average [2]. In addition, Richardson et al. have emphasised that six of the nine boundaries are transgressed, suggesting that Earth is now well outside of the safe operating space for humanity [3]. In response to this global devastation, companies must develop business and management practices to answer new and emerging challenges and speed economies' recovery, create new jobs and prosperity, boost resource efficiency, and achieve sustainable growth. Here is where Circular Economy (CE) is required, as one of its core principles is designing out waste. It strongly emphasises closing the loops and eliminating waste or leftovers within the systems. IS supports this approach, being one of the CE business models and representing a critical business process for transforming waste into a valuable resource [5-7].

Industrial Symbiosis (IS) is an efficient Circular Economy business model that encourages industries to share resources or production leftovers, minimise waste, and reduce their reliance on primary resources. While Industrial Symbiosis has the potential to contribute to the European Green Deal goals significantly, its large-scale adoption is often blocked by complex legal frameworks and outdated regulations. IS is seen as a strong facilitator for implementing the Green Deal concepts by significantly cutting primary resource consumption, strengthening intersectoral cooperation, retrieving vast amounts of

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8663
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valuable resources before they become waste and boosting resource efficiency. When using waste or by-products as input materials, companies enhance production efficiency, reduce waste disposal and input acquisition costs, and decrease dependency on primary resources [8, 9]. IS minimises waste by capturing, recovering, and reusing previously discarded resources, reducing industrial waste and the need for new material extraction [10, 11]. By facilitating resource sharing—such as byproducts, water, and energy—among industries, IS optimises material use, fosters sustainability, and promotes environmental conservation [12]. The history of IS is over 150 years old. A previously common idea was that industries are opposed to the environment. Later, Granovetter [13] identified that a cluster of entities in a territory achieved more success than others if they could develop untraded interdependencies such as flows of knowledge, customs or understandings, and trust. The historical progression of industrial symbiosis has also been scientifically proven [14].

II. MATERIALS AND METHODS

This study applies a qualitative research methodology combining a literature survey with secondary data analysis to assess the legal and policy obstacles to IS. Through a systematic review of the literature and public policy documents (Grey literature) on CE and IS, including assessing existing barriers and facilitators for establishing IS with a focus on the research gap, the study pinpoints significant regulatory barriers and possible facilitators for deploying IS.

The Author has initiated the research by performing a bibliometric analysis of the scientific literature using the Keywords: "Industrial symbiosis," "Regional development," "Policy planning," and "legal barriers," using specific selection criteria that included papers published between 2015-2025, focusing on European policies related to industrial symbiosis. Studies were excluded if they did not directly analyse regulatory frameworks or provide empirical evidence of policy barriers. These keywords were used to search for relevant research papers in the SCOPUS database, a significant collection of academic publications. The research papers were selected for the period from 2015 to 2025. The area covered was defined as Europe. The search results were further filtered out to identify the most relevant studies. The selected papers were assessed to gather information about the research type. The data was further exported into a CSV file and then visualised using VOS Viewer 1.6.20 software to represent the research trends visually. The results of the assessment are depicted in the Fig.1.

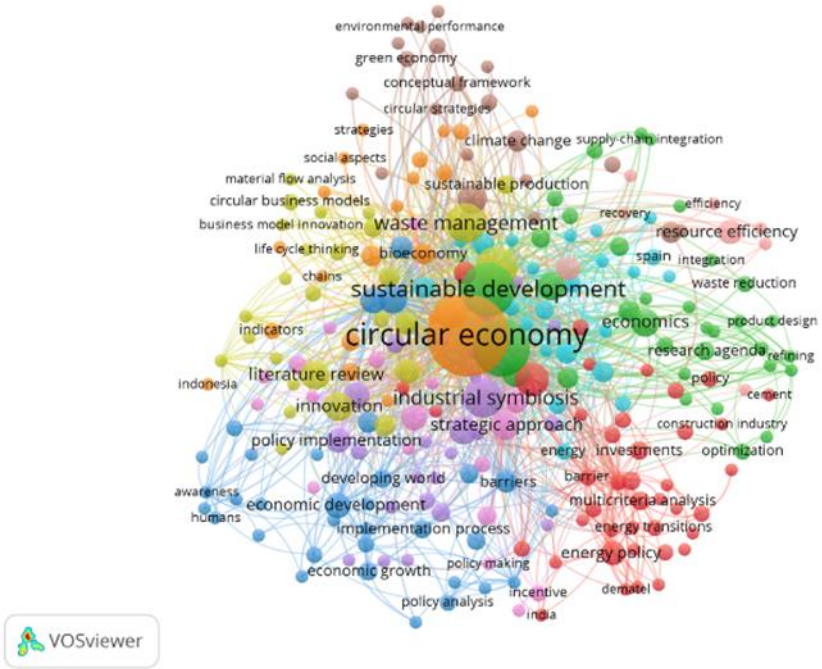

Fig. 1. Bibliometric analysis of the selected keywords.
Source: developed by the author via VosViewer.

Based on the qualitative research methodology, the author identified a range of topics, defined by various EU-level policy planning documents, that have direct or indirect support to IS, depicted in Fig.2.

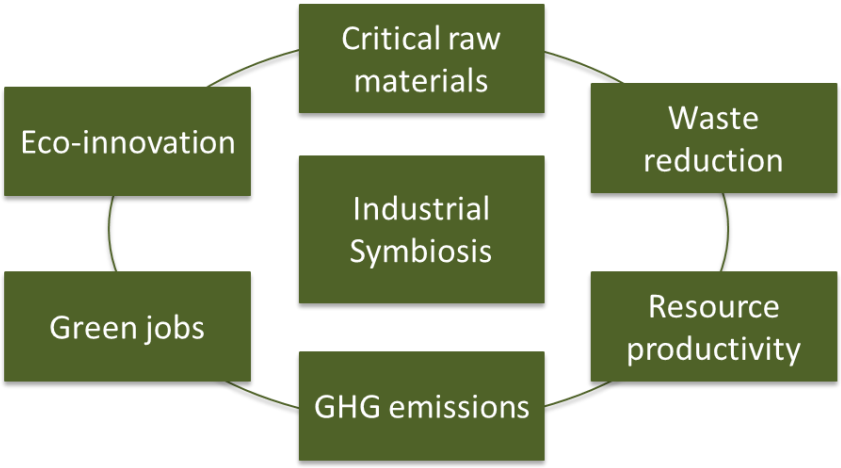

Fig. 2. Topics, fostering IS in the EU-level policy planning documents.
Source: developed by the author, based on [15-19].

III. Results and Discussion

When assessing the grey literature alongside scientific research undertaken up to date, the author has identified a range of regulatory and policy barriers to implementing IS in real economies. Below, the author provides an insight into the most significant obstacles.

A. Regulatory complexity and lack of unification

A 1. Waste and by-product definitions

The legislative framework of the EU frequently faces challenges when differentiating between waste and by-products. Due to concerns about non-compliance, these ambiguities may discourage businesses from implementing IS. Often, it has been emphasised that the regulation of waste leaves little opportunity for product reuse as feedstocks, highlighting how constrictive the categories of waste currently in use are [20].

A 2. Differences in EU Waste Framework Directive (WFD) implementation

Various approaches to implementing EU WFD into national legislation result in a disjointed regulatory landscape. Entities operating on a cross-country level face difficulties due to this inconsistency, which might obstruct the growth of IS networks. The report on the SCALER project (2020) states that "the main barrier concerning the existing legislative framework is a lack of cohesion and alignment between rules and laws at the national level and policies at the regional level" [21].

B. Legislative aspects

B 1. Waste Classification

Strict classifications may significantly limit possibilities for material reuse since some byproducts may be classified as waste and must be managed according to strict guidelines. This aspect substantially reduces the potential for symbiotic interactions, as it discourages industries with the potential to enter the waste management sector. It is identified that legislation focuses on the end of pipe solutions, such as waste treatment and disposal, instead of prioritising prevention and re-use [21, 22].

B 2. Bureaucratic Procedures

Entities may be discouraged from pursuing IS projects due to the complicated process of obtaining the required permits for waste management. Adoption of IS practices may be reluctant if the administrative strain of compliance exceeds the alleged advantages. According to a UK government report from 2023, one of the high-importance barriers to IS is a lack of knowledge about IS and general IS setup and capital costs [23]. In addition, it is essential that, at its core, IS deals with resources diverted from the waste stream. As such, the waste permits can be even redundant and become a significant barrier, for instance, when an entity is dealing with food processing. Still, its involvement in IS would require a specific waste management permit, and the entity would not want its stakeholders to associate it with waste management activities.

B 3. End-of-waste (EOW) criteria issues

Currently, EOW is being applied in the EU only for a limited type of resources:

- iron, steel, and aluminium scrap;
- glass cullet;
- copper scrap.

Although the Joint Research Centre has published a methodology to develop the EOW, the real-time activities are still limited and require much time. JRC has started creating new scientific proposals for end-of-waste criteria for plastics and plans to do the same for textiles. These criteria had to be developed in 2023 but are still unavailable [24]. Without precise and uniform EOWs across the EU, determining when a material ceases to be classified as waste, the whole process becomes challenging unless waste and by-product definitions are tackled. Of course,

implementing EOW for a broader number of resources would be a step towards fostering IS, but currently, this is not the case. Another option is for the EU to continually review the feasibility of subsidies, taxes, grant schemes, carbon prices, etc., and either enhance or constrain them to support IS.

C. Issues with Liability and Compliance

C 1. Legal Uncertainties

Considering the range of responsibilities involved in managing and transferring waste products, entities may be reserved to participate in IS. Entities are hesitant to join symbiotic agreements due to unclear legislation on one hand side and the other. If maintaining current legislation, an entity receiving specific waste/production residues would require a waste management permit, and in case the same company is operating in, i.e., the food processing industry, such a permit would not be well-seen from the client or Stakeholder perspective. Addressing accountability for environmental damage can result in legal conflicts. In addition, uncertainties in the legislative framework pose a serious obstacle to advancing IS [25, 26].

C 2. The Impact of Extended Producer Responsibility (EPR)

In a particular manner, IS activities may also be impacted by the existing EPR regulations. The regulations make manufacturers responsible for the end-of-life handling of their products placed on the market. EPR may add extra duties to manufacturers, which, as a result, could impact their willingness to participate in IS, even though EPR's initial goal is to encourage recycling and waste minimisation [27, 28].

IV. Assessment of IS Benefits

However, to overcome the barriers, it is essential to comprehend the benefits of establishing IS and how they can impact both country, region, and entity levels. IS lacks a standard solid definition, and it varies across economies. Still, in principle, the same message is conveyed. It is a process that promotes cooperation between companies and the efficient use of resources, reduces waste and environmental impact, and is closely related to the improvement of the circular economy in the country. IS is influenced by internal and external factors, as depicted in Fig. 3.

The IS ecosystem depicted is a compilation of the latest trends and developments on how IS interacts both internally within an entity and on the internal level. Three layers are assessed: environmental, economic, business development, and social. First, to implement efficient IS, it is necessary to secure the fulfilment of internal factors or consider them during the IS planning and implementation phase. Secondly, it is vital to consider the External factors; as per the assessment above, a range of these External factors also overlap with barriers to IS, so if not addressed in the initiation phase, the External factors may become quite significant obstacles to successful IS implementation. One more essential layer depicted in Fig.3 is the IS ecosystem – which shows how IS impacts the achievement of the United Nations Sustainable Development Goals (SDGs).

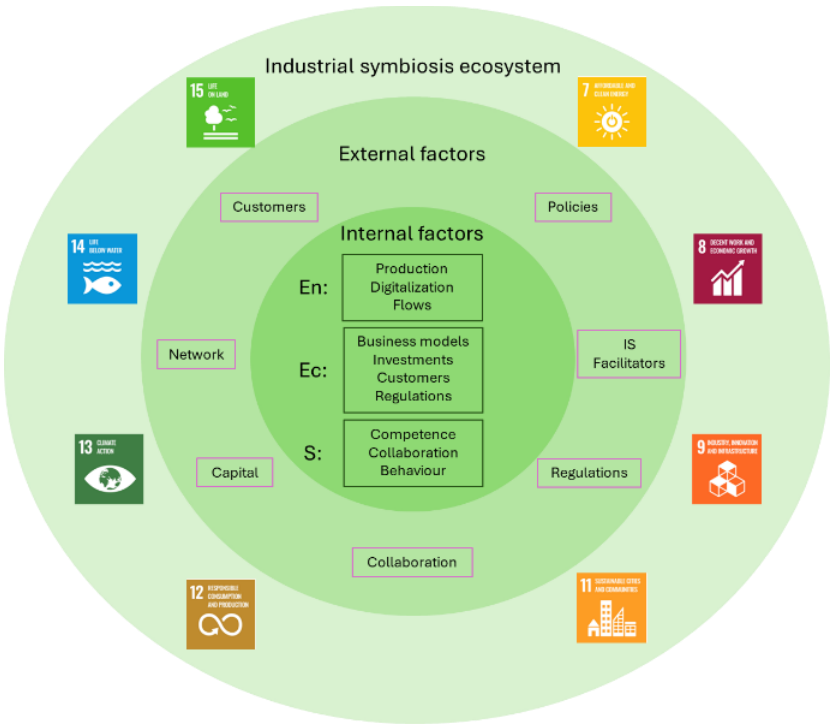

Fig. 3. IS ecosystem.
Source: developed by the author.

IS has a positive impact by promoting resource efficiency, waste reduction, and cross-sectoral collaboration. The main SDGs positively impacted by IS are listed in the Table 1, which is provided below. Considering this impact assessment on the SDGs, IS is an economically beneficial CE business model and a powerful tool for achieving sustainability by promoting resource efficiency, innovation, and cross-sector collaboration. It directly supports policies and strategies such as the Green Deal and contributes to a more sustainable and resource-efficient future.

One of the most critical points in promoting and implementing IS is the sustainability of the system and the benefits it provides.

TABLE 1 POSITIVE IMPACT OF IS ON SDGS

SDG	Positive impact
SDG 7 - Affordable and Clean Energy	IS improves energy efficiency by reusing heat and energy from industrial processes and promotes the integration of renewable energy sources.
SDG 8 - Decent Work and Economic Growth	IS promotes sustainable industrial practices and enables economic growth through resource efficiency and material flow optimisation; it also fosters new business opportunities and green jobs in the CE.
SDG 9 - Industry, Innovation, and Infrastructure	IS supports sustainable industrialisation and innovation through resource-sharing networks and strengthens industrial infrastructure by optimising resource use.
SDG 11 - Sustainable Cities and Communities	IS reduces industrial waste and pollution by promoting cleaner urban environments; it supports CE initiatives that benefit local communities.
SDG 12 – Responsible Consumption and Production	IS reduces waste by transforming by-products and waste materials into new valuable resources; it also encourages entities to adopt sustainable production methods and fosters cross-sectoral cooperation.
SDG 13 – Climate Action	IS reduces greenhouse gas emissions by optimising resource use and reducing energy consumption, and it also promotes low-carbon technologies alongside industrial processes.
SDG 14 – Life Below Water	IS reduces industrial waste and pollution that could contaminate marine ecosystems, thus stopping long-term pollution possibilities.
SDG 15 – Life on Land	IS reduces land degradation and deforestation by reducing the extraction of raw materials and supports sustainable land use practices in the long term.

After extensive literature research, three main areas of benefits were defined: economic, environmental, and social.

A. Economic benefits

A 1. Cost reduction

Sharing resources, thus reducing waste management costs, can significantly reduce the company's operating costs. For example, a company that obtains heat in production can sell it to its neighbour for process heating [29, 30].

A 2. Reduction in raw material imports

Limited resource availability in EU member states (especially regarding critical raw materials) makes the latter dependent on third countries. Eurostat data show that around half of the resources used in the European Union are imported [31]. Trade in raw materials between the EU and the rest of the world has skyrocketed over the past 20 years. Although the volume of raw materials exported is growing faster than that of imported raw materials, the EU still imports more than it exports. 2023, this imbalance resulted in a trade deficit of €29 billion. Between 2013 and 2023, the total EU trade in raw materials grew by 37%, equivalent to an average annual growth of 3.2%. In this period, exports grew faster (3.8%) than imports (2.8%). Recycling materials is one way to mitigate this risk, as it helps to stabilise prices, ensure the availability of raw materials, and reduce import dependency [32].

A 3. Job creation

An apparent increase in the number of people employed in the CE has been observed during the past decades. A steady growth between 2005 and 2021 shows the number of people employed in 2005 was 3,345,348 (1.7% of total EU employment) and in 2021, 4,284,745 (2.1%) [33]. According to a proposal published by the European Parliament for a new circular economy action plan, 700,000 new jobs could be created across the European Union by 2030, and EU GDP growth could increase by 0.5% [34].

B. Environmental benefits

The amount of waste is increasing with the increasing consumption of resources. Many valuable materials are still being disposed of as waste across the globe and also within the EU. However, efforts to recycle waste are starting to pay off, and a generally positive trend can be observed for municipal waste (which represents around 10% of the total waste stream, but simultaneously, due to its non-homogeneous compound, results are the most challenging to manage). Annual municipal waste generation is around 660 million tons; the per capita generation has decreased by 5% (to 530 kilograms per person compared to 560 kilograms in 2000), but is still high compared to other countries in the world and is still higher than in the early 1990s [35]. The introduction of the IS model will also allow for the diversion of certain waste types from landfills. In addition to effective waste management, abandoning the traditional production and consumption flow and

converting waste into new resources will reduce CO2 emissions. By reducing the emission of harmful substances into the environment, IS can improve air, water, and soil quality.

C. Social benefits

With the introduction of the IS model, cooperation between companies, municipalities, and other stakeholders will increase. Neighbouring regions and cities and their residents would benefit from greener ecosystems, reducing the burden on local resources. This would contribute to territorial conservation and waste reduction in surrounding areas.

V. BEST PRACTICE ASSESSMENT

IS involves entities operating in different sectors of activity or industries that engage in mutually beneficial cooperation activities to reuse waste and to use by-products properly, finding innovative ways to source inputs and optimising the value of the residues of their processes [25]. One of the main goals of IS is to avoid waste by identifying valuable resources and diverting them from the waste stream. Best practice from a sample of EU member states with regards to IS fostering is summarised in Table 2:

TABLE 2. ASSESSMENT OF EXAMPLES IS INTEGRATION INTO THE COUNTRY'S ECONOMY

Country	Action description	Method
Denmark	Kalundborg Eco-Industrial Park: A pioneering IS network for decades, where multiple stakeholders exchange materials, energy, and water to boost resource efficiency, cut raw material consumption, and obtain environmental benefits.	Initiative
Finland	Finnish Industrial Symbiosis System: Facilitates resource exchange between companies to promote circular economy practices.	Initiative
France	Regional initiatives are being implemented to encourage industrial collaboration to optimise resource use and reduce waste generation.	Initiatives
Germany	Resource Efficiency Program: Encourages industries to engage in resource-sharing practices to foster sustainability.	Legislation
Italy	A range of policies are in place to support sustainable industrial practices and efficient resource use.	Policies
Netherlands	Integrating IS into CE policies by promoting material and energy exchanges between industries to reduce waste generation.	Policies
Poland	A range of initiatives are based on developing strategies to incorporate IS into industrial sectors, thus aiming to improve resource efficiency and environmental performance.	Strategies
Spain	Regional programs facilitate IS and encourage collaboration in resource optimisation and waste prevention.	Programs
Sweden	Promotion of IS through regional networks that facilitate resource exchange between entities.	Networks
United Kingdom	National Industrial Symbiosis Programme: Facilitates resource exchanges between entities to promote IS.	Program

From the table above, the lack of specific legislation promoting IS is not a primary obstacle to fostering and developing IS projects and cross-sectoral cooperation. However, many countries and their regulatory bodies still consider that to avoid certain illegal activities that IS can unintentionally stimulate, it is vital to have a strict and transparent set of regulations, fostering the implementation of IS. Considering this, the author proposes a first set of recommendations (covering only part of the barriers identified in section III of the paper) for policymakers on supporting IS through regulatory adjustments. The key recommendations are summarised in Table 3 below.

TABLE 3. RECOMMENDATIONS FOR POLICYMAKERS

Policy Barrier	Recommended Action
Waste Classification Rigidity	Broaden EOW criteria to include more materials or revise the by-product criteria.
Fragmented EU Regulations	Harmonise national waste policies with EU directives.
Lengthy Permit Processes	Develop fast-track approval processes for IS projects.
Legal Liability Uncertainty	Establish clear accountability frameworks to protect entities and ensure transparency within IS monitoring and accountability.

VI. CONCLUSIONS

From the author's point of view, one of the most essential CE business models - IS, offers a comprehensive strategy for waste prevention, resource efficiency, and sustainable industrial practices. This research has identified key legislative and policy obstacles that prevent IS from being widely adopted throughout the EU. The obstacles include bulky permitting procedures, complex waste classification, regulatory fragmentation, and a lack of standardised end-of-waste standards for broader resource types. Liability issues and a lack of institutional support make IS deployment more difficult. One more vital aspect to be pointed out is that legislation often focuses on the "end of pipe" solutions like waste treatment and disposal

instead of prioritising waste prevention and different reuse strategies.

Despite the barriers identified, the study also points out several possibilities for policy changes and regulatory innovation that may speed up the adoption of IS and shift to a CE-offered business model.

The study's conclusions highlight that IS is a profitable and win-win business model for all stakeholders and an effective instrument for accomplishing sustainability objectives and supporting resource efficiency, innovation, and environmental preservation. By integrating IS into national and regional policies, EU member states can accelerate the transition toward a more resilient CE.

Future research will focus on exploring empirical case studies and assessment of the economic impact of IS initiatives to strengthen further the case for regulatory reforms supporting industrial symbiosis. Notwithstanding these obstacles, the study identifies significant chances for policy changes and regulatory innovation that can speed up the implementation of IS.

ACKNOWLEDGMENTS

The research is financed by the Recovery and Resilience Facility project "Internal and External Consolidation of the University of Latvia" (No.5.2.1.1.i.0/2/24/I/CFLA/007)., LU-BA-ZG_2024/1-0008.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 157-164

Challenges in Integrating a Virtual Project Office: a Survey of High-tech Enterprises in the Republic of Bulgaria

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***Abstract*—The publication deals with a current problem related to the challenges of integrating a virtual project office into the business activities of high-tech enterprises in the IT industry in the Republic of Bulgaria. Multi-layered emphasis has been placed, which is applied in a practical study, so as to establish the role of technology and the human factors in a digitalizing project environment. The survey emphasizes the opportunities for integrating a virtual project office, by studying a certain number of small and medium-sized high-tech enterprises in order to establish the main challenges. A survey has been conducted and an expert assessment method has been applied, through which empirical data has been generated in the business of small and medium-sized high-tech enterprises in the IT industry. Complex challenges and some management problems have been identified that affect the project activities of the studied enterprises in the integration of a virtual project office.**

***Keywords*—Virtual project office, high-tech enterprises, IT industry, projects in a digital environment**.

I. INTRODUCTION

Today, modern companies operate in a relatively unpredictable business environment when changing the business model from conventional to digital. This has forced a significant number of companies to digitize corporate activities so as to adapt to environmental factors, building strategic partnerships for joint initiatives and projects. In the context of digitization and adaptation of the business model to digital technologies and management systems, companies are faced with challenges in business process management. Automation is increasingly used in various project initiatives, and success will depend not only on the impact of environmental factors, but also on the level to which project activities are digitized. Key importance is given to the virtual project office for project management, since in the context of digitalization, the focus of corporate activities changes.

The integration of a virtual project office is a priority for companies to adapt to the digital transformation of business, implementation of strategic initiatives, work of the human factors in a digital environment, building project relationships with stakeholders, selection of technological infrastructure, achieving key performance indicators and project portfolio management.

This requires taking into account some challenges that play a significant role in designing a virtual project office for project management in the companies' business. With the digitalization of the virtual project office, the project activity is based on a cloud or digital platform that helps the project team work remotely, optimize project processes and share resources in an online environment. This is done through modern IT technologies and software tools for work and cooperation of the human factors in project management in a virtual environment.

With the development of digital technologies and the transition to an online working mode or a hybrid organizational environment, the requirements for the design and successful integration of project activities and processes have also changed. Working in a digital environment is not new for companies that develop international project activities, but this aspect of the organization and management of project initiatives has acquired other dimensions with the emergence and spread of the coronavirus disease.

One of the essential aspects of implementing projects in a digital environment is related to the successful

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8669
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integration of a virtual project office, so as to synchronize the work of people in the project digitalization system and to use appropriate IT technologies and software solutions. In the scientific literature and practice of digitalization of project activity, significant importance is given to the role, functionality and working approach of the virtual project office. The emphasis is placed on two interrelated activities that determine the key indicators in the process of planning and implementing the virtual project office. These challenges are becoming the subject of scientific interest and the search for good practices under the general name of virtual project office integration [1], [2], [3].

The main challenges regarding the purpose of the virtual project office arise from the digital transformation of business and the shift in focus to IT technologies, virtual teams and software tools [4], [5], [6], [7]. Some authors prioritize issues related to vision, mission and goal setting in the digital transformation of project activities [8], [9], [10].

The main focus when defining the vision for designing a virtual project office is the choice of a methodology for working in a digital environment, through the application of modern technological tools for coordinating project activities. The emphasis when defining the mission for designing a virtual project office is achieving digital leadership in coordinating corporate initiatives in terms of strategic priorities and business goals, resources and time for implementing project initiatives. When it comes to goal setting, the virtual project office must implement project goals and priorities with optimal use of resources for coordinating the companies' project initiatives.

Other authors consider the challenges in determining the scope and functionality of the virtual project office [11], [12], [13], [14]. The priority areas are related to business processes in a digital environment and key performance indicators. From the perspective of business processes, the strategic aspects of ensuring effective interaction between business process management, synchronization of cooperation between performers and the effectiveness of results are studied. The main IT business processes and software solutions related to IT technologies in the project office, cloud infrastructure, business process automation, software products used, automated analysis of project data and opportunities for integrating AI are monitored. The business processes for managing project technology in the digitalization of the office are studied, regarding technological activities in project initiatives, technological integration and implementation of project processes, monitoring and optimization of technological infrastructure and technological support systems. Business processes in the project portfolio are a specific tool in the digitalization of the work of the project office and require synchronization with the strategic priorities of the companies in order to achieve the planned goals. The challenges associated with structuring digital project activities in relation to workflows and procedures for performing tasks, key business processes in the project portfolio (portfolio strategy, portfolio resources, portfolio methodology, etc.), portfolio risk, the project portfolio management framework, decision-making for managing portfolio processes, etc. are taken into account.

One of the most important aspects in studying the challenges in the activity of the virtual project office is related to key performance indicators. Authors [15], [16], [17], [18] [19], [20] direct their attention to various areas for determining the effectiveness of the work of the virtual project office and the digitalization of project activity. From the perspective of strategic activities in a virtual project environment, attention is focused on priorities that relate to communication aspects for proper interaction between participants in a digital environment, the role of technological infrastructure and the possibility of adapting modern achievements in digital project activity. The effectiveness of the work of the human factors in the virtual project office is also examined as a key priority for optimal indicators of the digitalization of the project office. The knowledge of team participants about the project initiatives in the office and the trust that is built during teamwork in a project digital environment are important. The effectiveness of the use of information technologies for work in the virtual project office is also a key indicator of effectiveness, therefore various factors are taken into account to establish the degree of their usefulness.

In this regard, the extent to which business processes and tasks are automated is taken into account, to what extent IT technologies reduce company costs, do they help reduce human errors and omissions in work, to what extent is the work in the project office digitized and what is the ratio of digital to physical infrastructure in project activity, how the data necessary for the work of the virtual project office is generated, what is the level of cybersecurity, etc. In the work of the virtual project office, metrics are important that determine the extent to which progress has been achieved in the work of the office members and the effectiveness of the coordination of project activities and processes. Importance is given to the degree of fulfillment of the tasks of the virtual project office, monitoring the effectiveness of progress and achieved results, team commitment, improving administrative and decision-making in the field of IT technologies, studying working time that does not lead to added value, etc.

Naturally, a very important indicator of digital project activity in the office is the return on investment in the human factor and technological infrastructure. The return on investment from designing a virtual project office is determined in accordance with the optimization of project activity and resources used, cost reduction and efficiency increase.

According to authors [21], [22], [23], regulating the effective operation of the virtual project office requires defining challenges in forming the management structure, which is not an easy task in a virtual environment and should not be underestimated. Unlike the traditional (conventional) project office, the hierarchical share of management bodies is reduced, which can be under the auspices of a responsible person (leader), who in a digital environment can synchronize the work of internal and external stakeholders. For a significant number of companies, the challenge is structuring the requirements for the leader's work, his powers and his interaction in a virtual environment.

Some challenges of the virtual project office are related to the participation of stakeholders in the companies' projects, which requires their categorization and involvement in project initiatives. It is necessary to determine the types of stakeholders who, when digitizing business processes, have different initiatives and contribute to the success of project activities. Differentiating stakeholders requires dividing them into internal and external, by distinguishing their position in digital projects. In order for the coordination of the latter to be successful, the processes in the virtual project office are automated according to the direct or indirect participation of the parties, their commitment to the project processes and their investment behavior.

The analysis of stakeholders aims to establish which of them have a significant influence on digital projects and what their interests, goals, values, motives and intentions are. This will help the virtual project office team to actively manage project initiatives and better coordinate their participation in digital projects, developing a plan for communication and sharing feedback on the results.

Authors believe [24], [25], [26] that the challenges associated with the standards for the work of the virtual project office in coordinating digital projects of companies are reduced to standards for good management practices, for the implementation of project goals and objectives, for the work of the human factor, the selection and application of software tools, resource provision and budgeting, risk management, monitoring and reporting of results. Some challenges in managing the project portfolio of companies from the virtual project office are related to the coordination of projects in the digital transformation of business. The trend has become established as a catalyst not only for the accelerated digitalization of business processes, but also the search for effective solutions for projects in a digital environment in terms of resources, time and satisfaction of stakeholders.

The challenges in managing the project portfolio of companies are related to the overall coordination of initiatives in terms of strategic business goals and their achievement. For example, in the digital transformation of the business of companies, projects have different business goals synchronized in a common process, so that digitalization meets the needs of customers, integrates the portfolio of project goals, satisfies the interests of stakeholders, optimizes costs and resources for their achievement.

Since digitalization in the virtual project office has a key role in managing the project portfolio of companies for coordinating projects, a significant challenge is software assurance in the conditions of cloud architectures and digital business technologies [27], [28] Most providers of software services for project portfolio management offer tools such as SPM and APMR with a tendency for compatibility. Thus, the choice of software tools for project portfolio management by the virtual project office is a prerequisite for good coordination of strategic project priorities with possible options for an appropriate software platform. A challenge for the top management of companies is to identify the management problems that limit or hinder the work of the virtual project office.

II. MATERIALS AND METHODS

The main objective of the publication is to identify, from a group of respondents, experts in high-tech enterprises from the IT industry in the Republic of Bulgaria, the challenges of integrating a virtual project office for work in a digital project environment. The respondents are different categories of experts (project managers and coordinators, Scrum masters, software developers, IT specialists, data analysts and cybersecurity specialists), who participate in different roles in the activities of the virtual project office.

The study was conducted on the territory of the city of Sofia, the capital of the Republic of Bulgaria, where a significant number of IT enterprises are concentrated. 32 small and medium-sized companies from the IT sector were studied, and the authors do not claim to national representativeness of the sample, since a certain number of enterprises in the sector were studied. The surveyed enterprises in the IT sector are divided into two groups: 1) hardware and software development manufacturers (manufacturing computers, servers, network devices and IT hardware) and 2) cloud computing providers (offering cloud infrastructure, platform and software services), IT services and consulting (offering IT support, services and business consulting).

The publication presents the results of a preliminary study, which aims to identify one of the aspects related to the challenges facing high-tech enterprises in the IT industry in the Republic of Bulgaria in the integration of a virtual project office. The study was conducted for scientific purposes, which are part of the scientific and research activities of the authors in the field of project management and the adaptation of good practices in Bulgarian business environment conditions. The conducted study shows a certain trend regarding the challenges facing high-tech enterprises in the IT industry

in the Republic of Bulgaria in the integration of a virtual project office and is sufficient in scope to gain an idea of the studied processes.

A study was conducted and an expert assessment method was applied, and a survey was compiled to collect data from respondents at an interval of 49 days during the months of November and December 2024. The survey was sent to 45 small and medium-sized IT enterprises at random and was completed only by experts with different roles in the activities of the virtual project office. The completed and returned surveys were 117, to experts representing 32 small and medium-sized high-tech enterprises from the IT industry, due to the refusal of 13 enterprises to cooperate with the study. The completion of the questionnaire and the provision of information is with the voluntary consent of the respondents, and the requirements for confidentiality and ethics of the study were met, and the information obtained was used only in the form of a sociological sample for the purposes of the publication. The study did not set age restrictions and gender division of the surveyed specialists, but sought a comprehensive answer to the challenges of integrating a virtual project office for work in a digital project environment.

The results were obtained by allowing respondents to give more than one possible answer to each question in order to cover the main aspects related to the challenges of integrating a virtual project office for working in a digital project environment. The survey was conducted by structuring five questions so that respondents could share their perceptions and attitudes regarding the challenges of integrating a virtual project office.

III. Results and Discussion

The results of the study are presented in the following figures. For all questions, respondents have the opportunity to indicate more than one answer.

As can be seen from the figure 1, it is clear that technology and software tools play a crucial role in project management in a virtual environment. Of 117 experts surveyed, 101 of them indicated the answer - "*IT business processes and software solutions*". In turn, this includes the use of various project management platforms, cybersecurity and data protection, etc.

In second and third place, respondents indicated – "*Business processes in the portfolio of digital project activities*" (97 respondents) and "*Business processes for managing virtual project activities*" (74 respondents). This fact is not accidental. The integration of various project activities within the overall portfolio is of utmost importance, which in turn poses challenges for project managers such as synchronizing multiple virtual projects, the need for optimal allocation of resources between different projects, measuring efficiency and results in a digital environment, etc. All this corresponds to the main management aspects of virtual projects - communication and coordination within the team and between distributed teams, monitoring and control of work processes. Widespread flexible project management methodologies - using Agile, Scrum, Kanban, etc. - come to the rescue here.

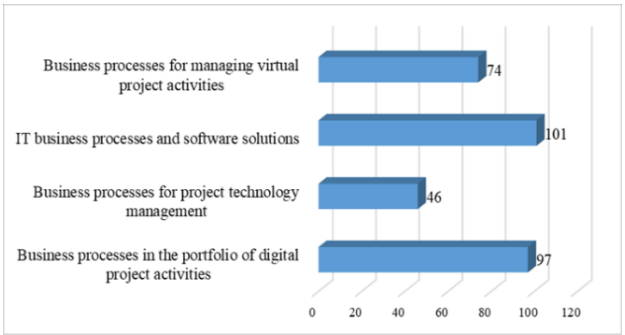

Fig. 1. Answer to the question: „*What do you think are the challenges associated with project activities in a virtual environment*?"

The last fourth place according to the respondents is occupied by the answer "*Business processes for project technology management*" (46 respondents). This means that although technologies are important (especially when we are talking about virtual project meetings, virtual project office), they are considered as part of a larger process / project, and not as a leading factor. In this regard, project managers need to make a choice of appropriate technological tools, tailored to the specifics of the specific project, integrating new technologies into existing business processes, etc.

Other key challenges faced by small and medium-sized high-tech enterprises are those related to key performance indicators in the virtual project office (Fig. 2).

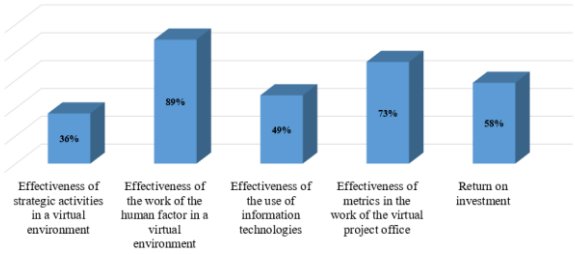

Fig. 2. Answer to the question: *What are the challenges associated with key performance indicators in the virtual project office?*"

As can be seen from Figure 2, according to the surveyed experts, the highest percentage is occupied by the efficiency of the work of the human factors in a virtual environment (89%), which is related to communication barriers, difficulties in coordination, lack of physical presence, lack of commitment. This in turn requires the determination of the correct, key indicators of efficiency in the work of the virtual project office (73%). New approaches are needed to measure the performance of individual project team members, which can lead to management difficulties.

Return on investment ranks third (58%), as virtual projects often require investments in technology, training, and adaptation of human resources to integrated processes and technologies, which do not always pay off in a short time.

In addition to the challenges faced by small and medium-sized high-tech enterprises related to the activities of projects in a virtual environment, the authors are also interested in the good management practices of organizations in this area.

This is shown in the following figure (Fig. 3), which reflects the results of the question "*What are the good management practices in the activities of the virtual project office?*".

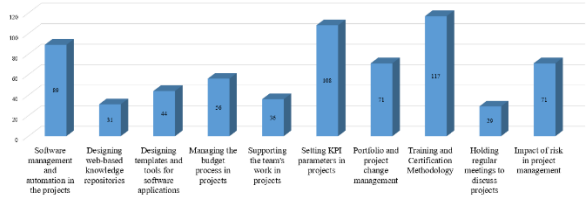

Fig. 3. Answer to the question*: What are the good management practices in the operation of the virtual project office?"*

Good management practices in the operation of the virtual project office focus on training and certification methodology (117 respondents), setting the parameters for measuring efficiency through KPI (108 respondents) and software management and automation in projects (89 respondents). Employee training is a key factor for successful project management and, accordingly, work in a virtual project office. As it became clear, this includes not only the acquisition / possession of technical skills, but also knowledge in the field of agile project management methodologies (Agile, Scrum and PMP (Project Management Professional) certifications).

Along with having this knowledge, another good management practice is to clearly define KPI parameters for monitoring and evaluating the performance of the project team. One way to improve the efficiency of the virtual project office is software management and automation. The organizations studied indicate this management practice, which occupies third place. It is through automation that productivity is increased and errors are reduced, facilitating the work of project teams. However, all this, in turn, requires good integration with existing systems and teams.

In fourth position are two of the possible answers, namely: "*Portfolio and project change management*" and "*Impact of risk in project management*" – 71 respondents. They represent significant management practices for the surveyed organizations. In order to be competitive, especially operating in a dynamic environment, in the era of technology, high-tech enterprises must proactively identify and manage risks to minimize losses, proper / flexible project management and adaptation to changes are critical for the success of the virtual office.

The last two positions of this question are occupied by the answers "*Holding regular meetings to discuss projects*" (29 respondents) and "*Designing web-based knowledge repositories*" (31 respondents). Regular meetings are useful because they provide transparency and efficiency, but they should be planned with such a frequency that they do not reduce productivity (if they are held too often). Regarding web repositories - they are a useful tool in managing a virtual project office, but nevertheless they are in one of the last places of the good management practices listed. This arises from the fact that they require maintenance, security and up-to-date content, although they allow easy access to information.

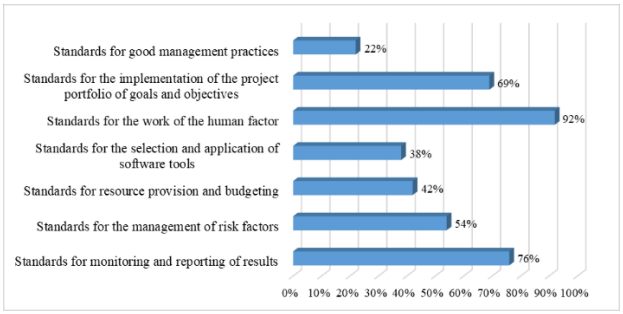

Fig. 4. Answer to the question: „*What are the challenges in setting standards for the operation of the virtual project office?*".

The results, visible in Figure 4, confirm that managing people in a virtual environment is the biggest challenge. 92% of respondents indicated the answer "*Human Factors Work Standards*". In addition to the difficulties in communication and synchronization of tasks, which also stood out in other questions, the lack of motivation and commitment in remote work, cultural differences and work habits of team members and between individual project teams, are some of the possible reasons for this.

This somewhat leads to other consequences, namely tracking work and efficiency in a virtual environment, which is complex and makes it difficult for organizations to define clear KPIs, measure productivity and evaluate results. 76% of respondents indicated the answer "*Standards for monitoring and reporting results"*.

The high percentage of the answer "*Standards for the implementation of the project portfolio of goals and objectives*" (69%) indicates that the implementation of standards for managing multiple projects is difficult in a virtual environment and, if there is no clear strategy and control tools, can lead to inconsistencies and low efficiency.

The lowest percentage of this question is the answer "*Standards for good management practices*" (22%), indicating that organizations largely have established management practices, however, they encounter

difficulties and problems with their implementation in specific situations.

The integration of a virtual project office in high-tech enterprises is accompanied by a number of management challenges that require careful planning and adaptation to the dynamic environment they operate in. Although virtual offices offer significant advantages – flexibility, easy access to various resources, cost reduction, their implementation often encounters a number of difficulties and problems.

Virtual project offices require well-defined processes that ensure task traceability and transparency, a well-established technological infrastructure, and protection of sensitive information, which is becoming increasingly complex, especially between several project teams.

In the survey, respondents were able to identify key management issues that hinder the integration of a virtual project office. In Table 1, these issues are examined separately for the two groups of high-tech enterprises. The authors' goal is to investigate whether there is a difference, and if so, what it is. To see which of the issues are perceived as critical for the organizations surveyed.

TABLE 1 MANAGEMENT ISSUES HINDERING THE INTEGRATION OF A VIRTUAL PROJECT OFFICE

Management issues hindering the integration of a virtual project office	**Researched enterprise groups**	
	Hardware and software development manufacturers (manufacturing of computers, servers, network devices and IT hardware)	**Cloud computing providers, IT services and consulting, IT support, services and business consulting**
Lack of appropriate methodology for working in a digital environment	68%	53%
Lack of resource provision for working in a digital environment	51%	81%
Lack of rational distribution of roles and tasks of the human factor	70%	65%
Lack of appropriate tools for coordinating projects in a digital environment	28%	76%
Lack of digital organizational culture	89%	38%
Inappropriate business model for digital transformation	45%	24%

For hardware and software manufacturers, the most serious problem, according to respondents, is the lack of a digital organizational culture (89%). Despite the availability of technologies and resources, there is still a lack of so-called digital thinking and a culture of teamwork in a virtual environment. One of the tools for dealing with such a problem is conducting more training on the digital transformation, which is already a fact in all spheres of activity, creating new communication strategies, stimulating proactivity for working in a digital environment, etc.

In the second group of surveyed high-tech enterprises, this problem is significantly less pronounced (38%). This fact is not accidental, since these companies have more experience working in a digital environment and their employees are more adapted to virtual working conditions. However, they still perceive this as a challenge, since the digital transformation is not yet fully completed. These organizations must continue to work in this direction by upgrading their digital culture, through training in managing virtual teams, digital leadership, etc.

For hardware and software development manufacturers, the second and third place among the management problems hindering the integration of a virtual project office are "Lack of rational distribution of roles and tasks of the human factor" (70%) and "*Lack of appropriate methodology for working in a digital environment*" (68%), respectively.

For cloud computing, IT services and consulting providers, these places are occupied, respectively, by *"Lack of appropriate tools for coordinating projects in a digital environment*" (76%) and "*Lack of rational distribution of roles and tasks of the human factor*" (65%).

In the second and third places mentioned above, one of the problems of both groups of enterprises is approaching, namely "*Lack of rational distribution of roles and tasks of the human factor*". Providers of cloud computing, IT services and consultations often work in so-called cross-functional teams that require daily coordination. Poor distribution of roles and tasks of the human factors in both groups of high-tech enterprises can lead to failure to complete the project on time, inefficiency, gaps in work, lack of commitment. One way to deal with such problems is to implement various digital tools for managing teams in a virtual environment, use platforms for distributing and managing tasks, etc.

The last places of management problems for both groups of enterprises are occupied by “Lack of appropriate tools for coordinating projects in a digital environment” (28%) for manufacturers of hardware and software developments and “Inappropriate business model for digital transformation” (24%) for providers of cloud computing, IT services and consulting, IT support, services and business consulting.

The low percentage (28%) of the lack of appropriate tools for coordinating projects in a digital environment shows that enterprises have a certain base of technological

solutions and tools, but still require optimization and integration of different platforms for joint work.

Similarly, for cloud computing, IT services and consulting providers, the least pronounced problem is "Inappropriate business model for digital transformation" (24%). They, like other enterprises, must also continue to develop innovative services that optimize the business models used so far for digital transformation.

The successful integration of a virtual project office depends not only on technology, but also on effective leadership, clear communication and building trust among team members.

IV. Conclusions

The digital transformation of business activity has imposed a new model for managing project activity. In addition to the role of the human factor in an environment of digitalization of project activity in the virtual office, it has an impact on the business of companies whose orientation is focused not only on internal business processes. The integration of a virtual project office creates conditions for the formation of potential strategic partnerships, both with external and internal stakeholders. It is necessary to create appropriate conditions for rethinking the organizational culture in a virtual project environment, primarily by changing the internal business orientation of the project office towards strategic coordination of projects in a virtual environment, i.e. to take into account the horizontal aspect of external integration.

The integration of a virtual project office creates conditions to improve the project process by engaging contractors and subcontractors in their involvement in decision-making, regardless of geographical location.

A virtual project office is a useful tool for working on projects in a virtual environment, as it sets the standards for managing project initiatives and improves communication between stakeholders. It reduces redundant processes and reduces management costs, shortens bureaucratic procedures, creating the necessary prerequisites to coordinate large and complex projects. Despite the flexible structure and the benefits of creating a virtual project office for project management, some challenges arise for companies that senior management should consider when integrating it into a virtual environment.

As a result of the publication, the following main contributions have been achieved:

- Based on a study of the scientific literature on the problem, some challenges and specific characteristics in integrating a virtual project office have been identified.
- The study identified the main challenges of a certain sample of respondents (small and medium-sized high-tech IT enterprises in the Republic of Bulgaria) regarding the integration of a virtual project office in business activities and in particular when implementing projects in a digital environment. In summary, it can be said that the surveyed companies perceive different types of challenges, which cover specific categories in the field of human factors, technologies and specific project activities.
- The study conducted to identify the main challenges of a certain sample of respondents (small and medium-sized high-tech IT enterprises in the Republic of Bulgaria) regarding the integration of a virtual project office is a prerequisite for generating information about the main problems and good practices in the digitalization of project activities. The generated data can be used to compare trends in future research in the relevant field and to establish the development of processes in digital business transformation and the level of progress achieved in the field of integrating a virtual project office into the business of high-tech enterprises from the IT sector in the Republic of Bulgaria.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 165-169

Research on the Factors that Influence on Sustainable Consumer Behavior

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Abstract- **In the modern economic conditions of digitalization and the use of artificial intelligence, consumers do not buy the product, but the expected benefit of this product in the consumption process, or the properties that the product possesses, created in the production process and realized in the consumption process. In the process of making a purchase decision, consumer behavior is influenced by many factors that are inherently factors from the surrounding environment, and others are factors that are the result of the internal attitude of consumers. In order to build and implement a successful marketing strategy, marketing managers should reflect the influence of factors that differ in their characteristics and strength of influence, when the goal is to achieve sustainable consumer behavior of the consumers themselves. By its very nature, the study of the factors themselves represents a special kind of challenge, requiring depth and multi-facetedness from a scientific perspective. The ability to study these factors is a sure indicator for the preparation of a successful strategic marketing strategy that satisfies all stakeholders.**

Keywords— competitive advantages, consumer behavior, marketing strategy, sustainability factors

I. INTRODUCTION

Sustainable consumer behavior, especially by individual consumers, is of fundamental and urgent importance for effectively improving the ecological quality of the earth and the living environment for future generations. It is essential to identify the factors that influence people's intentions to engage in sustainable consumption behavior.

Consumers make a number of choices every day, which are essentially the result of numerous preferences, tastes, desires and motives, which are predetermined by the individual characteristics of each individual.

Very often, this choice actually aims to satisfy the needs of consumers, but it depends on limited financial resources and in reality, the satisfaction of their expectations is carried out through the prism of quantity, quality, price and other characteristics of the product offered. A large part of consumer purchases are made rationally and emotionally, which also predetermines the inclusion of different types of factors in the final choice.

The aim of the article is to present the main factors that influence sustainable consumer behavior.

Consumers themselves do not buy the product, but the expected benefit of this product in the consumption process, or the properties that the product possesses, created in the production process and realized in the consumption process.

II. MATERIALS AND METHODS

In the process of making a purchase decision, consumer behavior is influenced by numerous factors that are inherently environmental factors, while others are factors that are the result of the internal attitude of consumers.

There are a number of classifications of factors in the specialized literature, and we will focus our attention on some of the classifications, because our main goal is to subsequently highlight the factors that influence specific sustainable consumer behavior.

Although consumers often intend to shop more sustainably, making a decision to shop for food is complex and involves a decision-making process that is shaped by factors that arise outside the moment of purchase.

Consumers are increasingly turning to information that aims to influence decision-making, but the

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8629
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mechanisms for changing such interventions are poorly understood.

The different views and concepts of sustainability and sustainable development have gained great importance in academic research, with the emphasis on problems related to the environment, its management policies, industrial production and agriculture. [12]

There is a connection between innovation, sustainability and environmental protection that managers must stimulate in order to ensure a comprehensive change in consumer behavior, which in turn will guarantee the achievement of sustainability. It is important to explain to consumers what standardized green rules are and to create a culture of nature protection, which will essentially be an extension of sustainable consumption. This will lead to lasting changes in consumer behavior.

It is clear to all consumers that the implementation of green rules is intended to be environmentally and sustainably oriented [16].

However, there are also consumers who consciously choose not to be sustainability oriented, even when shopping online [15].

The origin of the term sustainable consumption is usually traced to the Rio Summit in 1992, and since then it has become an increasingly important policy element in national sustainable development strategies. There is currently little consensus on the definition of sustainable consumption and it is widely acknowledged to be a contested concept [3] that encompasses "competing discourses" [5].

While some researchers have proposed definitions, others have drawn attention to the inherent difficulties in constructing such a definition. A number of definitions of sustainable consumption reflect the main definitions of sustainable development.

More simply, Dahl (2009) argues that sustainable consumption refers to the need to stay within the global sustainability of products [2].

At the same time, sustainable consumption has uncertain boundaries and it is not clear what the consequences of this type of consumption are.

Dolan (2002) argues that existing definitions of sustainable consumption are prescriptive, as they do not describe what consumption is, but what it should be, and Schaefer and Crane (2005) call for a revision of existing conceptualizations of sustainable consumption to include the social and cultural functions that consumption performs.[4]

Jackson [7] summarises different definitions, but notes that he takes different positions not only on the sufficiency of sustainable consumption and changes in consumer behaviour and lifestyles, but also from another perspective, namely more responsible and more efficient consumption.

Jackson further argues that sustainable consumption is dominant and should be achieved primarily by improving the efficiency with which resources are converted into economic goods. More generally, a distinction can be made between "weak sustainable consumption" and "strong sustainable consumption".

III. RESULTS AND DISCUSSION

Weak sustainable consumption represents "the choice of products and services that are either less resource-intensive, or less environmentally damaging, or less destructive to the people who actually produce them", while strong consumer behaviour involves "increases in consumption efficiency (often through more efficient production models or efficiency-friendly design) and fundamental changes in consumption patterns and reductions in consumption levels in industrialised countries.

The transformation towards sustainable food consumption will require the engagement of a wide range of actors along the food supply chain. However, changing consumer demand for food remains instrumental in achieving food system transformation, thereby underscoring that consumption patterns need to become more sustainable. It is well established that behaviour is the result of a dual decision-making process; which combines 'fast thinking', which is automatic, rapid and unconscious, and 'slow thinking', which is conscious, reflective and deliberate [1] [9]

Consumers do not necessarily have the intention to change their shopping behaviour towards more sustainable consumption. For example, research shows that over two-thirds of people want to buy food with a low climate impact; however, a much smaller number of consumers actually buy such products [13]

In reality, realizing a transformation towards sustainable consumption will rely on expecting consumers to make the right choices, by choosing the more sustainable option when available, and on implementing a range of actions by retailers and marketers to make this happen.

Efforts to influence consumer behavior have been developed to raise consumer awareness through information and education [10][19]. Information and education are most effective when combined with other strategies [19][8], for example, where nudges, marketing, and information embedded in smartphone apps are combined together and shared with consumers.

As with all actions to address climate change, there is unfortunately a gap between sustainable food shopping behavior at the individual level and the impact of that behavior. Positive impacts are often so far in the future and geographically unrelated to where consumption occurs that they may not even be felt within the consumer's lifetime.

In order to develop interventions that can induce long-term behavioral change towards more environmentally sustainable consumption patterns, an understanding of the mechanisms involved in the

behavior and what factors influence these mechanisms, both over time and space, is needed [18] and further research is needed to examine the relationship between current behavior, future intentions, and the underlying psychological factors of such behavior [18]

In general, we assume that sustainable consumption is an operational measure to measure how well major food retailers offer sustainable consumption in their stores. The dynamics of green consumer change are always multifaceted and different, and in reality, there is an increase in the consumption of more and more environmentally friendly products.[17]

It is an indisputable fact that consumers who consume more environmentally friendly products are younger, better educated, and more informed than other consumers.

Not only in the retail sector, but also in many other companies, the correct attraction of sustainable consumers undoubtedly has a significant impact on KPIs /Key Performance Indicators/ or key performance indicators.

In practice, each business defines its own individual set of KPIs, and then regularly measures them after a certain period of time in order to track the achievement of specific goals. In reality, these goals can be related to consumer sales, service, products.

In accordance with the purpose of the study and the defined tasks, we will highlight and identify the key factors that influence consumers' ability, opportunities and motivation to make more environmentally sustainable choices when shopping for food and the role and importance of the information available to consumers in making this choice.

The **COM-B (Capability, Opportunity, Motivation)** model will be used to determine how the ability, opportunity and motivation to participate in sustainable shopping are influenced and how consumers use information when shopping for food. The key factors motivating choice were found to be quality, health, locally produced food, animal welfare and convenience. The main constraints to consumers' ability and opportunity to engage in sustainable grocery shopping are price and time.

In fact, information can be a powerful technique for changing behavior if it is fully tailored to the individual stages of consumers' shopping journey, including planning, execution and reflection of their shopping actions.[14]

At the heart of changing sustainable consumer behavior for fast-moving food products is information and access to it.

The overall view of the study is subordinated to the information that consumers have, and three guiding questions are included, namely:

- Ability: Are consumers aware of the connection between their food shopping behavior and the impact on the environment?
- Opportunity: Do consumers have the opportunity to engage in sustainable behavior?
- Motivation: Are consumers motivated to engage in sustainable behavior?

The survey includes questions that will be linked to the main components of the COM – B model - ability, opportunity and motivation to engage in this behavior. Ability is defined as the physical and psychological capacity of an individual to engage in the relevant activity and can be, for example, knowledge and skills. Opportunity includes all factors that are external to the individual that make the behavior possible or encourage it, such as physical access and social norms. Motivation is understood as a thought process that energizes and directs behavior, not only goals and conscious decision-making, but also beliefs about consequences, values and emotions. [11]

TABLE 1 IDENTIFIED KEY CATEGORIES AND FACTORS IMPORTANT FOR CONSUMER DECISION-MAKING

Group of factors	Examples of factors in the group
Socio-demographic and physiological factors	age, level of education, gender, household composition
Socio-psychological factors	attitudes and beliefs, awareness, behavioral control, health concern and environment, brand sensitivity, expectations, experience, habits
Context of eating and buying	acceptance and support from loved ones, accessibility and type of retail outlet, choice of type of retail outlet, discounts and offers
Characteristics of sustainable food	brand, certificates, convenience, country of origin, credibility, ingredients
Social factors	infrastructure, region or country
Information and communication	advertising and marketing, education, food and nutrition information, media
Geographic and spatial factors	infrastructure, region or country
Institutional, political, economic factors	diet compliance, food shortages, food policies of individual companies, management of food production

Adapted from: Hoek, A.C., Malekpour, S., Raven, R., Court, E., Byrne, E. (2021) Towards environmentally sustainable food systems: decision-making factors in sustainable food production and consumption. Sust.Prod.Consum. 26 (April), 610-626 [6]

The survey participants strongly agree that /ordered by importance and percentage of the most respondents/:

- People's well-being depends on the state of the environment;
- Companies must necessarily implement sustainable practices;
- Online consumers should be informed about the extent to which the online store uses sustainable practices;

- Online stores should provide certificates of sustainability of food products;
- I will become a more sustainable consumer in the future;
- Sustainable consumer behavior is influenced by the company's brand;
- The inclusion of sustainable products increases consumer loyalty to the brand.

In fact, respondents are of the opinion that not all online retailers should offer alternative sustainable food products, that is, they are not obliged to do so, and they do not agree categorically that consumer satisfaction increases as a result of the company's increasing sustainable practices.

Regarding the COM-B model, respondents approve first of all the opportunity, namely having the opportunity to exhibit sustainable behavior, which raises doubts regarding the fact that they may have the desire but not the ability to realize this sustainable consumer behavior. Second, 56.3% of respondents believe that they should have the ability, and lastly, the motivation, that is, consumers first look for the opportunity, then look for the connection between their food shopping behavior and the impact on the environment, and finally assess how motivated they are to perform sustainable behavior.

334 respondents participated in the online survey, which varied in terms of age, gender, monthly income, number of household members, and education.

The results show that 73.1% of the respondents are women, and the remaining 26.9% are men, which clearly shows that the problems related to sustainable consumer behavior of fast-moving food products in retail are mainly of concern to women.

Regarding the hypothesis that states: "Sustainable consumer behavior of food products in retail in Bulgaria depends on a number of factors", the following conclusions were made. First, based on the results, we find that there is no difference in sustainable consumer behavior between the two genders. Second, the amount of income does not matter.

According to the data from the sample - sustainable behavior does not depend on various factors and tends to be the same in the groups considered - gender, age, level of education, income.

IV.CONCLUSIONS

The influence of factors on sustainable consumer behavior is of key importance in the preparation of the strategic marketing strategy in the retail sector and in the sale of fast-moving products. The specificity and dynamics of these factors must be constantly monitored and innovations must be updated and introduced to respond to changes in consumer behavior.

The main conclusions that can be drawn and have theoretical and practical application are the following:

- The factors themselves are very diverse and difficult to study and apply.
- There is a connection between innovation, sustainability and environmental protection that managers must stimulate in order to ensure a comprehensive change in consumer behavior, which in turn will guarantee the achievement of sustainability. It is important to explain to consumers what the standardized green rules are and to create a culture of nature protection, which in its essence will be a continuation of sustainable consumption. This will bring about lasting changes in consumer behavior.
- Consumer behavior itself changes extremely dynamically and for this reason its relationship with the factors that modify it must be constantly studied and reflected.

Timely study of these factors and their influence on consumer behavior will contribute to the creation and implementation of an appropriate sustainable marketing strategy.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 171-177

Building a System for Monitoring and Controlling Pollution of Water Bodies

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***Abstract*— Unregulated waste disposal is becoming increasingly widespread throughout our planet. Waste of various types is being dumped - plastic, glass, nylon, construction waste and others, which decompose very slowly and cause irreversible pollution and changes in the environment. These illegal dumps are particularly dangerous when they are located near water bodies or in the catchment area of drinking sources that supply settlements. The fight against these illegal dumps is still not at the required level and decisive measures are needed to limit them. The report presents a principle scheme for building a system for controlling the catchment areas of large sources of drinking water, which can be implemented very easily and quickly. This will help reduce environmental pollution near water bodies, groundwater and catchment areas of drinking sources. As a consequence, the risk of floods, landslides and other phenomena resulting from the impact of this waste will be reduced.**

Keywords*— *groundwater, monitoring, pollution, system, unregulated landfill, waste, water body.

I. Introduction

In recent decades, there has been an increase in the use of various types of plastic and plastic packaging, which have replaced the usual paper, glass or cloth packaging that was used until 50-60 years ago. Along with increased consumption, environmental pollution with this type of product has also increased. Numerous unregulated landfills have appeared around settlements and even in water bodies in the continental part of the planet. For these reasons, environmental protection and preserving ecological balance have been a hot topic for the last 40-50 years [1].

And while degradable waste does not pose such a danger, non-degradable waste causes serious consequences for the plant and animal world. This is due to the fact that in natural conditions they cannot decompose or the decomposition process takes thousands and tens of thousands of years. Plastic and plastic waste are some of the most dangerous non-degradable waste that humanity generates [2], [3]. Satellite images are available showing that in the Pacific Ocean there are several islands of plastic and other waste with a total area larger than the area of an average European country, for example. In the ocean waters, many developed economic countries dump part of their waste, and it is also a graveyard for space debris, which is obtained from the re-watering of decommissioned artificial space satellites. It cannot be mentioned with alarm that the amount of used and unrecycled plastic is increasing every year, and at a significant rate [4]. Many developed countries have exported their production facilities to underdeveloped countries, where the requirements for collecting plastic and nylon products that have gone out of circulation are significantly lower or absent altogether.

Despite the restrictions introduced on the use of plastic packaging, they are still extremely widely used. The pollution of the earth's surface with non-degradable waste is increasing every year and, for example, in Bulgaria this is visible everywhere around us – in settlements, in mountains and forests, along roads and railways and especially along streams and rivers. There is a lack of elementary culture in the disposal of waste and traveling around Bulgaria by car, bus, rail or even on foot we come across large amounts of waste, including plastic [5], [6], [7]. Almost every settlement has unregulated landfills and places littered with construction, plastic, household and other waste. Manufacturers of plastic products are obliged to buy back used plastic or nylon products, but almost nothing is done for their recycling and reuse.

II. Materials and Methods

The purpose of the development is to continue the author's research from previous publications and to build a model of a system for controlling water bodies and the territories around them to monitor these objects for the presence of pollution with non-degradable waste [5], [8], [9]. In this way, it will help to limit environmental pollution

Online ISSN 2256-070X
https://dx.doi.org/10.17770/etr2025volX. 8693
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with this type of waste and illegal dumps will be discovered in a timely manner even in hard-to-reach areas in rugged and forested areas where there are flowing water masses [7], [8]. According to observations of specialists and the population, the greatest pollution is in water bodies, regardless of whether it is the world ocean or continental waters.

As mentioned in previous reports, the project is conditionally divided into two parts, initially paying attention to waste in water bodies on the continental part of the Earth, and in the second part, the main attention is paid to pollution of the world ocean. In both parts there are many places polluted by man, but each has its own specificity for monitoring, mapping and taking measures to reduce existing waste. Each pollution can also have its own specifics for its tracking and subsequent removal [1], [9]. Transboundary pollution is especially dangerous, where the polluter cannot always be identified, but the consequences of this can be determined. There are industrial enterprises that dump their waste on weekends or at night, when the controlling authorities are not working, and therefore one of the directions for limiting pollution is the use of sensors and cameras that operate continuously and can be traced back in time when, who and how caused the pollution of water bodies and the coast or dumped hazardous waste in an unregulated manner [10], [11].

Fig. 1. Waste along the Iskar River, 02.2021

The background of this development begins with a major pollution incident 6 years ago on the Iskar River in the Iskar Gorge, near the town of Svoge. As it was later found, there are a number of other such pollution incidents that sometimes become known, but are more often hidden from the general public. For more than a week, activities were carried out to clean the water surface next to the wall of the Prokopanik Hydroelectric Power Plant in the Iskar River from the accumulated miscellaneous waste, the area of which was more than 12 acres. Additional equipment was provided at the expense of taxpayers to prevent interruption of the process while trucks transported the removed garbage to the Kostinbrod regional landfill near Sofia. The main goal is to prevent part of the garbage from passing through the facilities of the Hydroelectric Power Plant, so as not to pollute the riverbed towards Svoge and further north. The heavy rains and the torrential downpours that followed on January 11 and 12, 2019, collected all the discarded waste from the ravines of the Sofia Field. The garbage is mainly the result of unconscious human activity, but there are also those that are the result of conscious and deliberate work. Work needs to be done in several directions, first of all, changing consciousness, along with the control and sanctions system, and no less important factor is the prevention policy. In the presence of facilities such as hydroelectric power plants, there should be barrier filters for collecting waste before them, along the river.

It was this pollution that sparked the interest in creating systems for monitoring pollution in or around water bodies and limiting environmental pollution. To create these systems, initial information collection was used, mainly for Bulgaria, but information from other countries was also analyzed. The first pilot projects in the municipalities of Sofia, Burgas and Yambol were also studied, where pollution control systems using drones and other unmanned aerial vehicles are being tested [2], [9], [12], [13]. This information was systematized and analyzed, and based on the results obtained, the main tasks that need to be solved when building the systems were identified. Various methods for environmental monitoring were discussed and a mixed control system is proposed using autonomous vessels and autonomous aerial vehicles to achieve optimal monitoring of water areas and adjacent territories to obtain a complete picture of the surface. It is striking that preventive and comprehensive measures with subsequent control are not taken, but decisions are made piecemeal and instead of improving the situation, the situation is getting worse. Uncleaned riverbeds and the presence of a lot of non-degradable waste in and around them leads to silting of the water body bed, the formation of artificial dams and floods when the water level in the water bodies rises [3], [14]. Over the last 4-5 years, there have been numerous floods in Bulgaria and around the world, the causes being uncleaned water catchment areas and the presence of plastic and nylon waste, which are lighter than water and float on the surface, contributing to the formation of barriers in the path of water flows [1], [15], [16].

Fig. 2. Riverbed pollution

After the waters recede after heavy rains, snowmelt or spring floods, in normal conditions, heaps of waste, especially plastic and nylon, remain on the banks of water bodies and the vegetation around them. An unpleasant sight is the riverbeds in the summer, when after the flowing of the violent spring waters and the increased level of the rivers, they return to their normal beds and we see "flags" of polyethylene bags, foil and other items left on the branches of trees on the banks on the surrounding vegetation. Very often, you can even notice "landed" plastic bottles, tubes and even more voluminous objects, which cause an unpleasant sight. And the initiatives to clean the riverbeds in April and September cannot compensate for the pollution during the rest of the year [3],

[17]. Reporting the activity with photos of the cleaned waste instead of with actually collected waste, which is in abundance, is very negative. Similar initiatives are organized annually in different parts of Bulgaria, but the media hype does not yield results, and real daily activities are needed - a little, but without interruption. and in other areas throughout the year. But we cannot clean up everything that we have polluted the other 364 days of the year in 1 day. It would be much better if we did not pollute 365 days a year, then there would be nothing to clean in this 1 day to clean the river, lake or dam and a person would feel pleasant in nature [2], [18].

If you go along the banks of many streams and rivers, you will see that there are many unregulated dumps in the riverbeds and thousands of waste channels connected to the river networks. As a result of the "cleaning" of the riverbeds, long-standing trees are cut down and bushes are obtained instead of them, and thus the condition of the riverbeds worsens. As a result, instead of improving the permeability of the waterbed after 2-3 years, it is significantly overgrown with shrubby vegetation and when the river level rises, the flow of water masses is hindered. At the same time, numerous plastic bags and other waste that people have illegally thrown away near the river are retained on the branches of this low and medium vegetation. In recent years, we have witnessed many such pollutions, some of which are shown in Figures 1 and 2.

The goal of the project, which was generated at the first stage in the gatherings of the "Curious" club at the National Military University "Vasil Levski", is to make a prototype of a floating device that can move autonomously along the riverbed and photograph and study the terrain of the riverbed and the surrounding area for the presence of waste and channels that flow into the river. At a later stage, the idea of using drones or other autonomous unmanned aerial vehicles to photograph water areas and the territories around them from the air was born. In this way, these devices will complement each other and it will be difficult to leave a place unphotographed that the filming equipment does not have access to. The devices will record and transmit information to a central point. The information will be collected and a characterization of the riverbeds along the entire length of the river and its adjacent tributaries will be made, based on the information collected, maps of the rivers, landfills and waste pipes will be made. This is extremely important given the current levels of dams in Bulgaria, which are filled below the sanitary 67% of their volume and provide quality drinking water to the population. This information will be very valuable, because the state authorities do not know or do not care about such landfills and there are many waste channels built and discharged that are not regulated, legal and do not have elementary treatment facilities [5], [9], [19]. The devices will be small in size, which will allow them to pass through small streams, and an all-terrain vehicle function may also be offered, so that it can pass through fords even when the water level drops.

Where access to vessels is limited, information will be collected from the air using drones. There will also be navigation for management and tracking of the location for detection if necessary and the ability to autonomously return to the starting point in the absence of a communication network. At the same time, the watercraft or air devices will store and transmit information about the condition of the areas they have inspected. After completing their mission, an operator will download the collected information from memory and it will be processed by a team. It is planned that the autonomous vehicles will have a module for online transmission of information. In this way, the operator can, if necessary, use the autonomous device to conduct a more detailed examination of a specific terrain and locate available non-degradable waste and its origin. In this way, a detailed analysis of the location and type of waste can be achieved, and measures can be identified for their removal or limiting disposal. If necessary, a prolonged inspection of the terrain can be carried out with a view to identifying the violators and their administrative punishment [6], [20].

Fig. 3. Collection of plastic waste in the Varna Bay [2]

III. Results and discussion

In many countries around the world, restrictions and bans have been introduced in some industries on the use of plastic and plastic containers, bottles, tubes and other products. There is a legislative order in place in which countries must comply with the requirements and stop the production of plastic and nylon items described in the regulations. In some countries such as Austria, the Czech Republic, Greece, Germany, France and others, the use of plastic products has already been significantly limited, but in countries such as Bulgaria, these measures have lagged behind and practically nothing is being taken or is being taken to a very limited extent. Usually, the last moment is waited for the bans to come into effect and reasons are found to extend the period of entry into force of the specific regulatory act. Going this way, things will not happen, strict measures and appropriate penalties are needed for non-compliance. The next measure that will be proposed is to install nets on all drainpipes in water bodies to collect large waste found in the flowing water. Such developments have already been made in Australia and other countries around the world. Large nets can also be placed at the inlets of streams where large amounts of waste have been detected. These nets will be equipped with overflow-type devices that will signal when their capacity is filled. The waste is then removed, sorted and recycled. This will help limit the spread of waste in our surrounding nature [7], [21]. The effect will be double - reducing waste and environmental

pollution and collecting raw materials for recycling, which will be used in the production of secondary products. In the summer of 2020, the Australian authorities installed a new water filtration and waste collection system. This system is incredibly simple and useful. Both the government and citizens have already seen the benefits of its use and its effectiveness. It consists of a simple net placed at the outlet of a drainage pipe, which helps to capture large waste and protect the environment from pollution. These pipes discharge running water from residential areas into natural water bodies, and the waste from these places can be in huge quantities, which is extremely harmful to the environment. In addition, this garbage is usually washed away by heavy tropical rains, which drag it into the drainage systems. In this way, waste that has fallen into the water streams of the streets and neighbourhoods after heavy tropical rains is collected.

Fig. 4. Plastic waste collection in Australia [6]

The Australian authorities initially started by installing 2 nets and were amazed by the results – their new filtration system was able to collect more than 360 kilograms of bulky waste over a period of several weeks. This had an extraordinary effect on society and led to a reduction in pollution in water bodies. So, a decision was made to install these facilities and minimize pollution of nature and water in particular. Although installation and maintenance cost money, the overall system is quite cost-effective, as the authorities save significant costs for maintaining the state of the environment. For example, one of the main advantages is that they save on the cost of manual labor, which previously had to be paid to people to collect all this waste from large areas [6].

The designed device will also carry out subsequent control to monitor the change in pollution. When conducting the study, information will be collected over a certain period of time, half a year, one year or more, and a comparison and analysis of the distribution of waste in the studied water bodies will be made. The collected and processed information will be transmitted to the competent state authorities, and they have the authority to impose sanctions on violators and to grant or revoke relevant permits. After a certain period of time, more frequent control can be carried out at the most critical points, and even a transition to continuous monitoring of the situation and the disposal of non-degradable waste can be made. In this way, in the club, by implementing extracurricular employment for cadets and students, we stimulate the development of their habits, skills and creative solutions [4], [22].

The problem of the accumulation of non-degradable and plastic waste in ocean waters should not be ignored. Every year, over 14 billion tons of waste are dumped into the waters of the World Ocean, the majority of which is plastic and nylon. Many world experts have gone so far in their studies that they predict that if pollution continues at the same pace, in 30 years there will be more waste than life in the oceans. More and more animals are dying as a result of eating plastic or nylon waste in the sea waters or getting entangled in these piles of floating waste and dying in them. And this is tantamount to an ecological disaster and a disruption of the ecological balance in the world.

The reason why this type of waste occupies the largest share is that the material is cheap, easy to shape into various products and at the same time, it is very light and relatively durable [12], [23]. However, it is the latter factor that makes it extremely harmful to the environment. It is recyclable, but not in all its forms. At the same time, when burned, it releases many gases that are harmful to the atmosphere [2], [5]. When it enters nature, its decomposition takes an extremely long time. One of the most important directions in the fight against waste from plastics, nylons and other organic compounds is to increase the share of recycling. A partial solution to the problem is the use of rapidly degradable plastic and nylon components. But the most important thing is not to throw away unnecessary, difficult-to-degrade materials into nature, because they disrupt the ecological balance.

According to various sources, there are about 180 million tons of plastic and nylon waste in the world's oceans, and every year between 4.8 and 12.7 million tons of additional plastic waste enter the seas and oceans. And this is without collecting or recycling the existing waste. According to data from the European Parliament, over 730 tons of plastic waste enter the Mediterranean Sea alone annually. The area of floating islands in the Pacific Ocean alone is larger than the territory of a country like Bulgaria. And this is as of today, and we can imagine what it will be like in 20 or 30 years if adequate measures are not taken. Plastic and nylon do not only mean uglier beaches, even in places untouched by man. Marine animals can get entangled in larger floating pieces or get confused and swallow smaller particles. Plastic also releases toxic substances that enter the digestive system of fish. From there, it can reach humans through the food chain [9]. The effect on human health is unknown, at least for now, because no relevant studies have been conducted, but it is certain that the harm is significant.

Waste also brings economic losses to the chemical, oil refining and other sectors of the economy and people connected to the sea, but also to manufacturers. Only 5% of the value of plastic packaging finds reuse in the economy, the rest is simply wasted. Despite the measures taken to limit the use and increase the recycling of these materials, they are not yet leading to the desired result. The need for more recycling and to prevent more plastic from entering the oceans is obvious [8], [23]. If the entire amount of plastic or nylon is collected and recycled, this will provide a resource for the chemical industry for more than

8 years and save raw materials, which will be replaced with recycled plastics and nylon.

Fig. 5. Plastic waste in ocean waters [16]

In 2022, the National Military University "Vasil Levski" purchased a telescope and an adjacent dome. Now, after completing another public procurement, we are about to build our own astronomical station, from where we will be able not only to carry out relevant observations, but also to use databases with space and satellite photos and images of the surface of our planet. In cooperation with fellow teachers and astronomers from related universities such as Sofia University, N. Y. Vaptsarov Naval Academy, Georgi Benkovski Naval Academy, and the Stara Zagora Observatory, we will begin joint activities of our club with related clubs in the field of astronomy, and in particular, work on projects and programs of the EU, NASA, and others [10], [24]. One of our priorities will be the observation and mapping of both space debris and debris in sea and ocean areas that cannot be hidden when observed from space. With this, we will contribute, albeit a little, to a better future for the planet.

Fig. 6. Coexistence of plastic waste with the animal world [16]

The team now plans to refine the technology so that it can more accurately detect floating debris in murky coastal waters and large rivers. The idea is to combine this method with drones to track plastic pollution and assist cleanup operations. Scientists are categorical that the only way to clean up our polluted oceans is to drastically reduce the amount of plastic we produce. Based on the information collected and analyzed, a schematic diagram of a system for collecting information on pollution in and around water bodies was developed. The developed basic device consists of a device that moves on water, powered by a self-propelled autonomous engine device, and collects information from the water surface and the adjacent coastline. At low water levels, the device can move along the bottom of the water body with the help of an all-terrain chassis powered by the same engine. The device transmits the collected information and also stores it with itself, because there may be no continuous connection due to movement in rugged and difficult-to-pass areas. After the study is completed, the collected information is downloaded from the device's memory and stored on a large and powerful medium. The information is analysed and summarized, and the terrain is mapped based on the data, allowing data to be superimposed and information to be obtained about the dynamics of processes and the results of previous studies to be obtained.

When building the astronomical observatory, the same observation will be possible through satellite systems and monitoring of areas potentially threatened by pollution. The general information will be analysed and submitted to the relevant state control authorities. The developed pollution control system will be summarized and a principle model of the system will be developed, which will be patented at a later stage of development. The conceptual design is only the first stage of the overall construction project and there is hope that at a subsequent forum, when finding funding, it will be possible to move to the next stage of implementing the idea [25], [26].

As a result of the study and the possible implementation of monitoring and mapping of water bodies, it is expected that environmental pollution will be reduced and contaminated areas and their pollutants will be detected in a timely manner. This will lead to both an economic and environmental impact for society, an impact that will be calculated upon final completion of the prototype.

The idea is extremely inspiring and aimed at a truly significant global problem - pollution from plastic and other waste. This is an example of initiative that can have a real impact on the environment and quality of life.

1. The autonomous vessel sounds like an innovative solution for collecting pollution data. The technology could prove to be key for monitoring areas that are difficult to access and will provide important information for taking adequate measures.

2. The emphasized need for individual action is also very important. Even small changes in everyday life can start a large movement to limit plastic. This is a message that needs to be spread and supported.

3. Presenting the development to government institutions and companies is the right approach to finding funding. This idea has the potential to attract attention and support if it is communicated clearly and with data on its effectiveness.

Prototyping a riverbed waste monitoring prototype is a challenge, but it’s also an exciting opportunity to apply innovative technologies. Here are some of the ones you could use:

1. IoT devices (Internet of Things): Small sensors that measure pollutants, water level, temperature, and other parameters. Connectivity via Wi-Fi, Bluetooth, or GSM for real-time data transmission.

2. Water drones: Small autonomous or semi-autonomous GPS-enabled floating drones that can navigate riverbeds and collect data. Use lightweight and durable materials such as carbon fiber for the construction.

3. Machine vision and artificial intelligence: Integrate high-resolution cameras and AI algorithms to recognize waste, such as plastic or other pollutants. These algorithms can help automatically identify and classify waste.

4. Energy autonomy: Install solar panels or other renewable energy sources to power the device. Energy-efficient electronics that allow for longer operating times.

5. Communication technologies: LoRa (Long Range) for long-distance communication in areas without internet. 5G for fast data transmission in areas with coverage.

6. Modularity: Creating a design that allows for easy replacement or addition of sensors and other components for future development.

7. GIS systems (Geographic Information Systems): For visualization and analysis of collected data on mapping platforms.

You should start with a basic functional prototype that includes the basic elements such as sensors, GPS and communication. You can gradually add additional functions.

IV. CONCLUSIONS

Over the past 5 years, researchers at the university have collected data on the pollution of water bodies and adjacent terrain. A thorough analysis of these data and the results obtained showed the need to develop a system for monitoring and collecting information on pollution, including in hard-to-reach areas. Based on the assessment, 4 models were proposed for monitoring the spread of plastic and other non-degradable waste. After analysing their effectiveness and costs, an option was selected to create a conceptual scheme that includes the use of a light floating vehicle with the ability to move autonomously, even in reduced water resources. Although the results are not expected easily, it is important to take the first step towards improving our planet in order to create a better world.

Although the proposal is not revolutionary, we do not need to wait for revolutionary changes to deal with the huge amount of plastic waste around us. Everyone can make their small contribution to ensuring a better life for everyone by limiting the use of plastic in their daily lives.

The idea and prototype of the device for tracking waste in riverbeds are yet to be developed. Much work remains to be done, but the first steps have already been taken. Work continues on building the specific segments of the system with the aim of presenting it at the next conference. It is hoped that this development will attract the interest of state institutions and the private sector in order to secure funding for the completion of the project.

On the topic of water pollution and the need for its monitoring and control, some more significant conclusions can be drawn:

1. Environmental impact: Water pollution significantly affects biodiversity, leading to habitat loss and a decrease in populations of aquatic organisms. This is a serious problem that requires urgent measures.

2. The role of technology: Modern technologies such as autonomous systems and IoT devices play a key role in improving pollution monitoring and management. The integration of sensors, GPS and AI can significantly increase the efficiency of information collection systems.

3. Global nature of the problem: Plastic waste in riverbeds is only part of the overall pollution, which has a global dimension. International cooperation and the exchange of good practices are important to address this problem.

4. Education and awareness: Engaging the population in information campaigns to reduce plastic use and be environmentally responsible is crucial. Small changes in everyday life can have a significant impact.

5. Economic aspect: Pollution affects industries such as tourism, fisheries and water supply, leading to economic losses. Investments in sustainable technologies can contribute to long-term economic benefits.

6. Need for financing: In order to implement innovative solutions such as autonomous floating monitoring vehicles, resources are needed, which can be provided through public-private partnerships and support from government institutions.

7. A step towards sustainability: The implementation of a project to control and collect information on pollution represents a significant step towards sustainable management of water resources and environmental protection.

ACKNOWLEDGMENTS:

This report is supported by the National Scientific Program "Security and Defense", approved by Decision No. 171/21.10.2021 of the Council of Ministers of the Republic of Bulgaria.

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A New Approach to Sustainable Aquaculture Management – Impact of Fish Feed on Aquaculture Farm Costs

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***Abstract*— Analysing feed efficiency and identifying the most cost-effective feeding strategies are critical aspects of the fish farming process, as they play a pivotal role in promoting the sustainable development of aquaculture. In fish farming, as in other livestock sectors, the quality of the product is closely linked to the feed, its quality and the impact of the feed on the profitability of the enterprise — the utilisation and cost of the feed. Animal feed is formulated using a diverse range of ingredients specifically designed to fulfil the nutritional requirements necessary for supporting an animal's physiological functions, including immune system maintenance, growth and reproduction. The sustainability of fish feed is a critical concern in the aquaculture industry, given the emerging demand for fish products and the environmental pressures associated with traditional feed sources. The reliance on fishmeal and fish oil, derived from wild fish stocks, raises significant issues, including overfishing and habitat degradation. On average, consumption of fish feed grows by 3% each year. Therefore, the Development of alternative feed ingredients that are Both Economically viable and environmentally friendly is essential for the future of aquaculture. The purpose of this study is to assess the importance of fish feed in aquaculture on the basis of environmental, economic and social parameters and the perception of Latvian fish farmers regarding the importance of fish feed in aquaculture. A partially structured questionnaire was used to collect data. Both descriptive and indicative methods were used for statistical analysis of the collected data. Collected data was analysed using Linear Regression model. Linear Regression is used to study the linear relationship between a dependent variable in fish feed type and independent variable the farms used fish feed costs. The results showed that the type of extruded fish feed reduce the cost of feed for fish in aquaculture farms.**

***Keywords*— *aquaculture; fish farms; feed type; sustainability*.**

I. INTRODUCTION

The sustainability of fish feed is a critical concern in the aquaculture industry, given the increasing demand for fish products and the environmental pressures associated with traditional feed sources. The reliance on fishmeal and fish oil, derived from wild fish stocks, raises significant sustainability issues, including overfishing and habitat degradation [1]. Therefore, the development of alternative feed ingredients that are both economically viable and environmentally friendly is essential for the future of aquaculture.

The economical production of a healthy, high-quality product with rich survival, growth, reproductive performance, spawning success, and body composition in fish culture depends on proper nutrition [2]. Since feed usually accounts for half of the variable production cost in aquaculture, nutrition is essential. The creation of new, balanced commercial diets that support the best possible growth and health for fish has led to a significant advancement in fish nutrition in recent years [3].

In fish farming, as in other livestock sectors, the quality of the product is closely linked to the feed that is fed to the animals, its quality and the impact of the feed on the profitability of the enterprise — the utilisation and cost of the feed. Animal feed is formulated using a diverse range of ingredients specifically designed to fulfil the nutritional requirements necessary for supporting an animal's physiological functions, including immune system maintenance, growth and reproduction [4].

Factory-produced fish feed is divided into 3 categories — pelleted, extruded and grain. One of the primary advantages of pelleted feed is its lower production cost compared to extrusion technology; however, pelleted feed

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8652
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also has several limitations, many of which can be mitigated through the use of extrusion technology [5].

One of the major disadvantages of pelleting is the rapid sinking rate (about 10 to 15% of pelleted feed is lost due to sinking), which means higher feed costs, a less profitable product and a higher environmental impact due to pollution [6]. In addition, the nutrients in pellets dissolve more quickly in water, making the pelleted feed a lower quality fish feed than extruded feed [5].

In fish farms, fish need to be fed several times a day. The feed is eaten, digested and used metabolically to provide fish with energy and ensure growth and other physiological processes [7]. Oxygen (O_2) is taken in through the gills and is used to provide energy and break down proteins. This process produces carbon dioxide (CO_2) and ammonia (NH_3) as waste products. Undigested feed enters the water with faeces, suspended solids and organic matter. Carbon dioxide and ammonia are also released into the water through the gills. Thus, as the fish consume food and oxygen, the water system becomes polluted with faeces, ammonia and carbon dioxide, with significant environmental impacts [7].

To ensure nutrient uptake, digestion, absorption, and transport to the cells of the animal's body, more and more feed additives are being used in fish feed [8]. The range of feed additives used in fish feed is very diverse and focuses on the quality of the feed. Feed additives in fish feed include pellet binders, antioxidants and feed preservatives (anti-mould and anti-microbial compounds). Enzymes are also used to improve the availability of certain nutrients (protease, amylase) and to prevent the presence of certain antibodies (phytase, non-starch polysaccharide enzymes) [9].

The effectiveness of probiotics in aquaculture depends on their origin and application [10]. The combination of probiotics with prebiotics also contributes to improving the health and growth results of fish [11]. In his study, Wei highlights the positive effects of combining probiotics with medicinal herbs, which can improve the growth results, immune system and disease resistance of fish species [12]. This synergy between probiotics and plant extracts can improve feed efficiency and overall fish health, making it valuable in the diet of fish.

Several studies have reported that the gastrointestinal tract of fish is sensitive to stress. Some of the most common signs are degeneration of the intestinal mucosa and impaired feed intake. Fish health is closely associated with a balanced gut microflora, which plays a crucial role in digestion, nutrient absorption, and disease resistance [13;14;15]. To maintain a healthy gut microflora, fish feed is supplemented with dietary supplements, probiotics, immunostimulants, phytogenic substances, and organic acids [10]. The health of fish also has economic implications, because if fish are sick, they cannot be caught and consumed, reducing income and sales for aquaculture businesses.

The suitability of fish feed is also determined by the way the fish are farmed. In recirculating systems, only extruded feed is recommended for fish, but in freshwater ponds, supplementary feed is used. Extruded feed is safe and one of its advantages is that it is formulated according to the actual biological needs of the fish. Extruded feeds are available in different pellet sizes to suit each stage of fish development. Its composition is combined to provide specific feed for juveniles, breeders, commodity fish, etc. In a recirculation system, a high feed utilisation is desirable to minimise waste and faeces, thus also reducing the load on the water treatment system [16].

On a professionally managed farm, all the feed that is fed is used in full, minimising the uneaten part. Feed conversion is a measure of how many kilograms of feed are used for each kilogram of fish produced. The fish farmer is seeking more production at a lower load on the filter system. Uneaten feed is money wasted, which also hampers the operation of water treatment system [17].

The aim of the study was to investigate which type of fish feed is more economically viable for fish farms in Latvia. Other studies have reported that fish feed costs account for 30–50% of the total costs of a business [23], which is a significant share. The present study also aims to find out also how much of the total cost is accounted for by feed costs in fish farms in Latvia.

II. MATERIALS AND METHODS

A survey prepared for Latvian aquaculture operators was used to collect the data. The survey consisted of structured and open-ended questions to investigate the costs of fish feed incurred by aquaculture enterprises and the link between the costs and the type of fish feed used by the enterprise. In 2024, there were 61 economically active aquaculture entrepreneurs in Latvia. 30 aquaculture entrepreneurs (n=30) took part in the survey, representing 50% of the Latvian aquaculture entrepreneurs.

Multiple linear regression method was used to analyse the data, which involves two linearly related variables, one dependent variable (Y) and one independent variable (X), which are linearly related to each other [18,19,20]. The main objective of linear regression is to fit a linear equation to the observed data, thus allowing the effects of the predictor variables to be predicted and interpreted. In this study, the dependent variable (Y) is the type of fish feed used in the aquaculture enterprise and the independent variable (X) is the cost of fish feed. The aim of the regression analysis was to test a general underlying model linking two variables and to show the relationship between X and Y to predict Y for a given value of X [20].The linear regression method assumes that the relationship between the predictor and target variables is linear: a constant unit of change in one implies a constant unit of change in the other. This simplicity usually makes linear regression the optimal choice for analyses with small samples, and also makes these models relatively easy to interpret and understand.

Analysis, synthesis, the logical construction method, the induction and deduction methods were employed to execute the research tasks. Scientific literature review was used as well.

III. RESULTS AND DISCUSSION

Based on the survey data on the total costs of the enterprise, it can be concluded that feed costs represent the largest share (48%), followed by purchase of juvenile fish (16%), energy (8%) and other costs (28%). See Figure 1 for the cost structure of Latvian aquaculture farms.

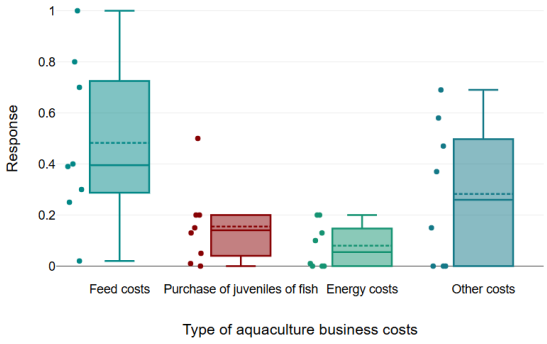


Fig. 1. Cost structure of Latvian aquaculture farms.

A multiple linear regression analysis was performed to examine the influence of the variables of fish feed type granular, extruded and grains on the variable Feed costs.

The regression model showed that the variables of fish feed granular, extruded and grains explained 13.794% of the variance from the variable feed costs. An ANOVA was used to test whether this value was significantly different from zero. Using the present sample, it was found that the effect was not significantly different from zero, F=0.12, p = 0.971, R^2 = 0.138.

Table 1 shows the results for each dependent variable in the model, including the constant (intercept). The unstandardized coefficient B indicates the expected change in the dependent variable Feed costs for each one-unit increase in the respective dependent variable.

TABLE 1 THE LINEAR REGRESSION MODEL COEFFICIENTS

Model	**Constant**	**Type of fish feed**		
		Granular	***Extruded***	***Grains***
B	0.525	-0.13	-0.225	-0.015
Beta	0	-0.186	-0.246	-0.021
Standard error	0.324	0.459	0.562	0.459
t	1.618	-0.283	-0.4	-0.033
p	0.204	0.795	0.716	0.976
lower bound	-0.507	-1.59	-2.013	-1.475
upper bound	1.557	1.33	1.563	1.445

Y-intercept of the regression line represents the expected value of the dependent variable when all dependent variables are zero. In this context, it means that when type of fish feed Granular, Extruded and Grains are zero, the independent variable Feed costs is expected to be around 0.525. The p-value is 0.204, indicating that the intercept is not statistically significantly different from zero. More precisely the null hypothesis that the coefficient of Constant is zero in the population is not rejected.

If the value of the variable Type of fish feed Granular changes by one unit, the value of the variable Feed costs changes by -0.13 units. The p-value is 0.795, indicating that this coefficient is not statistically significantly different from zero, which means we cannot confidently say that Type of fish feed Granular impacts the independent variable. More precisely the null hypothesis that the coefficient of Type of fish feed Granular zero in the population is not rejected.

If the value of the variable Type of fish feed Extruded changes by one unit, the value of the variable Feed costs changes by - 0.225 units. The p-value is 0.716, indicating that this coefficient is not statistically significantly different from zero, which means we cannot confidently say that Type of fish feed Extruded impacts the independent variable. More precisely the null hypothesis that the coefficient of Type of fish feed Extruded is zero in the population is not rejected.

If the value of the variable Type of fish feed Grains changes by one unit, the value of the variable Feed costs changes by - 0.015 units. The p-value is 0.976, indicating that this coefficient is not statistically significantly different from zero, which means we cannot confidently say that Type of fish feed Grains impacts the independent variable. More precisely the null hypothesis that the coefficient of Type of fish feed Grains is zero in the population is not rejected. When all dependent variables are equal to zero, the value of the variable Feed costs is 0.525.

The standardized coefficients betas are independent of the measured variable and are always between -1 and 1. The larger the amount of beta, the greater the contribution of the respective dependent variable to explain the independent variable Feed cost. In this model, the variable Type of fish feed Extruded has the greatest influence on the Feed costs. A scatter diagram shows the points (Xi, Yj) on a rectangular coordinate system. Figure 2 shows a Scatter diagram of fish feed.

The calculated regression coefficients refer to the sample used for the calculation of the regression analysis; therefore, it is of interest whether the individual coefficients only deviate from zero by chance or whether they also deviate from zero in the population. To test this, the null hypothesis was made for each coefficient that was equal to zero in the population. The standard error now indicates how much the respective coefficient will scatter on average when the regression analysis is calculated for a further sample. The test statistic t is then calculated from the standard error and the coefficient. scatter diagram of the

two variables can be plotted. Figure 3 shows Pareto diagram of standardized effects.

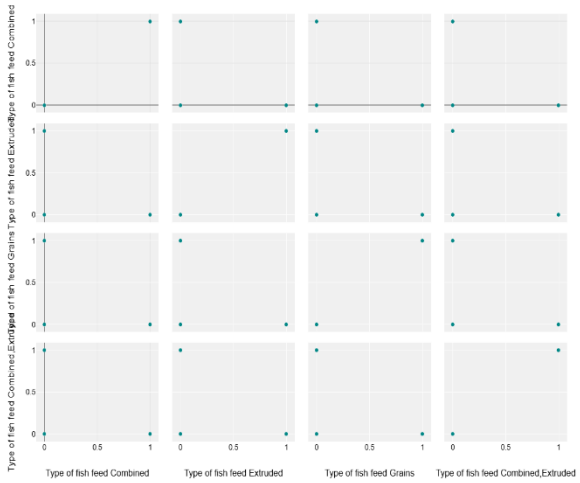
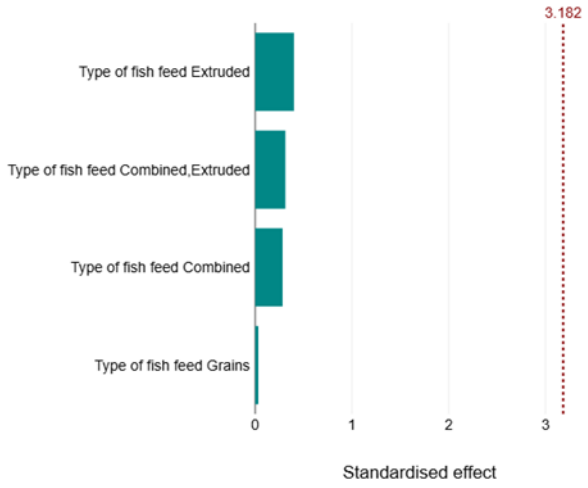


Fig.2 Scatter diagram of fish feed.



Note: p-value=0.5.

Fig.3 Pareto diagram of standardized effects.

IV. CONCLUSIONS

Analysing feed efficiency and identifying the most cost-effective feeding strategies are critical aspects of aquaculture, as they play a pivotal role in promoting the sustainable development of aquaculture. Mathematical optimisation tools, such as optimal control models, are needed to determine the optimal choice of growth factor, e.g., dose rate, throughout the growth cycle. They have been used in several aquaculture systems and are considered time-dependent due to their flexibility and simplicity.

In aquaculture, rationing can have both economic and environmental consequences, as any inefficiency in feed use can increase production costs and exacerbate negative externalities associated with feed consumption [21;22;23;24]. Excess feed can increase waste, leading to higher environmental impacts and loss of financial resources, while insufficient feed supply can reduce the digestive efficiency of fish due to feed competition and quantity imbalances [25]. From a productivity point of view, the ideal feed ration promotes optimal growth and feed conversion ratio (FCR).

Optimizing feed composition and feeding practices can lead to better growth performance and health in farmed fish, ultimately contributing to more sustainable aquaculture systems. The integration of sustainability into fish feed production also requires a comprehensive understanding of the nutritional needs of fish and the environmental impacts of various feed ingredients. The study confirmed that dependent variable Type of fish feed Extruded has the greatest influence on the independent variable Feed costs.

ACKONOWLEDGEMENTS

This research was supported by project “Strengthening the Institutional Capacity of LBTU for Excellence in Studies and Research”, funded by The Recovery and Resilience Facility.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 185-189

Economic and Environmental Aspects of Agri-food System in the EU Member States and Ukraine in Context of the European Green Deal Objectives

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***Abstract* — The main objective of the European Green Deal is to achieve full climate neutrality of the EU by 2050, including the agri-food system, which occupies a prominent place in the community economy. Producing zero net greenhouse gas emissions and promoting the sustainable development of the sector in the long term means a green transformation of all components of the EU agri-food system, primarily agricultural production and food industry. It has been determined that agricultural production is one of the main GHG emitters in the agri-food system of the EU and Ukraine, ahead of the food and processing industry. It has also been revealed that the amount of GHG (in carbon dioxide equivalent) from agricultural production per one US dollar of value added significantly exceeds the same value from the food and processing industry. This proves the fact that production of finished food is more sustainable than production of agricultural raw materials. Thus, progress in addressing the issue of achieving climate neutrality and ensuring sustainable development of the EU agri-food system largely depends on the greening of agriculture and the deepening of the degree of processing of agricultural raw materials. It is substantiated that in the context of Ukraine's integration into the EU, it is advisable to pay significant attention to the development of its own food and processing industry, which is not only beneficial from an economic side, but should also contribute to better achieving the European Green Deal purpose. It was clarified that in Ukraine and the EU, household food consumption and food waste disposal account for a relatively high percentage of GHG in the structure of the agri-food system. The study is based on 2022 data.**

Keywords* — *Agri-food system, European Green Deal, GHG emissions, value added.

I. INTRODUCTION

The implementation of the «Farm to Fork» strategy, which occupies a prominent place in the European Green Deal, provides for a sustainable agri-food system. The latter should provide Europeans with healthy, affordable and sustainable food, protect the environment and preserve biodiversity, promote increased organic farming, guarantee fair economic profits in the food chain and fight climate change [1].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8675
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Since global climate change is closely related to GHG emissions, it is obvious that modern agri-food systems that produce about 1/3 of all GHG are serious culprits. At the same time, a deeper degree of processing of agricultural raw materials should contribute to an increase in the added value in the food chain. However, it still remains unclear how the issue of increasing the gross added value of the agri-food system with GHG emissions is consistent.

II. MATERIALS AND METHODS

The study is based on the current statistical database (2022) of the Food and Agriculture Organization of the United Nations (FAOSTAT), in particular in the section "Climate Change: Agri-food systems emissions." The theoretical basis was formed by the scientific works of Ukrainian and foreign scientists. Also, the strategy "From farm to fork" for a fair, healthy and environmentally-friendly food system was taken as a methodological basis.

The scientific research was conducted using the following general scientific methods: a comparison method that made it possible to compare generalized and derived economic and environmental indicators of the development of agri-food systems in the EU Member States and Ukraine; method of analysis, which made it possible to study the structure of agri-food systems according to the criteria for the formation of gross added value and GHG emissions.

At the same time, the article used several specific scientific methods, in particular: statistical methods of grouping and ranking - to establish the rank of EU member states in terms of gross value added created in the agri-food system per hectare of agricultural land; method of structural analysis - in the process of a detailed study of the specific gravity of each element of the agri-food system in terms of GHG emissions; method of economic analysis - to detect the fact of exceeding the GHG emissions (in carbon dioxide equivalent) from agricultural production per one US dollar of the added value of the corresponding indicator value in the food and processing industry; tabular and graphical methods in order to improve the analytical perception of statistical data and build correct research conclusions.

III. RESULTS AND DISCUSSIONS

Bartłomiej Bajan, Joanna Łukasiewicz, Aldona Mrówczyńska-Kamińska and Lukáš Čechura confirm that one decade before the European Green Deal announcement the total amount of GHG emissions from the agri-food production system in the EU Member States decreased while the share of the agri-food system in total GHG emissions increased. Moreover, the scientists revealed that the intensities between EU countries were varied and independent of economic development. Also, they observed the highest emission intensity at agricultural production stage [2].

In turn, Francisco José Castillo-Díaz, Luis J. Belmonte-Ureña, María J. López-Serrano and Francisco Camacho-Ferre revealed that more significant economic progress of the EU agricultural activity was associated with a lower quality of environmental indicators [3].

There are also many studies in which scientists reveal various aspects of the influence and interaction of economic and environmental criteria for the development of agri-food systems including in the EU [4] – [8].

Well-known, agri-food systems are all the interconnected activities and actors involved in getting food from field to fork. Their main components are agricultural production, food processing, food distribution, food consumption and food wate management [9]. Economic dimension of agri-food systems can be assessed by the different indicators, particularly by value added. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources [10]. It should be noted that added value generated by the EU agri-food system in 2022 was 900 billion Euro [11].

In order to compare the value added of the agri-food systems between the EU Member States and Ukraine, its ratio to the area of agricultural land was calculated. In 2022 the average meaning of this indicator in EU was 3505,24 USD (current USD). Among the Member States, Netherlands, Malta and Belgium had the highest level of agri-food value added – 19297; 13802 and 9523 USD accordingly (Fig.1). At the same time, more than half of the EU countries had below the average of this indicator. Mostly, these were Central and Eastern European countries, Balkan and Baltic countries. It should be noted that Ukraine, as a candidate country for accession to the EU, which has an international agri-food specialization and a high level of competitive advantages in this industry, demonstrated the lowest value added of the agri-food system per hectare of land - only 417 USD.

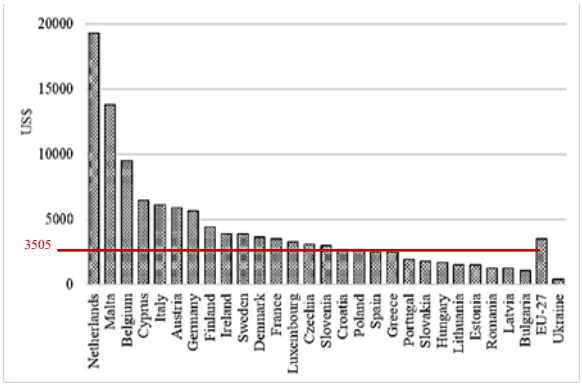

Fig. 1. Agri-food value added in the EU Member States and Ukraine in 2022, USD per 1 ha of agricultural land
Source: complied by the authors based on [12]

However, the Ukrainian agri-food system emitted in 3 times less CO2eq than the European system, particularly 2,2 t per 1 hectare of agricultural land. This indicates a higher level of greening of the agri-food system in Ukraine towards achieving the Green Deal objective. Among the main components, agricultural production was the leader

by GHG emissions not only in Ukraine but in the EU Member States too. Thus, if in the candidate country for accession the share of agriculture in total emissions equeled 30,3% then the meaning of indicator in EU – 37,9% (Fig.2).

Furthermore, among the activities of agricultural production, synthetic fertilizers using in the Ukrainian agricultural enterprises occupied the highest share in GHG emissions – 7,3% while the EU farmers produced the biggest part of emissions by enteric fermentation – 15,1%. It means that mostly agriculture of Ukraine specializes in crop cultivation, and European - in animal husbandry.

Globally, among the three components of agrifood systems in 2020, farm-gate emissions were nearly half of the total (7.4 Gt CO2eq), followed by emissions from pre- and post-production (5.6 Gt CO2eq) and land-use change (3.1 Gt CO2eq) [13].

The share of GHG emissions from food processing in Ukraine and the EU was only 4,7 and 12,6% accordingly.

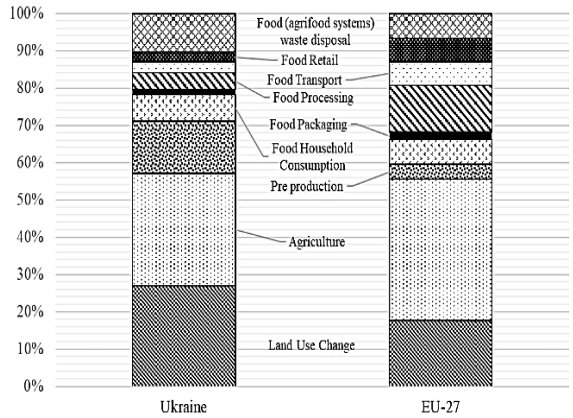

Fig.2. The structure of GHG emissions (CO_2 eq) in the EU and Ukrainian agri-food systems in 2022, %
Source: complied by the authors based on [12]

It should be noted that France and Italy were the leading states by this indicator – 25% and 29%. In contrast Latvia, Lithuania and Sweden had the smallest share – 1,7; 1,6 and 1,2 % accordingly.

Also, it was clarified that in Ukraine and the EU, food consumption and food waste disposal account for a relatively high percentage of carbon dioxide equivalent emissions in the structure of the agri-food systems. Particularly, the biggest share of GHG emissions from food household consumption was in Germany – 15,2%; Czechia – 13,2% and Portugal – 12,3%. In turn, Greece and Malta were the leaders by the share of carbon dioxide equivalent emissions from food (agri-food systems) waste disposal – 25,2% and 22,6% accordingly.

It has also been revealed that the amount of GHG (in carbon dioxide equivalent) from agricultural production per one US dollar of value added exceeds the same value from the food and processing industry. By the method of induction, it can be assumed that such a pattern will be inherent in other countries as well. However, it should be studied.

TABLE 1 $CO_{2\ EQ}$ EMISSIONS PER VALUE ADDED IN AGRICULTURE AND FOOD PROCESSING BETWEEN THE EU MEMBER STATES AND UKRAINE IN 2022

№	Country	Value added (current bln US$)		CO_2eq emissions, Mt		CO_2eq per value added, kg per 1 US$	
		Agriculture[1]	*Food Processing*[2]	*Agriculture*	*Food Processing*	*Agriculture*	*Food Processing*
1	Austria	6,5	8,8	8,5	1,3	1,3	0,1
2	Belgium	4,1	8,8	10,6	3,8	2,6	0,4
3	Bulgaria	3,3	2,0	3,8	1,2	1,2	0,6
4	Croatia	2,4	1,8	3,2	0,6	1,3	0,3
5	Cyprus	0,4	0,4	0,6	0,2	1,5	0,5
6	Czechia	6,3	4,6	8,3	2,6	1,3	0,6
7	Denmark	3,2	6,3	11,5	1,6	3,6	0,3
8	Estonia	0,9	0,5	1,6	0,5	1,8	1,0
9	Finland	6,3	3,7	5,3	0,6	0,8	0,2
10	France	49,3	50,1	79,6	42,5	1,6	0,8
11	Germany	41,8	62,2	60,4	16,9	1,4	0,3
12	Greece	8,2	6,0	8,2	1,6	1,0	0,3
13	Hungary	5,5	3,1	7,9	2,1	1,4	0,7
14	Ireland	6,0	10,9	23,0	1,4	3,8	0,1
15	Italy	39,8	40,1	42,7	39,8	1,1	1,0
16	Latvia	1,9	0,6	2,6	0,2	1,4	0,3
17	Lithuania	2,8	1,6	3,6	0,4	1,3	0,3
18	Luxembourg	0,2	0,2	0,7	0,06	3,5	0,3
19	Malta	0,1	-	0,1	0,03	1,0	*
20	Netherlands	17,2	17,6	29,3	6,5	1,7	0,4
21	Poland	19,5	18,2	36,6	10,5	1,9	0,6
22	Portugal	4,9	5,0	8,7	1,2	1,8	0,2
23	Romania	11,3	4,9	16,8	1,8	1,5	0,4
24	Slovakia	2,2	1,1	2,6	0,4	1,2	0,4
25	Slovenia	1,0	0,8	1,8	0,2	1,8	0,3
26	Spain	33,4	32,7	50,2	6,1	1,5	0,2
27	Sweden	6,0	6,1	7,3	0,6	1,2	0,1
	EU-27	284,7	298,2	436,1	144,1	1,5	0,5
	Ukraine	13,9	3,6	27,8	4,3	2,0	1,2

Source: compiled by the authors on based [12]

Note: [1] - Agriculture, forestry, and fishing; [2] – Food, beverages and tobacco.

In formalized form, this could be written by:

$$\frac{EM^i_{agr}}{VA^i_{agr}} > \frac{EM^i_{food}}{VA^i_{food}} \quad (1)$$

where EM^{i}_{agr} – GHG emissions (carbon dioxide equivalent) in agriculture in country i;

EM^{i}_{food} – GHG emissions (carbon dioxide equivalent) in food processing in country i;

VA^{i}_{agr} – value added in agriculture in country i;

VA^{i}_{food} - value added in food processing in country i;

For example, in Luxembourg, Austria and Ireland it was in 12, 13 and 38 times over. However, the average level of GHG emissions in the EU agriculture per 1 USD of value added was in 3 times bigger than relative indicator in food processing. In turn, in Ukraine the difference was less here (table 1).

Generally, this proves the fact that production of finished food is more sustainable than production of agricultural raw materials. As rule, it should be explained by relatively smaller carbon dioxide emissions from food processing industry. Obviously, in Austria, Finland, Ireland, Sweden, Spain and Portugal this component of agri-food system has been the most sustainable where the volume of GHG emissions per 1 USD of value added was between 0,1 to 0,2 kg. In contrast, Estonia, Italy and Ukraine demonstrated the lowest level of the indicator – approximately, 1 kg CO_2 eq emissions per 1 USD of value added.

Also, it should be noted that particularly agriculture mostly met sustainability criteria by the dimension in Finland, Greece and Italy. Another situation could be noticed in Belgium, Denmark, Ireland and Luxembourg.

In terms of the EU integration Ukraine has not enough level sustainability (first of all, economical dimension) of agri-food system totally and, particularly, agricultural production and food processing. Therefore, it should be the key direction in the transforming of the Ukrainian agri-food sector under conditions of negotiation process on EU accession.

IV. Conclusions

As a result of analysis which is based on the current statistical database (2022) of the Food and Agriculture Organization of the United Nations, it was determined that agricultural production has been being one of the main GHG emitters in the agri-food system of the EU and Ukraine, ahead of the food and processing industry.

It was revealed that the amount of GHG emissions (carbon dioxide equivalent) from agricultural production per one US dollar of value added, as rule, exceeds the same value from the food and processing industry in the EU and Ukraine. This proves the fact that finished food production is more sustainable process than production of agricultural raw materials.

It was found that the Ukrainian agri-food system ahead of the EU system by CO2eq emissions per 1 USD of value added in agricultural production and food processing and indicates the weaker sustainability of these parts of agri-food chain in Ukraine.

Among the EU Member States, relatively, the highest level of sustainability of agriculture was in Finland, Greece and Malta while more sustainable food processing was in Sweden, Ireland and Austria.

It was substantiated that in terms of the Ukraine's integration into the EU, it is advisable to develop, mostly, its own food and processing industry, which is not only beneficial from an economic dimension, but should also contribute to better achieving the European Green Deal objectives.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 191-196

Medical Aspects of Emergency Rescue Activities in Radiation Accidents

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***Abstract*— Radiation damage that can be caused to humans through exposure and ingestion (incorporation) of radioactive substances depends primarily on the amount and type of radiation and radioactive substances ingested. To exclude the possibility of radiation damage through the ingestion of radioactive substances, the maximum permissible concentrations (MPC) should be monitored as far as possible. This concept defines the limit values of the activity concentration of food products, drinking water and general consumption, after being exposed to radioactive contamination, which within a certain period of consumption does not cause serious damage to the population and people conducting emergency and rescue activities.**

Keywords*— *biological effects, emergency and rescue activities, radiation accident and ionizing radiation, radioactive contamination.

I. INTRODUCTION

The occurrence of an accident in a nuclear power plant (*NPP*), radiochemical plants, etc. can lead to the release of radioactive substances (*RS*) into the atmosphere and contamination of the adjacent territory [1]. In such cases, one of the first actions that must be carried out is the dosimetric control of the external environment. It will provide information about the level and volume of radioactive contamination of the territory. The problem of changes in the system of education, training and scientific research in the sphere of security and the possibility for their management is particularly relevant and at the same time very complex [2].

The degree of radioactive contamination determines what sanitary and hygienic measures should be taken further.

The workers at the enterprise/nuclear power plant where the accident has occurred are subject to individual dosimetric control with individual dosimeters that are fixed to their clothing. In the second half of the twentieth century, the use of sources of ionizing radiation expanded significantly - nuclear power plants were built, medical diagnostics expanded, and radiation using these rays also entered industry [3].

In the event of a nuclear accident, the capabilities of the health care system are exceeded, local authorities and a number of central organizations are involved in the implementation of protective measures. Much of them are important as communication and transport hubs, and some are of great importance because of their proximity to certain sites or important stretches of the area [4]. The specificity of protective measures is such that measures are effective only when they are applied early - in the first hours and days [5]. This requires the program to provide, first of all, rapid dosimetric information, and secondly, determining the level of contamination. It is assumed that two main hazards are important as a criterion for decision-making:

- Danger of external radiation.
- Danger of incorporation of radioactive substances.

As the main pathways for radiation exposure to the population in the event of emergency contamination of the external environment:

- External exposure from the radiation cloud and contamination of the territory.
- Contact exposure due to contamination of skin and clothing.
- Internal exposure due to entry of PE into the respiratory system.
- Internal exposure due to consumption of contaminated food and water.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8643
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The radiation hygiene measures that must be taken in general terms are the following:

- Temporary shelter of the population in homes and shelters.
- Elementary sealing of the premises.
- Restricting the movement of the population in the contaminated territory.
- Blocking the thyroid gland to prevent exposure to radioactive iodine through iodine prophylaxis.
- Temporary evacuation of the population from the contaminated territory.
- Sanitary treatment of exposed skin surfaces of persons contaminated with radioactive substances.
- Simple processing to remove surface radioactive contamination of food products by washing and separating the surface layer.
- Exclusion from use of contaminated exposed food products.
- Moving dairy animals to uncontaminated pastures.
- Exclusion from use of radioactively contaminated milk.
- Sanitary - hygienic control of drinking water.

II. MATERIALS AND METHODS

A radiation accident is an event that could have led to or has led to unplanned exposure of people or radioactive contamination of the environment above the values regulated by regulatory documents for controlled conditions, occurring as a result of loss of control over the source of ionizing radiation caused by equipment malfunction, incorrect actions of personnel, natural disasters or other causes.

A distinction is made between the source of the accident and the areas of radioactive contamination of the area:

- The source of the accident is the territory of the scattered structural materials of the emergency facilities and the action of α-, β- and γ- radiation.
- A radioactive contamination zone is an area in which radioactive isotopes have appeared.

The type of radiation accidents is determined by the sources of ionizing radiation used in the objects of the national economy. They can be conditionally divided into the following groups: nuclear, radioisotope and those creating ionizing radiation due to acceleration (*deceleration*) of charged particles in an electromagnetic field (*electrophysical*).

In nuclear power plants, as a result of an emergency release, the following factors of radiation pollution and impact on the population are possible:

- external exposure to a radioactive cloud and radioactively contaminated surfaces - land, buildings, structures, etc.;
- internal exposure from inhalation of radioactive substances in the air and consumption of food and water contaminated with radionuclides;
- contact radiation due to contamination of the skin with radioactive substances.

In order to increase the monitoring of the radioactive situation, the nuclear accidents in Chernobyl in 1986 and in Fukushima in 2011 played a major role [6]. The Chernobyl nuclear power plant accident [7] with the destruction of the fourth reactor occurred on 26 April 1986, during an experimental test (*training*) of the electronic control system, when the reactor was shut down for routine operation. The RBMK-1000 reactor (*powerful boiling reactor*) of slow neutrons, with nuclear fuel of 114.7 tons of uranium-238 dioxide, enriched with 2% uranium-235, water for cooling, with graphite moderators. The operators then, in violation of safety regulations, turned off important control systems and allowed the reactor to enter an unstable operating mode. Due to that, the uncontrolled increase in power and the subsequent increase in temperature, caused excessive overproduction of steam, which led to a steam explosion that tore the reactor vessel apart [8]. This caused the destruction of the core and the reactor building. Fortunately, a critical mass of uranium-235 was not formed, otherwise a nuclear explosion could have occurred. The Chernobyl reactor does not have a protective shell and therefore there were emissions of radioactive gases and large quantities of radioactive substances (*3.5% of the nuclear fuel and its decay products*). The release contains up to 20% isotopes of radioactive iodine, 23% isotopes of radioactive Cesium, 8% isotopes of radioactive strontium, 18% plutonium and neptunium, uranium-238, uranium-235 and other radionuclides. The highest emission intensity was observed in the period from April 26 to May 6. Subsequently, the emission intensity decreased. Radioactive gases and particles of radioactive substances (*RAW*) were carried by the wind first in the westerly and northern directions, and then in all directions. The deposition of radionuclides on the ground, buildings and other infrastructure occurs mainly through precipitation during the passage of the radioactive cloud. The resulting picture of radioactive contamination in the affected region is complex and variable. The total activity of emergency release products (*ESP*) during the Chernobyl accident in 1986 alone was 50 MKi. The accident contaminated with radioactive substances more than 150,000 square kilometers of territory in several regions of Belarus, the Russian Federation and Ukraine, and deposits of the released radionuclides have been recorded in Sweden, Finland, Poland, Germany, France, Belgium, the Netherlands, England, Bulgaria, Greece, Israel, Kuwait, Turkey, Japan, China, Canada and the USA.

As a result, an immediate evacuation began in 1986 of about 116,000 people from the area adjacent to the plant, and the resettlement of about 220,000 people to permanent residence after 1986. The Chernobyl accident led to the deaths of 30 workers over several days and weeks and to radiation injuries to more than 100 other workers. On the morning of April 26, 1986, out of 600 workers, 134

received large doses (*0.7–13.4 Gy*) and developed radiation sickness. 28 of which died within three months, and two others soon after. In 1986–1987, about 200,000 people involved in the restoration work received doses ranging from 0.01 to **0.5 Gy** [9]. They were at potential risk of late effects of radiation, such as cancer or other diseases. Radiation exposure was highest in the areas surrounding the reactor. The radiation dose from **iodine-131 was 1–10%, from caesium-137 was 65–75%**. In the first year after the accident, the highest average annual radiation doses for any region in Europe outside the former USSR were less than **50%** of the dose received from the natural radiation background. Subsequently, radiation exposure rapidly decreased. The radiation level in the area contaminated with radioactive substances from the Chernobyl accident decreased by a factor of 2 in the first ***24*** **hours**, and by a factor of 90 in the first year. Areas of hazardous contamination of food products with an exposure dose rate of **1 mR/h** and higher are considered to be the territories of the Chernobyl Nuclear Power Plant Emergency Release Zone (*ES*). After the decay of radioactive iodine isotopes and the reduction of the iodine hazard, the area of dangerous contamination with radioactive waste is considered a territory with an exposure dose rate of **1 to 2 mR/h**. The population is evacuated from the area contaminated with radioactive waste if the exposure dose rate of gamma radiation constantly **exceeds 0.3 mR/h**. Special treatment with surfactants was carried out if the skin has been contaminated with levels above **0.1 mR/h** (*130 Bq/cm*^{2}). On April 26, the population began receiving iodine preparations for iodine prophylaxis. The consumption of milk and products contaminated with radioactive substances was strictly prohibited. Monitoring of the radiation situation was organized. Measures were taken to prevent a nuclear explosion in the reactor and stop the release of radionuclides into the atmosphere. The decontamination work on the territory and facilities of the NPP and in the 30-kilometer zone, and the preservation of the destroyed reactor, has been completed. Similar to the Chernobyl accident, significant releases of radionuclides occurred during two other reactor accidents: at Windscale (*United Kingdom*) in October 1957 and at Three Mile Island (*United States*) in March 1979.

An emergency situation in facilities for the storage of radioactive materials and waste poses a great danger, as it can lead to long-term radioactive contamination of vast territories with highly active radionuclides and require large-scale intervention. An accident is also possible during deep burial of liquid radioactive waste in underground horizons due to a sudden collapse of the bottom of the well.

An accident could occur at a radiochemical production facility, where the radionuclide composition and the magnitude of the accidental contamination (*discharge*) depend significantly on the technological part of the process and the structure of the radiochemical production facility. On April 7, 1993, an accident occurred at a radioactive waste processing plant in Tomsk. The trace of the radioactive cloud with a width of 9-10 km stretched for 100-120 km. Accidents with radionuclide sources are associated with their use in industry, gas and oil production, construction, scientific research and medical institutions. The peculiarity of an accident with a radioactive source is associated with the difficulty of establishing the fact of the accident. Unfortunately, the presence of such an accident is often established after severe radiation exposure is recorded.

Large-scale nuclear decommissioning activities and technologies for processing, conditioning and storing radioactive waste, as well as all nuclear activities, have a significant potential for major accidents that would pose a risk to society [10]. This has necessitated the adoption of international binding instruments with a global scope for nuclear risk prevention, emergency response and liability for nuclear damage [11] as well as a system for supervision and control of the use of nuclear materials, radioactive substances and other sources of ionizing radiation and relevant security measures in accordance with Euratom legislation [12].

Accidents during the transport of radioactive materials are also possible [13]. Based on the extent of the spread of radioactive substances and the possible consequences, radiation accidents are divided into **local, regional and general**.

Local accident - Local accident is an accident with the release of radioactive products into the sanitary protection zone in quantities exceeding the values standardized for normal operation, which may lead to exposure of personnel to doses exceeding permissible levels.

General accident - an accident with the release of radioactive products outside the sanitary protection zone in quantities exceeding the normal values for normal operation, which may lead to exposure of the population and pollution of the environment above the established norms. Accidents can occur either with or without the destruction of a nuclear reactor.

There are three-time phases of the accident: ***early, intermediate and late*** (*recovery*).

The early phase is the period from the beginning of the accident until the moment when the release of radioactive substances into the atmosphere and the formation of a radioactive trace on the ground ceases. The duration of this phase, depending on the nature, scale of the accident and meteorological conditions, can vary from several hours to several days.

The intermediate phase of the accident begins from the moment of completion of the formation of a radioactive trace and continues until all necessary measures are taken to protect the population and the necessary volume of sanitary-hygienic and medical and preventive measures are carried out. Depending on the nature and scale of the accident, the duration of the intermediate phase may vary from several days to several months after the accident occurs.

The late (recovery) phase can last from several weeks to several years after the accident (*until the moment when*

the need for implementing measures to protect the population disappears), depending on the nature and degree of radioactive contamination. The phase ends simultaneously with the removal of all restrictions on the life of the population in the contaminated area and the transition to the usual sanitary-dosimetric control of the radiation situation, characteristic of the conditions of "*controlled irradiation*". In the late phase, the sources and paths of external and internal irradiation are the same as in the intermediate phase. The scale and degree of contamination of the area and air determine the radiation situation.

The radiation situation is a set of conditions that arise as a result of contamination of the terrain, the ground layer of the air and water sources with radioactive substances (*gases*), and which affect emergency response (*rescue operations and life support of the population*).

Identification of the ground radiation situation includes determining the scale and degree of radioactive contamination of the area and the ground layer of the atmosphere. The assessment of the ground radiation situation is carried out in order to determine the degree of impact of radioactive contamination on people involved in the elimination of the consequences of an accident and on the population inhabiting this territory.

The method for assessing the radiation situation based on radiation reconnaissance data is used after an accident at a radiation facility (*installation, technological process*) [14]. It is based on establishing the real (*current*) situation by measuring the degree (*dose rate*) of ionizing radiation and radioactive contamination of the area and objects.

The conclusions formulated by specialists (*experts*) in radiation intelligence and dosimetric control as a result of an assessment of the radiation situation must indicate the following facts:

- the number of people affected by ionizing radiation and the necessary health resources;
- the most correct actions of the NPP personnel/ radiochemical plants, liquidators and emergency medical personnel;
- additional measures to protect different groups of people.

The main guidelines for preventing and reducing losses and damages in radiation accidents are as follows:

- location of radiation-hazardous territories and facilities, taking into account the possible consequences of an accident;
- special measures to limit the spread of radioactive emissions outside the sanitary protection zone;
- measures to protect personnel and the population.

The doses of ionizing radiation that do not lead to acute radiation injuries, reduced working capacity, and do not worsen concomitant diseases are as follows:

- single (single dose) - up to 50 rad (0.5 Gy);
- repeated: monthly - up to 100 rad (1 Gy), annual- up to 300 rad (3 Gy).

III. Results and discussion,

A distinctive feature of the structure of damages occurring during radiation accidents is their diversity, which is associated with a large number of variants of the development of radiation situations.

The structure of radiation consequences (*damages*) for the affected population is represented by ***the following main forms of diseases*** [15]:

- acute radiation sickness from combined external γ-, β- radiation (γ-neutron) and internal irradiation;
- acute radiation sickness from extremely uneven exposure to γ-radiation; – local radiation damage (γ, β);
- radiation reactions;
- radiation sickness from internal radiation;
- chronic radiation sickness from combined irradiation.

Acute radiation sickness Acute radiation illness (ARS).

The modern classification of acute radiation sickness is based on the firmly established experimental and clinical dependence of the severity and form of damage on the received radiation dose.

Mild (I) grade. The primary reaction, if it occurs, is mild and occurs rapidly. Nausea and sometimes vomiting may occur. The duration of the primary reaction does not exceed 1 day and is usually limited to a few hours.

Medium (II) degree. The periodization of ARS is clearly expressed. The primary reaction lasts up to 1 day. Nausea and 2-3-fold vomiting, general weakness and subfebrile body temperature appear.

Severe (III) degree. Violent primary reaction up to 2 days, nausea, repeated vomiting, general weakness, subfebrile body temperature and headache.

Extremely severe (IV) degree. The primary reaction is violent, lasts 3-4 days and is accompanied by uncontrollable vomiting and severe weakness, reaching adynamia. General skin erythema, loose stools and collapse are possible.

Depending on the possible manifestations, cerebral, toxic, intestinal and bone marrow forms of ARS.

Cerebral form. When irradiated with a dose of more than ***50 Gy***, a cerebral form of acute radiation sickness occurs. In its pathogenesis, the leading role belongs to damage at the molecular level of brain cells and cerebral vessels with the development of severe neurological disorders. Death occurs from respiratory paralysis in the first hours or the first ***2-3 days***.

Toxic or vascular-toxemic form. At radiation doses in the range of ***20-25 Gy, ARS*** develops, which is based on

toxic- hypoxic encephalopathy caused by a violation of the hemodynamic of the cerebral cerebrospinal fluid and toxemia. With hypodynamia, prostration, clouding of consciousness with the development of stupor and coma, the patient dies between the ***4th and 8th*** day.

Intestinal form. Irradiation in a dose of ***10*** to ***20 Gy*** leads to the development of radiation sickness, the clinical picture of which is dominated by signs of enteritis and toxemia, caused by radiation damage to the intestinal epithelium, disruption of the barrier function of the intestinal wall for microflora and bacterial toxins. Death occurs in ***the 2nd*** week or at the beginning of ***the 3rd***.

Bone marrow form. Irradiation at a dose of ***1-10 Gy*** is accompanied by the development of a bone marrow form of ARS, which, depending on the magnitude of the absorbed dose, varies in severity. When irradiated with a dose of up to ***250 rad, 25%*** of those irradiated may die (*without treatment*), with a dose of ***400 rad*** - up ***to 50%*** of those irradiated, a radiation dose of ***600 rad*** or more is considered absolutely lethal.

Chronic radiation sickness is a general disease of the body that occurs with prolonged, systemic exposure to small doses of ionizing radiation (*above safe levels*).

It is difficult to strictly distinguish the degrees of severity of the disease, but chronic radiation sickness is conditionally classified as ***mild (I), moderate (II), severe (III) and extremely severe (IV)***.

Chronic radiation sickness from external radiation of II, III and especially IV degree of severity is rarely diagnosed under modern conditions of strict radiation dose control. Its development is more likely with accidental inclusion of long-lived radioactive substances. The radiological parameters of soils, bottom sediments and waste materials are assessed through analysis [16].

IV. Conclusions,

Combined radiation damage will be observed relatively frequently in various radiation incidents, as they are usually accompanied by explosions, frequent fires, release of various harmful chemical substances into the atmosphere, etc.

The consideration of this problem is of interest because of its peculiar course. The practical experience gained by the survivors of such injuries in previous nuclear accidents is not sufficient to form general conclusions. This necessitates the use of experimental results obtained from animals, modelling different forms in type and degree of the relatively large range of combined radiation injuries. These experimental results are extrapolated to humans while observing the dependencies in the biological scale. Reasoned opinions are expressed that pure radiation injury will rarely be observed in accidents. A striking example, in addition to frequent injuries, is the combined injury of the body with a radiation factor and fire gases. In this regard, not only their in-depth scientific study is necessary, but also familiarization of medical personnel with the main features of their course.

In general terms, combined radiation damage to the body in accidents can be divided into two main groups:

- combined damage from radiation factor and mechanical or thermal trauma;
- combined damage from radiation and chemical factors.

Combined radiation damage and mechanical or thermal trauma are characterized by some common features that need to be paid ¬attention to. One of the characteristic features is that the damage occurs against the background of an altered reactivity of the organism. Lethality increases 1.5-3 times compared to pure radiation exposure. Early development of radiation sickness and a significant shortening of the latent phase are observed. This is important from a surgical point of view, because the time for surgical intervention is shortened.

Another feature is the frequent occurrence of shock. This explains the impact of radiation on the central nervous system and the disruption of its regulatory functions. In addition, hypoxia, which regularly accompanies radiation sickness, predisposes to rapidly manifesting and severe shock. In this regard, the severe psychological trauma that the radiation accident represents should not be ignored. Taken together, this leads to increased sensitivity of the body to various additional traumas.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 197-203

Israel as a Global Leader in Smart Agriculture: Technology Development and Transfer Mechanisms

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Abstract*—Israel has established itself as a global leader in smart agriculture, leveraging technological innovation to enhance agricultural efficiency and sustainability. This study examines Israel's contributions to smart agriculture and its mechanisms for technology transfer, with a particular focus on its cooperation with China. The topicality of this research lies in the growing global demand for sustainable agricultural solutions, driven by climate change, resource scarcity, and food security challenges. Israel's expertise in precision farming, drip irrigation, agri-biotechnology, and water resource management has made it a key partner in international agricultural development, with China serving as a prominent recipient of its technological innovations. The purpose of this study is to analyse the mechanisms and effectiveness of Israel's agro-technology transfer, assessing its impact on China's agricultural sector and its replicability in other national contexts. The research explores the role of public-private partnerships, government policies, innovation hubs, and financial protocols in facilitating international technology transfer. This study employs a mixed-methods approach, combining case study analysis, policy reviews, expert interviews, and on-site observations. Primary data was gathered through fieldwork at China-Israel Technology Transfer Centres, interviews with local agricultural stakeholders, and reviews of bilateral agreements. Secondary data includes government reports, legislative documents, and academic literature on technology transfer and smart agriculture. The findings indicate that Israel's structured, government-backed approach to technology transfer has led to successful adaptation and implementation of its agro-technologies in China. The China-Israel cooperation serves as a model for other nations, demonstrating the importance of strategic frameworks, knowledge-sharing platforms, and capacity-building programs in agricultural modernisation. However, challenges remain, including bureaucratic barriers, differences in regulatory frameworks, and the need for localised adaptations. This study concludes that Israel's technology transfer model represents a scalable and effective strategy for addressing global agricultural challenges. Strengthening international cooperation, fostering innovation-driven policies, and enhancing financial support for technology adoption are key recommendations for advancing global sustainable agriculture.

Keywords*— *Israel, PR China, smart agriculture, technology transfer.

I. Introduction

In an era of rapid population growth, climate change, and dwindling natural resources, the demand for sustainable and efficient agricultural practices has become a global priority. Smart agriculture, which integrates advanced technologies such as precision farming, data analytics, and resource-efficient solutions, is emerging as a critical response to these challenges. Among the global leaders in agricultural innovation, Israel has distinguished itself by developing and transferring cutting-edge agro-technologies that enhance productivity, water efficiency, and sustainability. Understanding Israel's advancements and mechanisms for technology transfer is essential for scaling these innovations globally, particularly in regions facing similar agricultural and environmental constraints.

Israel's agricultural success stems from its necessity-driven ingenuity, as the country has historically faced extreme resource limitations such as water scarcity and arid soil conditions. These constraints led to the development of pioneering solutions like drip irrigation, precision farming, agri-biotechnology, and vertical farming [11]. These technologies have been successfully

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8626
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transferred to numerous countries, particularly China, where environmental conditions and agricultural challenges mirror those of Israel [19]. However, the mechanisms of this transfer, as well as its effectiveness in local adaptation, remain almost unexplored [6].

A notable example of successful technology transfer is the China-Israel agricultural partnership, which has facilitated the implementation of Israeli innovations through joint demonstration farms, irrigation system adaptation, and knowledge exchange programs [18]. This cooperation underscores the significance of public-private partnerships, government policies, and international collaboration in advancing agricultural sustainability [9]. While previous studies highlight Israel's role in agro-innovation [2], [11], fewer have examined the practical aspects of bilateral technology transfer, financial agreements, and local adoption frameworks [10].

The purpose of this study is to analyse Israel's mechanisms of agro-technology transfer, assess their impact on China's agricultural sector, and explore how these strategies can be replicated in other national contexts. The research specifically examines the role of government policies, financial frameworks, and research institutions in facilitating technology transfer; the effectiveness of China-Israel cooperation in smart agriculture, focusing on case studies and real-world applications and the challenges of agro-technology adoption, including regulatory, infrastructural, and economic barriers.

Several scholars have analysed Israel's agricultural innovation and its impact on global sustainability. M.Singh [16] explores Israel's leadership in precision agriculture, while D.Abraham, Th.Ngog, J.Said and M.Yachin [1] provide insights into how Israeli technologies enhance resource efficiency in developing nations. X.Zhang and E.Lazin [19] offer a case study of Sino-Israeli agricultural cooperation, focusing on projects in Shandong Province, whereas M.Dor [6] examines China's growing demand for Israeli agro-tech solutions.

From a policy perspective, Y.Liu [9] and D.Guang [7] discuss how bilateral agreements shape technology exchange and innovation hubs. Studies H.Naftali [11] highlight the establishment of technology transfer centres, emphasising public-private collaboration. Meanwhile, W.Li [10] explores the financial and institutional challenges in implementing large-scale agro-technology projects.

By synthesising existing research, case studies, and field data, this study provides a comprehensive analysis of Israel's agricultural technology transfer model, its practical applications, and its potential for global adoption. Understanding these mechanisms is critical for enhancing international cooperation in agricultural sustainability and addressing pressing food security challenges worldwide.

II. Materials and Methods

The research utilised a multidisciplinary approach combining primary data collection, case studies, policy analysis, and literature review. This comprehensive methodology ensured a well-rounded analysis of the subject matter, incorporating both theoretical and practical insights. The key materials and methods employed are outlined below:

- Personal Experience of the Author. Firsthand observations during professional visits to China served as a foundational resource for this study. These visits included engagements with China-Israel Technology Transfer Centres, where Israeli agro-tech innovations are showcased and adapted to local contexts. Fieldwork also encompassed visits to local agricultural communities employing Israeli technologies, such as drip irrigation and precision farming systems. Semi-structured interviews were conducted with local government officials and agricultural stakeholders to gather qualitative insights into their experiences, perceptions, and future plans for incorporating Israeli technologies into their agricultural practices.
- Case studies Method incorporated detailed case analyses of cooperative initiatives between Israel and China (China-Israel Technology Transfer Centres, partnerships with local communities adopting Israeli innovations, and pilot projects implemented under bilateral agreements). Each case study provided a granular understanding of the mechanisms and outcomes of these collaborations. The data was drawn from project documentation, site visits, and interviews with key stakeholders, offering a multi-dimensional perspective on the technology transfer process.
- Study of Chinese Government Policy. An in-depth examination of Chinese government policies supporting the adoption of international agricultural technologies, particularly from Israel, formed a critical part of the research. This analysis focused on policy directives that encourage collaboration with foreign technology providers, such as subsidies for technology adoption, incentives for international partnerships, and the inclusion of Israeli technologies in China's strategic agricultural development plans. The long-standing history of Israeli-Chinese agro-tech cooperation was contextualised within China's broader agricultural modernisation goals.
- Study of Israeli Normative and Legislative Documents. The research reviewed Israeli policies, regulations, and financial agreements that facilitate international technology transfer, with a particular emphasis on bilateral agreements with China. Key focus areas included the Israeli-Chinese

financial protocol agreement, which governs technology exports, and the supportive legislative frameworks that ensure intellectual property protection and encourage public-private partnerships in the agro-tech sector.

- Literature Review. The study drew on a wide range of academic and mass media publications, industry reports, and government white papers addressing smart agriculture, technology transfer mechanisms, and Israeli-Chinese collaborations. These sources provided theoretical foundations, historical context, and comparative insights that complemented the primary data.

By synthesising these diverse materials and methods, the study offers a holistic understanding of Israel's leadership in smart agriculture and the mechanisms that underpin its successful technology transfer model, particularly in the context of Israeli-Chinese cooperation.

III. Results and Discussion

In the 21st century, the global demand for sustainable, efficient, and innovative agricultural practices has reached unprecedented levels. With challenges such as climate change, resource scarcity, and population growth putting immense pressure on traditional farming methods, nations are seeking transformative solutions to ensure food security and environmental sustainability. At the forefront of this revolution is Israel - a nation that has turned its harsh environmental conditions into an opportunity to become a global leader in smart agriculture [11].

Israel's journey to becoming a smart agricultural powerhouse is rooted in necessity. The country's arid climate, limited water resources, and scarce arable land forced it to innovate or perish [1]. This adversity-driven ingenuity led to groundbreaking technologies that have transformed not only Israel's agricultural landscape but also that of nations worldwide.

In this research, the term "smart agriculture" is understood within the Israeli context as the integration of advanced technologies and innovative practices into farming to enhance efficiency, sustainability, and productivity. This approach leverages data-driven tools such as sensors, drones, satellite imaging, and information technology to optimise the management of resources like water, fertilisers, and pesticides. Israeli smart agriculture priorities the efficient use of limited natural resources while focusing on increasing crop yields and reducing environmental impact [16].

By blending traditional agricultural knowledge with cutting-edge technologies, Israeli smart agriculture addresses key challenges such as arid conditions, water scarcity, and the need for sustainable food production. This practice not only enhances the economic viability of agriculture but also supports ecological preservation and global food security [1], cementing Israel's reputation as a pioneer in agricultural innovation.

One of Israel's most groundbreaking contributions to global agriculture is drip irrigation technology, pioneered by Israeli engineer Simcha Blass in the 1960s. Today, this innovation is utilised in over 100 countries and is celebrated as a transformative solution for water-scarce regions [16]. By delivering water directly to plant roots, drip irrigation minimises water consumption while maximising crop yields, enabling sustainable farming practices even in the world's most arid areas.

Israel has also taken the lead in developing precision farming solutions, incorporating advanced technologies like drones, satellite imaging, and sensors to monitor crop health and optimise resource use. These systems empower farmers to make data-driven decisions, reduce waste, and enhance productivity, setting new benchmarks in sustainable agriculture.

In agri-biotechnology, Israel has achieved significant milestones, including the development of drought-resistant and pest-resistant crop varieties. These innovations help farmers adapt to climate change and reduce reliance on chemical inputs, aligning with global efforts toward ecological sustainability.

Urbanisation and shrinking farmland have driven Israel to embrace vertical farming techniques that maximise output in limited spaces. Utilising hydroponics, aeroponics, and artificial lighting, these systems enable year-round cultivation in controlled environments. Similarly, Israel's advances in pest management — through natural predators and sophisticated monitoring systems — have reduced the need for chemical pesticides while maintaining ecological balance [1], [11], [16], [18].

Driven by environmental challenges and a commitment to sustainability, smart agriculture has become a defining feature of Israeli innovation. From pioneering irrigation technologies to advancing biotechnology and precision farming, Israel continues to transform global agricultural practices. Its ability to integrate technology with sustainable methods underscores its leadership in addressing modern agricultural challenges.

Through its pioneering work in smart agriculture, Israel not only addresses its own agricultural needs but also provides solutions to global challenges. The country's ability to integrate technology, sustainability, and efficiency positions it as a leader in the future of global agriculture [18]. Through partnerships, training programs, and technology transfer centres, Israel has empowered other nations to adopt and adapt its cutting-edge solutions to their unique agricultural challenges. A prominent example of international collaboration can be seen in the Sino-Israeli partnership in agriculture. Technological transfer in the field of crop production has established itself as historically robust, with the first transfers of Israeli technologies to China's agricultural sector dating back to the late 1970s.: Agricultural Demonstration Farm

in Shandong Province (1978, aimed at introducing Israeli irrigation and farming techniques to enhance crop yields and water efficiency), Drip Irrigation Systems in Xinjiang (1985), Flower and Vegetable Greenhouses in Beijing (1990). Additionally, the Beijing Sino-Israel Demonstration Farm, launched in 1993, showcased advanced Israeli agricultural technologies, such as irrigation, fertilisation, and greenhouse systems, to modernise farming practices [6], [19]. These early initiatives laid the groundwork for sustained cooperation in agricultural innovation.

The second wave of active agro-technology transfer occurred in the first decades of the 21st century, focusing primarily on innovative water resource management. Key projects from this period include the China-Israel Water City Project (2011), the Billion-Shekel Water Technology Export Agreement (2012; the export of Israeli water technologies worth over 1 billion of Israel shekel to China, focusing on aiding Chinese farmers with advanced irrigation and water management solutions), and the Shouguang Water Technology Demonstration City (2014), along with various other local initiatives [4], [6], [8]. These efforts emphasised sustainable water use and laid a strong foundation for addressing global agricultural challenges, further solidifying the partnership between Israel and China in agriculture.

Currently, this collaboration is experiencing its third wave. China has shown increasing interest in acquiring advanced technologies in areas such as sheep and goat breeding and milk processing for these animals. Other key areas of interest include smart agricultural production systems (such as online platforms and mobile applications), the development of biopesticides and natural fertilisers for land restoration, and innovative approaches to the preservation and processing of plant products [3], [9]. These modern advancements reflect the evolving priorities in the Sino-Israeli agricultural partnership.

Technology transfer is a complex and multifaceted process that requires consideration of numerous factors, including international and local legal frameworks, cultural and psychological differences, local customs, and the extent of support and permissibility provided by participating states. Over decades of practical collaboration, Israeli-Chinese technology transfers have established a variety of mechanisms that formalise and streamline these processes, often adapting to the specific needs of each project. These mechanisms, refined through experience, serve as models for effective collaboration. Below, we will explore the main approaches, recognising that each instance of technology transfer in the agricultural sector is unique, often combining elements from multiple mechanisms to achieve optimal results. Additionally, the influence of evolving bilateral agreements and emerging innovations has further diversified the methods used, reflecting the dynamic nature of this collaboration:

- The China-Israel Technology Transfer Centres (CITTCs) are a cornerstone in the transfer of Israeli agro-technologies to China. Supported by state and local governments, these centres, along with university innovation hubs and parks, play a vital role in fostering innovation, collaboration, and knowledge exchange. By 2024, China has established five technology transfer centres, three university innovation hubs, and two parks, focusing on green and smart technologies for sustainable agriculture. Key facilities include the China-Israel Changzhou Innovation Park (2014), Shanghai China-Israel Innovation Hub (2019), and Shenzhen Belt and Road Environmental Technology Exchange and Transfer Center (2021), complemented by local initiatives in Shandong, Fujian, and Hebei Provinces. Rooted in personal collaborations between Israeli researchers and Chinese partners, some centres even maintain offices in Israel, such as the Changzhou Innovation Park's office in Tel Aviv, facilitating direct access to Israeli startups. Supported by the Ministries of Ecology, Education, and Agriculture, these centres provide platforms for Israeli agro-tech companies to showcase and adapt innovations, promote joint research, and offer training programs and demonstration farms. Additionally, CITTCs often provide grants to Israeli specialists and startups, fostering a sustainable ecosystem for technology adoption. This system of CITTCs as active institutions aims to bridge Israeli innovation and China's agricultural needs, ensuring impactful knowledge transfer.Inviting Israeli Specialists for Joint Research and Development is a critical mechanism for technology transfer. These professionals collaborate with local researchers, farmers, and policymakers to adapt Israeli technologies to China's unique agricultural landscape. In projects like the Beijing Sino-Israel Demonstration Farm (1993), Israeli specialists trained Chinese farmers in using drip irrigation and greenhouse systems. This hands-on approach ensured the successful integration of technologies into local farming practices. The joint research on drought-resistant crops between Israeli and Chinese institutions (Ben-Gurion University of the Negev (Israel) and Huazhong Agricultural University (China), start 2015) has resulted in the development of crop varieties tailored to arid regions of China, combining Israeli genetic expertise with local agricultural knowledge [2], [12], [13], [14], [15];
- Private-sector initiatives play a significant role in driving technology transfer, with individual entrepreneurs and local

governments purchasing Israeli technologies for specific regional needs. The implementation of hydroponic systems in Weifang (2012), Shandong Province, by a local agricultural enterprise, showcased how Israeli innovations can improve the efficiency of vegetable production. This project utilised Israeli technologies for soilless cultivation, increasing yields and reducing resource consumption. The Dagan Demonstration Farm in Fujian Province (2013) introduced integrated fish and crop farming systems, utilising Israeli expertise to promote sustainable and profitable agricultural practices 10, [17];

- Inviting Israeli specialists to China for joint R&D projects and the training of Chinese professionals is a key component of China's broader strategy to integrate global expertise into its agricultural sector. This initiative aligns with China's "Thousand Talents Plan" (2008) and other national programs, such as The Medium- and Long-Term Plan for the Development of Science and Technology (2006–2020), The Agricultural Modernisation Plan (2016–2020), and The Regulations on the Administration of Introducing Foreign Intelligence (2020). These policies aim to attract international specialists across various sectors to accelerate China's modernisation efforts. Within agriculture, Israeli experts contribute significantly to precision farming, water-efficient irrigation, and biotechnology. Collaborative research projects, like drought-resistant crop development, and training initiatives in smart agriculture enable Chinese professionals to adopt and innovate upon Israeli technologies, fostering long-term sustainability and food security. [5], [8];
- The Israel-China Financial Protocol is a government-backed framework designed to finance large-scale technology transfer projects, fostering bilateral investment in advanced sectors, particularly agriculture. This mechanism facilitates agreements between Israeli and Chinese financial institutions, enabling the seamless adoption of cutting-edge technologies. A prime example is the Billion-Shekel Water Technology Export Agreement (2012), which provided significant funding for Israeli companies to export innovative water management solutions to China. These technologies were successfully integrated into large-scale agricultural irrigation systems across multiple provinces, mitigating water scarcity and enhancing crop yields. Beyond irrigation, the protocol has also supported projects in precision farming, agri-biotechnology, and smart greenhouse development, reinforcing the role of financial cooperation in advancing sustainable agricultural transformation and long-term food security in China [4], [6];
- Both Israeli and Chinese Government-Led Initiatives play an active role in promoting agricultural technology transfer through bilateral agreements, research funds, and policy support. The China-Israel Joint Committee on Innovation Cooperation in 2014 established a framework for collaboration in agricultural innovation, water management, and biotechnology, providing funding for joint projects that foster advancements in precision agriculture and sustainable farming. Additionally, China's Thousand Talents Plan and other national strategies actively recruit foreign experts, including Israeli specialists, to enhance local agricultural capacity. Government-backed technology transfer centres and financial protocols further streamline adoption processes, ensuring innovations are financially viable, scalable, and aligned with national development goals [7], [9].

Despite the significant benefits of agro-technology transfer and the clarity of its mission, vision, and expected outcomes, practical implementation through various mechanisms often encounters specific challenges. Table 1 presents the results of author's analysis of the advantages and difficulties associated with different mechanisms of agro-technology transfer. This assessment, based on the mechanisms employed in the transfer of agricultural technologies between Israel and China, provides insights into their practical application and highlights the complexities involved in achieving effective technology adaptation and integration. Each mechanism offers unique benefits while facing distinct challenges, requiring careful consideration and tailored approaches for successful outcomes.

China's experience in agro-technology transfer with Israel offers a valuable blueprint for global collaborations. Through mechanisms like technology transfer centres, government-supported innovation hubs, and joint R&D initiatives, China has successfully adapted Israeli technologies to meet local agricultural needs. These structures, supported by state funding and bilateral agreements, enable effective knowledge exchange, localised innovation, and scalable technology adoption. Replicating such mechanisms globally can enhance Israel's ability to share its advanced agricultural innovations with other countries. Establishing technology transfer centres, inspired by the China-Israel model, would create platforms for training, R&D collaboration, and

technology demonstration. Joint ventures, involving Israeli expertise and local partnerships, can address region-specific challenges like water scarcity or crop resilience. China's emphasis on structured, government-backed frameworks ensures both scalability and long-term impact. By leveraging these mechanisms, Israel can strengthen its global leadership in agro-technology, fostering sustainable agricultural development worldwide.

TABLE 1 BENEFITS AND CHALLENGES OF ISRAEL-CHINA AGROTECH TRANSFERRING MECHANISMS

Menchanism	**Benefits**	**Challenges**
China-Israel Technology Transfer Centers (CITTCs)	provide structured platforms for technology demonstration and adaptation; foster collaboration through joint R&D and training; supported by government funding, ensuring sustainability.	bureaucratic processes in setting up and operating centres; differences in technology adoption readiness across regions; difference in seeing the process of technology transferring, technology adoption and start-ups as a concept.
Private-sector initiatives	allows flexibility and rapid implementation; encourages innovation tailored to specific regional needs; facilitates direct investment.	lack of alignment with national policies can limit scalability; uneven results due to varying levels of local capacity.
Inviting Israeli specialists to China	builds local expertise and fosters independence in using Israeli technologies; scales up knowledge dissemination through trained local teams.	cultural and language barriers; high costs of deploying experts and ensuring continuity of their involvement.
Israel-China Financial Protocol	reduces financial barriers for large-scale technology adoption; encourages private and public sector partnerships.	complex financial arrangements may delay project execution; overdependence on subsidies can affect project sustainability.
Government-Led Initiatives	ensures alignment with national priorities; provides legal and financial support for large-scale projects; encourages long-term collaboration.	slower decision-making due to bureaucratic processes; limited flexibility in adapting technologies to specific contexts.

The examination of Israel's role as a global leader in smart agriculture highlights its ability to innovate under challenging conditions and its commitment to sharing these innovations through effective technology transfer mechanisms. Israel's advancements, such as drip irrigation, precision farming, and agri-biotechnology, address critical challenges like water scarcity, climate change, and sustainable food production. These technologies not only transform Israel's agricultural landscape but also significantly benefit partner nations. China's adoption of Israeli agro-technologies exemplifies the successful implementation of these innovations on a global scale. Mechanisms such as technology transfer centres, government-supported financial protocols, and joint R&D initiatives facilitate seamless collaboration and adaptation to local needs. The China-Israel partnership demonstrates how structured frameworks and bilateral agreements can enable technology transfer that is both scalable and sustainable.

Despite the successes, challenges remain in integrating Israeli technologies into diverse agricultural contexts. Differences in cultural, economic, and regulatory environments can affect the efficacy of technology transfer. Additionally, the high initial investment required for some technologies may limit adoption in resource-constrained regions. Addressing these challenges through tailored strategies, capacity-building initiatives, and long-term partnerships can further enhance the global impact of Israeli agro-technologies, solidifying Israel's position as a leader in sustainable agricultural innovation.

IV. CONCLUSIONS

Israel's experience in smart agriculture and technology transfer offers a strategic roadmap for countries striving to balance agricultural efficiency, sustainability, and economic viability. By fostering knowledge-sharing networks, adaptive policy-making, and investment in cutting-edge agricultural solutions, Israel's model serves as a cornerstone for future global agro-innovation strategies. Theoretically, the article contributes to innovation diffusion models by demonstrating how necessity drives technological advancement and adaptation. Israel's development of resource-efficient agricultural practices - exemplified by drip irrigation and precision farming - aligns with frameworks that emphasise the interplay between innovation, policy, and collaborative networks. The research reinforces that structured technology transfer mechanisms, such as technology transfer centres, government-led initiatives, and public-private partnerships, provide a replicable blueprint for enhancing global agricultural sustainability. These mechanisms not only validate existing theories on knowledge transfer and diffusion but also introduce nuanced perspectives on how cultural, economic, and regulatory environments shape technological adoption. Practically, Israel's experience offers tangible solutions to critical global challenges, such as water scarcity, food insecurity, and climate change. The systematic adaptation of Israeli innovations by partner nations, notably China, illustrates that tailored technology transfer can lead to improved resource management and heightened agricultural productivity. Initiatives like the China-Israel Technology Transfer Centres exemplify how localised implementation - backed by robust governmental support

and bilateral agreements - can transform abstract technological potential into concrete benefits for farming communities. These outcomes encourage policymakers and agricultural stakeholders worldwide to invest in similar models that integrate research and development with hands-on training and local capacity-building. Furthermore, the study highlights the importance of adaptive policies that accommodate the challenges of cross-cultural technology transfer, urging continuous refinement of support structures to overcome economic and regulatory disparities. In doing so, it establishes a clear roadmap for sustainable development initiatives that combine technological innovation with environmental stewardship worldwide.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 205-212

Critical Considerations for Advancing Sustainable People Mobility in Latvia: from Transport Poverty to Sustainable Mobility

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Abstract*—Sustainable transport provision in a country with low population density, a relatively small population and relatively low numbers of tourists is significant for transition toward a greener, more inclusive, and cost-efficient transport system. Latvia's transport policy aligns with the European Green Deal, which aims to shift towards sustainable and smart mobility. While prime concerns are carbon dioxide (CO2) emissions and developing a multimodal public transport network with rail as its backbone and inclusive mobility, transport poverty has not been a priority. To ensure truly inclusive mobility in terms of transport poverty as well, a holistic approach is needed—one that unites social and environmental considerations into transport planning through targeted subsidies, expanded rural transport services and equality in less populated and remote areas, and investments in multimodal infrastructure. The aim of this study is to analyze the current state of sustainable people mobility in Latvia, focusing on the interaction between environmental goals and active transport, accessibility and social equity. Particularly focus on the problem of transport poverty, which is a key challenge for achieving inclusive mobility, especially for the most disadvantaged populations. This study uses the transport poverty indicators mentioned in the European Commission's final report (2024) on transport poverty and data from various sources to identify the situation in Latvia and the European Union. Such a study has not been conducted before in Latvia. This study contributes to the growing discourse on sustainable mobility, highlighting the critical need to address transport poverty in the context of Latvia. Key findings include proposals for promoting active mobility and the transition to low-emission vehicle technologies, as well as how to make mobility more equitable. The results show that Latvia has made progress in reducing greenhouse gas emissions and implementing a public transport policy. Although obstacles such as uneven infrastructure development, the high cost of sustainable transport options and the lack of integration of urban and rural transport networks continue to perpetuate inequalities in mobility access.

Keywords*—green deal, rural mobility, sustainable people mobility, transport poverty.

I. Introduction

Transport sustainability is a critical pillar of sustainable development, encompassing economic growth, social inclusion, and environmental stewardship. A strategically planned transport system enhances accessibility while mitigating adverse effects such as pollution, energy consumption, and resource depletion. However, challenges persist—particularly in low-density regions such as Latvia's border areas, where limited public transport infrastructure contributes to social and economic marginalization.

This paper investigates the dynamics of sustainable mobility and transport poverty within the Latvian context. The analysis is informed by key policy frameworks, including European Union (EU) guidelines, Latvian national planning documents, and the United Nations Sustainable Development Goals (SDGs). Central to this investigation are the concepts of "sustainable transport" and "transport poverty", which require careful clarification due to their conceptual complexity and multidimensional nature.

The 2030 Agenda for Sustainable Development, adopted by all United Nations (UN) Member States in 2015, provides a comprehensive framework for global development, within which transport plays a cross-cutting role [1]. Several SDGs—such as those related to food security (SDG 2), clean water (SDG 6), sustainable cities and communities (SDG 11), responsible

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8622
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consumption (SDG 12), and climate action (SDG 13)—are directly or indirectly linked to transport systems. For instance, in Latvia, the improvement in access to quality drinking water from 75% in 2006 to 87% in 2019 [2] reflects broader infrastructural and societal shifts that impact transport needs and patterns. Additionally, the predominance of urban living (with approximately 70% of Latvians residing in urban areas) [3] underscores the importance of sustainable urban mobility strategies, including investment in clean technologies and active transport solutions.

The notion of transport poverty emerged in the early 2000s and has since evolved into a key area of research. Despite the diversity of definitions and methodological approaches, there is growing consensus that transport poverty—encompassing factors such as accessibility, affordability, adequacy, and social dimensions—constitutes a significant barrier to economic opportunity and social inclusion [4], [5], [6], [7]. This paper aims to contribute to the discourse by analyzing how sustainable transport policies can address transport poverty in Latvia and promote more equitable mobility outcomes.

II. Materials and Methods

This study uses qualitative and quantitative methods to evaluate promoted sustainable mobility options for people in Latvia in the context of transport poverty.

This study uses qualitative and quantitative methods to evaluate promoted sustainable mobility options for people in Latvia in the context of transport poverty. Latvia is a Northern European country, a member of the European Union, with a well-developed but evolving transport network. A total area of 64,589 km², a population of around 1.9 million [8] as of the latest data (2024), and a population density of around inhabitants 30 per km² (2024) [9], making it one of the least densely populated countries in the EU. The rail network has a total length of around 1,831 kilometers of which 14% is electrified in 2023 [10]. The total length of other transport infrastructure in Latvia includes 50,000 km of state and municipal roads, as well as 161 km of tram lines and 204 km of trolleybus lines in cities. Since 1990, the total length of these all-transport lines has decreased [11].

The Latvian Sustainable Development Strategy until 2030, in the context of the spatial development perspective, emphasizes the fundamental values of accessibility and availability, (Latvian: sasniedzamība), and individual domestic mobility opportunities for everyone in Latvia [12]. As the strategy was formulated 15 years ago with a target date of 2030, its orientations need to be reassessed considering the key themes addressed in this article, namely transport poverty, sustainable mobility and the green deal. It also raises the question of how far we are from the intended goals and what adjustments may be needed to adapt to the changing sustainability and mobility landscape.

The research methodology includes a policy analysis reviewing international, European and Latvian policy documents related to sustainable transport and mobility planning as well as transport poverty.

Transport poverty is characterized by compilation of the recommended indicators considering four dimensions: availability, accessibility, affordability and adequacy [13]. The method used for this purpose is descriptive statistics sourced from official statistics databases like Eurostat or National Statistical Institutes. The data sources selected for this purpose included time series from 2019 where possible and using the latest available data for comparisons and ranking of the indicators. The indicators of transport poverty were from the Household Budget Survey data (2015; 2016 and 2019), the National Travel Survey (2017 and 2021), EU Statistics on Income and Living Conditions (2019-2024), The Quality of Life in Cities survey (2017 and 2022), Urban Audit (2015, 2019 and 2023), European Union Labour Force Survey (2019 for module of commuting time). Use of comparison method of descriptive statistics was employed where possible with EU (27) averages and neighbouring countries – Lithuania and Estonia.

The indicators were compiled in a separate MS Word document, structured in two parts: Part I: Table 1. Analysis of the availability of transport poverty indicators in Latvia, providing an overview of the indicators identified in the literature for the different dimensions of transport poverty, based on the European Commission's final report on transport poverty, as mentioned earlier in the article. Part II: List of 14 indicators with appropriate coding from Table 1 presented in 18 tables, detailing the available reference years, country comparisons and breakdown. The document included references, enabling consultation of methodologies, additional breakdowns, and reference years for a more comprehensive analysis for experts.

In the next stage of the analysis, the experts carried out the assessment and ranking of the selected indicators. The expert group included four representatives of policy makers with experience in the field of transport policy and transport poverty, and two transport system users with contrasting perspectives: one of them represented a car-oriented perspective, car ownership and mobility in the Riga metropolitan area. The other was car-free, preferring active mobility and public transport.

The experts were invited to familiarize themselves with the dimensions and indicators of transport poverty and to rank the 14 indicators based on their relevance for measuring transport poverty in Latvia, with "1" being the most relevant and "14" the least.

In future studies, expanding the number of transport user representatives, especially from rural and remote areas, would increase the representativeness and depth of the study.

III. Results and Discussion

A. Sustainable transport

Table 1 describes the alignment of sustainable transport objectives with key policy planning documents at the global (UN), European and Latvian national levels,

highlighting their link to the SDGs and strategic frameworks that guide integrated transport planning.

TABLE 1 SDGS RELATED TO TRANSPORT TARGETS

SDG	Europe	Latvia
SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents (Road safety)	3.7 Road traffic fatalities remain stable, but the number of injuries is falling significantly, but mostly this SDG in Latvia is related to mental health and oncology.
SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.3 By 2030, double the global rate of improvement in energy efficiency (Energy efficiency)	7.2, 7.3. Promote low- and zero-emission vehicles through support for users and infrastructure, especially in cities, as part of broader plans for green and renewable energy through 2027.
SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all (Sustainable infrastructure)	9.1, 9.4., 9.5. Build an integrated, sustainable transport system, promoting the use of rail as the backbone of a modern and environmentally friendly public transport system. Digitalization as one of priorities.
SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.2 Ensure inclusive access to safe, affordable, and sustainable transport, especially through public transit, with a focus on vulnerable groups by 2030.	11.1, 11.2, Introduce a unified public transport ticketing system. New electric trains for passenger transport, phased in from 2022, mobility points at railway stations and stops. Increase train speeds. Priorities related to public housing and grants for renovations of housing.
SDG 12. Ensure sustainable consumption and production patterns	12.c Phase out inefficient fossil fuel subsidies that encourage overconsumption, by adjusting taxes and prices to reflect environmental costs—while considering national contexts and protecting vulnerable groups. (Fuel subsidies)	12.4, 12.5. Circular economy as priority in relation with waste management.

Regarding the Sustainable Development Goals and active transportation, a common approach is the implementation of greenways. In Latvia this term describes communication routes reserved exclusively for non-motorized journeys, usually former infrastructure of narrow-gauge railway lines around Latvia. Greenways can help achieve three goals: (1) nature conservation and maintenance of biodiversity by creating ecological corridors in urban areas [14]; (2) the provision of recreational spaces by providing areas for recreation, walking, running, and cycling in vegetated areas having trees, shrubs, and bushes [15]; and (3) active mobility by providing an opportunity for walking or biking instead of moving with motor vehicles [16]. Greenways play a significant role in advancing sustainable development by facilitating eco-friendly and non-motorized transportation modes and strengthening urban ecological resilience. In Latvia, their implementation into transport planning promotes active mobility while contemporaneously preserving natural ecosystems, enhancing public well-being and helping with transport poverty as well.

The main transport document in Latvia is Transport Development Guidelines 2021-2027. The objective of the transport policy is to provide an integrated transport system that provides safe, efficient, accessible, smart and sustainable mobility, contributes to national economic growth, regional development and ensures progress towards a climate-neutral economy. The definition follows: sustainable transport is putting the needs of transport users first by offering them more affordable, accessible, well-being-focused and low-emission alternatives to their current mobility habits [17]. This is only an official definition, but authors have established a more concise definition: sustainable mobility is environmentally and transport system user-available and accessible mobility.

The 2024 evaluation of Latvia's Transport Policy Guidelines indicates that the planned reduction in greenhouse gas (GHG) emissions in the transport sector has not been achieved [18], road transport and privately owned cars would undoubtedly impact that.

The transition to sustainable mobility in Latvia is characterized by the dominance of private cars in daily travel, largely driven by accessibility and affordability constraints as dimensions of transport poverty. In several areas, there are no comparable alternatives to private vehicles in terms of travel time or distance, creating similar challenges as in other countries. As climate goals require policy interventions, including restrictions on hypermobility in travel (French: hyper-mobilité) [19] and freedom of owning a private car, however empirically results from travel surveys already show that not only in Latvia, but also in France, distances traveled, and time spent on the road have been gradually increasing over the years suggests that people may be choosing to live further away from their workplaces due to rising living costs or preferring less populated areas.

An increase in key mobility indicators in Latvia between 2017 and 2021: the average daily travel distance per person increased to 32.2 km (+9%). The average daily travel time per person reached 80.1 minutes (+1%) and the number of trips per day increased by 4%. A similar gradual increase in these indicators has been observed in France, highlighting a broader European trend of increasing travel demand despite efforts to promote sustainable mobility solutions [20].

B. Transport poverty

In 2023, the European Union established the first definition of transport poverty in Regulation 2023/955 concerning the Climate Social Fund. Transport poverty is defined as the inability or difficulty of individuals and households to afford private or public transportation, or their limited access to the transport necessary for reaching essential socioeconomic services and activities. This definition considers the national and spatial context.

Since 2024, the concepts of energy poverty and transport poverty have gained increased attention at both EU and national levels, as National Social Climate Plans are being prepared, aiming to facilitate the implementation of the Social Climate Fund (SCF). This initiative addresses the social impact of climate policy by ensuring equal access to affordable energy and sustainable mobility. The SCF, established alongside Emissions Trading Schemes (ETS2), supports a fair transition towards climate neutrality by mitigating the social and economic impacts of carbon pricing. It provides targeted funding to EU Member States, ensuring that vulnerable groups, including those facing energy and transport poverty, receive direct support during the green transition [21]. Support to address transport poverty can be provided to initiatives that improve accessible and affordable public transport, as well as initiatives that promote access to zero- and low-emission vehicles and bicycles, providing more sustainable and inclusive mobility solutions [22].

In Latvia transport poverty is understudied and needs more research and case studies like in Slovakia, which is similar economically to Latvia (population density in Slovakia - 112 per km2, Latvia - 30 per km²) [8][23]. A significant portion of the rural region of Banská Bystrica faces public transport disadvantages due to high costs, limited availability, and inadequate connections, preventing same day return trips between rural municipalities and the regional center. As a result, residents of small rural municipalities, particularly those outside main transport routes, mitigate social exclusion by purchasing private vehicles rather than relocating. No similar studies have been carried out in Latvia, but based on statistical data, the situation is similar.

The latest National Travel Survey conducted in Latvia in 2021 revealed that 87.6% [24] of annual passenger kilometers were travelled by car. At that time, only 1,205 electric vehicles (EVs) were registered, accounting for just 0.16% of the total passenger car fleet. By 2024, this proportion has increased to 0.81% [25], reflecting the increasing shift towards EV adoption. However, the still dominant use of private cars, accounting for almost 90% of passenger kilometers, is not considered a sustainable mobility option and remains a priority to reduce through policy measures and alternative transport solutions.

Due to the structural limitations of the Latvian transport system, successfully implementing mobility changes necessitates active public engagement and behavioral adaptation through innovative behavioral (green nudging) policies at the city level [26]. Achieving this transition requires significant changes in mobility patterns, including changes in transport mode choices and possible changes in travel time forecasts [27]. Public engagement and awareness are crucial to fostering a more sustainable and adaptive mobility culture that is in line with long-term transport and environmental policy goals. Future mobility will move away from strictly defined modes of transport and the conflicts between them, focusing instead on complementarity, multimodality and intermodality [28]. There are three principles that contribute to the development of sustainable mobility. Firstly, a systemic approach combined with technological integration, using data exchange mechanisms between mobility stakeholders, is essential to improve coordination and optimize transport systems. Secondly, mobility in the future must be transversal, ensuring interconnection between transport modes (including private cars, public transport and active mobility) and between organizations. Transparent data exchange systems are crucial to facilitate informed decision-making and improve mobility management. Finally, the concept of rational mobility must be prioritized, striking a balance between hypermobility and immobility, promoting efficient and rational travel behavior [29].

Exploring the development of sustainable mobility in Latvia using available data sources, the main dimensions of transport poverty are highlighted (Fig.1), which underpin potential reduction strategies. Of particular importance is the reduction of passenger car dependency or the transition to low or zero-emission vehicles. However, such changes are contingent not solely on affordability factors but particularly on the adoption of electric vehicles (EVs). Furthermore, the availability of EV charging infrastructure and its geographical coverage are crucial in ensuring accessibility and feasibility. This perspective highlights the need for a holistic approach to sustainable mobility, incorporating both economic and infrastructure considerations.

The Latvian Sustainable Development Strategy until 2030, from the perspective of spatial development, underscored the importance of equitable access to public transportation services across all regions. The Strategy establishes minimum standards for public transportation, ensuring that residents can access regional centers daily. Additionally, by 2030, the Riga metropolitan region will benefit from enhanced road and street infrastructure to accommodate the rising traffic levels. There will also be improvements in public transport travel times, which will promote greater efficiency and accessibility.

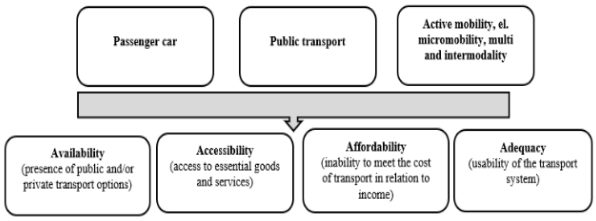

Fig.1. Modes of transport and their interconnectivity with transport poverty dimensions.

Considering the population at the beginning of the year and the positive demographic trends observed in early 2024 compared to 2023, the administrative territories within a 50 km radius of the Riga metropolitan area – Ādaži, Ķekava, Mārupe and Ropaži municipalities – which lack rail access, show a steady population growth and currently account for 7% of the total population. Commuters from these municipalities mostly rely on private cars when traveling to Riga, as public transport options are often not a viable or efficient alternative.

The expert ranking of transport poverty indicators presented in Table 2 ranges from 1 (most relevant) to 14 (least relevant) and includes 14 indicators that characterize transport poverty and its various dimensions. The abbreviations used in Table 2 for these dimensions are as follows: "Av" for Availability, "Acc" for Accessibility, "Aff" for Affordability, and "Ad" for Adequacy.

The outcome of the consultation with experts highlights the distance travelled per person per day (48.6 km) (indicator 2.2.) and travel time (69.4 minutes) (indicator 2.3.) as key indicators. Both indicators show increasing value for passenger cars, making them the dominant mode of transport compared not only in terms of distance, time but also regarding the number of trips, compared to other private and public transport options, except for trains.

Affordability is an important key dimension of transport poverty. According to expert ratings, the indicators monthly transport expenditure per household member in Latvia (62 euros) (indicator 1.2) and the percentage of people who cannot afford to purchase a personal car (10%) (indicator 5.1) received the same total score, highlighting their comparable importance in assessing transport affordability and financial burden. Another affordability-related indicator (1.1.1.), which complements the previous one, looks at the composition of household transport expenditure. It reveals that almost 90% of annual transport expenditure is spent on the purchase and operation of private vehicles, while only 1–4% is spent on public transport services.

Although 13 out of 14 indicators are objective measurements, one (indicator 5.1) is partly subjective. In addition, indicator 4.2.1, which reflects self-reported satisfaction with various aspects of transport, was rated as the least relevant by the experts in Table 2. However, integrating both objective data and subjective perceptions could provide policymakers with a more comprehensive understanding of transport poverty, providing deeper insight [30].

TABLE 2 RESULTS OF THE EVALUATION OF TRANSPORT POVERTY INDICATORS FOR LATVIA BY EXPERT RANKING AND DIMENSIONS

Ranking	Transport poverty indicator in Latvia	Dimensions
1	2.2. Average distance travelled per person per day by main mode of transport for short trips (<300 km) in 2017 and 2021 (kilometers) [31]	Av;Acc
2	2.3. Average time spent per person per day by main mode of transport for short trips (<300 km) in 2017 and 2021 (minutes) [32]	Av;Acc
3	1.2. Absolute expenditures on transport per household member per month in Latvia separately in urban and rural territories (euros) [33]	Aff
4	5.1. Persons who cannot afford a personal car in Latvia, Lithuania and Estonia and EU (2019-2024) (per cent) [34]	Av;Acc; Aff
5	2.1.1. Average number of trips per person per day by main mode of transport for short trips (<300 km) in 2017 and 2021 [35]	Av;Acc
6	1.1.1. Detailed composition of household consumption expenditure on transport goods and services (ECOICOP) on average per household member annually in 2015, 2016 and 2019 (euros) [36]	Aff
7	2.1. Proportion of number of short trips (<300 km) per year by main mode of transport in 2017 and 2021 (per cent) [37]	Av;Acc
8	6.5. Average walking time per trip to the nearest public transport stop (2017; 2021) (minutes) [38]	Av;Acc
9	6.3. Average commute time per trip (travel time between home and workplace) to work with private and public transport (2017; 2021) (minutes) [39]	Av;Acc
10	1.1. Proportion of goods and services related to transport of total household consumption expenditure in 2015, 2016 and 2019 (per cent) [40]	Aff
11	6.1.1. Proportion of people in employment with commuting time 30 minutes or over in 2019 (per cent) [41]	Av;Acc
12	3.1. Proportion of disposable income of households (with expenditure greater than zero) spent on transport goods and services by income quantiles in Latvia, Lithuania and Estonia and EU in 2020 (per cent) [42]	Av;Acc; Aff;Ad
13	9.2. Proportion of trips by public transport commuters as proportion of total commuter trips in Latvia and its urban area (2017; 2021) (per cent) [43]	Av;Acc
14	4.2.1. Self-reported satisfaction with public transport and other aspects of mobility in the cities and its functional urban area with chosen opposite categories: different set of indicators (per cent) [44]	Av;Acc; Aff;Ad

IV. CONCLUSIONS

The 2017 National Travel Survey analyzed the main reasons why people choose cars as their primary mode of transportation. The results revealed that 38% prioritized personal comfort, while 31% cited time efficiency as the main factor. Although the share of passenger kilometers by private cars remained similar to 2017 in 2021 (87.6%), no national survey has been conducted to assess whether individuals using private cars have reasonable alternative transport options.

The most recent statistical data available in Latvia comes from the 2021 National Travel Survey. However, this reference year directly follows the COVID-19 pandemic, a period marked by significant disruptions to mobility patterns due to lockdowns, increased teleworking, and changes in daily travel. Therefore, the 2021 data may no longer accurately reflect current travel behavior, highlighting the need for up-to-date empirical data.

In 2024, the Central Statistical Bureau submitted an EU grant proposal to Eurostat for a travel survey and study entitled: "Analysis of sustainable urban mobility in Latvian cities by 2026: current transport modal split and future growth potential for promoting greener transport solutions."

This study aims to evaluate current mobility patterns and examine opportunities to encourage more sustainable transportation alternatives in urban settings, with the objective of developing a methodology for identifying sustainable mobility options as substitutes for passenger car usage. The primary objective of this methodology is to analyze whether there are viable, rational alternatives (in terms of travel time, distance and travel costs) to passenger car use for trips made by Latvian residents. The analysis endeavors to evaluate the potential for reducing the high share of passenger car use in the modal split by understanding whether alternative sustainable mobility options, such as public transport, active mobility (walking, cycling) or shared mobility (car sharing), are realistic for the relevant trips. This will help urban planners to identify which factors, apart from comfort, municipalities can influence through infrastructure development, public campaigns, or policy measures. Along with the survey, a data collection on cycling infrastructure based on international standards is expected.

In addition to electric vehicles (EVs), active mobility and complementary transport access, there are several proven alternatives to private cars around the world. These include car sharing and carpooling, often combined with high occupancy vehicle (HOV) lanes that allow vehicles with two or more passengers (namely, the car occupancy rate in Latvia in the 2021 National Travel Survey was 1.7).

Other effective measures include zero emission zones (ZEZ) in urban areas, which significantly reduce car use, and express buses that operate in dedicated lanes, as well as express services from park and ride. In rural areas, solidarity buses and on-demand transport solutions have proven valuable in improving accessibility while reducing reliance on private vehicles.

There is a significant shift towards private transport, particularly passenger cars, and a decline in the use of public transport and bicycles. Electric micro mobility vehicles have emerged as a new mode of transport; however, they also contribute to longer commuting distances to workplaces (~50 km). The data also illustrates changes in mobility habits between 2017 and 2021, showing a notable shift toward private vehicles and active mobility while public transport usage has significantly declined. Passenger car trips increased from 46.9% to 52.4%. To sum up, these trends suggest a growing dependency on private and long-distance public transport, the increasing role of micro-mobility, and a shift in travel behaviors that may be influenced by urban planning, policy changes, or external factors like the COVID-19 pandemic. It should be stressed that the market for old cars is very notable, and the railway represents only 4% of the transport sector, while the personal vehicle sector accounts for 86% of road transport. Meanwhile, Latvia's car fleet, on average 15 years old, is one of the oldest in Europe.

As mentioned before in Latvia transport poverty is understudied and needs more research in all aspects not only with the focus on sustainability.

V. Acknowledgment

This research partly is funded by the Latvian Council of Science project “Assessment of Resources and Processes for Implementing Circularity and the Green Deal in the Tourism System (CirToS), project No. lzp-2023/1-0478.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 213-220

Sustainable Tourism and Climate Change: a Bibliometric Analysis of Environmental Impacts (2014-2024)

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***Abstract*—This article conducts a bibliometric analysis of research on sustainable tourism (ST) and its environmental and climate impacts from 2014 to 2024, using data from the Scopus database. The study explores trends, key contributors, and the relationship between sustainable tourism and environmental challenges. Two main themes are examined: 1) the environmental and climate impacts on sustainable tourism, which dominates due to the sector's vulnerability to climate change, and 2) the impacts of sustainable tourism on the environment, a growing area aligned with the Sustainable Development Goals (SDGs) and the Paris Agreement. The analysis identified 244 publications, with research output surging since 2018, reflecting the urgency of climate change. Studies on climate change impacts dominate, focusing on adaptation strategies, biodiversity loss, and resource depletion. Research on sustainable tourism's environmental impacts, though less prominent, has grown, emphasizing waste reduction, energy efficiency, and greenhouse gas mitigation. China leads with 36 publications, followed by the UK, Italy, and Malaysia. The UK and Sweden produce highly impactful research, while the US leads in volume but with lower impact per paper. Raihan, A. leads with four articles, followed by several authors with two each. Common themes include responsible tourism, ecosystem protection, and the need for effective policies. Citations have risen sharply, with 1,332 citations for 38 papers in 2024, indicating growing influence. The UK and Sweden have the highest citation-to-document ratios. "Climate change" and "tourism" are the most frequent keywords, showing strong interconnections. Sustainable development and environmental impact are also significant but less represented, indicating gaps in broader sustainability research. Sustainable tourism practices are essential to mitigate climate change and environmental degradation. Policymakers and industry stakeholders should prioritize sustainable practices and adaptation strategies. Increased international collaboration, interdisciplinary research, and funding are needed to address research gaps. Future research should focus on local climate impacts, social sustainability, and integrating sustainable development goals into tourism practices. Overall, the study highlights the critical role of sustainable tourism in addressing global environmental challenges and calls for integrated approaches to ensure the sector's resilience and sustainability.**

***Keywords*—climate action, environmental impacts, tourism development.**

I. Introduction

Research on sustainable tourism (ST) has increased steadily, especially after the adoption in 2015 of the United Nations Sustainable Development Goals (SDGs), 17 ambitious targets covering different areas such as poverty eradication, equitable education, climate action and sustainable consumption, with the aim of achieving sustainable development worldwide by 2030. They are intended as a comprehensive tool to promote economic, social and environmental sustainability [1].

Almost simultaneously, in December 2015, the Paris Agreement was signed as an international treaty to fight climate change. The agreement aims to limit global warming to 2°C (preferably 1.5°C) above pre-industrial levels by reducing greenhouse gas emissions and promoting sustainable development [2].

The focus on sustainability in tourism has increased as stakeholders seek to balance economic growth with environmental protection [3]. The urgency of climate change has further increased the number of these studies,

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8699
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particularly in relation to tourism's contribution to global emissions [4]. The IPCC report [5] highlights the dual role of tourism as both a contributor and a victim of climate change, calling for more research on sustainable solutions.

Bibliometric analyses have become a popular research method in sustainable tourism to identify trends in scientific publications, key researchers, networks and research areas [6] – [9].

The aim of this study is to conduct a Scopus analysis of articles on the climate and environmental impacts of sustainable tourism (STI) for the period 2014-2024, focusing on its impacts on the environment and climate, in order to explore the relationship of sustainable tourism to environmental challenges and opportunities to address them.

II. MATERIALS AND METHODS

The study uses data from the international database Scopus, indexes over 25,000 peer-reviewed journals, including those with high impact factors, ensuring broad coverage of high-quality research [10] – [13].

The search for publications was based on TITLE-ABS-KEY (impact AND sustainable AND tourism AND climate AND environment) with restrictions document type article (ar), conference paper (cp) for the period of 10 years from 2014-2024.

The selected articles were downloaded in "CSV Excel" format and a visual map was extracted using VOSViewer software [14].

The study applied quantitative research methods and bibliometric analysis techniques to conduct a systematic review of scientific publications on sustainable tourism, focusing on its environmental and climate impacts and possible solutions to mitigate the problems.

To achieve the research objective, the questions were answered in the following order [15]:

Q1: What are the research trends on STIs 2014-2024?

Q2: What co-authorship in different countries?

Q3: What is the information about co-occurrence with author keywords?

Q4: What is the co-occurrence of all keywords and the strength and importance of their relationships?

Q5: Which countries, organisations have more ST publications?

Q6: What are the number of articles and citations from 2014-2024?

Q7: What is the highest number of articles per author and their contribution?

III. RESULTS AND DISCUSSION

For **Q1**, the bibliometric sample identified 244 publications with TITLE-ABS-KEY (impact AND sustainable AND tourism AND climate AND environment) from 2014 to 2024. Conference paper and Article ratio is 1:4. Fig. 1 shows the evolution of number of documents on Environment and climate impacts of sustainable tourism and Environment and climate impacts on sustainable tourism from 2014 to 2024.

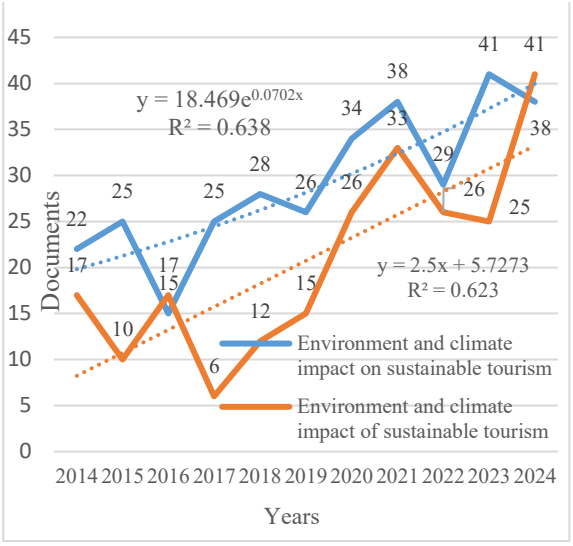

Fig.1. Environment and Climate and Sustainable Tourism Cross-Cutting Impact Papers, Scopus, (2014 - 2024).

Research on the environmental and climate impacts of tourism has long been a focus of attention in academia, and the number of studies has increased significantly since 2018. The number of papers is growing exponentially (R2 reaching 0.638 and 0.623), indicating a rising interest among academics in this field (Fig. 1). The urgency of climate change has further reinforced the importance of this research, particularly in relation to tourism's contribution to global emissions [4]. As evidence of this, a trend has been observed that while the number of studies on the environmental and climate impact of ST was almost twice as low until 2019, the increase in the number of studies surpassed that of studies on the environmental and climate impact on ST in 2023.

In order to compare research trends on the environmental and climate impacts of sustainable tourism and the environmental and climate impacts of sustainable tourism, it is important to understand that these two trends are interlinked but have a different focus:

1. Environmental and climate impacts on sustainable tourism

This trend is dominant because climate change and environmental degradation are pressing global issues that have a direct impact on the tourism sector. Research in this area focuses mainly on: the impacts of climate change tourism destinations (e.g. coastal and mountain tourism); adaptation strategies for the tourism sector in the context of climate change; environmental challenges such as biodiversity loss and depletion of natural resources. The reasons for dominance are, firstly, that climate change is one of the most important global challenges affecting all economic sectors, including tourism. Secondly, the

tourism sector is particularly vulnerable to environmental and climate change because it depends on natural resources and favourable climatic conditions [16] – [17].

2. Sustainable tourism impacts on the environment and climate

This trend is less pronounced, but it has become an important area of research, especially in the last decade. Research in this area focuses mainly on: the environmental impacts of tourism, such as waste generation, water and energy consumption; the adoption of sustainable tourism practices to reduce negative environmental and climate impacts; and the contribution of the tourism sector to reducing greenhouse gas emissions. The reasons for the lower dominance are firstly that the environmental and climate impacts of Sustainable Tourism is a relatively newer field of research that has developed with the growing awareness of the need to protect the environment and secondly that research on this trend is often linked to the Sustainable Development Goals (SDGs), which were only adopted in 2015 [18] – [18].

In response to **Q2**, the data provided on co-authorship across countries reveal interesting patterns in research output (measured by number of papers, "doc") and impact (measured by citations, "cit").

Key observations:

1) the USA has the highest number of docs (59), indicating that it is the most active in research among the countries listed; 2) the UK follows closely with 46 docs, indicating strong research activity; 3) Canada and the Netherlands are moderately active with 33 and 25 docs respectively; 4) Sweden is the lowest among the countries listed with 18 docs.

Research impact:

1) despite having the largest number of papers, the US has fewer citations (3,361) than the UK, suggesting that its research has the greatest impact or visibility in this area; 2) Despite having the largest number of papers, the US has fewer citations (3,361) than the UK, suggesting that its research is likely to have less impact per paper; 3) Canada has a high number of citations (2905), which is remarkable given its moderately high number of papers; 4) Sweden has a relatively low number of citations (1768), which is consistent with its lower number of papers; 5) The Netherlands stands out with a surprisingly low number of citations (57) despite having 25 papers, suggesting that its research may have limited visibility or impact.

Citation-to-Document Ratio (Impact per Document): UK: 94.17 cit per doc; USA: 56.97 cit per doc; Canada: 88.03 cit per doc; Sweden: 98.22 cit per doc; Netherlands: 2.28 cit per document; The UK and Sweden have the highest citation-to-document ratios, indicating that their research is highly impactful relative to the volume of output. The Netherlands has an exceptionally low ratio, suggesting that its research may not be widely cited or recognized.

Analysis of Co-Authorship Patterns UK Dominance in Impact:

The UK's high citation count and citation-to-document ratio suggest that its researchers are producing highly influential work. This could be due to strong collaborations, high-quality institutions, or a focus on impactful research topics; USA: High Output, Moderate Impact. The USA leads in document output but has a lower citation-to-document ratio compared to the UK and Canada. This could indicate a larger volume of research that is less focused on high-impact studies or may reflect differences in research dissemination and collaboration patterns. Canada: Balanced Output and Impact. Canada demonstrates a strong balance between output and impact, with a high citation-to-document ratio. This suggests efficient and impactful research practices. Sweden: Low Output, High Impact. Sweden's low document output but high citation-to-document ratio indicates that its researchers are producing fewer but highly influential studies. Netherlands: Low Impact Despite Moderate Output. The Netherlands' low citation count and citation-to-document ratio are unusual given its moderate document output. This could be due to factors such as limited international collaboration, less visibility in high-impact journals, or a focus on niche areas with lower citation potential.

Possible explanations for the observed patterns include:

1) *Networks*: countries with stronger international networks (e.g. UK, USA, Canada) may benefit from increased visibility and references;

2) *Research focus*: differences in research (e.g. theoretical and applied research) can affect citation rates;

3) *Institutional support:* access to funding, resources and high quality institutions can lead to greater outputs and impact;

4) *Publication practices*: differences in publication practices, such as targeting high-impact journals, can affect citation rates.

For **Q3.** Fig.2 by analysing the co-occurrence information with the authors' keywords, conclusions can be drawn about the thematic focus and interrelationships of the studies, that 1) the most popular keywords are "climate change" (148) is the most frequent keyword, indicating that climate change is the dominant theme in the studies. "Tourism (81) is the second most popular keyword, showing that tourism is closely linked to climate change. Other keywords, such as "impact," "sustainable tourism," "sustainability," "sustainable development" and "climate impact," are less frequent, but their correlation (total link strength) shows their importance in the research context; 2) the correlation (total link strength) between "climate change" and "tourism" (125) is the strongest a couple of them, indicating that the impact of climate change on tourism is one of the main areas of research.

"Tourism" and "impact" (41) also show a strong correlation, suggesting that the impact of tourism on the environment and society is an important topic. "Sustainable tourism" (22) and "sustainability" (16) are less prominent, but their association with other key words shows their importance in the context of sustainable development. "Climate impact" is less well represented as a keyword (11), but its association with other keywords indicates its importance in climate change impact studies.

Thematic groups and their meaning:

1) *Climate change and tourism*. Fig.2 "climate change" (148) and "tourism" (81) are the two most frequent key words with a strong interconnection (125). This indicates that research is mainly focused on the impacts of climate change on the tourism sector, such as changing tourism destinations, environmental changes and economic consequences.

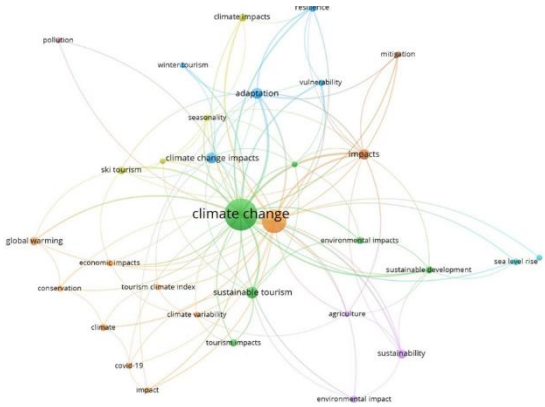

Fig.2. Co-occurrence with author keywords analysis map, Scopus, 2014 -2024.

2) *Sustainable tourism and sustainability.* "Sustainable tourism" (20) and "sustainability" (12) are less prominent, but their combination with other key words shows that sustainability principles are being explored in the context of tourism, especially in relation to climate change. "Sustainable development (8) is even less well represented, which may point to the need to promote more research on the integration of sustainable development in the tourism sector;

3) *Impact and climate impact studies:* "impact"(16) and "climate impact" (9) are less frequent, but more likely to be associated with other key words. These keywords are likely to reflect research on the wider impacts of tourism and climate change, such as environmental degradation, economic consequences and social change.

4) *Sustainable development.* "Sustainable development" (8) has the lowest frequency, but it is still an important link strength (15). This indicates that although sustainable development is not a central theme, it is still being explored in the context of tourism and climate change.

Analysis of research gaps and opportunities:

1) *Dominance of climate change and tourism*. The strong focus on climate change and tourism reflects the urgency of addressing environmental challenges in the tourism sector. However, this dominance may overshadow other important themes such as social sustainability and community-based tourism;

2) *Under-representation of sustainable development.* The low frequency of "sustainable development" (8) reflects a gap in research that explicitly links "tourism" and "climate change" to broader "sustainable development" goals (e.g. poverty reduction, gender equality and resource efficiency);

3) *Limited focus on climate impacts.* The relatively low frequency of "climate impacts" (9) suggests that specific studies on local or sectoral impacts of climate change (e.g. on coastal tourism or winter sports) may be under-represented;

4) *Opportunities for interdisciplinary research.* The advantages of moderating the link between "sustainable tourism" and "sustainability" suggest opportunities for more interdisciplinary research integrating environmental, social and economic aspects of sustainability.

Q4 *Co - occurrence to all keywords*. The analysis of co-occurrence with all keywords showed the following keywords, their strength and importance:

1) "Climate change." This is the most frequent keyword with 129 occurrences and an overall association strength of 347. This indicates that climate change is an important topic that is closely related to the other topics covered;

2) "Sustainable development." With 90 occurrences and a total linkage strength of 260, this keyword is also highly significant. It shows that the principles of sustainability are relevant in different contexts, including tourism and environmental protection;

3) "Tourism." Tourism occurs 77 times with a total association strength of 243. This indicates the importance of tourism, especially in relation to sustainability and environmental impact;

4) "Sustainability." This keyword has 51 occurrences and an overall commitment strength of 160. This shows that sustainability is an important aspect, especially in the context of tourism and environmental protection;

5) "Environmental impact." With 31 occurrences and an overall association strength of 143, this keyword highlights the importance of environmental protection, especially in the context of tourism and sustainability;

6) "Sustainable tourism." This keyword has 30 occurrences and an overall commitment strength of 92 shows that sustainable tourism is an important trend that combines tourism and sustainability principles;

7) "Tourism development." With 26 occurrences and an overall commitment strength of 86, this keyword highlights the importance of tourism development,

especially in relation to sustainability and environmental protection;

8) "Carbon emission." This keyword has 14 occurrences and an overall commitment strength of 51. It highlights the importance of reducing carbon emissions, particularly in the context of climate change and sustainable development.

Overall, these keywords show the close link between climate change, sustainability, tourism and environmental protection. They underline the need for sustainable development and environmental impact reduction, especially in the tourism sector.

For **Q5** the author analysed the ST publications most produced by countries and researchers. Top 15 countries with ST publications: China (36); United Kingdom (15); Italy (14); Malaysia (13); Greece (12); Germany (11); Indonesia (11); United States (9); Australia (8).

The Chinese Academy of Sciences is the leader when comparing the higher education institutions with the highest number of publications over the period (9). Universiti Kebangsaan Malaysia, University of Chinese Academy of Sciences, Tailor's University of Malaysia have four publications each, while Universidade do Algarve, Asian Institute of Technology Thailand, University of Piraeus, Oulun Yliopisto and Northwest Institute of Eco-Environment and Resources have three publications each.

In response to **Q6**, from 2014 to 2024, there were a total of 4,985 articles on sustainable tourism and its environmental and climate impacts in the Scopus database.

The study found that in 2024, four papers had 161 citations. Since 2020, the number of articles increased to 24 papers with 306 citations, and in 2024, 38 papers already had 1,332 citations.

Answer to **Q7**: The highest number of articles per author on the topic of environmental and climate impacts of sustainable tourism is four for Raihan, A., while Bausch, T., Du, J., Fleming, L.E., Grigiene, J., Ichisugi, Y., Itsubo, N., Karkour, S., Kitamura, Y., Panagopoloulos, T., Tuspekova, A., Wang, S. and another 13 authors had two articles each.

The author conducted a concise analysis of the contributions of authors with high citation value such as Asif Raihan, Thomas Bausch, Almagul Tuspekova and Shuxin Wang on sustainable tourism, its impact on the environment and climate:

1) Raihan Asif:
   - *Key focus:* The role and impact of sustainable tourism on the environment and climate;
   - *Research*: Sustainable tourism as a tool to protect the environment and mitigate climate change;
   - *Strategies:* Responsible tourism, ecosystem protection, public awareness;
   - *Benefits:* Environmental conservation, economic development, social well-being;
   - *Challenges:* Balance between tourist inflow and environmental protection, need for stricter regulations.
2) Thomas Bausch:
   - *Focus:* Sustainable tourism development and environmental and climate impacts;
   - *Research:* Reduced negative environmental impacts, climate change mitigation;
   - *Strategies:* Energy efficiency, renewable energy, waste reduction;
   - *Benefits:* Job creation, involvement of local communities;
   - *Challenges:* Need for effective policies and regulations.
3) Almagul Tuspekova:
   - *Focus:* Sustainable tourism development and environmental and climate impacts;
   - *Research: Sustainable tourism as a tool to protect the environment and mitigate climate change;*
   - *Strategies:* Ecotourism, green technologies, involvement of local communities;
   - *Benefits:* Job creation, preservation of cultural heritage;
   - *Challenges:* Balance between tourism and environmental protection, effective policies.

.4) Wang Shuxin:
   - *Focus:* Sustainable tourism development and environmental and climate impacts;
   - *Research:* Reduced negative environmental impacts, climate change mitigation;
   - *Strategies*: energy efficiency, renewable energy, waste reduction;
   - *Benefits*: Job creation, involvement of local communities;
   - *Challenges*: Need for effective policies and regulations.

Overall conclusions:

All authors stress the importance of sustainable tourism in protecting the environment and mitigating climate change. Common themes: responsible tourism, economic and social benefits, need for effective policies and regulations. Each author brings a unique perspective, but all agree on the potential of sustainable tourism to have a positive impact on the environment, climate and society.

IV. CONCLUSIONS

Q1. The bibliometric analysis identified 244 publications from 2014 to 2024, with a ratio of conference papers to articles of 1:4, indicating strong academic

interest in the impact of sustainable tourism on climate and the environment.

The number of studies has increased significantly since 2018, reflecting the growing relevance of climate change and its impact on tourism. This trend aligns with global awareness and urgency surrounding climate issues.

Research emphasizes the tourism industry's vulnerability to climate change and its dependence on natural resources, which drives the focus on mitigating environmental challenges.

Emerging Focus on Sustainable Tourism's Impact: While less pronounced, research on the impact of sustainable tourism on the environment and climate has gained traction in the last decade. This includes studies on sustainable practices, reducing greenhouse gas emissions, and mitigating tourism's environmental footprint.

The field's growth is closely tied to the Sustainable Development Goals (SDGs) adopted in 2015, particularly those related to climate action, sustainable cities, and responsible consumption.

By 2023, studies on the environmental and climate impact of sustainable tourism surpassed those on the impact of climate change on sustainable tourism, indicating a shift toward proactive solutions and sustainable practices in the tourism industry.

Global Relevance: The research reflects the urgency of addressing climate change and environmental degradation, underscoring the need for sustainable tourism practices to ensure the industry's resilience and long-term viability.

Key Implications: 1) The findings highlight the need for continued research and innovation in sustainable tourism to address climate change and environmental challenges; 2) Policymakers and industry stakeholders should prioritize sustainable practices and adaptation strategies to mitigate the tourism industry's vulnerability to climate change; 3) The alignment with SDGs reinforces the importance of integrating sustainable tourism into global climate action and environmental conservation efforts.

The dominant theme is "Environmental and climate impacts on sustainable tourism", highlighting the focus on how climate change and environmental degradation affect tourism destinations. Key areas of study include adaptation strategies, biodiversity loss, and resource depletion.

Future Directions: 1) Continued research is essential to address the dual challenges of mitigating tourism's environmental impact and adapting to climate change; 2) Emphasis on sustainable tourism practices and policies will be crucial in aligning with global sustainability goals and reducing the sector's carbon footprint.

Overall, the research highlights the critical interplay between sustainable tourism, environmental preservation, and climate change mitigation, underscoring the need for integrated approaches to ensure the sector's sustainability and resilience.

Q2. The UK and Sweden are notable for producing highly impactful research relative to their output. The USA, while leading in volume, may need to focus on enhancing the impact per paper. Canada demonstrates a commendable balance between output and impact. The Netherlands should consider strategies to increase the visibility and impact of its research, possibly through enhanced international collaboration and targeting high-impact journals.

These insights highlight the importance of not only increasing research output but also ensuring that research is impactful and widely recognized, which can be influenced by collaboration networks, research focus, institutional support, and publication strategies.

Q3. The research landscape is heavily focused on the impacts of climate change on tourism, reflecting the sector's vulnerability to environmental changes. There is a need for more balanced research that also addresses social sustainability, community-based tourism, and broader sustainable development goals. Specific studies on local or sectoral climate impacts are under-represented, indicating a potential area for future research. Interdisciplinary approaches that integrate various aspects of sustainability could provide more comprehensive insights and solutions for the tourism sector in the context of climate change.

These conclusions highlight the importance of broadening the research scope to include a more diverse range of themes and interdisciplinary approaches to address the complex challenges at the intersection of tourism, climate change, and sustainability.

Q4. The analysis reveals a strong interconnection between climate change, sustainability, tourism, and environmental protection. These themes are deeply intertwined, indicating that addressing one often involves considerations of the others. There is a clear emphasis on the need for sustainable practices across different sectors, particularly in tourism. This includes reducing environmental impacts, lowering carbon emissions, and integrating sustainable development goals. The research focus on the importance of the keywords used suggests that future research should further explore the intersection of these themes, focusing on the development of practical solutions for sustainable tourism and environmental protection.

The findings highlight the importance of policies and practices that promote sustainability and mitigate the impacts of climate change, particularly in the tourism sector. This includes strategies for sustainable tourism development and reducing carbon emissions.

These findings highlight the need for a holistic approach to addressing the challenges posed by climate change, ensuring that sustainability and environmental protection are an integral part of tourism and development strategies.

Q5. China leads significantly in the number of ST (Science and Technology) publications, with 36 publications, far ahead of other countries. This highlights China's strong focus and investment in scientific research and development.

The United Kingdom, Italy, Malaysia, Greece, Germany, Indonesia, the United States, and Australia follow China in terms of ST publications, though with significantly lower numbers. This indicates a global distribution of research output, with certain countries emerging as key contributors.

The Chinese Academy of Sciences is the top higher education institution with 9 publications, reflecting its prominent role in global scientific research. Other institutions, such as Universiti Kebangsaan Malaysia, University of Chinese Academy of Sciences, and Taylor's University of Malaysia, also contribute significantly but with fewer publications.

Institutions from Asia (e.g., Malaysia, China, Thailand) and Europe (e.g., Italy, Greece, Germany) are well-represented, indicating a strong regional focus on ST research.

The presence of multiple institutions with similar publication counts suggests potential collaborations or shared research efforts, particularly in regions like Malaysia and China.

Recommendations: 1) Countries and institutions with lower publication counts (e.g., the United States, Australia) could benefit from increased collaboration with leading countries like China and institutions such as the Chinese Academy of Sciences to enhance their research output; 2) Countries lagging behind in ST publications should consider increasing funding and resources for scientific research to compete globally; 3) Institutions in regions like Southeast Asia (e.g., Malaysia, Indonesia) are showing strong potential. Supporting these regions through partnerships and funding could further boost global ST research; 4) Institutions should explore interdisciplinary research and emerging fields within ST to increase their publication output and global impact; 5) Institutions with fewer publications (e.g., Universidade do Algarve, Asian Institute of Technology Thailand) could focus on capacity building, training researchers, and improving infrastructure to increase their research productivity; Governments should implement policies that incentivize research and development, such as grants, tax incentives, and academic-industry partnerships, to foster a culture of innovation and publication.

By addressing these recommendations, countries and institutions can enhance their contributions to global ST research and bridge the gap with leading contributors like China.

Q6. From 2014 to 2024, the Scopus database recorded 4,985 articles on sustainable tourism and its environmental and climate impacts, indicating a substantial and growing body of research in this field. The number of articles and citations has increased dramatically since 2020. In 2020, there were 24 papers with 306 citations, and by 2024, this number rose to 38 papers with 1,332 citations. This reflects a surge in academic interest and the growing urgency of addressing climate and environmental issues in sustainable tourism. The sharp increase in citations (from 306 in 2020 to 1,332 in 2024) suggests that recent studies are highly influential and widely referenced, highlighting the relevance and importance of this research area. The data underscores the increasing focus on the environmental and climate impacts of sustainable tourism, aligning with global concerns about climate change and sustainability. The rapid growth in publications and citations since 2020 indicates that this field is evolving quickly, with new research trends and findings emerging to address contemporary challenges. Key Implications: 1) The growing number of publications and citations reflects the critical role of sustainable tourism in addressing climate change and environmental degradation; 2) Researchers and practitioners should continue to prioritize this area, as it is gaining significant traction and influence in the academic community; 3) Policymakers and industry stakeholders should leverage this growing body of research to inform sustainable tourism practices and policies, ensuring alignment with global climate and sustainability goals.

Q7. Raihan, A. leads four articles, followed by Bausch, T., Du, J., Fleming, L.E. and 24 other authors with two articles each, highlighting their significant contributions to the field. All authors emphasize sustainable tourism's role in environmental protection and climate change mitigation. Responsible tourism, energy efficiency, renewable energy, waste reduction, ecotourism, and community involvement are widely recommended. Environmental conservation, economic development, job creation, social well-being, and cultural heritage preservation are key outcomes. Environmental conservation, economic development, job creation, social well-being, and cultural heritage preservation are key outcomes. Balancing tourism growth with environmental protection, stricter regulations, and effective policies are recurring challenges. Overall Agreement: All authors agree on the potential of sustainable tourism to positively impact the environment, climate, and society, while underscoring the need for robust policies and regulations to achieve these goals.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 221-227

Unlocking the Power of Process Management in Public Administration: a Theoretical Perspective on Implementation Benefits

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***Abstract*- Process management as an interdisciplinary field is developing rapidly, driven by its close relationship with information technology and artificial intelligence solutions for process automation and optimization. The increasing number of scientific publications on process management demonstrates its relevance across various fields, including social sciences, medicine, environmental sciences and others. In the context of public administrations, process management serves as a crucial tool for enhancing efficiency, transparency and service quality while ensuring an innovative management approach. This study aims to identify and summarise the potential benefits of implementing process management in public administrations, as presented in scientific articles, by employing theoretical research methods: the deconstruction method, the descriptive method and the synthesis-analysis method. The significance of this research lies in the increasing necessity for public administrations to enhance their adaptability to dynamic, socio-economic and technological challenges by delivering more efficient, data-driven services tailored to citizens' needs. The findings of this study indicate that the adoption of process management in public administrations can yield over 20 distinct benefits, encompassing both economic and social dimensions thus not only enhancing the operational efficiency of public administration institutions but also contributing to sustainable, innovative and results-oriented governance.**

Keywords- benefits, effectiveness, efficiency, process management, public administration, public sector.

I. Introduction

The role of public administration is reflected in its ability to ensure transparency, accountability and efficiency in its operations, thereby ensuring the social well-being of the country, economic development and the protection of human rights.

Treager and Jenkins [1] highlight that process management as a comprehensive and effective management philosophy is gaining increasing recognition. This is further supported by Truong et al. [2], who confirms that research on digital transformation and process management has attracted significant scholarly attention in the fields of business and management over the past seven years by conducting a comprehensive bibliometric analysis of global research on digital transformation and process management, based on an examination of 326 research articles from the Web of Science and Scopus databases covering the period from 2007 to 2022.

Gulledge and Sommer [3] emphasize that "process" is a word that means different things to different people, so their study conceptualizes a process as a chain of event-driven activities that span all functions of an organization. In contrast, Devenport and Short [3] define a process as a set of logically interrelated tasks designed to achieve a certain outcome. László [4] describes a process as a set of multifunctional, sequential activities operating within a given organizational, mechanical, and information system to generate added value for the end-user. While all definitions underscore that a process consists of distinct activities or tasks and follows a systematic approach to achieving a specific outcome, Gulledge and Sommer, along with László, adopt a broader perspective of a process that connects various organizational functions, whereas Devenport and Short present a more task-focused, narrower definition. This study does not challenge these existing interpretations. Instead, it adopts an "end-to-end" process definition, which conceptualizes a process as having a

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8676
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clearly defined beginning, a structured sequence of steps, and a specific intended outcome [5], [6] (a clearly defined end-product of the process).

Different studies present varying opinions on the key components of process management, for example, Gulledge and Sommer [7] describe process management as a structured approach encompassing process documentation to enhance understanding of workflow dynamics, the identification of process owners to establish accountability, process management to optimize activities, and process improvement initiatives aimed at improving the quality of outputs and overall performance. Beerepoot [8] expands that process management involves the analysis, design and administration of processes within an organization and across inter-organizational boundaries, integrating various information technologies. László [4] identifies the core tasks of process management as including process identification and definition (encompassing activities, their sequence, and the required competencies of process participants), assessment of process necessity, establishment of tools and metrics for performance evaluation, implementation of process monitoring systems, exploration of development opportunities, and managerial decision-making support. While all these perspectives emphasize the need for process analysis, documentation, administration, and continuous optimization to enhance efficiency and quality, a key distinction is that Beerepoot underscores the role of technology in process management, whereas László highlights the function of process management in supporting institutional decision-making – an aspect not explicitly emphasized in other frameworks.

Although process management methodologies have been widely applied in the private sector since the 1990s, their adoption in the public sector remains relatively recent and is still regarded as an innovative approach to public administration. The need for process management in public administration is driven by various external and internal factors, including the increasing collaboration between public and private sectors, necessitating adaptive changes in public governance [9], the limited financial resources [10], and the growing demand for digitization and service enhancement [1]. In addition to these driving forces, Gębczyńska and Wolniak [11] emphasize that the pursuit of greater operational efficiency has been a key motivator for public administrations to explore process management. Gabryelczyk and Jurczuk [12] argue that public administrations only began adopting process management after research indicated that substantial process reorganization and workflow restructuring were required to reduce costs and improve service quality.

This study seeks to address the question of what benefits the implementation of process management can offer to public administrations by systematically analyzing the scientific literature on process management and structuring the identified potential advantages of its application in the public sector, as documented in existing research.

II. Materials and Methods

The potential benefits of implementing process management are synthesized based on a selection of research articles identified through a keyword search using "process management in public institutions".

The study employs theoretical research methods, including the deconstruction method, descriptive method and synthesis-analysis method, ensuring a structured compilation of potential process management benefits and a systematic interpretation of the findings.

III. Results and Discussion

Based on the scientific article on process management research, the authors have identified and summarized a total of 22 potential benefits of process management implementation in public administration institutions (Fig. 1).

The benefits of implementing process management can be categorized into economic and social benefits. The economic benefits relate to the strategic planning and management of the institution, enhancements in performance, productivity and efficiency, as well as the optimal utilization of financial and material resources, process management and monitoring. These benefits are important for the institution's sustainable development. Social benefits relate to the impact of public administration activities on clients and society. These include the adoption of a client-centered approach, the improvement of public service quality, increased client satisfaction, strengthened public trust and the promotion of a positive institutional image. Furthermore, social benefits extend to the development and reinforcement of the internal organizational culture, encompassing social values and ethical principles. The authors have divided the identified potential benefits of process management implementation in public administrations into five categories: strategic management, institutional performance, process management and monitoring, client service, social values and ethics.

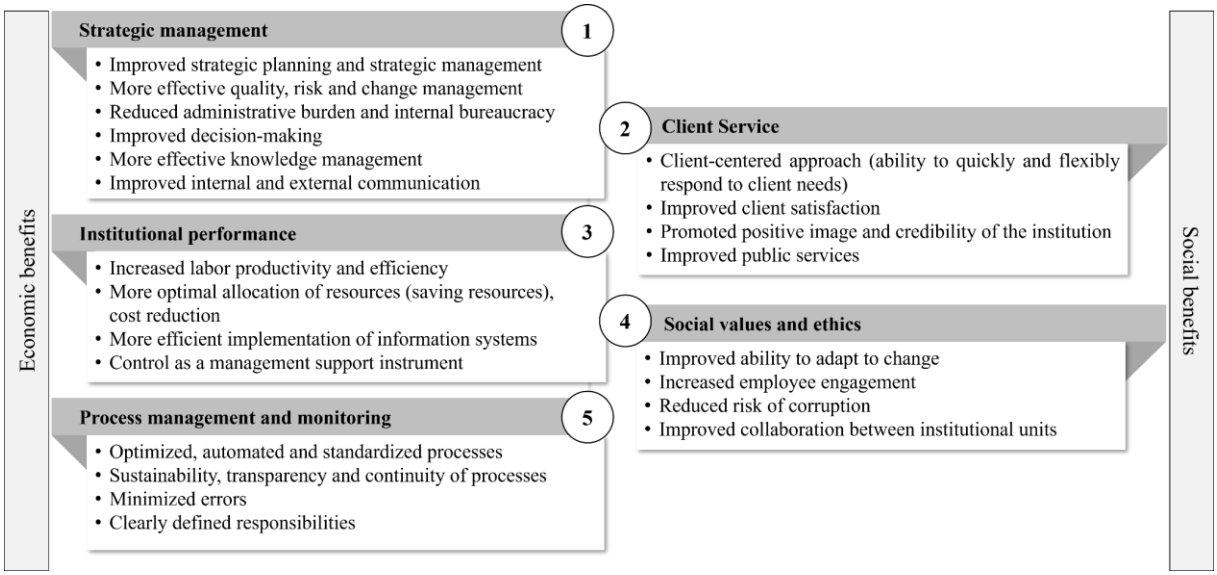

Fig. 1. Benefits of process management implementation in public administration institutions.

Strategic management. Mcbain and Chartered [13] emphasize that strategic management is a fundamental tool for public administrations to generate value for society and structure institutional operations. Furthermore, Pietrzyk et al. [9] highlight that dynamic changes in the organizational environment necessitate the adoption of innovative management approaches to enhance the effectiveness of strategic goal attainment.

Process management serves as a crucial instrument to support public administration leaders in improving strategic planning and institutional governance, by enabling data-driven decision-making through the measurement of process indicators and data analysis, it facilitates evidence-based management. Additionally, process management enhances communication within public administrations, both internally (among departments of the institution) and externally (between different public administration institutions). It aids in identifying informational barriers, cooperation gaps, administrative burdens and bureaucratic constraints.

Public administration managers play a pivotal role in the successful implementation of process management, as it is a long-term initiative whose benefits will not always be immediately evident. Effective implementation requires strategic vision and consistent action, as it entails organizational transformation and the adoption of new operational methodologies. Consequently, process management is inherently complex, posing various challenges for managers. Leadership research underscores a strong correlation between effective leadership and successful organizational management [14]. This suggests that public administration managers must possess robust leadership competencies [15] not only to guide strategic change but also to inspire and motivate employees to embrace and implement reforms. Beyond the necessity of strong leadership, Syed et al. [16] emphasize the importance of communication and managerial support in mitigating employee resistance to change, particularly concerns related to new work methodologies and approaches. This involves articulating a clear vision of the benefits of process management for public administration and fostering effective internal communication to engage employees and enhance their awareness of the need for transformation. However, leadership is not the only factor influencing the success of process management implementation. Fakhrutdinova et al. [17] highlight that for effective implementation, all public administration employees must possess a comprehensive understanding of process management principles, their significance and methodological foundations. In this context, the introduction of targeted training and professional development programs is essential to equip employees with the necessary competencies for effective process management. Furthermore, employee awareness of the potential advantages of implementing process management is a critical success factor [18]. When employees recognize how process management can improve their daily tasks and overall institutional performance, resistance to change diminishes and organizational support for the initiative increases. A holistic approach that integrates these factors – strong leadership, effective communication, employee engagement, and continuous professional development – is essential to ensuring the successful implementation of process management and fostering sustainable improvements in public administration performance.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8676
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Institutional performance. Ziemba and Obłąk [19] emphasize that the success of public administrations in increasing efficiency, reducing costs, improving service quality and increasing client satisfaction is fundamentally linked to the performance of their processes, as the institution is viewed not only through the lens of their functional structures but also as a network of interconnected processes. The primary advantage of implementing process management is increased efficiency and productivity of institutions. According to Gulledge and Sommer [7], this is achieved through the restructuring of work according to cross-functional processes. In the context of public administration efficiency, Koreňová and Cepelova [20] highlight the critical role of human resources, asserting that employees constitute the most valuable asset of public institutions. However, they are not the only one. Gabryelczyk and Jurczuk [12] highlight finance resources, time and information systems as key resources that support the effective execution of public administration functions. Process management methodologies such as Lean and Six Sigma reflect the concept of identifying and eliminating process wastes or non-value-adding activities. Within the public sector, this approach fosters the optimal utilization of budgetary resources, potentially leading to secondary benefits such as an enhanced institutional reputation and increased public trust in public administration decisions. Amidst the accelerating digital transformation, the digitization of public administration services has become a priority. This shift involves the integration of technological solutions and information systems to improve service delivery and operational efficiency. Kiss et al [21] caution that information systems should not be developed without prior process mapping, as the design and functionality of information systems must be aligned with institutional workflows, in otherwise system development may result in incomplete or inefficient information system implementations, necessitating continuous financial investments for future corrections and refinements. Process mapping or process flow diagram is a visual representation of the process or the flow of sequential process activities. Becker et al. [22] describe this approach as the "Picture-Method" because it visually captures the overall "process landscape". Additionally, Pietrzyk [9] underscores the significance of systematic monitoring and evaluation mechanisms as integral components of effective public sector governance. These monitoring mechanisms should be designed as a management support tool, equipping institutional management with real-time, data-driven insights to enhance strategic decision-making and overall administrative effectiveness.

Process management and monitoring. Gabryelczyk and Jurczuk [12] describe process management as an approach utilized by process-oriented organizations to promote process analysis, improvement, and control. This approach enables the systematic restructuring, optimization, and enhancement of process efficiency. One of the most widely adopted process management methodologies is Lean, which is based on three core principles: the elimination of wasteful resource usage (identifying and removing process losses), ensuring value for customers (focusing on processes that directly create value for the client/end-user), and continuous process improvement (ongoing analysis and optimization to reduce errors and increase productivity). Traditionally, Lean methodology identifies eight potential types of process wastes, however, Kadarova and Demecko [15], referring to research on Lean methodology in the public sector, identify six types of process wastes: defects (data errors, incomplete or missing information), overproduction (preparing unnecessary reports, performing unrequested tasks), waiting (unnecessary approval cycles and bureaucratic barriers that slow process progression), motion (excessive movement of personnel or documents), complexity (unnecessarily complicated actions or procedures), and transportation (inefficient file storage and document flow, hindering quick access to necessary information).

In the context of process improvement, the standardization and automation of processes play a crucial role. Standardization ensures uniform and consistent execution of processes, preventing potential variations, while automation enhances process efficiency, reduces bureaucratic procedures, and optimizes manual tasks. Gabryelczyk and Jurczuk [12] emphasize that the modernization of public administration institutions is fundamentally based on the integration of technology, which facilitates innovative services for citizens and supports organizational change. In this context, digital transformation, data analysis, and process automation must function in an integrated manner. Survey results from the study "The State of Business Process Management" indicate that 72% of respondents agree or strongly agree that the implementation of process management practices and technologies has improved their organization's operational efficiency and customer satisfaction [23]. These data underscore the significance of the synergy between process management and digitalization in improving organizational performance, particularly highlighting the need for modernization in the public administration sector. Kiss et al. [21] further emphasize that the primary goal of such modernization is to increase productivity and enhance process transparency.

Alongside technological solutions, clearly defined roles and responsibilities within the framework of process management are also of critical importance. Effective process management requires that all involved participants are aware of their duties and the boundaries of their responsibilities, as only a structured approach and precise task delegation can ensure the successful implementation of process management and sustainable change outcomes.

Client service. Public administration institutions need to provide high-quality services through which value is created for society. At the same time, this necessitates the continuous search for a balance between the needs of the citizens (or clients) and the resources of the public administration institution to ensure optimal service quality at the lowest possible cost. Luna et al. [24], in their study on the value of public digital services, highlight that focus group participants identified time and cost savings as the

most significant benefits of digital services. Digital solutions reduce the need for in-person visits, thus eliminating additional costs for citizens associated with receiving services, such as travel expenses, work delays, and potential lost income for businesses. This study illustrates the importance of digital services and their positive impact, but the full realization of these benefits is not possible without effective process management. Both service management and process management place significant importance on the perspective of the client, or the "Voice of the Client" (VOC) analysis, which enables the precise identification and understanding of client needs. This, in turn, promotes the targeted and citizen-oriented development of services. For public administration institutions working for the public good, service quality and continuous improvement are strategically significant priorities. Moreover, Anderson et al. [25] emphasize that enhanced and customer-tailored services lead to a series of positive side effects. For instance, high-quality public services promote citizen satisfaction with the functioning of public administration institutions, which, in turn, strengthens trust not only in the specific institution but also in public administration as a whole.

Social values and ethics. Schmiedel et al. [26] highlight that both practitioners and academics agree that organizational culture is a critical factor that can determine the success or failure of process management implementation. Moreover, the culture of process management itself plays a significant role in supporting the implementation of process management and the achievement of its goals, as well as ensuring the adherence to process management approaches in everyday operations. This also implies that the organizational culture should include values that promote the concept of process management, such as client orientation, excellence, responsibility, and teamwork.

Specific public administration institutions operate under a set of unified values. For instance, in Latvia, public administration employees adhere to values such as professionalism and efficiency, integrity, responsibility, working for the public good, sustainability, societal welfare, openness and accessibility of public administration, and cooperation within public administration [27]. Additionally, each public administration institution defines its specific values, which are typically included in the institution's operational and development strategy. These values form the foundation of the institution's internal work culture and promote employee engagement in achieving unified goals. A suitable organizational culture not only helps ensure the success of process management implementation, but process management implementation can also enhance the institution's organizational culture.

Pietrzyk et al. [9] emphasize that one of the most significant benefits of implementing process management in public administration institutions is the improvement of their adaptability to change, which is critically important in the dynamic and complex administrative environment. Process management not only provides greater flexibility in the operations of public administration institutions but also fosters strategic thinking and continuous adaptation to changing external and internal factors.

Implementing process management often requires significant structural and organizational changes. In a study on the challenges of implementing process management in the Swedish public sector, Lönn and Uppström [28] identified several factors that can influence successful implementation, such as organizational structure, initiative leadership, legal regulations, the impact of policies and management agendas, defining responsibility areas and the role of process owners, information management, lack of methodological approaches, fragmentation of information systems, issues with system integration, legacy and proprietary systems, routine, and education levels. These factors highlight the need for a systematic approach to change management that takes into account not only technological and administrative aspects but also employee engagement, proper communication, and strategic change management.

Furthermore, Matei and Gaita [10], as well as Koreňová and Cepelova [20], emphasize the essential role of process management in reducing corruption risks, as it promotes process transparency and accountability. Within the framework of process management, it is possible to implement monitoring mechanisms and internal control systems that allow for more effective identification and mitigation of potential corruption risks. Gębczyńska and Wolniak [11], Lönn and Uppström [28], and Kadarova and Demecko [15] further point out that process management improves not only communication between the parties involved in the process (process performers) but also fosters cooperation between different levels of public administration and within the institution itself. This aspect is especially important given that public administration processes form a complex, interconnected system, where support processes ensure the successful execution of core activities.

Despite the numerous benefits that process management provides, it is also crucial to address the challenges associated with its implementation and execution. Beerepoot [8] identifies several critical challenges in contemporary process management, such as determining the appropriate level of process detail that would balance process transparency with flexibility. The lack of objectivity in the creation of process descriptions, which can lead to interpretational ambiguities and affect collaboration between parties involved in the process, is also highlighted. Other significant issues include the complexity of process transformation, the need for a deeper understanding and expertise in the specific field, and the lack of employee engagement in process management. The latter aspect is particularly important, as a lack of employee-oriented process management can hinder the public administration institution's ability to effectively implement changes.

IV. CONCLUSIONS

1. Process management is becoming increasingly important in the public sector as a crucial tool for enhancing the efficiency of public administration institutions, the effectiveness of resource use, and improving employee productivity.
2. A key factor for the successful implementation of process management in public administration institutions is the level of readiness of the institutions, strategic management, strong leadership that drives and supports change, organizational culture, and employee attitudes and competence.
3. Process management in public administration institutions is not just about improving operational efficiency but often involves radical changes in operations, including the transformation of service delivery. Therefore, process management is not a one-time event but a continuous improvement over the long term, although it is considered a significant benefit for public administration institutions.
4. Properly implemented process management provides both economic and social benefits. It not only contributes to administrative efficiency but also fosters sustainable and results-oriented governance. Moreover, more transparent and efficient processes increase public trust in public administration, improving service quality and citizen satisfaction.
5. Public administration institutions must be prepared to face various challenges when implementing process management, such as inflexible organizational structures, complex bureaucracy, and a lack of cross-functional collaboration. Therefore, process management implementation strategies should include not only the application of technical and methodological approaches but also a systematic approach to employee involvement, knowledge management, and continuous process optimization.
6. This theoretical analysis lays the foundation for further research on the impact of process management on the operational efficiency of public administration institutions, service quality, and customer satisfaction, as well as the interaction of the benefits of process management, through quantitative analysis.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 229-234

Analysis of Scientific Research in the Library Sphere

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***Abstract*—The development of the library sector is closely linked to the advancement of information technologies and the processes of storing and presenting scientific research. Libraries serve not only as centers for collecting and disseminating information but also play a vital role in conducting scientific research and preserving cultural heritage. Scientific research in the field of library and information science encompasses a wide range of directions. The significance of these studies lies in the evolving role of libraries—not merely as repositories of knowledge, but as dynamic institutions actively supporting scientific inquiry and digital transformation. Furthermore, the analysis of dissertation trends provides a comprehensive understanding of national and international research priorities and reflects broader socio-economic and cultural changes. Understanding these trends is essential for shaping future library policies, educational programs, and innovation strategies. The purpose of this article is to examine the activities, scientific research, and outcomes in the field of library and information science. The article presents the findings of research conducted in this area, including a retrospective analysis of both foreign and domestic studies, as well as an in-depth review of dissertations related to the field. The study employs several scientific methods, including the analysis of statistical data, bibliometric analysis of global research in library science, and a detailed examination of research conducted in Uzbekistan. The essence of the retrospective analysis method lies in its ability to identify the most actively developing scientific areas and to draw conclusions about a country's political, economic, and cultural state based on the flow of dissertations. Moreover, it is essential to investigate the scientific priorities for the development of the information and library sector. Based on the analysis of scientific research in library science, it is possible to evaluate how the quality of library systems is improving and how these developments influence scientific and cultural advancement.**

***Keywords*—analytics, bibliometric analaysis, education, library science, research, scientometrics.**

I. Introduction

The introduction of information technologies, including digital technologies, into our society has brought significant changes in the field of librarianship, particularly through the organization of global computer systems and networks. These changes are currently the focus of library researchers worldwide. Such transformations are reflected in the scientific research of librarians both in our country and abroad. Today, the current state of librarianship, amidst ongoing innovative development processes, as well as the challenges related to libraries' adaptation to these changes, are regularly discussed in academic periodicals. In recent years, there has been a growing number of studies in the fields of computer science, information technology, digital libraries, information retrieval systems, and library services. Research conducted in these areas aims to explore how libraries can effectively integrate information technologies, improve the quality of services, and support knowledge creation in the digital age. It is

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8632
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crucial to provide recommendations based on the content of scientific works conducted in each field, reflecting the current issues within that domain. This includes the analysis of scientific work in the field of library science, examining development trends in foreign countries, and evaluating the efforts undertaken in this area within Uzbekistan.

The aim of this research is to examine the scientific studies conducted in the field of librarianship, determine the scope of the subject, analyze scientific research in the field of librarianship in developed countries from the perspectives of years, universities, and research topics, as well as assess the scope of scientific research and indicators of the subject scope in the field of librarianship in Uzbekistan. Furthermore, the study seeks to analyze the significance of research topics, the underlying causes of changes, and emerging trends in this field.

II. MATERIALS AND METHODS

In this study, the outcomes of scientific research conducted in the field of librarianship were examined through the following analytical approaches:

- Retrospective analysis of scientific research within the domain of librarianship;
- Bibliometric analysis of global scholarly publications related to librarianship;
- Analytical review of research activities and scholarly works in the field of librarianship in Uzbekistan.

A. Retrospective analysis of scientific research in the field of librarianship

Social changes within society significantly influence the content and direction of library activities, as well as the system of library services provided to readers. Events, conferences, and forums held across various disciplines-including librarianship-are increasingly focused on global issues, reflecting the current state of international librarianship. Scholars and professionals in the global library community emphasize the need to address challenges confronting libraries, anticipate future developments, and seek solutions to overcome the global crisis affecting the library sector.

Crucial, unresolved issues requiring scientific inquiry are regularly raised by scholars, researchers, and practitioners as topics of scholarly and practical importance. The outcomes of these research efforts are presented at academic conferences and symposia. Scientific advancements are reflected in the work of both international and national researchers, with the latest findings often documented in academic dissertations. Dissertations, by their nature, are regarded as original, unpublished scientific documents governed by intellectual property rights. The academic quality and thematic focus of dissertations serve as indicators of a country's scientific potential and are thus directly relevant to its current condition and future development. Through the analysis of dissertation trends, it is possible to identify the most advanced fields of science and draw broader conclusions regarding the political, economic, and cultural state of the nation.

Scientific research in the field of librarianship has a long and gradual history of development. While initial scholarly interest in the organization and management of libraries emerged much earlier, systematic and structured research in the modern academic sense began to take shape in the 19th and 20th centuries. Globally, the first notable studies in librarianship can be traced back to 1904. In Uzbekistan, scientific research in this field began to emerge by the 1960s.

Research into library automation started to gain momentum in the mid-20th century, marking a significant shift in how library operations were conceptualized and implemented. From the early 2000s onwards, the focus of scientific inquiry expanded considerably to include advanced topics such as the application of artificial intelligence, cloud technologies, digital libraries, big data analytics, and blockchain technologies in the library and information sector.

Overall, the state of scientific research in librarianship in both developed countries and Uzbekistan demonstrates a dynamic trajectory, with increasing attention paid to technological integration, innovation, and the evolving roles of libraries in the digital age.

B. Bibliometric anaylsis of research works on librarianship in the world

In recent years, the possibility of using ProQuest, EBSCO, Elsevir, Springer electronic foreign resources, databases of dissertations, including dissertations created in English in the field of scientific and educational resources created in the field of librarianship in developed foreign countries, including dissertations made it possible to study and evaluate. Including our country, Uzbekistan, has been subscribing to world information resources and using them on a large scale in the last few years [1]. The use of these databases allows to make conclusions about the latest achievements of science. It can be seen in many countries, including the USA, Germany, France and Spain, works related to the methodology and the philosophy of librarianship [2]. Among these, C.S.Finlay [3], T.Russell, C.R.Sugimoto [4], F.Shu [5], M. Buckland, C.R.Sugimoto, D.Lee, T.G.Russell, S.C.Finlay, Y.Ding [6] studies have covered similar topics.

Based on the analysis of research works by global scholars in the field of librarianship, the following key findings can be highlighted: The top ten universities of Canada and the USA, included Columbia University (5.5% of the total number of dissertations in the researched period), Florida State University (6.2%), Indiana University (4.7%), Michigan State University (5,3%), New Brunswick State University (4.3%), Rutgers State University of New Jersey (4.0%), City University of Chicago (5.2%), University of California (5.7%), University of Illinois Urbana-Champaign (6.5%),

University of Pittsburgh (9.0%), University of Toronto (3.5%) (Fig.1.)[7].

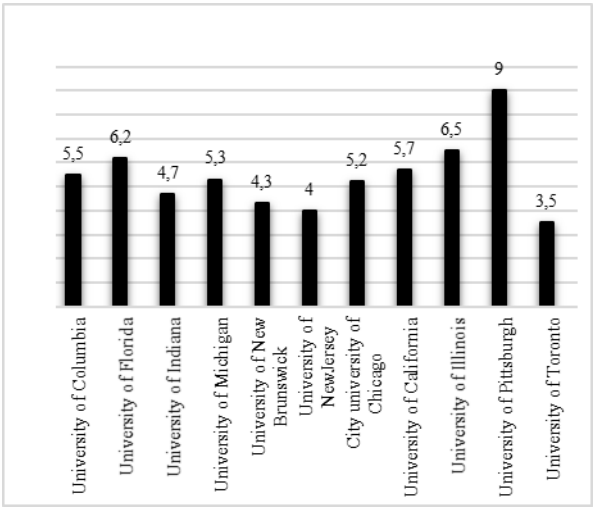

Fig. 1. Rates of dissertation defenses in librarianship at US universities.

C. Analysis of research works on librarianship in Uzbekistan

While studying the scientific research carried out in the field of librarianship in Uzbekistan, the analysis of the most relevant researched issues in the field was studied. While researching the topics of dissertations of a number of scientists, from 1969 to today, research works related to librarianship were tried to be covered on this purpose. The initial studies were mainly related to the history of librarianship, issues of development of network libraries in our country, these are: A.I.Kormilitsyn, A.Ya.Konarev, A.G.Kasymova M.Rakhimova, as well as the work of bibliography in Uzbekistan, M.Turapov, H.Mamatraimova, Book history in Central Asia and issues related to book studies was researched by M.Rustamov. The researches related to the study of librarianship in foreign countries have also been carried out, which were the works of Ibaragim Nazmi Mohamad Mukhsin, Raid Djamel Yakub Suleyman. In libraries, growing up the upcoming young generation and the studies of book reading in sociological aspects were carried out by A.O.Umarov, D.A.Ganieva and B.I.Ganieva [8].

As a result of the introduction of information technologies into the library field after 2000, several researches on the technologies used in libraries E.N,Bugibaev, bibliographic information re-processing in the corporate network J.A. Atadzhanov, issues such as ensuring information security Sh.B.Normatov and integration of library systems with other systems U.U.Karimov were carried out [9].

III. RESULTS AND DISCUSSION

In bibliometric analysis, the thematic focus of dissertations defended in the field of librarianship holds significant importance. Of these, 88 dissertations, or 2.8%, are dedicated to the theory of librarianship, while 269 works, or 8.6%, address the economics, organization, and management of library activities. Library management is closely tied to the issue of personnel training; in this regard, 263 research studies—accounting for 8.4%—have been conducted. Interest in this topic notably increased during the periods 1970–1979 and 1990–1999. Overall, the topics related to the management and organization of library services make up 17% of the total. In addition, 248 studies were conducted on library education, representing nearly 8% of the research output. Below, based on the analysis of global experience, the topics of scientific dissertations from the period between 1903 and 2004 are summarized in a table 1 compiled by the scholar Romanov.

TABLE 1. DISTRIBUTION OF DISSERTATIONS BY TOPICS 1903–2004 [10].

№	Topics	Total
1	Automation of library processes. Information technologies. Electron libraries.	745
2	School libraries	270
3 4	Organization of library work. Management. Economy.	269
5	Human resources. Librarian profession	263
6	Library services	261
7	Library education	248
8	Organization of library work abroad	234
9	Book studies. Book history	182
10	Organization of library funds	158
11	Cataloging Systematizing	155
12	Librarianship history	145
13	Bibliography	141
14	Reading. Interests of readers	110
15	Theory of librarianship	88
16	Technical equipment of libraries	18
	Total	**3285**

Research on the development of school libraries in foreign countries has played a significant role, with considerable attention being paid to the scientific investigation of library activities, particularly in relation to the growing generation. Notably, 745 dissertations, which constitute 23% of the total research output, focus on topics such as information technologies, electronic databases, automation of library processes, electronic libraries, and Internet-related subjects. Key issues, such as information retrieval by researchers, the formation of user requirements, and ensuring the compatibility of library services with the Internet, have emerged as prominent topics over the past 15 years. Furthermore,

over the last 25 years, intellectual property and copyright concerns have become critical areas of focus.

The history of librarianship, as well as works dedicated to librarian scholars, account for 145 dissertations, or 4.6% of the total research. Additionally, a significant body of work has been devoted to studying the state of librarianship in foreign countries, with 234 dissertations (7.5%) examining library practices across various regions. These studies primarily focus on library work in the Middle East, Africa, Southeast Asia, the former Soviet Union, and Southern European countries.

Approximately 10% of the research pertains to the development of library collections, including the completion of library funds, while 7.8% is dedicated to service-related issues within libraries. An analysis of recent dissertations indicates that nearly all aspects of librarianship have been addressed over the years, with variations of 5-10% annually, with the exception of information technology, which consistently represents 20.2% of the research output.

Recent research in the field of librarianship has included bibliometric analyses of leading organizations, prominent publishers, and key scholars, particularly M.Ashiq, S.Ur.Rehman, N.Ahmad, I.Atoum, M.Aqil, and S.Ahmad, among others. these analyses are presented and examined in scientific articles published by highly productive organizations within the field of librarianship [11].

According to it, the following organizations are defined as highly productivly organizations:

The top three contributing countries were the United States of America, Australia, and the United Kingdom, with 59, 46, and 41 articles, respectively. They also highlighted that most of the published papers were related to library management, library services, knowledge management, human resources management, and staff professional development. Furthermore, most contributions were from universities (267, 79.64%) and colleges/institutes (26, 7.43%). He depicts by the table the top 10 highly productive countries in terms of publications in the field of library. There are three countries with over 20 publications. The United States of America is at the top of the list with 313 publications (62.6%),17,191,269 citations, and 5.49 average citations. However, out of these 313 publications, 89 items have not been cited yet. The United Kingdom stands in the second position, with 27 publications (5.4%), 182 citations, and 6.74 average citations, followed by Canada with 25 publications (5.0%), 142 citations, and 5.68 average citations. It is interesting to highlight that Denmark has produced only nine publications; however, it has the highest average citations (11.78%). In contrast, India is at the bottom of the list, with eight publications and only five citations.

Additionally, Han X's research examined the evolution of research topics in library and information science from 1996 to 2019, utilizing the latent Dirichlet allocation topic model. The evolution of research topics in the field is presented in the following table 2.

TABLE 2. EVOLUTION OF RESEARCH TOPICS IN LIS BETWEEN 1996 AND 2019 [12].

The evolution of research topics over the years				
1996-2000	**2001-2005**	**2006-2010**	**2011-2015**	**2016-2019**
Digital library/services	Information retrieval	Citation analaysis/impact factor	Bibliometric analysis	Citation analaysis/impact factor
Academic library/librarianship	text processing	text processing	Research performance	Social media
Information systems/ Information management	Organizational information activities	Information retrieval/user	Citation analaysis/measurement	Organizational information activities
Citation analaysis/impact factor	Information systems	Organizational information activities	Scientific collobaration	text processing
Scientific collobaration	Digital libraries/services	Government	Citation analaysis/impact factor	Knowledge sharing
Information retrieval	www	Scientific collobaration	Information management	Government
Citation analaysis	Network communities	Semantic analysis/models and algorithms	Government	Organizational innovation/performance
Patent anaylsis	Technology application	Patent anaylsis	Online/community	e-commerce
Information-seeking behavior	Citation analaysis	Technology application	Organizational information activities	Mobile application
Information systems/design	Information- seeking behavior	Research performance	Ranking research	Knowledge management

This table illustrates that the initial research topics focused on areas such as digital libraries, services, and information management. After 2006, research topics expanded to include areas such as bibliometric analysis, impact factor, mobile applications, and artificial intelligence-based search systems.

During the research, the evolution of research topics in the field in Uzbekistan over recent years was analyzed using this model. The data is presented based on the following table 3.

TABLE 3. EVOLUTION OF RESEARCH TOPICS IN LIS UZBEKISTAN

The evolution of research topics over the years				
2000-2005	**2005-2011**	**2012-2016**	**2016-2020**	
Digital library/serv	Information retrieval	Mobile application	Citation analaysis/impa	

ices			ct factor	
Information systems	Information systems/design	Information retrieval	Bibliometric analysis	
Librariansh ip/school libraries	Digital libraries/service s	Technology application	Ranking research	
Academic library/libr arianship	Information systems	Scientific collaboration	Information retrieval/user	
Informatio n- seeking behavior	Information-seeking behavior	Scientific collobaration	Social media	

From these analyses, we can conclude that scientific research in the field of librarianship in Uzbekistan is still in its developmental stages and is gradually increasing. The topics of scientific research are also beginning to align with those of global research. In other words, when examining the evolution of these topics, we observe that they have slightly differed over the years. This can be attributed to the fact that the concepts of automated libraries and digital libraries began to emerge in Uzbekistan only after the year 2000.

TABLE 4. ANALYSIS OF RESEARCHES IN THE FIELD OF LIBRARIANSHIP IN UZBKEISTAN (1960-2024)

Researches' theme and number of each decade									
№	**Topics**	**1960-1969**	**1970-1979**	**1980-1989**	**1990-1999**	**2000-2009**	**2010-2019**	**2020-2024**	**Total**
1	Automation of library processes. Information technologies. Electronic libraries.				8	27	62	89	186
2	School libraries		2	5	11	16	12	23	69
3	Organization of library work abroad				2	3	12	18	35
4	Book study. Book history	9	12	37	23	12	10	9	112
5	History of book studies	3	2	25	8	12	19	18	87
6	Bibliography	16	15	25	19	27	18	13	133
7	Reading. Interests of readers	6	12	16	32	21	16	21	124
	Total								746

The number and topics of scientific works conducted by local scholars from 1960 to 2024 are summarized in the following table 4.

IV. RECOMMENDATIONS

In order to advance any field, scientific research plays a critical role, as science serves as a driving force for development. In particular, the study of the experiences of developed countries and the integration of innovative ideas into science and education provide a significant impetus for the overall growth of the sector.

In recent years, Uzbekistan's library sector has experienced notable progress, with increased scientific activity, especially in the context of digital transformation, library modernization, and the development of information and library services. Currently, the most relevant research directions in this field include:

- Study of International Experience – analyzing global best practices and their applicability to the local context.
- Support for Education and Science – exploring the library's role in supporting academic and scientific advancement.
- Digitalization of Libraries – including the digitization of collections, methods for preserving and providing access to rare and unique documents (particularly in national and university libraries), and the development of digital libraries, such as the National Electronic Library of Uzbekistan, studied in the context of accessibility and usage.
- Electronic Catalogs and Databases – research on the implementation of international metadata standards (e.g., MARC, RDA).
- Development of Libraries as Cultural and Information Centers – investigating the library's evolving role in community engagement and cultural preservation.
- Libraries in Higher Education Systems – analyzing how university libraries provide academic support and contribute to the development of students' and faculty members' information culture.
- Scientific Research Activities in Libraries – studying the role of libraries in fostering a research environment, particularly in the context of universities transitioning to international education standards.
- Issues Related to Human Resource Development and Professional Training – focusing on library staff development and continuing education.

Additionally, research into improving information literacy is increasingly relevant, including studies on training programs that teach users how to search for, evaluate, and use information effectively. Studies dedicated to the preservation of the nation's literary heritage also remain consistently important.

V. CONCLUSIONS

The development of research in the library sector is a crucial step towards modernizing libraries, enhancing their role in science, education, and society. By studying and analyzing the research experiences and topics in foreign countries, particularly the American school of librarianship, and comparing them with the current state of scientific research in the library field in Uzbekistan, the following conclusions were drawn:

- Strengthening the research base and establishing research groups at universities and major libraries (e.g., the National Library or university libraries);
- Establishing grants and competitions to support research in the fields of library science and information sciences;
- Supporting research, particularly at the intersection of librarianship, IT, sociology, pedagogy, and history;
- Developing international cooperation and organizing joint research projects with foreign universities and libraries, becoming more actively involved in programs by IFLA, EIFL, UNESCO, and other international organizations;
- Encouraging publications in international journals on library and information science;
- Developing human resources by creating platforms for the exchange of experience and research.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 235-240

The Impact of Nature Tourism on the Environment: Challenges and Solutions

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***Abstract*—Tourism is an important industry that can provide economic benefits, but at the same time also create negative impacts on the environment and local communities. The aim of this study is to assess the impact of tourists on the environment by analyzing various aspects related to the creation of nature trails, active tourism, pollution, and economic factors. During the study, various sources of information about nature trails and environmental quality were explored, as well as research and practical examples were used. The study found that the creation of nature trails is a promising opportunity for the development of nature tourism, but requires professional planning and a sustainable approach. It was also concluded that active tourism can have both positive and negative effects on the environment, so it is important to exercise caution and adhere to the principles of sustainable tourism. The study identified a pollution problem that can negatively impact the natural environment and tourism sustainability, and concluded that effective control and monitoring is necessary. It was also concluded that the economic potential of tourism must be balanced with the requirements of environmental protection and sustainable development. The results of the study show that sustainable tourism is possible if measures are implemented that promote environmental awareness, regulate tourist flow, develop environmentally friendly infrastructure, and promote cooperation between all interested parties. The results of the study are essential for understanding the impact of tourism on the environment and working out sustainable tourism development strategies that take into account environmental protection requirements and ensure a balance between economic, social and environmental interests.**

***Keywords*—*Creative industries*, *Environmental Impact, Latvia, Nature Tourism, Tourists, Virtual reality (VR)*.**

I. INTRODUCTION

To attract tourists, nature is used as a tourism resource, it is "a set of natural and man-made factors and events that attract the emotional, spiritual, physical and healing interests of tourists" [1]. Therefore, in many countries, nature is positioned as a valuable, unique tourist attraction. For example, Azerbaijan is known for its untouched nature: flora and fauna, mineral springs, geological monuments such as mud volcanoes, deep gorges, waterfalls, etc., because the country has 11 climatic zones where you can relax in all seasons [2]. The Latgale region (Latvia) could also gain competitive advantages as an international tourism destination, taking into account its geographical location, rich natural and cultural resources, and opportunities for international support in the development of tourism products [3]. The natural resources of Latvia are [4]-[5]:

- waters (rivers, lakes, springs, wells, etc.),
- forests,
- caves,
- meadows,
- swamps,
- rural landscape,
- flora,
- fauna.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8666
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Latvia's geographical location is suitable for biologically diverse development, and it is positive that bees, through pollination, also improve the agricultural environment, which promotes the development of agriculture and plant diversity [6]. However, tourism activities in nature are often associated with environmental pollution [7]. The aim of this study is to assess the impact of tourists on the environment by analyzing various aspects related to the creation of nature trails, active tourism, pollution, and economic factors. The study will use various information sources, research and practical examples to provide a comprehensive insight into the impact of tourism on the environment and the opportunities for sustainable tourism development in Latvia.

II. Materials and Methods

During the study, various sources of information about nature trails and environmental quality were explored, and the results obtained were supplemented with insights from research and practical examples over several years.

The results obtained during the development of the work were processed using three research methods:

- economic analysis method;
- the method of graphically displaying data;
- descriptive method.

III. Results and Discussion

Tourism is a dual industry. Tourism brings profit if the tourism product is sold profitably. However, tourism also has another side, i.e. its impact (both positive and negative) on the environment and local society. [7] (Fig.1). In order to attract tourists and visitors, it is recommended to combine the visit of the tourist trail with the educational and practical part about nature [6]. Currently, the creation of various nature, cognitive and educational trails is popular. There is a lack of information on how often environmental and tourism specialists are involved in the development of nature trails and other types of routes. As a result, for the purposes of "environmental improvement", the undergrowth which is important for birds and other species is cut down, for example, by turning the forest into a park [8] Overall, the development of nature trails and related tourism infrastructure can be assessed positively (Fig. 1). In addition, developing a trail is also a kind of tool for reducing the negative impact of tourism on the environment. However, man-made tourist attractions often degrade the environment if they are not maintained properly or are neglected [9].

Article 1 of the Tourism Law states that “Active tourism is a type of tourism aimed at active recreation and physical activities during travel” [1]. Active tourism (cycling, hiking, water tourism, etc.), where a person is most closely connected to the natural environment, i.e., moves through natural habitats and "wild" places where there is no infrastructure and is in closer contact with wild animals, can, in summary, cause much more negative impacts and consequences than a motorist who moves mainly through urbanized and semi-improved territories [8]. Therefore, the belief that active tourism types – cycling, hiking, water tourism, etc. – are environmentally friendly, while car tourism is an environmentally unfriendly type of tourism, is not always true.

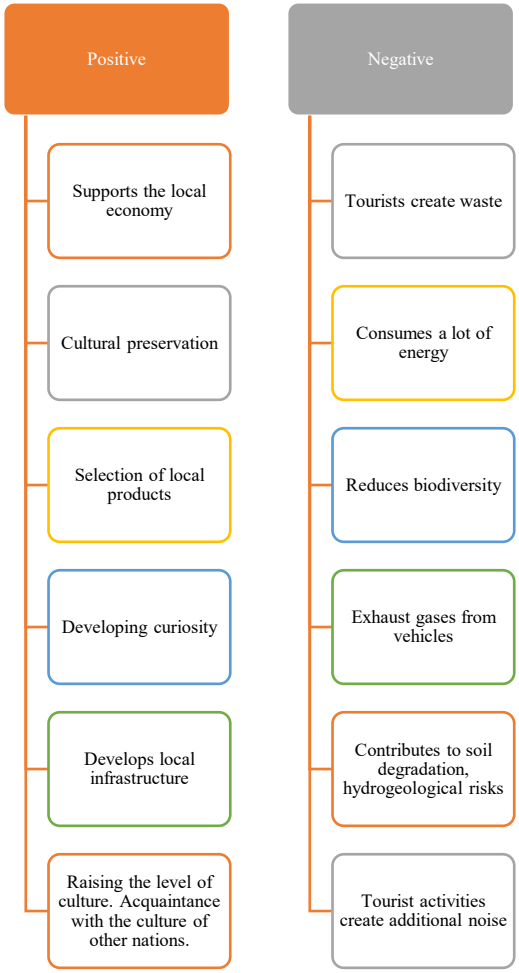

Fig. 1. Assessment of the impact of tourists on the environment [5], [7] - [8].

Humans cause environmental pollution through their activities, resulting in:

- Heavy metals are found in living organisms, for example, the presence of heavy metals in plants of the same field can be found in spring and not in autumn [10] – [14].
- By polluting the air, thereby worsening its quality [15] – [19].
- Using pesticides [20], which also contain substances hazardous to human health and nature [21].
- In the measurements carried out by the Center for Environment, Geology and Meteorology of Latvia, have found that in several sources and boreholes, pesticides have been detected in groundwater monitoring, the amount of which exceeds the permissible concentration norms, for example, in Vidzeme, Cēsis district, in two public sources - Lielā Ellīte and Dāvida dzirnavas source, where people like to take drinking water,

an excess of 10 and 50 times the norm of the herbicide bentazone has been found [22] – [23].

This pollution can negatively affect biodiversity, ecosystem stability and human health (Fig.2). In Latgale, which is rich in natural areas and popular with tourists, the problem of pollution is particularly acute. It is necessary to strengthen environmental monitoring and control to ensure that pollution levels are not exceeded, as well as to promote tourists' understanding of responsible behavior and environmental protection principles.

Tourism is a significant economic driver that can promote regional development by creating new jobs, increasing revenues from tourism services and attracting investment. As the price decreases, demand increases, which in turn encourages an influx of tourists, resulting in lower prices per tourist, which can make a given country or region more attractive to tourists, resulting in increased economic revenue. In turn, income generates wages, the more tourists, the higher the wages that will be paid, the more money will be returned to circulation. As income increases, there are also greater opportunities to attract investments. As a result, more money will be spent in local businesses, which will again contribute to the development of both the region and the country. However, 2016 in Latvia was marked by a negative trend, when income in the rural tourism sector decreased by 10 - 15%, which was facilitated by the state's tax policy, as there was an increase in the prices of services, including electricity, etc. [24]. Currently, Latvia is also experiencing an increase in prices, which is related to political decisions.

In the tourism industry, it is recommended to create competitiveness indicators in the following four categories [3]:

- indicators that measure tourism performance and impact;
- indicators that monitor the destination's ability to provide high-quality and competitive tourism services;
- indicators that monitor the attractiveness of a tourist destination;
- indicators that characterize support policies and economic opportunities.

A number of steps must be taken to create a nature trail, but it is important to remember that the choice and configuration of the site play a significant role in this process, as the trail must be accessible, safe, with a diverse nature, interesting, and, importantly, easy for visitors to navigate. The ideal length of a tourist trail is 3 km [6].

A nature trail is an attractive, valuable sequence of natural objects in a natural area, where a trail suitable for visitors has been created and the goal of which is to attract people to nature, to give them the opportunity to enjoy and explore it in an environmentally friendly way [26]. By creating a nature trail, tourists and visitors can not only enjoy the proximity and beauty of nature, but also gain new knowledge by exploring nature, plants, etc. [6]. One of the most influenced and interesting habitats in Latvia are caves – both natural and man-made. The life living in caves, accustomed to the constant underground world, is unable to adapt to their regular visits and disturbance, which is why the invisible part of the underground world has been lost – not only the lower plants and animals, but also bats, which in Latvian caves have decreased several times over the past ten years [8].

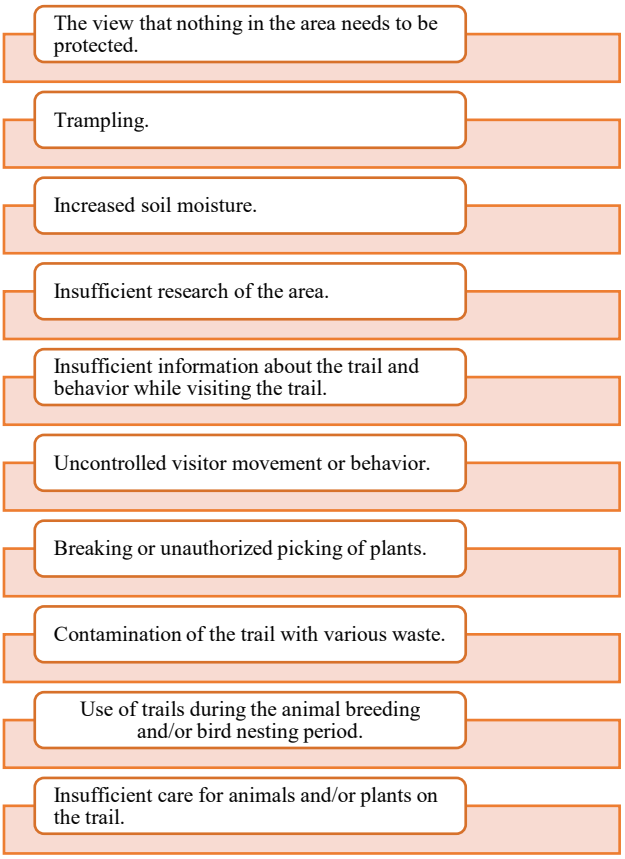

Fig.2. Conditions that pose threats to the environment on various trails [6] - [8], [13], [15], [25].

In every settlement, the number of tourist visits must be regulated in order to ensure both public order and a clean environment (Fig. 3). In order to regulate the number of tourists in a certain place, it is necessary to conduct research on the given region and plan the reception of tourists depending on the number of local residents, the number of accommodations, the level of service, catering options, the level of infrastructure development, and communications [7].

A popular compromise method is the creation of high-quality nature tourism infrastructure [8]:

- Directing the flow of tourists in the right direction at the right time, thus satisfying both the interests of tourists and the requirements of nature

protection. This is currently being successfully implemented in Latvia in specially protected nature areas.

- develop a tourism impact assessment or methodology for each specific location, case or object separately.
- Everyone should think (and, within their means, act) about creating nature tourism infrastructure.

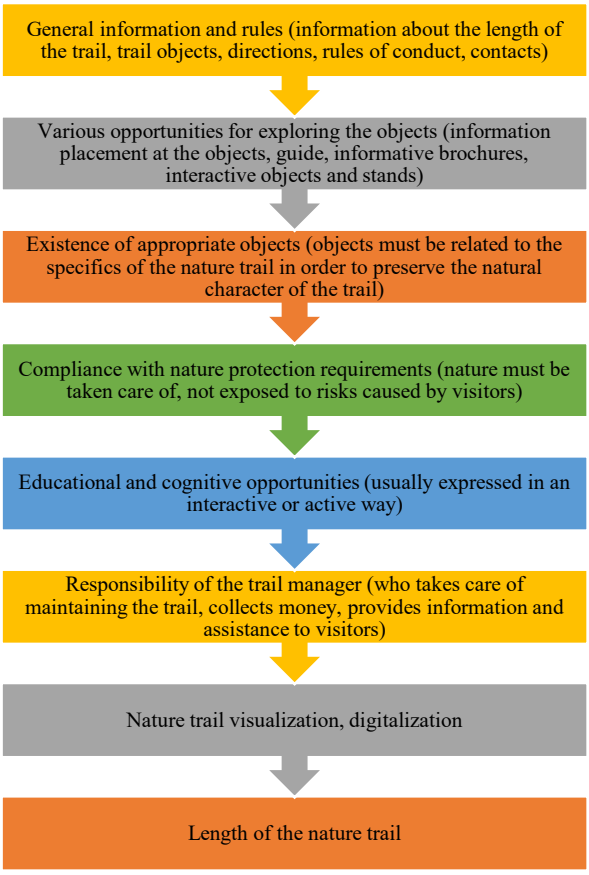

Fig. 3. Elements of nature trails [6] - [8], [15], [25].

There are several challenges in the tourism industry, such as providing a high level of service; positioning one's country as a tourist destination; building the tourism industry as part of the experience economy, developing tourism in a sustainable way; increasing the value of existing tourism resources by learning to earn more with them; and maintaining the cleanliness and naturalness of the surrounding environment.

In order for tourists not to cause negative behavior to the surrounding environment, it is also important for tourists to observe several conditions (Fig.4). Correct behavior of tourists is:

- Choose a certified tour operator.
- Travel out of season: this helps reduce tourist concentration and pressure on the environment.
- Use public transport: it reduces carbon dioxide emissions.
- Buy local products: it supports the local economy and reduces transportation costs.
- Respect local culture: follow local rules and traditions.

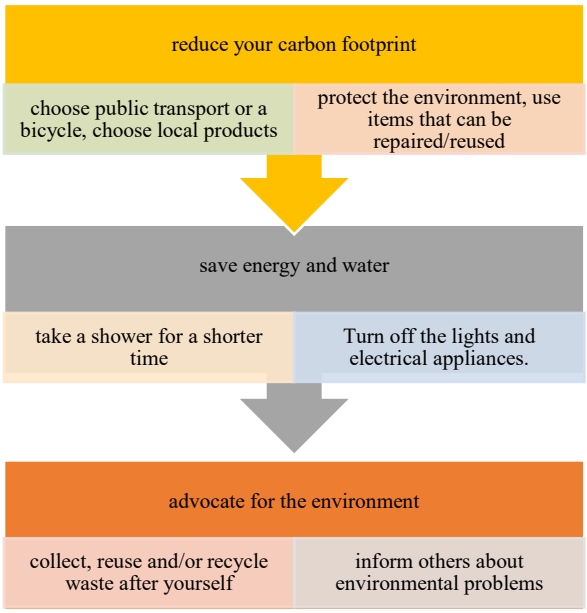

Fig. 4. Environmental improvement measures for tourists.

There is growing interest in the study of the relationship between people and the environment worldwide [27]. There is an increasing trend towards sustainable development in tourism that does not endanger natural, cultural and social resources [28], therefore it is important to seek environmentally and people-friendly and educational solutions. Action 1 of the Tourism Law [1] provides explanations of the terms used in the law, stating that "Nature tourism is a type of tourism whose purpose is to explore nature, view characteristic landscapes and habitats, observe plants and animals in natural conditions, as well as to educate oneself on nature conservation issues."

Virtual reality (VR) technologies are increasingly applied in sustainable tourism communication as a tool to provide emotionally engaging, informative, and non-invasive experiences of natural and cultural sites [29]. These immersive solutions allow users to explore protected areas, nature trails, or ecologically sensitive locations without physically being present, thereby reducing environmental degradation and visitor pressure on fragile ecosystems [30]. For example, VR-based tours of national parks or conservation zones can simulate real-world exploration while promoting environmental awareness and responsible tourism behaviour [31].

Moreover, VR enables the development of interactive educational programmes that simulate the consequences of environmental choices, helping users understand sustainability principles in a more impactful way. By combining learning with emotional engagement, such

experiences can foster long-term environmental consciousness and inspire visitors to adopt more sustainable behaviours in real life [32].

Integrating VR technologies into cultural tourism initiatives opens new possibilities for presenting lesser-known heritage – including minority traditions, endangered languages, and local customs – in an engaging and accessible format [33]. Interactive VR experiences can reconstruct historical scenes, traditional crafts, and everyday life practices, helping preserve intangible cultural heritage and make it more visible to a broader audience. Crucially, the creation of such content should involve local communities to ensure authenticity, cultural sensitivity, and shared ownership of the narrative [34].

These initiatives not only enhance the visitor experience but also contribute to reinforcing local identity and community pride [35]. By offering new platforms for storytelling and participation, VR tourism can empower regional actors, especially in areas with limited access to conventional tourism, supporting local economies and cultural entrepreneurship in alignment with sustainability goals [36].

The leading state institution in the tourism sector, responsible for the development and implementation of the state policy for tourism development, is the Ministry of Economics. The competences, functions and tasks that are binding on the Ministry of Economics in the field of tourism are determined by a number of regulatory acts, the main ones being the Tourism Law and the Ministry's regulations. The Department of Business Competitiveness of the Ministry of Economics is responsible for the tourism sector. The state administrative institution responsible for the implementation of tourism policy is the Investment and Development Agency of Latvia, which is directly subordinate to the Ministry of Economics and whose main task is to promote the recognition of Latvia as an attractive and safe tourism destination abroad, as well as to stimulate the development of the local tourism sector [37], which is also one of the main priorities of the tourism sector, in accordance with the Latvian Tourism Development Action Plan for 2021-2027, where great emphasis is also placed on the preservation of local values [38].

Nature tourism as a component of the tourism sector (industry) with its diverse opportunities and types has great potential, because Latvia, with its geographical location and rich natural resources, could attract not only local tourists, but also tourists from other countries. It is increasingly being said that the government should be more involved in regional development, however, support from the state and local governments is still not sufficient to make maximum use of the available resources.

IV. CONCLUSIONS

The creation of nature trails is a promising opportunity for the development of nature tourism, but requires professional planning and a sustainable approach.

Active tourism can have both positive and negative impacts on the environment, so it is important to exercise caution and adhere to the principles of sustainable tourism.

Pollution is a serious problem that can negatively affect the natural environment and the sustainability of tourism, therefore effective control and monitoring are necessary.

The economic potential of tourism must be balanced with the requirements of environmental protection and sustainable development.

Sustainable tourism is possible if measures are implemented that promote environmental awareness, regulate tourist flows, develop environmentally friendly infrastructure, and promote cooperation between all stakeholders.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 241-247

Building a Morphological Model for Determining Hazards in the Working and Surrounding Environment

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***Abstract*- The paper presents a new morphological model for determining occupational and environmental hazards. The modern terminology and the complex of concepts intended for determining a hazardous and safe environment are examined. A classification of hazards is proposed depending on their origin and a morphological model is built. The latter can be used to determine hazards in the working and surrounding environment. Its significance is expressed in the possibility of transforming the ongoing phenomena into the effect of a defined hazard. Occupational and environmental factors in industrial enterprises are systematically presented in the following figures. Each production system operates in the conditions of a specific occupational and surrounding environment and can be represented by a generalised cybernetic scheme. In it, the control object is characterised by a large number of input control disturbing factors and output parameters. Their interaction is characterized by functional and non-functional inputs and outputs, respectively. When defining the hazard, the interaction of production systems with the working and surrounding environment or with other systems is taken as a basis. Presented are System S_1 for a production system at an industrial enterprise and S_2 for a system of its environment, which can be natural, artificial, urban, other production (human-machine) systems, etc. The environment S_2 is safe when the output impact factors (functional and non-functional parameters) created by the production system S_1 do not create hazards. The presented morphological model in industrial enterprises reflects a situation represented by the chain 'phenomenon → action → effect' described in a tuple. The process of building a morphological model for determining hazards in the occupational and surrounding environment of industrial enterprises goes through the following three stages.The universality of indicated morphological model application is dictated by the consideration of actually existing environmental factors and the transformation of the hazardous phenomenon into a hazardous effect.**

Keywords – effect, environment, hazard, model, morphological, system.

I. INTRODUCTION

Our society is subject to the impact of numerous and diverse hazardous phenomena, situations and events.

Depending on the causes of occurrence, hazardous events can be classified as anthropogenic, natural and combined.

• **Anthropogenic hazardous events** are divided into production, social, political, mixed, etc.

- *Production hazardous events* are related to the labour activity of people aimed at obtaining socially useful products. They can occur at all stages of the life cycle of production. They are associated with the extraction of natural resources; production of materials, energy and goods; storage, distribution, transportation; consumption, maintenance, reuse; recycling; waste, destruction.

Incidents, accidents, breakdowns, and catastrophes are production and technological hazardous events characteristic for all stages of the life cycle of production.

- *Politically hazardous events* are military conflicts which lead to human casualties, destruction of settlements, large economic losses, refugee flows and a number of other critical consequences of a humanitarian nature. The reasons for them can be social, ethnic tension, religious conflicts, border incidents, satisfaction of domestic and foreign political interests.

• **Natural hazardous events** are disasters, and they are classified into three main groups:

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8677
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- *geotectonic disasters* – earthquakes, landslides, volcanic activity;
- *meteorological and climatic disasters* – storms, hurricanes, cyclones, tornadoes, floods, extreme warming or cooling, prolonged droughts, rainfall, snowstorms, icing, hail;
- *other disasters* – desertified territories, forest and steppe fires, invasion of insects and plant pests.

• **Combined hazardous phenomena** are observed when a natural disaster interacts with a hazardous technical accident on a given territory.

In the Bulgarian language, the main interpretation of the word ‘’hazard’ is the possibility of trouble, misfortune. This concept is used and applied in theories and models of industrial hazardous phenomena in order to describe them sufficiently fully and at the same time understand them in principle.

Each of the hazards has a source that increases and transmits them to the working and surrounding environment. The sources of the hazard can be of a subjective and/or objective nature, as well as the combination between them. Individuals, groups and organisations could generate individual and interconnected events, phenomena and processes in the natural environment and society.

Hazards arise from and can be associated with natural phenomena (such as earthquakes, floods, hurricanes, etc.) happening beyond the control of people and from situations (such as industrial accidents, ecological and social catastrophes, environmental pollution) in which man is the main risk factor. Risk factors in the working and surrounding environment are defined as a situation, event, impact or process that can lead to the occurrence of a certain hazard [1, 2].

A number of definitions of the term *‘hazard’* are known, formulated over time by various researchers. For example:

• ‘material, energy source or function that have the potential to cause illness, injury or death to personnel and damage to technical means and the environment’;

• ‘action or condition that causes harm and damage’;

• ‘physically defined situation with the potential for injury to people, destruction of physical and surrounding environment, as well as a combination of them’;

• ‘inherent potential that causes injury or damage to human health’;

• ‘something or some condition that acts or has the potential to cause trauma, damage or illness to health’;

• ‘probability of damage caused by a natural phenomenon, technical, organisational or human errors’;

• ‘potential for damage having the properties of a material or cause’;

• ‘activity, location, circumstance, event, phenomenon, process, situation or substance (regardless of where it occurred or was caused – within the boundaries of the workplace or outside it) that is an actual or potential cause or source of harm’ [3].

A hazard is the source that can cause injury or damage to health.

A situation can be defined as hazardous when risk circumstances exist and they can become a reason and conditions for violation of generally significant interests as well as when society is harmed.

A ***hazardous situation*** is any situation in which a person is exposed to one or more hazards. The zone of influence in and around the source where a person is exposed to the risk of injury or damage to health is defined as a ***hazard zone*** [4, 5].

The term *‘hazard’* is appropriate to be used in combination with other words that define its origin or the nature of the expected injury and damage to health such as: electric shock hazard, crushing hazard, cutting hazard, poisoning hazard, etc.

II. MATERIALS AND METHODS

Mechanical hazards – they are created by machine parts (or machined parts) and can be quantitatively and qualitatively defined in the production risk.

Electrical hazards – they are divided into two main groups in the working environment. In the first one, we have people touching live parts, i.e. parts that are normally under voltage (direct contact). The second group is more extensive and diverse in impact, but it is defined as people touching parts that have become live due to a malfunction, in particular due to insulation damage (indirect contact). The second group of hazards includes people approaching live parts, especially those with high voltage, inadequate insulation for the intended conditions of use or when people (or objects dropped by people) fall as a result of surprise caused by an electric shock. This group also includes electrostatic phenomena, such as people touching electrically charged parts or when creating conditions for static electricity.

Thermal hazards – this group includes direct impacts related to burns and scalds when in contact with objects or materials with extreme surface temperature, flames or explosions and radiation from heat sources. In summary, we can indicate that this group includes impacts harmful to health caused by a hot or cold working environment.

Hazards caused by noise (sound) impact – in the working and surrounding environment, sound waves are the main factor and source of impact. In the working environment, the hazards for personnel are associated with permanent loss of hearing acuity (with sound wave intensity above 130 *Db*), tinnitus, fatigue, stress, etc. With prolonged exposure to sound waves below the upper hearing threshold of 130 *Db*, other consequences may be loss of balance, weakening of attention, disturbances in the perception of spoken speech, sound signals, etc.

Hazards caused by vibrations – this group of hazards is associated with the propagation of mechanical waves in a rigid (inelastic) environment, and local vibrations (for example, when using hand tools) can lead to damage to the

peripheral nervous system and blood vessels. In occupational medicine, diseases resulting from vibration exposure are defined as neuralgic, bone and joint disorders, lumbalgia, sciatic nerve neuropathy, etc. Production premises can be a source of general vibrations that affect the entire body.

Hazards caused by radiation – the first group of radiations are related to the impact of electromagnetic waves from the electromagnetic spectrum. They can be low-frequency, radio-frequency and microwave radiations, as well as infrared, from the visible and ultraviolet part of the spectrum. *X*-ray and gamma radiations are part of the electromagnetic spectrum, with wide application in medicine and scientific research activities. The second group of radiations are a consequence of the spread and use of radioactive chemical elements in the working and surrounding environment. Their impact is expressed in the spread of α- and β-particles, as well as a flow of electron or ion, neutron radiations. The third group of radiations covers the application of laser technologies in the working environment [6].

Hazards created by materials and substances – depending on their origin and distribution in the environment, these can be chemical hazards – caused by contact with liquids, gases, vapours, fumes and dust having a harmful, toxic, corrosive and/or irritating effect, energy hazards from fire and explosion, or biological (for example, mold) and microbiological (viral or bacterial sources of infection) hazards [7].

Hazards created by failure to comply with ergonomic principles when designing a machine – first of all, the use of devices and appliances beyond their intended purpose leads to human errors and specific behaviour causing physiological consequences, resulting for example of unfavourable working postures, great or repetitive muscle efforts. The fundamental rejection of ergonomic requirements when designing production equipment can cause psychophysiological consequences, as a result of mental overstrain or insufficient mental load and stress, which arise from the nature of the work, control or maintenance of the machine. The main group of hazards in the working environment arises when working without or with incorrect use of personal protective equipment. Another group of hazards is associated with the conditions of the working environment, such as insufficient lighting of the specific workplace, inappropriate construction, location and recognition of controls or means of presenting information.

Combined hazards – the combination of various hazards from the aforementioned groups and their joint impact creates a hazard with a high degree of risk [8, 9].

The determination of hazards in the working and surrounding environment is applied and is the subject of research in production systems and in the field of technical, fire, emergency, explosion and other types of safety. The authors imply into the concept of *'hazard'* a meaning and content that they adapt mainly to their capabilities for collecting and processing data. Both many common characteristics of the introduced terms and many differences have been established. In a number of cases, some imaginary meaning is implied. This leads to idealised and unrealistic definitions. The result is inadequate assessments, non-objective understanding of the 'mechanism' of emergence and development, and hence ineffective protective activities.

III. RESULTS AND DISCUSSION

Occupational and environmental factors in industrial enterprises are systematically presented in the following figures. Hazard, as well as safety, can exist in specific real systems – production, ecological, ergonomic, domestic, etc. [10, 11].

Figure 1 presents a model for the systematic presentation of an industrial enterprise, with the hazards contained therein.

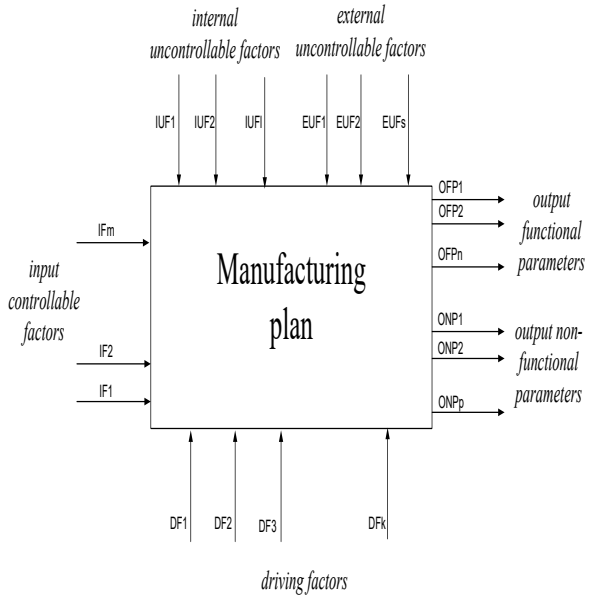

Fig. 1 Systematic presentation of an industrial enterprise.

Each production system operates in the conditions of a specific occupational and surrounding environment and can be represented by a generalised cybernetic scheme – Fig. 1. In it, the control object is characterised by a large number of input control disturbing factors and output parameters.

The factors and parameters can be combined into the following sets:

- *Set of input controllable factors enabling the operation of the production enterprise (IF), IF={IF$_i$}; i=1, m,* which unites factors such as input materials, energy, information and the like.

They determine the nature of the processes and can be continuously or periodically controlled. Information about their current values is obtained objectively (through control and measuring devices), subjectively (through laboratory analysis, calculations, etc.) and indirectly (by results of other measurements and factors).

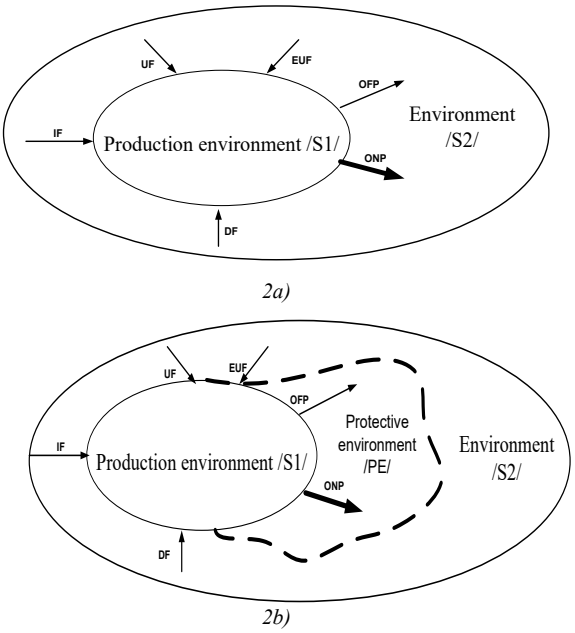

Fig. 2. Hazard (risk factors of occupational and surrounding environment) (a) and protection measures (b).

• *Set of driving factors* (*DF), DF={DF$_i$}; i=1, k*, which includes the quantities the target change of which supports a certain mode of operation of the production system. Related to organising the technological production process.

• *Set of internal uncontrollable factors of the occupational environment (IUF), IUF={IUF$_i$}; i=1, l*, i.e. all uncontrollable impacts that change the normal production process. They include risk factors such as technical breakdowns, accidents, incidents, etc.;

• *Set of external uncontrollable factors of the surrounding environment (EUF), EUF={EUF$_i$}; i=1, s*, i.e. all uncontrollable impacts related to natural phenomena and processes (earthquakes, floods, external radioactive, electromagnetic and noise pollution) which change the normal production process.

• *Set of output functional parameters (OFP), OFP={OFP$_i$}; i=1, n*, which unites controllable values determining the quantity, composition and quality of production. This set characterises the main function of the system. These parameters are called functional or functional outputs.

• *Set of output non-functional parameters harmful to the external environment (ONP), ONP ={ONP$_i$}; i=1, p*, this set characterises parameters that do not determine the main function, but are its derivative – type and characteristics of waste, environmental impacts, impacts on other production systems with risk factors, etc.

When defining the hazard, the interaction of production systems with the working and surrounding environment or with other systems is taken as a basis.

System S_1 (Figure 1) is a production system at an industrial enterprise. S_2 (Figure 2a) is the system of its environment, which can be natural, artificial, urban, other production (human-machine) systems, etc.

The environment S_2 is safe when the output impact factors (functional and non-functional parameters) created by the production system S_1 do not create hazards.

Provided that the output impact factors (functional and non-functional parameters) created by the production system S_1 cause hazards in the system S_2 (Figure 2a), it is necessary to create the so-called protective environment PE (Figure 2b) designed to limit, localise and stop their hazardous action. Examples of the construction of protective environments are the installation of purification equipment, filters, screens, fences, etc.

The integral hazard G at an actual operating production enterprise, written in tuple form, will be:

$$G = \{[G_1]; [G_2]; [G_3]\} = [P(C)]; [P(S)]; [U] \quad (1)$$

where:

- G_1 is a differential hazard of the first kind and represents the possibility P of the occurrence of a phenomenon C with a harmful effect S:

$$G_1 = [P(C)] \quad (2)$$

- G_2 is a differential hazard of the second kind which describes the probability that the on-going hazardous phenomenon C has a harmful effect S and causes damage U:

$$G_2 = [P(S)] \quad (3)$$

- G_3 is a differential hazard of the third kind and denotes the degree and type of harm as well as the severity of the damage caused U.

When damage U occurs, the actions aim at maintaining it at a possible low level or avoiding secondary consequences – rescue, medical assistance, treatment, etc. In this case, an attempt is made to limit the number of evaluation indicators and the intensity of damage development. These actions are compensatory actions.

As a result of the presented analysis of the term 'hazard', the safety SI of production systems, as an alternative, can be formally described as follows:

$$SI = 1 - \{G\} = 1 - \{[P(C)]\};[P(S)];[U]] \quad (4)$$

Therefore, the task of safety SI in production systems is reduced to the search for solutions in which

SI - max, a *G – min*, which shows that the safety analysis is reduced to the analysis of the hazard.

Based on the presented logical and methodological arguments, a research morphological model of hazards is presented (Figure 3).

The purpose of the presented morphological model is the possibility of the process of determining the hazard to be transformed from a hazardous phenomenon into a hazardous effect (damage):

- the differential hazard of the first kind G_1 represents a hazardous phenomenon;
- the differential hazard of the second kind G_2 – a hazardous action;
- the differential hazard of the third kind G_3 – a hazardous effect.

Each of the differential hazards is characterised by its indicators shown in Figure 2.

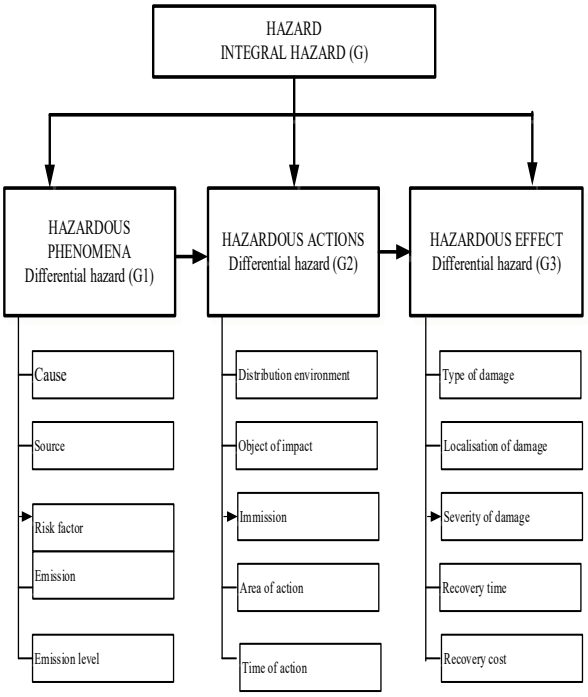

Fig. 3 Morphological model of hazard in industrial enterprises.

The process of building a morphological model for determining hazards in the occupational and surrounding environment of industrial enterprises goes through the following stages:

A. First stage: Defining hazards of the first kind G_1 represents a hazardous phenomenon.

At this stage, cause-and-effect relationships and sources of hazard are sought in the operating mode of the enterprise. It is possible to use a ranking of hazards according to their probability.

Sources of hazard in industrial enterprises are the technological operations performed. These are manual machines and tools with hot and cold surfaces, machines for pressing, stamping and drawing, flow machines with fast-moving elements, etc. The implementation of certain operations is the cause of the appearance of hazard in the ergonomic system.

The sources of hazardous phenomena are the technological equipment in a given workshop and its interaction with the subjective factor (operators of machines, facilities and equipment), which leads to the generation of risk factors.

The main indicator of hazardous phenomena is the presence in production processes of risk factors related to physical, chemical and biological impact.

Physical risk factors include:

- exposed and moving parts of machines;
- sharp edges and rough surfaces of workpieces;
- tools and tooling (stamps, dies, templates, etc.);
- conventional heat radiation from heated surfaces of workpieces and products;
- noise generation from mechanical hammers (pneumatic and hydraulic), hydraulic presses, transport and lifting equipment, aspirating and heating air systems;
- light radiation from the surface of workpieces and semi-finished products;
- sparking in the process of burning microparticles, through oxidation during plastic processing of surface-heated workpieces;
- electromagnetic fields created by induction and hardening machines;
- devices using the effect of absorbing ionizing radiation [9] – devices for technological control such as radiation level gauges, thickness gauges, densitometers, etc.

Chemical risk factors [12] are classified according to the nature of their impact on human physiology, more precisely:

- irritating and toxic chemical substances released during the use of conventional fuels – coal, coke, fuel oil, petroleum.
- harmful chemical substances released during evaporation from oil and salt baths and during heat treatment of blanks and parts.

Psychophysiological risk factors, according to the way they affect a person, can be defined as:

- neuropsychic overloads associated with the complex action of various factors of the production environment;
- physical overloads, a consequence of specific operations performed by the subject in production.

In the working and environmental conditions of industrial enterprises, risk factors are the generation of noise, vibrations, heat, light and radioactive radiation, the spread of electromagnetic waves. They must be additionally assessed, depending on the degree of impact (the amount of their emission into the environment).

Emission is one of the indicators of differential hazard of the first kind. There are two categories of emissions – functional and emergency. Each emission is characterised by a level of quantitative indicator. The level of emission in the working and surrounding environment is subject to ranking and determining the impact according to the regulatory limits of biological impact.

A hazardous phenomenon develops into a hazardous action when at the moment of its occurrence, there is an impact on the object or subject of the ergonomic system.

B. Second stage: Assessment of the environment of distribution of the hazardous impact.

The indicator of distribution environment is associated with the contact of the object and the subject with the hazardous impact. In industrial enterprises, two distribution environments are defined – working and surrounding. The first environment is defined as the workplace which provides optimal conditions for the functioning of the ergonomic system. The surrounding environment includes the working area, the workplace, the work room or the boundaries of the production enterprise.

The object on which the hazardous phenomenon acts is the object of impact and is the main indicator characterising the hazardous action. In industrial enterprises, the object of impact is the working personnel, machines, facilities and technical equipment.

Immission is an indicator of the hazardous action and is the result of the emission of a specific risk factor at a certain point in the working area, the workplace or the boundaries of the production enterprise. Immission as an indicator of the hazard has qualitative and quantitative characteristics. Qualitative characteristics are determined by the type of impact (chemical, radiation, noise, etc.). The emission level is a quantitative characteristic of the intensity of the impact and, accordingly, a quantitative indicator for a certain point of the working and surrounding environment.

The indicator of space and action is limited in industrial enterprises, this is the area of production and storage of finished products. The time of the hazardous action is a crucial indicator for the scale of distribution and the damage caused. It is correlated with the concentration of the emission at a certain point of the working and surrounding environment.

C. Third stage: Determination of the final effect of the hazard on the working and surrounding environment.

The course of the hazardous action ends with the occurrence of a hazardous effect. When ranking the indicators by degree of significance, the type of damage is dominant. It is quantitatively measurable with the material, economic and health damage caused. Material damage is characterised by the degree of damage and is associated with the occurrence of malfunctions, breakdowns and accidents of technical equipment. Health damage is characterised by a diagnosis, temporary incapacity for work and disability to varying degrees. Health and material damage are interrelated and lead to a decrease in the economic efficiency of production.

Localisation, as an indicator, characterises the specific place of occurrence of the hazardous effect. It is characterised by the numerical value of the area and volume of distribution of the damage.

Recovery time, as an indicator of hazardous effects, is relatively related to the object and subject of impact and depends on the degree and nature of the impact on the working and surrounding environment in the industrial enterprise.

IV. Conclusions

The indicated morphological model for determining hazards in the working and surrounding environment uses information that can help to determine all risk factors that affect the given system – production, environmental, domestic. The universality of its application is dictated by the consideration of actually existing environmental factors and the transformation of the hazardous phenomenon into a hazardous effect.

The implementation of a thorough analysis of risk factors in a system is decisive for its efficiency and operability. The construction of a morphological model in the process of determining hazards (risk) and the associated characterisation of the sources and cause-and-effect relationships for their occurrence is a guarantee for increasing environmental safety.

When analysing the aetiology of all hazards (risk factors), it is necessary to take into account and build a protective environment to ensure and guarantee the safety of the functioning of the environment under consideration.

V. Acknowledgements

The paper was financed by the National Scientific Program 'Security and Defence' of the Ministry of Education and Science of the Republic of Bulgaria, in implementation of the Decision of the Council of Ministers of the Republic of Bulgaria № 731/21.10.2021 and under Agreement № D01-74/19.05.2022.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 249-254

Long-Term effects of Thinning in Natural Pine Forests Undergrowth

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***Abstract*— Ground cover vegetation is crucial for biodiversity in northern conifer forests, providing habitat, food, and ecosystem functions like seedling regeneration and nutrient cycling. Their composition is shaped by tree species, canopy structure, and environmental factors like temperature, light, water, and soil nutrients. Forest management can modify these processes by increasing light availability, fostering conditions more typical of a natural pine forest biotope, and promoting plant growth. This study aimed to assess whether natural pine forest management influenced ground cover vegetation over 20 years. Six plots across three locations were analyzed. In the studied managed plots, first-story pine trees were thinned by removing second-story spruces between 2004 and 2005. Some plots were thinned (managed), while others remained untouched (control). Initial vegetation assessments recorded species in 10×10m plots before thinning. In 2024, vegetation was reassessed using transects with three 1×1m plots placed along cardinal directions. Vegetation was categorized into trees and shrubs, herbs, mosses, and lichens. The 2024 assessment of managed plots revealed a decline in moss and lichen species, a slight increase in herbaceous species, and a more pronounced increase in tree and shrub species. The opposite trend was observed in control plots. Shannon index values showed significant differences between years (p=0.03) across all vegetation layers but not between management types or factor interactions. Similarly, the total species count varied significantly between years (p=0.02) but not between management types. However, within small 1×1m plots (2024), species count differed significantly between management types (p=0.004). These findings suggest that thinning influences ground cover vegetation composition over time, promoting tree and shrub growth while reducing moss and lichen cover. Species diversity shifts appear more pronounced at finer spatial scales, highlighting the importance of localized conditions in shaping ground cover vegetation dynamics.**

Keywords*— *pine, thinning, undergrowth.

I. Introduction

The composition of tree species is a fundamental characteristic of forest ecosystems, yet is frequently shaped by silvicultural practices [1]. Various stand attributes, including forest age, tree density, and sub-canopy retention, influence ground cover vegetation by affecting key environmental factors such as light availability, temperature, moisture, and soil nutrients [2], [3], [4], [5], [6], [7]. Overstory tree species richness has been positively linked to ground cover vegetation diversity and biomass [8], [9], though this relationship can be moderated by forest density, which regulates sub-canopy climate conditions [10], [11]. The structure and density of the canopy and shrub layers play a crucial role in shaping understory vegetation by influencing light penetration, moisture retention, and litter quality, which

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8683
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in turn impact soil properties such as temperature, pH, and nutrient availability [1], [12]. Light is often the primary limiting factor for understory plant diversity and cover [13], greater canopy openness can enhance resource availability and promote understory growth [14]. The presence or absence of a sub-canopy layer also significantly affects understory vegetation [15]. Forest density, defined by tree abundance in terms of basal area, stem density, or volume per unit area, can override the effects of species composition by limiting light availability on the forest floor and intensifying below-ground competition for resources [16]. In boreal forests, where understory vegetation is essential to ecosystem functioning, it contributes to overstory succession, nutrient cycling, and long-term stand productivity [17], [18]. As the dominant component of floristic diversity in northern conifer forests [19], understory vegetation supports biodiversity by providing habitat and food for wildlife, facilitating tree seedling regeneration, and enhancing soil nutrient cycling [20], [21]. While the overstory largely determines overall forest productivity through biomass accumulation, understory vegetation plays a critical role in nutrient cycling and soil carbon storage due to its significantly higher turnover rate [18], [22]. Identifying the factors that shape ground cover diversity, abundance, and composition is vital for sustainable forest management, particularly for ensuring successful overstory regeneration and the conservation of biodiversity.

II. Materials and Methods

For the purpose of this study, three locations of natural pine forests were selected (Fig. 1). The stands represented *Myrtillosa* and *Vacciniosa* types, and their age was between 183 and 258 years. In 2004 – 2005, in each of them, two plots were established (10 x 10m): one managed and one left unmanaged as a control. Large overstory pines were thinned in managed plots with the complete removal of Norway spruce growing in the understory. Before thinning, vegetation assessments were conducted in each 10 x 10 m plot. Three layers were distinguished: moss and lichen, herbs, and trees and shrubs. For each plot, the percentage cover and species present were recorded. In the tree and shrub layer, trees with a diameter $\leqslant$ 6 cm and height $\leqslant$ 2 m were included. In 2024, a re-evaluation of the overstory vegetation was carried out in the same plots, with transects established along four cardinal directions and 1 x 1 m sampling plots (Fig. 2). Likewise, the percentage coverage occupied by litter, exposed soil, fallen deadwood and tree root necks in the sample area was assessed, which together with the moss and lichen layer made 100% coverage. The percentage coverage of these categories was assessed only during the 2024 survey. For data analysis, linear mixed-effects models were used to compare Shannon indices. Poisson generalized linear mixed-effects models were applied to compare species numbers, while Tweedie generalized linear mixed-effects models were used to compare species cover.

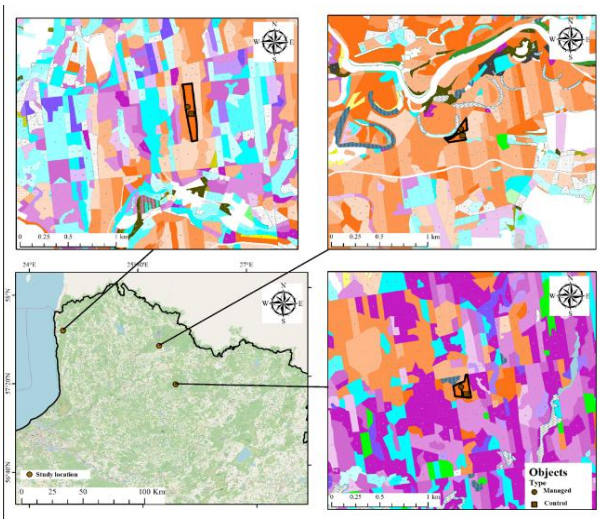

Fig. 1. Location of the studied forest areas and the sample plots.

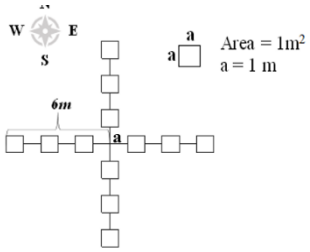

Fig. 2. Vegetation data collection transect scheme.

III. Results and Discussion

The composition and abundance of understory plant communities in forest ecosystems are largely shaped by competitive interactions among understory species, constrained by soil resources and light availability regulated by the overstory [23]. Light transmission is lower under spruce, resulting in reduced resource availability [24]. Before pine thinning in 2004, the species composition in both managed and control stands was similar, with only slight differences (Fig. 3). While tree and shrub proportions were comparable, herbaceous plants were more abundant in the control stands, whereas mosses and lichens were more prevalent in the managed stands. By the second vegetation assessment in 2024, notable shifts had occurred. In the managed stands, moss and lichen species declined, herbaceous species had a slight increase, and tree and shrub species became more dominant. The herb layer is relatively less affected by canopy closure than the shrub layer [14]. In contrast, the control plots followed the opposite trend: tree and shrub species declined, moss and lichen species increased, and herbaceous plants experienced a slight increase. Vascular and nonvascular species tend to replace one another in proportion to varying site conditions, leading to relatively consistent total understory cover and species richness across different overstory types and stand ages [3]. Carpet-forming bryophytes [25] and *Vaccinium* species may inhibit the establishment of additional plant species [7], [26]

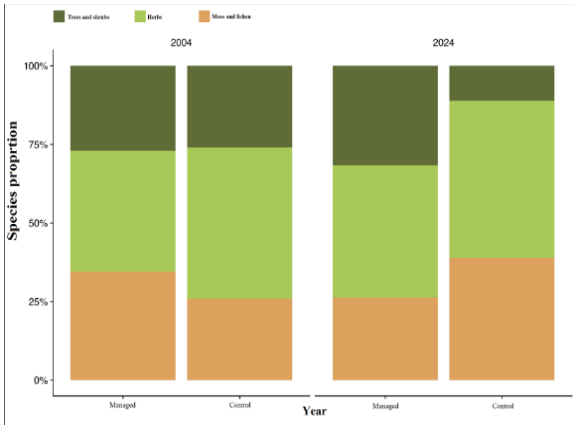

Fig. 3. Proportion of species in different vegetation layers by management type in the 2004 and 2024 surveys.

Old-growth boreal forests generally sustain understory communities characterized by low species diversity and limited productivity [27]. As the overstory matures, shifts in understory plant diversity can be expected, driven by changes in light availability, litter accumulation, nutrient cycling [28], and disturbance patterns [29]. In the first assessment (2004), a total of 36 species were identified, whereas in the 2024 assessment, this number decreased to 25. This may be partially attributed to stand age, as a decline in species richness has been observed in ageing Scots pine forests [26], [29], [30]. To compare species numbers across years (Table 1), data were analyzed at the plot level. The total number of species differed significantly between years ($p = 0.02$), but no significant differences were found between management types or factor interactions.

TABLE 1 MEAN SPECIES NUMBER IN SAMPLING PLOTS UNDER DIFFERENT MANAGEMENT TYPES ACROSS TWO ASSESSMENT YEARS

Type	Total	Herbs	Moss and lichen	Trees and shrubs
2004				
Managed	14.67±2.50	5.67±1.53	5.33±1.15	3.67±2.08
Control	14.00±3.61	6.0±3.61	4.33±1.15	3.67±1.53
2024				
Managed	5.75±1.40	4.33±1.15	3.67±1.15	3.00±2.65
Control	4.03±1.44	4.33±3.21	3.67±1.15	0.67±0.58

A higher number of unique species—those recorded only in a specific year—was observed in 2004, with 11 unique species compared to just 5 in 2024 (Table 2). Notably, the unique species in 2024 were primarily mosses, while in 2004, unique species were found across all vegetation layers. This may be due to more favourable growth conditions for mosses, as the tree layer was also composed of Norway spruce, which supports bryophyte growth better than Scots pine [1], [7], yet Scots pine supports higher coverage of vascular plants [26].

TABLE 2 LIST OF UNIQUE SPECIES DOCUMENTED FOR THE OBSERVATION YEAR

2004		2005	
Species	***Vegetation layer***	***Species***	***Vegetation layer***
Coryllus avellana L.	Trees and shrubs	*Populous tremula* L.	Trees and shrubs
Salix caprea L.	Trees and shrubs	*Aulacomnium palustre* (Hedw.) Schwägr.	Moss and lichen
Rubus idaeus L.	Herbs	*Plagiomnium affine* (Blandow ex Funck) T.J.Kop.	Moss and lichen
Rubus saxatilis L.	Herbs	*Plagiomnium ellipticum* (Brid.) T.J.Kop.	Moss and lichen
Vaccinium uliginosum L.	Herbs	*Rhytidiadelphus triquetrus* (Hedw.) Warnst.	Moss and lichen
Brachythecium oedipodium (Mitt.) A.Jaeger	Moss and lichen		
Dicranum montanum Hedw.	Moss and lichen		
Dicranum scoparium Hedw.	Moss and lichen		
Polytrichum juniperinum Hedw.	Moss and lichen		
Sphagnum capillifolium Hedw.	Moss and lichen		

The Shannon index values varied significantly between years ($p = 0.03$) when all vegetation layers were analyzed as a single dataset. However, no significant differences were found between management types or their interactions. Species diversity might increase following a disturbance [29], [31], [32], however, low-intensity disturbances, such as canopy gap formation, provide less of an increase in understory resource availability compared to stand-replacing disturbances. As a result, they lead to smaller, more transient increases in diversity and cover, with only minor shifts in composition driven mainly by changes in the relative abundance of pre-existing species [30], [33]. Or even 17 years after density reduction treatments, there may be no impact on understory succession [34]. In 2024, Shannon index values remained similar across different management types, with an average of 1.66 ± 0.35 in the managed stand and 1.63 ± 0.12 in the control stand. Over time, the index declined, reaching 1.55 ± 0.25 in the managed stand and 1.10 ± 0.24 in the control stand by 2024. When considering only the 2024 data, a significant difference ($p = 0.03$) emerged between stand types, with the managed stand maintaining a notably higher Shannon index (1.28 ± 0.22) than the control stand (0.79 ± 0.29).

No distinct grouping of the analyzed plots was observed during the DCA analysis (Fig. 4). Mature pine forests are distinguished by the presence of Ericaceae species [29]. It appears that the coverage and frequency

of dwarf shrubs, such as *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L., remained stable over time and across different forest management types. The frequency of these species was consistently around 80% between years. For *Vaccinium myrtillus*, the percentage cover slightly decreased from an average of 24% to 16%, while *Vaccinium vitis-idaea* increased from 2% to 8%. Excessive increases in light conditions may have a negative effect on *Vaccinium myrtillus* [29], and data from Scandinavian boreal forests have shown a decrease in the dominance of Ericaceous species following cutting [35]. However, it is important to consider the differences in sampling plots between the two observation years, so the interpretation should be made with caution. The reduced light levels in the control plots might promote the growth of shade-tolerant plants in the understory [36]. However, no clear connection was found between the control plots and shade-tolerant species (Fig. 4). Late-successional bryophyte species (*Dicranum polysetum* Sw*., Hylocomium splendens* (Hedw*.) Schimp., Pleurozium schreberi* (Brid.) Mitt.) showed an increase in both frequency and percentage cover during the second observation [37], indicating the maturity of the studied stands.

This can affect bryophyte cover that often respond to these changes differently than herbaceous plants [1].

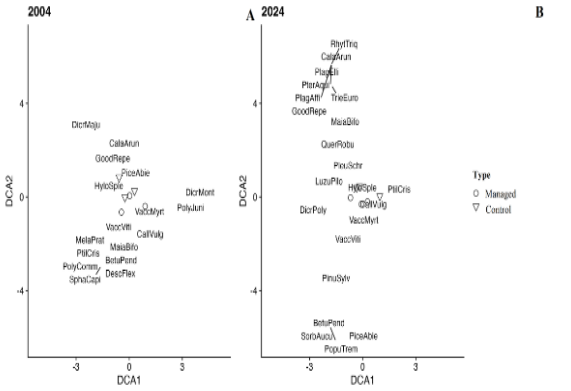

Fig. 4. DCA ordination of ground cover vegetation species and sample plots based on their projective cover. The management approach is indicated by type.

In 2024, the percentage cover of perennials, mosses, and lichens was significantly higher in managed stands compared to control stands ($p < 0.001$ and $p = 0.001$, respectively). A decline in bryophyte cover with increasing forest density, along with a more pronounced reduction in vascular plants in spruce-dominated forests, has been observed in other studies [7]. However, no significant differences were observed in tree cover between management types ($p = 0.104$). Litter cover was significantly lower in managed stands than in control plots. The average litter cover within a 1×1 m sample plot was 5.06 ± 5.49% in managed stands, compared to 9.53 ± 10.86% in control stands. This can affect bryophyte cover that often responds to these changes differently than herbaceous plants [1]. A comparison with 2004 was not possible, as litter cover was not assessed in that year.

Understory plant species play a crucial role in maintaining forest ecosystem stability and supporting key ecological functions. Determining appropriate forest management is essential for promoting their growth and development. Research indicates that stand density and canopy structure influence both the understory environment and vegetation growth [38]. In this study, it remains unclear whether the changes in species diversity and coverage were driven by management practices improving light conditions or by the removal of Norway spruce, as tree species is a key limiting factor for vascular plant diversity [1]. Our study, along with others, suggests that lower-density management strategies better support species conservation and ecosystem function [39].

IV. CONCLUSIONS

In managed plots, mosses and lichens decreased, while trees, shrubs, and herbaceous species increased. In control plots, the opposite trend occurred, with a slight rise in perennials. Species numbers varied significantly between assessment years but not between management types, with higher numbers in the first year. In 2024, species count differed significantly both within the year and across management types, with managed plots having more species. Managed stands in 2024 had significantly higher herbaceous, moss, and lichen cover than control plots. The litter layer was significantly lower in managed forests.

ACKNOWLEDGEMENTS

This study was funded by "Effect of forestry on the forest ecosystem and related ecosystem services (LVM, No. 5-5.9.1_007n_101_21_76) and No. VPP-ZM-VRIIILA-2024/2-0002 'Forest4LV – Innovation in Forest Management and Value Chain for Latvia's Growth: New Forest Services, Products and Technologies'.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 255-260

Innovative in Situ Technologies for Remediation of Energetics

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***Abstract*— The main purpose of the energetic materials is their reactive behavior. All their forms therefore have a footprint on human, animal, and plant systems. The demilitarization operations like Open Burn and Open Detonation, the manufacturing process and the accumulation of disposed munitions create severe contamination of water and soil and that is why it is crucial to understand and influence the caused adverse effects. Managing the munition requires knowledge and great care to avoid public concerns and comply with legislation. The objective for novel "green" energetics in the last years discovers chemical compounds and compositions, which will increasingly be used in munitions. Remediation of the contaminated area can be achieved by employing three main groups of methods: physical, chemical, and biological. Advanced oxidation processes (AOPs) are utilized in applications for which conventional oxidation methods, like chlorination, are insufficient, when process kinetics are slow, or contaminants are resistant to chemical oxidation. In some cases, pollutants become only partially oxidized, resulting in the creation of stable by-products of possibly higher toxicity than the starting substrate. Innovative AOPs using the benefits of combining different methods or utilizing different catalysts to speed up reactions are considered as competitive remediation technics during removal of complex munition pollutants resulting in easy operation and simple preservation in field. AOPs such as Fenton reactions, heterogeneous photocatalysis, Ozonation, and Electrochemical oxidation are effective in removing persistent emerging contaminants that cannot be treated by conventional physicochemical and biological methods. The results show that AOPs could be effective processes for the degradation of explosives. Utilizing in-situ treatment approach for explosive degradation has potential benefits for complete degradation of contaminants, reduced cost and infrastructure compared to traditional methods and reduced overall remediation time.**

***Keywords*— AOPs, explosives, pollutants, remediation.**

I. INTRODUCTION

It is not allowed anymore to dump the munitions at sea or leave them to landfill sites. Moreover, caution must be taken to follow up and monitor the contamination of the already stored materials since metal corrosion and subsequent chemical leakage can harm. The current energetics are and will be the main environmental pollutants in the future and the remediation activities must employ new technologies for better cleaning up and restore contaminated water and soil. The chemical compositions of munitions significantly differ in their properties, generating their versatile behavior in the environment. The new direction in the environmental protection laws moves from the general statement to more precise determination like "Polluter Pays." This concept ensures that the organization or the person causing the contamination will take ownership on the cost for remediation or cleaning up. In the USA, the EPA has announced almost $1 billion to help states and territories implement PFAS testing and treatment at public water systems. This comes from a pot of $9 billion that will be available to help 'communities with drinking water impacted by PFAS and other emerging contaminants". But there is more, the EPA has made an additional $12 billion – just over €11 billion for 'general drinking water improvements, including addressing emerging contaminants like PFAS [1].

Environmental Management is the process of identifying, preventing, and mitigating the environmental impact from energetic materials. Munitions are a small part of Environmental Management, but they cannot be ignored. The environmental risks remain low and the remediation costs for contaminated land and water need to be minimized using the principle for the best available

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8621
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technology (BAT) to keep up with industry standards of environmental protection.

Referring to the data provided by The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP), approximately 100 million pounds of energetic materials waste, or 41 percent of the total life-cycle energetic waste production, is generated during manufacture. An additional 449,000 tons of energetics waste is produced during demilitarization [2]. It is well known that almost all the explosive material is consumed during first order detonations. Second order detonations, blow in place and open burning may produce deposition of significant quantities of explosives. Thousands of buried unexploded ordnances are corroding and leaching their chemical contents into the environment. Explosives such as RDX, trinitrotoluene (TNT) and octogen (HMX) are frequently detected in soil and water and can lead to cumulative environmental consequences as heavy metals and other chemical compounds are known toxins and carcinogens. As the authors Hristo P. Hristov and Hristo I. Hristov correctly remark the explosive detonation as a chemical process which never fully completes, and it is expected that the residual energetics will be spread over broad areas [3]. There are numerous factors influencing the detonation behaviors and it is difficult to precise the complex mechanisms between the chemical compounds, the formation of residues and the influence of climate conditions. To support the assessment, a widely used framework of environmental management is used that enables identification and mitigation of environmental impacts.

The mitigation may be defined as reducing, avoiding, or offsetting any adverse environmental consequences of specific activities and can be summarized as [4]:

- Minimizing impacts by limiting the magnitude of the action and its implementation.
- Rectifying the impact by repairing or remediating the affected area.
- Reducing or eliminating the impact over time by preservation and maintenance during the life of the activity.
- Compensating for or offsetting the impact by replacing or providing substitute resources.

Physical methods like excavation and disposal are effective, their applicability is constrained by cost and logistical challenges for large, contaminated areas. Physical measures are suitable in cases when the detonation processes would not destroy the containment systems. Chemical methods, such as oxidation and reduction, focus on transforming explosives into less toxic byproducts. In biological technologies, the breakdown of explosives can take place with bacteria under aerobic or anaerobic conditions, where the explosive compound serves as a source of food. Physicochemical methods outperform biological actions, as they are faster and can be applied to a wider range of compounds. The additional benefit of possible process control flags these methods as more favorable.

In situ chemical oxidation (ISCO) is a remediation technology that involves the injection of chemical oxidants. It is important to select an appropriate oxidant, dosing, and activation agent (if needed) based on the contaminants present since not all compounds can be treated effectively by a single oxidant.

The Advanced Oxidation Processes (AOPs) is defined as the process which uses strong oxidants to transform contaminants or pollutants in the aquatic system to a less toxic or non-toxic substance by the reduction-oxidation system. One of the first definition states that AOPs are water treatment processes which occur at ambient temperature and pressure and involve generation of a powerful oxidizing agent, like hydrogen radical ($HO^{\bullet}$). Further research extended that concept to electrochemical systems generating $HO^{\bullet}$ on an anode surface under the application of high current density. Currently, as AOPs are considered degradation processes based on the generation of highly reactive oxygen species (ROS), such as hydroxyl radicals (HO•), superoxide radicals ($O^{2\bullet-}$) and singlet oxygen (O_2). ROS participates in the degradation of organic matter, which mostly leads to the creation of CO_2 and H_2O or more biodegradable species with less environmental impact.

There are few innovative methods of generation of ROS of high potential to be applied in practice which combine the benefits of the previously known AOPs: Fenton reaction, Heterogeneous photocatalysis, Ozonation and Electrochemical process.

II. MATERIALS AND METHODS

A. Fenton reaction

Fenton process is based on an application of iron as a catalyst for improvement of oxidative potential of hydrogen peroxide (H_2O_2). Iron catalyst (Fe^{2+}, Fe^{3+}, iron oxides) is the most applied material during the Fenton process [5]. It is worth mentioning that the most appropriate material for catalytic applications besides good processing parameters is one that is easily removed from the process contaminants and should be reusable without reducing process efficiency. The basic reaction of the Fenton process runs in accordance with the reaction in Eq. 1:

$$Fe + H_2O_2 \rightarrow Fe^{3+} + \dot{O}H + OH^- \qquad (1)$$

Hydroxyl radicals created during Fenton reaction can be utilized during decomposition of the explosive compounds. The reaction is performed at acidic conditions (pH ≈ 3), which promotes the creation of radicals.

Since nearly all explosives are manufactured by the nitration of organic compounds, the Fenton reaction is considered a promising method for organic wastewater treatment, owing to its high efficiency, simplicity, non-toxicity, and cost-effectiveness. However, there are still some limitations, such as narrow operating pH range, a large volume of iron sludge produced, an excessive amount of Fe^{2+} required, and possible corrosion of the equipment, as well as poor cost-effectiveness under high pollution load and necessity for the recovery of precipitated catalyst after the process. Moreover, the sludge can contain organic compounds and heavy metals and must be treated further. The processing of used catalysts can significantly increase overall process operation costs. The mentioned drawbacks still prevent Fenton process from widespread application. it is important to mention that the efficiency of the Fenton reaction during the treatment of water containing many various contaminants is lower comparing with its degradation efficiency with one component. This can be attributed to competition of pollutants for reactive oxygen radicals.

B. Heterogeneous Photocatalysis

The term photocatalysis describes all processes carried out with semiconductor materials. The process consists of the creation of free radicals by the interplay between photons such as those from a surface of a semiconductor and molecules of chemicals provided in the solution. The principle of operation of the process is based on the absorption of light, which subsequently induces a charge separation process with creation of positive holes. The created holes possess the ability to oxidize organic substrates of concern. During photocatalysis nanomaterials are irradiated with light, in which filled valence band, and an empty conduction band are present. When the irradiation of photon energy exceeds its band gap energy, photogenerated holes are created. These holes react with the pollutant or generate reactive oxygen species like OH^-, O_2, H_2O_2 which can oxidize organic molecules. The process of photocatalysis is depicted in Fig.1. [6].

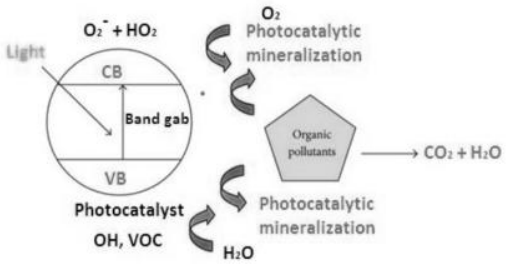

Fig. 1. The oxidation path of heterogeneous photocatalysis

One of the most important features of the application of solid catalysts is the simplicity of their separation from the reactor in most cases by filtration and their reusage without significant diminishing of activity. Photocatalysis also enables the chemical transformation of complex chemicals under mild conditions, what is in most cases unreachable using the other methods. The process can be successfully applied during wastewater decontamination, water splitting to generate hydrogen and for synthetic purposes.

A photocatalyst is a substance, which can be activated by the photon and helps acceleration of a reaction. It is important to explain that during an accelerated reaction the photocatalyst is not consumed. There are several compounds described as potentially good semiconductors, such as TiO_2, ZnO, ZnS and CdS with titanium oxide exhibiting the most promising potential for the photocatalytic application due to its non-toxicity, relatively low cost, and high efficiency. Recent research proves that metal–organic frameworks (MOFs) and graphene-based nanostructures are listed as potential photocatalysts. The application of MOFs as catalysts is still at an early stage of development and requires further investigations in terms of safe operation, lifespan, reusability, process conditions, and stability in aqueous conditions.

C. Ozonation

Ozonation is a method utilized for the degradation of inorganic or organic molecules and for inactivation of microorganisms. The method requires the generation of ozone directly during the process owing to the instability of O_3. Ozone (O_3) can be generated during the reaction of an oxygen molecule with an oxygen atom via gas discharge, photochemical excitation, and electrochemical reaction. Ozone acts as the initiator of the oxidation process and oxygen-containing products are obtained following the process. This type of method does not demand extreme conditions and can be performed at low and ambient temperatures.

Ozone is thirteen times more soluble in water than oxygen, which speeds its application in remedial works. Additionally, O_3 is highly reactive thanks to its molecule structure. Ozone is composed of three oxygen atoms, of which one is the central atom, and two others are connected to the central one by covalent bonds. Owing to that, one of the oxygen atoms is electron-deficient with electrophilic properties, whereas the other one is electron-rich with nucleophilic properties. As a result, one part of the molecule reacts preferably with unsaturated functional groups, whereas the second part reacts rather with carbonyl and carbon–nitrogen bonds molecules. O_3 possesses very reactive properties and can oxidize a wide spectrum of pollutants by direct ozonation or by an indirect reaction performed by oxygen containing radicals, generated during O_3 decomposition. The transformation of the pollutants by ozonation is performed by the two strong oxidants: molecular O_3 and hydroxyl radicals (OH^-) as presented in Fig. 2.

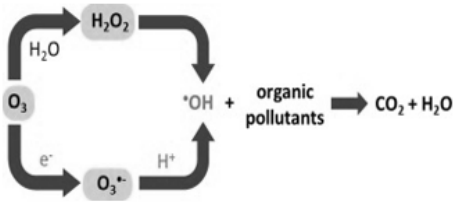

Fig. 2. The double effect mechanism of the Ozone treatment process

O_3 works as a selective oxidant and readily reacts with amines, phenol and double bounds in aliphatic compounds, whereas the hydroxyl radical (OH^-) is less selective reactant.

The efficiency of ozonation during elimination of micropollutants depends on the chemical properties of the removed compounds, operating conditions like oxidant dosage and pollutant concentration. For the successful completion of the process a comprehensive understanding is essential in the areas of the reaction kinetics, decomposition pathways, formation of by-products, and toxicity.

The main limitation of the ozonation process is low Chemical Oxygen Demand (COD) removal, which results in high ozone dosages to be utilized for treatment of substrates. The higher financial requirements are a serious obstacle during the evaluation stage. Another drawback related to the dosage is that if an O_3 dose rises above the optimal application level, a creation of toxic byproducts may occur.

D. In situ Electrochemical process

The electrochemical oxidation process converts the electric energy into chemical energy utilizing a cathode and anode placed in the environment of external electric field. This method can be divided into direct and indirect oxidation reactions. Direct oxidation takes place on the anode surface where the pollutants are adsorbed and oxidized into small molecules. Indirect oxidation generates the formation of strong oxidizing intermediates like hydroxyl radicals involved with the pollutants in the second stage of the process. Electrochemical oxidation results in good degradation of organic matter and lower chemical oxygen demand (COD) and toxicity.

The increasing challenges of the remediation of different kinds of effluents coupled with the presence of new insensitive high explosives with greater solubility drive the development of advanced technologies based on the electrochemical process. A new technology combining oxidation and reduction processes has been found to be promising in cleaning complex pollution of explosives [7]. The technology setup depicted in Fig. 3 has two columns. The reduction in the first column degrades the contaminations through nitro group reduction, transforming the nitramine compounds into more susceptible to ring cleavage and further degradation. Hydrogen peroxide is injected in the second column where in the presence of nanosized manganese dioxide catalyst and granular activated carbon is converted to hydroxyl radicals. Hydroxyl radicals, being thermodynamically active oxidants, react with nitramines and nitroaromatics in an indiscriminate approach. During the new upgraded process, the hydroxyl radicals degrade the aromatic rings into nitroaromatic compounds which was not observed in the single electrochemical oxidation method. Electrochemical reduction directly occurs at the cathode surface providing the electrochemical system with the advantage of absence of chemical reductant. These munitions containing nitro groups are susceptible to the reduction process.

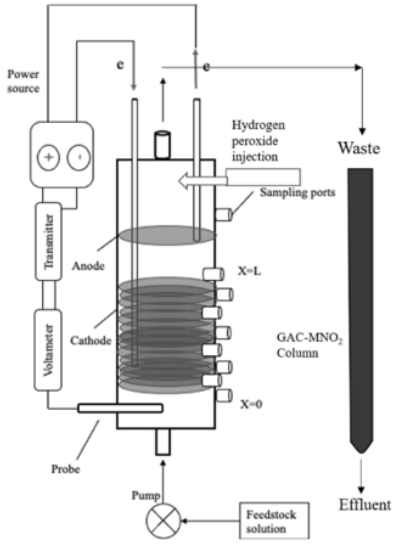

Fig. 3. Schematic of electrochemical reduction oxidation reactor with hydrogen peroxide injection

The new oxidation reduction system can be utilized in situ conditions because the low power voltage and current settings make it practical in field work. However, there are still research needs for realizing flow-through oxidative processes featuring hydroxyl radicals for explosives. The generation of hydroxyl radicals needs to be constant and sustained process, and the ease of hydrogen peroxide synthesis supports the possibility of incorporating the synthesis into the electrochemical reduction reactor. To simplify the system, direct injection of hydrogen peroxide can be suitable, but this option stays open for further research.

III. RESULTS AND DISCUSSION

The chemical nature of almost all explosives is based on organic compounds, and they exhibit extreme heterogeneity. These characteristics challenge the remediation process requesting site-specific approaches dependent upon pollutant concentration and environmental specifics. A conducted study evaluated the inhibition of the hydroxyl radical and the theory of crystal field stabilization energy. The results for all the

explosives proved that the oxidation rates significantly increased with the concentration increase of Fe (II) and UV (ultraviolet) light [8]. AOPs are attractive methods for successful in-situ transformation of explosives but are not yet considered cost-effective [9].

Creative improvements based on the traditional Fenton method like Electro-Fenton technology exhibit unique advantages in versatility, high efficiency with reduced secondary contamination. Electro-Fenton has been reported as suitable for treating refractory organics. One of the most appealing advantages of Electro-Fenton is the ability to generate peroxide (H_2O_2) in situ through a two-electron transfer oxygen reduction using oxygen in aqueous solution. This ability minimizes the costs, and the risk associated with the peroxide transport while increasing the efficiency of the treatment method [10].

Another recent development of AOPs is using UV light in efforts to cost reductions. Effective removal of nitramine explosives was obtained in a trial by UV mediated method in near- neutral conditions. The effective treatment was also economical due to the replacement of electrical energy with UV light. This modification in the process achieved reduced electrical energy consumption and cost [11].

Remarkable improvements are accomplished with the implementation of metal-organic frameworks (MOFs) acting as a catalyst for the AOPs. The remedial treatment of explosives needs sustainable and economically justified solutions to remove the high concentrations of persistent pollutants. A catalyst-mediated AOPs form free radicals with high oxidizing potential speeding up the degradation process. The adaptive properties and the porous surface of MOFs suit as a catalyst of reduction and oxidation reactions. There are several combinations of compounds tailoring the properties of MOFs to achieve excellent remediation results for different applications. The treatment efficiency is controlled by alterations of the pore size. Pyrolysis is considered an appropriate method to synthesize carbon and metal oxide derivatives. It was reported that Fe_3O_4 nanoparticles adsorb contaminants with good magnetic properties. It was observed that the simultaneous addition of metal oxide derivative achieves higher degradation of contaminants. Additionally, achieving a more uniform dispersion of metal oxide in MOFs enhances the adsorbing properties of the resulting material. Adopting carbon composites like activated carbon, graphene oxide, graphite, carbon nanotubes in the MOFs framework produces large surface area for the adsorption of organic pollutants. It was found that the performance of the material is influenced by the degree of graphitization and the texture of the carbon supports. Furthermore, hierarchical pores with large specific areas allow better diffusion of pollutants [12].

IV. CONCLUSIONS

Remediating explosives requires utilizing methods that are highly efficient in treating high concentrations of organic pollutants, possible to degrade much quicker than the traditional biodegradation and not producing secondary pollutant generation. The recent research in AOPs outlines these methods as promising in situ conditions. However, the mechanism about the exact process of AOPs is still not completely investigated. The most challenging subject is to design the most appropriate AOPs system for the given pollutant at economical rates. AOPs prove excellent results with non-easily biodegradable organic compounds. To further develop their application and reduce the overall financial load the research is looking for improvements in the following:

1. Alternative and abundant energy sources for the generation of oxidant radicals like, for example, UV light.

2. Employing Electro-Fenton technology in situ condition for better cost efficiency.

3. Utilizing MOFs as a catalyst for strong adaptability, ease of operation, simplicity of design and possibility of catalyst recycling leading to cost reduction.

ACKNOWLEDGMENTS

We gratefully acknowledge the financial support by The Defense Institute "Professor Tsvetan Lazarov", Sofia, Bulgaria.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 261-265

The Potential of Agritourism in the Rural Environment of Latvia

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***Abstract*—Agritourism in Latvia is experiencing rapid growth, offering a unique opportunity to experience rural lifestyle and natural diversity. In addition to traditional agricultural activities, agritourism farms offer tourism services, thus diversifying their sources of income. The agritourism product corresponds to farms that preserve the traditions of agriculture, fishing, crafts and food production, while educating visitors and providing an opportunity to enjoy the beauty of nature, plant diversity and animal behavior. Agritourism is developing rapidly in Latvia because the countryside is rich in natural resources and ecological diversity. The aim of the study is to investigate and analyze the types of agritourism and their potential in Latvia, identifying the main trends and opportunities. The theoretical basis of the study is based on the study of various sources of information, supplemented with findings from studies and practical examples over several years. The study defined: the keywords characterizing agritourism: "Rural environment. Crafts. Recreation. Health. Nutrition", types of agritourism by purpose: agricultural, educational, gastronomic, health, recreational agritourism. Agritourism is a natural fit for Latvia's landscape, culture, and business traditions. Agritourism activities and services are diverse, including not only accommodation and meals, but also farm tours, educational and inclusive participation in farm work, master classes in making crafts and traditional art objects, traditional cooking from local products and their tasting, nature hikes, fishing, horseback riding and other forms of active recreation**

Keywords*— *agritourism, Latvia, types of agritourism.

I. Introduction

Agritourism, also called rural tourism, is a dynamically growing type of tourism that offers recreation and experiences in a rural environment. According to the Academic Term Database [1], agritourism is defined as "one of the types of tourism in which the purpose of the trip is to relax on a farm, observe the rural environment and farm work, or even participate in them." This is a popular type of niche tourism that encompasses not only recreation in the traditional sense, but also visiting farms and spending the night there [2]. Agritourism is closely linked to agricultural activities. For small farms, these activities are often an important source of income [3].

Latvian rural tourism service providers create important tourist destinations, however, successful operation is unthinkable without cooperation with other participants in the industry. The recognition and ability of an entrepreneur to form partnerships directly affects its turnover [4]. Agritourism is one of the most dynamic tourism segments in the European Union, which is fueled by the growing interest in closeness to nature, traditional values and sustainable lifestyles. The Latvian countryside, with its ecological diversity and natural wealth, offers an excellent environment for the development of this type of tourism [3].

The modern rural environment is undergoing changes in which agricultural activity is supplemented with new, non-agricultural functions, which are an inevitable part of the development of rural space [5]. Improving the tourism

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8627
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industry requires an effective management mechanism and close cooperation between various related areas – transport, culture, environment, education and rural development, ensuring regular exchange of information, coordination and implementation of joint activities [6]. The support of the state and local governments plays a vital role in regional development, promoting employment, the growth of the population's income and the growth of the national economy as a whole [7].

The agritourism product is characterized by rural farms that preserve the traditions of agriculture, fishing, handicrafts and food production. It is important to educate visitors and provide them with the opportunity to explore the beauty of nature, the diversity of plants and animals, gaining both theoretical and practical knowledge in direct contact with nature.

Taking into account the limited availability of research and statistical data on agritourism in Latvia, this study is particularly important in order to summarize and analyze the types of agritourism and their development potential. The object of the study - types of agritourism. Subject of the study – research of types of agritourism in Latvia. The aim of the study – to study and analyze types of agritourism and their potential in Latvia, identifying the main trends and opportunities.

II. Materials and Methods

The theoretical basis of the study is based on the analysis of diverse sources of information, including scientific studies, publications and practical examples. The following methods were used in the study:

- **Sociological methods:** Data collection was carried out using observation and literature analysis methods.
- **Statistical methods:** Statistical grouping (descriptive statistics), sampling method and graphical data presentation were used in data processing.

III. Results And Discussion

By compiling information from various sources [8] – [16], a classification of agritourism was developed, based on the keywords: "Rural environment," "Crafts," "Recreation," "Health" and "Nutrition" (Fig. 1). These keywords describe the nature and diversity of agritourism. Tourism destinations can be divided into two types: natural and human-made. Natural attractions are natural tourism resources that are supplemented by human input so that visitors can more fully enjoy and learn about nature and rural lifestyles in accordance with the rhythms of nature (Fig. 2 – 6).

Tourist demands have changed in recent years, with a growing demand for higher-quality and nature-friendly recreation [9]. People are increasingly eager to engage in rural activities and learn new skills, so the development of the agritourism industry is essential. The offer of agritourism is wide, including not only accommodation and meals, but also educational programs, active involvement in farm work, volunteer work in agriculture, craft workshops, the production of traditional art objects, and dishes made from local products [10]. Agritourism also includes beekeeping tourism [9].

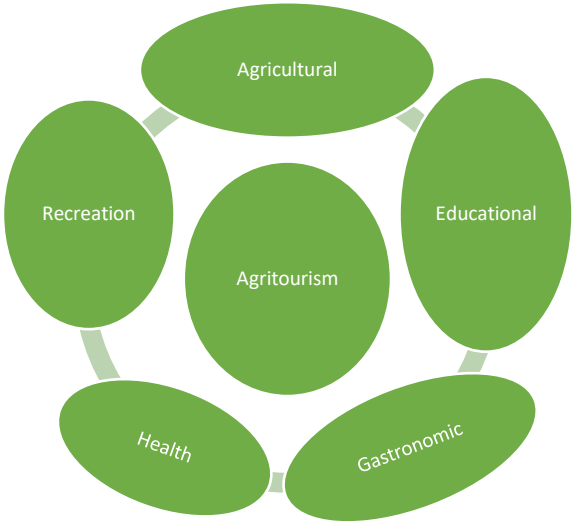

Fig. 1. Distribution of agritourism facilities by purpose of use.

Latvian scientific institutions regularly organize educational events, such as demonstrations comparing agricultural crop varieties, where interested parties can learn about different plants, their cultivation methods, and view agricultural machinery (Fig. 2). Such measures promote the development of local tourism (Fig. 3), which, according to the Tourism Law [17], is "tourism of Latvian residents in Latvia." The Latvian Rural Tourism Association "Lauku ceļotājs" began developing a Code of Ethics for Nature Tourists in 2023 to reduce the negative impact of humans on the environment [18].

Fig. 2. Classification of agricultural agritourism.

Gastronomic tourism, which often includes visits to farms, is very popular [11]. The farms offer tours of production facilities, demonstrating agricultural processes from raw material extraction to finished products, as well as organizing workshops, tastings and offering to purchase

local products (Fig. 4). Agritourism farms have two interconnected stages [8]: the technical and productive side, which includes the processing of natural products, and the economic side, which deals with the production process, pricing, and financial management.

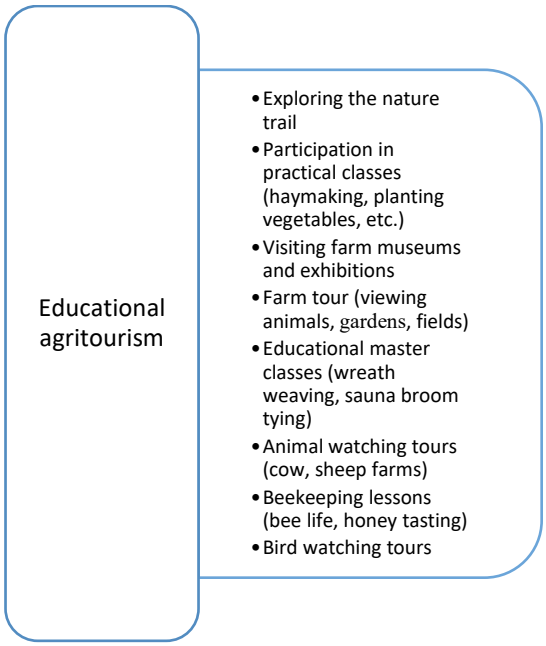

Fig. 3. Classification of educational agritourism.

In the context of globalization, local products have a special value, as the demand for authenticity and quality is growing in modern gastronomy. Global chefs use fresh, local, and organic ingredients, but the concept of "local" is undergoing a new interpretation today [11].

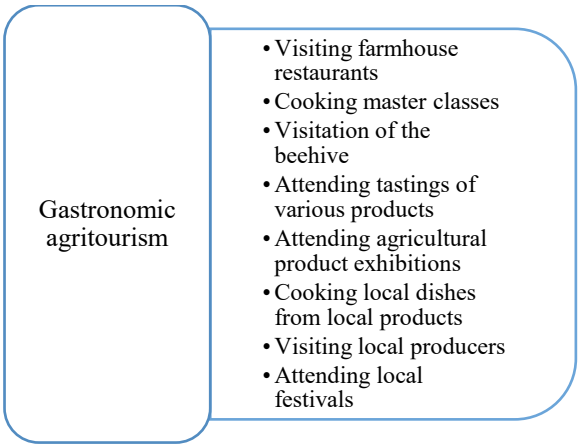

Fig. 4. Classification of gastronomic agritourism.

There is growing interest in the planning of rehabilitation and sensory gardens around the world, which could be more widely implemented in Latvian medical institutions [15]. When obtaining raw materials from plants found in nature, it is important to ensure their preservation and regeneration [19]-[20]. Visiting agritourism facilities promotes environmental awareness and reminds us of a careful attitude towards nature.

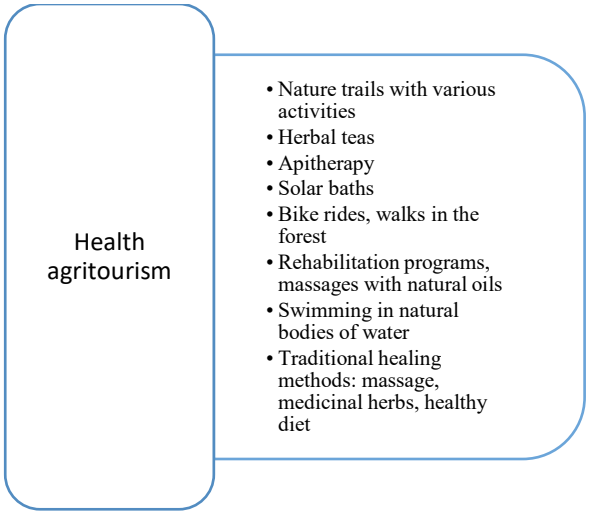

Fig. 5. Classification of health agritourism.

Health and leisure agritourism (Fig. 5 - 6) are closely related, as well-being and recreation are complementary factors. Recreation in a clean rural environment is particularly valuable. One of the goals of European environmental policy is to promote corporate responsibility for environmental impacts [21]. The economy of rural farms is related to the market, agricultural sectors, consumption, and agricultural policy [22]. As demand for natural environments and products increases, interest in beekeeping and apitourism also increases. The development of beekeeping is related to the preservation of the country's natural beauty, traditions, and cultural heritage [9]. The synergy between agriculture and tourism promotes the economic development of both sectors [10]. Regional support is also important for the preservation of natural landscapes that are characteristic of rural Latvia, especially Latgale [23]. Bees are in the closest contact with their surroundings. Changes in plant cover, its depletion, switching to a monoculture, herbicide treatment, slope leveling, clearing and land reclamation of scrub, plowing of meadows and floodplains, and urban expansion have a very strong impact on the life of bees, changing the conditions of their existence [24] -[25]. Interest in the development of bee products and their medicinal, health, nutritional, and beauty benefits has increased, but little attention has been paid to the crucial role of beekeeping in maintaining ecological balance [26]. Despite the fact that there is talk on a global scale about the need for environmental protection measures, people themselves are also destroying it. The beekeeping industry is an industry that can and should be developed, however, environmental pollution and the destruction of the natural environment can hinder it [25], [27]-[28].

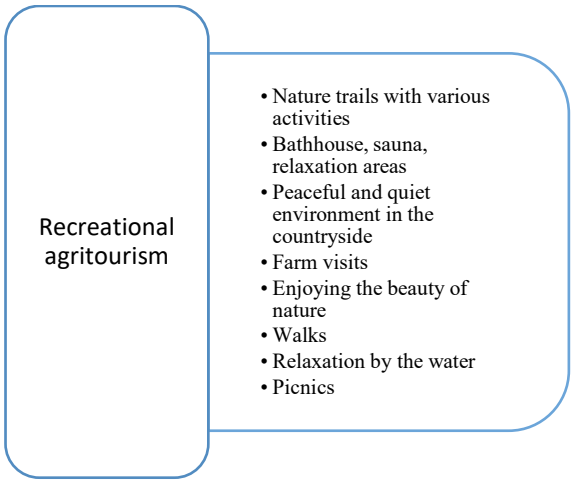

Fig. 6. Classification of recreational agritourism.

This study confirmed the multifaceted importance of agritourism in Latvia, highlighting its connection with rural development, preservation of cultural heritage, and sustainable use of natural resources.

IV. Conclusions

Main conclusions:

- Agritourism is a multidimensional industry that encompasses recreation, active involvement in rural work, education, gastronomy and health promotion. The main keywords characterizing agritourism are "Rural environment. Crafts. Recreation. Health. Nutrition"
- Local products and traditions are the foundation of agritourism, contributing to the preservation of cultural heritage and offering authentic experiences.
- Cooperation between farms, tourism companies and government institutions is essential for the development of the industry.
- The development of agritourism must be sustainable, respecting the principles of environmental protection.
- Promoting education and awareness about agriculture and nature is an important aspect of agritourism.
- Beekeeping is an essential part of agritourism and a significant element of the ecosystem.
- Types of agritourism by purpose: agricultural, educational, gastronomic, health, recreational agritourism.

Agritourism as a component of the tourism sector (industry) with its diverse opportunities and types has great potential, because Latvia, with its geographical location and rich natural resources, could attract not only local tourists, but also tourists from other countries.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 267-274

Integrating ESG and Sustainability in the Raw Materials Sector

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***Abstract*— The global demand for raw materials continues to grow, intensifying the need for responsible mining practices that balance economic growth with environmental stewardship and social responsibility. This paper explores the integration of Environmental, Social, and Governance (ESG) principles into sustainable mining practices, highlighting their critical role in reshaping the industry's future. Focusing on case studies and industry trends, the research examines how mining companies are adopting ESG frameworks to minimize environmental impact, enhance community engagement, and promote transparent governance. The paper also analyses findings on the financial and operational benefits of ESG integration, including risk mitigation, improved stakeholder trust, and long-term value creation. By aligning business goals with sustainable development objectives, mining companies can enhance their social license to operate and remain competitive in a rapidly evolving market. The findings underscore the importance of a holistic approach to responsible mining, advocating for collaborative efforts among industry stakeholders, policymakers, and communities.**

Keywords*— *responsible mining, ESG, social responsibility, raw materials

I. INTRODUCTION

The global demand for raw materials continues to grow, intensifying the need for responsible mining practices that balance economic growth with environmental stewardship and social responsibility. In recent years, the mining and geological exploration industry has witnessed a significant shift towards the adoption of Environmental, Social, and Governance (ESG) frameworks, which aim to reduce environmental impact, strengthen community engagement, and improve governance transparency. ESG-focused practices not only help mitigate operational and financial risks but also enhance stakeholder trust and create long-term value.

One of the key drivers of this transition is the growing recognition that a sustainable approach to mining can not only mitigate reputational and operational risks but also enhance long-term value creation [1]. As financial institutions and investors increasingly prioritize sustainable investment opportunities, mining corporations are under pressure to demonstrate their commitment to environmental and social sustainability [2]. Furthermore, the green energy transition has presented both challenges and opportunities for the mining sector, as the demand for certain minerals, such as copper, lithium, and rare earth elements, is expected to surge to support the development of renewable technologies [3].

Studies reveal that mining companies use multiple ESG frameworks to track environmental performance (primarily water and emissions), community impact, and governance transparency, though implementation remains unstandardized across the sector [4][5][6]. To effectively embed sustainability throughout the mining value chain, companies must take a comprehensive approach that integrates environmental, social, and governance considerations into every stage of the mining life cycle, from exploration and extraction to processing, waste management, and site rehabilitation [7][8]. Moreover, the success of mining operations is increasingly dependent on securing the social license to operate, which requires meaningful engagement with local communities, Indigenous groups, and other stakeholders. Initiatives such as the Responsible Mining Index and the Kimberley Process Certification Scheme have emerged to promote ethical and conflict-free mineral sourcing, fostering transparency and accountability within the industry [9].

One of the key findings from the literature is that the mining industry can play a vital role in the green transition by providing the necessary minerals for low-carbon and renewable energy technologies (Zhu et al., 2011)[3]. However, the industry has historically been perceived as

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8692
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one of the least committed to sustainable development, largely due to its inherent challenges, such as low conversion efficiencies, high energy intensity, and large volumes of tailings and emissions. [10].

This overview explores how mining and geological exploration companies are adopting ESG frameworks to reduce environmental impact, strengthen community engagement, and improve governance transparency. Key strategies include lowering carbon emissions, implementing responsible waste management, protecting biodiversity, and promoting ethical labour practices [1]; [11]. Through industry trends, this overview highlights the financial and operational benefits of ESG adoption, demonstrating how responsible mining practices can drive both profitability and sustainability. Key sources are the EU Commission funded Sustainable Management in the Extractive Industries project (SUMEX project) reports, which provide empirical insights into ESG implementation through variable manipulation and scenario-based assessments.

II. MATERIALS AND METHODS

This overview article employs qualitative data in project case studies to analyze the financial and operational benefits of ESG integration in the mining sector. The research draws on experimental data gathered from policy briefs, sustainability frameworks, analytical models, and case studies.

The experimental data used in this study comes from five key SUMEX reports, each offering relevant findings on sustainable mining practices:

- Regulatory and policy insights. Policy briefs on sustainable mining practices.) – Analysis of how policy frameworks impact ESG adoption.[12]
- Sustainability framework development. Examination of ESG indicators and their integration into mining operations.[13]
- Case studies on extractive projects: Assessment of real-world applications and the effectiveness of ESG strategies.[14]
- Analytical frameworks for ESG assessment: Methodological approaches to measuring environmental and social impact.[15]
- Capacity-building strategies: Evaluation of workforce training and governance improvements in mining.[16]

The study analyses reports to identify patterns and correlations between ESG integration and financial/operational performance.

A. Analytical Approaches for ESG Performance Assessment

The analytical framework developed in the SUMEX project provides a methodological foundation for assessing ESG performance in mining operations. The findings highlight three key evaluation models:

- Leverage Points Model: Identifies critical intervention areas for sustainability improvements. [17]
- Seven Questions to Sustainability (7QS, Fig. 1): Serves as a qualitative assessment tool to evaluate the long-term impacts of ESG initiatives. [18]
- Institutional Resource Regime (IRR) Model: Examines governance structures and assesses policy effectiveness in resource management. [19]

Fig. 1. The Seven Questions at a glance. [18]

These analytical tools enable both mining companies and policymakers to systematically measure sustainability performance, identify gaps, and develop targeted ESG strategies. The results indicate that a data-driven approach to ESG assessment facilitates more informed decision-making and enhances accountability in the sector.

III. RESULTS AND DISCUSSION

The analysis of the SUMEX project reports provides significant insights into the integration of Environmental, Social, and Governance (ESG) principles within the extractive industry. The findings illustrate how sustainable development frameworks, policy guidance, analytical tools, and capacity-building initiatives contribute to responsible mining practices. The results are categorized based on core themes emerging from the data: sustainability frameworks, policy integration, case study analysis, analytical methodologies, and capacity-building approaches.

A. Development of a Sustainable Mining Framework

The SUMEX Sustainability Framework presents a structured approach to sustainable management in geological exploration and mining. An analysis of 31 international and EU policies on sustainability identifies three key priorities: economic transition, social responsibility, and environmental stewardship. The findings suggest that integrating extractive industries into a circular economy, assessing natural and social capital, and implementing long-term planning strategies beyond a mine's lifecycle are critical to sustainability. Additionally, transparent stakeholder engagement, equitable benefit-sharing mechanisms, and improved worker well-being

emerge as essential components of social responsibility. From an environmental perspective, integrated water management, greenhouse gas emission reductions, and responsible waste management with an emphasis on secondary resource utilization are identified as priority areas.

The framework aligns with the European Green Deal and the United Nations Sustainable Development Goals (SDGs) [20], providing a foundational structure for ESG integration across the mining lifecycle, from exploration to post-closure. These findings underscore the importance of a standardized approach to sustainability assessment in extractive industries.

B. Policy Integration and Governance in the Extractive Sector

An evaluation of policy briefs highlights the role of regulatory frameworks in facilitating ESG adoption. The analysis indicates that policy coherence and regulatory certainty significantly influence industry-wide implementation of sustainable practices. The effectiveness of governance mechanisms in ensuring compliance with ESG standards is identified as a key factor in determining the success of policy interventions. Furthermore, incentives such as tax benefits and subsidies are shown to play a vital role in encouraging mining companies to integrate ESG principles into their operations.

The study also emphasizes the necessity of harmonizing national and international regulatory frameworks to promote cross-border investments in sustainable mining. Regulatory transparency and active stakeholder participation are found to be essential for building public trust and securing a social license to operate. These findings suggest that a well-defined governance structure and policy incentives can drive ESG implementation across the extractive sector. For the implementation and review of the situations local study visits in mining regions has been organized (examples Fig. 2; Fig. 3).

Fig. 2. SUMEX regional workshop North fieldwork to quarry mining. Helsinki, Finland, April 2022.

C. Case Study Analysis of Extractive Projects

An assessment of extractive projects reveals variations in ESG adoption based on geographical location, resource type, and company size. The case study analysis demonstrates that companies implementing ESG frameworks report measurable improvements in operational efficiency, financial performance, and stakeholder engagement. Specifically, firms that integrate ESG principles experience reduced environmental risks through lower emissions, enhanced biodiversity conservation, and improved waste management strategies. One site of the case study are shown in Fig. 3.

Fig. 3. SUMEX regional workshop South fieldwork to open pit mining. Seville, Spain, June 2022.

Additionally, the findings indicate that companies prioritizing community engagement achieve stronger relationships with local stakeholders through participatory decision-making processes and fair compensation practices. Financially, ESG-aligned businesses benefit from lower capital costs, increased investor confidence, and long-term profitability. However, despite these advantages, challenges such as high initial implementation costs and inconsistencies in regulatory enforcement are identified as persistent barriers to widespread ESG adoption.

D. Environmental Impact Reduction in Mining and Geological Exploration Companies.

Key achievement in environmental impact reduction can be divided into the following categories:

- Enhanced Biodiversity Conservation: Successful integration of biodiversity protection policies in sensitive ecosystems.
- Reduced Carbon Emissions: Companies like Canteras La Ponderosa and Rio Tinto have achieved significant reductions in operational greenhouse gas emissions.
- Improved Waste Management: Innovations in waste recycling and by-product recovery have improved environmental performance in companies like Boliden and BHP.
- Stronger Community Engagement: Transparent EIA practices have fostered trust between mining companies and local communities, reducing social conflict.

Mining and geological exploration companies are increasingly adopting Environmental, Social, and Governance (ESG) frameworks to reduce their environmental impact. These strategies are reshaping operational practices to align with sustainability goals while maintaining productivity and compliance. One key

method employed by these companies is the enhancement of Environmental Impact Assessment (EIA) processes. Companies like Anglo-American have implemented comprehensive EIA procedures to assess environmental risks before initiating major projects. By involving local communities in these assessments, Anglo-American has fostered greater trust and ensured that environmental concerns are addressed early in the project lifecycle.

In addition to improved EIAs, biodiversity protection and restoration are becoming crucial strategies. Dundee Precious Metals in Bulgaria has successfully integrated biodiversity conservation plans that align with EU Natura 2000 conservation objectives. Their proactive measures have led to the successful restoration of local habitats, achieving a net positive biodiversity outcome post-extraction.

Waste management has also seen considerable advancements, with companies like Boliden AB in Sweden introducing closed-loop waste management systems. These systems focus on recycling by-products and reducing water pollution, resulting in a 30% reduction in waste discharge and improved mineral recovery from waste streams.

Efforts to reduce carbon emissions are also gaining momentum. Canteras La Ponderosa S.A. in Spain has adopted solar-powered machinery and optimized fleet management systems, significantly lowering its energy consumption. As a result, the company reduced its operational emissions by 25% within five years, demonstrating how renewable energy solutions can effectively reduce the carbon footprint of mining operations.

Water management strategies are another focal point in sustainable mining practices. Rio Tinto, a major global mining company, has developed a robust water stewardship program to monitor and manage water usage in drought-sensitive regions. By integrating efficient recycling and resource conservation methods, Rio Tinto reduced water consumption by 20% across its key extraction sites.

Finally, circular economy practices are being increasingly implemented to minimize waste and enhance resource recovery. BHP, with operations in Australia and Chile, has introduced innovative processes to extract valuable minerals from waste streams. This approach has improved their resource recovery rates by 40% in selected sites, showcasing how circular economy principles can significantly reduce environmental impact.

Several EU-funded initiatives have also played a crucial role in promoting sustainable practices in the mining sector. The SUMEX project, for instance, has developed a Sustainability Toolkit to help mining companies adopt environmentally responsible strategies. Similarly, the Finnish Network for Sustainable Mining has provided comprehensive guidance for responsible environmental practices, improving knowledge-sharing among industry stakeholders.

Through these combined efforts, mining companies are achieving significant milestones in reducing environmental impact. Enhanced biodiversity conservation, reduced carbon emissions, improved waste management, and stronger community engagement are contributing to a more sustainable future for the extractive industry. By aligning their operations with ESG principles, companies are demonstrating that economic success can coexist with environmental stewardship and social responsibility.

E. Strengthening Community Engagement

Mining and geological exploration companies are increasingly prioritizing community engagement as part of their commitment to Environmental, Social, and Governance (ESG) frameworks. By fostering transparent communication, building trust, and supporting local communities, these companies are mitigating social conflict and strengthening their social license to operate. Key strategies on community engagement as a vital aspect of ESG integration include:

- Inclusive Decision-Making: Mining companies are encouraged to develop relationships with local communities through early-stage engagement, ensuring social concerns are addressed.
- Education and Capacity Building: The SUMEX Capacity Building Podcast was launched to educate professionals, permitting authorities, and policymakers about sustainability practices in the mining industry.
- Social Responsibility and Livelihood Support: Mining companies are investing in programs to support local employment, improve working conditions, and promote health and safety practices within mining communities.

One notable example of effective community engagement is demonstrated by Anglo-American, which operates globally with significant projects across Europe, Africa, and the Americas. The company has actively integrated community engagement strategies into its operations by establishing dialogue platforms where community members can express concerns and collaborate on project-related decisions. This participatory approach has enabled Anglo-American to align its development plans with local priorities, resulting in improved trust and reduced opposition to its mining activities.

Similarly, Dundee Precious Metals in Bulgaria has adopted proactive engagement practices to involve local communities in decision-making processes. The company has partnered with local municipalities, educational institutions, and community leaders to provide insights into mining activities and address public concerns. Dundee's initiatives include community consultation sessions and environmental monitoring programs that involve residents directly. By fostering this inclusive approach, the company has improved public trust and minimized social tensions linked to mining operations.

In Spain, Canteras La Ponderosa S.A. has demonstrated success in strengthening ties with local communities through targeted social investment programs. The company has supported infrastructure development projects, such as

improving local roads and public amenities, as well as investing in educational initiatives to build local capacity in mining-related fields. These efforts have not only benefited the community but also enhanced the company's reputation and operational stability.

Boliden AB, a Swedish mining company, has integrated comprehensive community engagement strategies across its European operations. Boliden places strong emphasis on communication transparency by regularly publishing detailed environmental and social impact reports accessible to the public. The company also maintains open-door policies at its mining sites, allowing local residents to visit and gain a firsthand understanding of operational activities. By providing clear, accessible information, Boliden has built stronger community relationships, reducing resistance to its projects.

Furthermore, mining companies are increasingly adopting structured frameworks to formalize their engagement practices. The SUMEX Project, a European Union initiative, promotes best practices in community engagement by encouraging mining firms to align with established sustainability frameworks. SUMEX highlights the importance of building partnerships with local communities, authorities, and NGOs to ensure mutual benefits from mining activities. The project's Knowledge Repository serves as a platform for sharing case studies and proven methods for effective community engagement, further advancing best practices in the sector.

The Finnish Network for Sustainable Mining has similarly played a key role in supporting mining companies to enhance community relations. Through their guidance, Finnish mining companies have improved stakeholder engagement processes by incorporating community feedback into project planning, ensuring that social concerns are prioritized alongside economic goals.

These examples demonstrate that mining companies are increasingly recognizing the importance of meaningful community engagement. By fostering trust through dialogue, supporting social development initiatives, and maintaining transparent communication, companies such as Anglo-American, Dundee Precious Metals, Canteras La Ponderosa S.A., and Boliden AB are successfully strengthening their ties with local communities. These efforts not only enhance social well-being but also contribute to the long-term stability and success of mining projects, illustrating the critical role that community engagement plays in the modern extractive industry.

F. Improving Governance Transparency

Mining and geological exploration companies are increasingly prioritizing governance transparency as a core component of their Environmental, Social, and Governance (ESG) frameworks. By adopting robust reporting standards, improving stakeholder communication, and embracing ethical governance practices, these companies are enhancing accountability and strengthening their social license to operate. Key governance strategies for responsible mining operations are:

- ESG Reporting and Compliance: Mining companies are aligning with international reporting standards such as the Global Reporting Initiative (GRI) and Initiative for Responsible Mining Assurance (IRMA).
- Policy Integration and Compliance: the SUMEX Sustainability Framework aligns ESG principles with key European policy frameworks such as the EU Green Deal and Critical Raw Materials Act.

Several notable examples illustrate how mining firms are improving governance transparency, demonstrating significant achievements across Europe and beyond.

One key example is Anglo-American, a global mining corporation with significant operations in Europe, Africa, and the Americas. Anglo-American has integrated comprehensive reporting practices aligned with internationally recognized standards such as the Global Reporting Initiative (GRI) and the Task Force on Climate-related Financial Disclosures (TCFD). By publishing detailed annual sustainability reports, the company provides clear insights into its environmental performance, social impact, and governance practices. These disclosures include information on greenhouse gas emissions, water use, employee welfare, and corporate decision-making processes. Anglo-American's commitment to transparency has significantly improved stakeholder trust, particularly among investors and regulatory authorities.

Boliden AB, a major Swedish mining company, has also made significant strides in strengthening governance transparency. The company has developed a structured approach to ESG reporting, ensuring consistent and accessible communication with stakeholders. Boliden regularly publishes environmental, social, and governance updates, emphasizing compliance with EU environmental directives and Sweden's sustainability standards. By establishing open communication channels with local communities and authorities, Boliden has improved public awareness of its environmental and operational performance, reinforcing its commitment to accountability. This proactive approach has been particularly effective in regions with heightened environmental concerns.

In Finland, Outokumpu, a prominent stainless steel producer that operates large-scale mining and smelting facilities, has implemented rigorous governance standards to ensure responsible mineral sourcing. Outokumpu actively engages with third-party auditors to validate its supply chain transparency, ensuring that raw materials are sourced ethically and responsibly. The company's dedication to traceability has improved its reputation in both domestic and international markets, positioning Outokumpu as a leader in responsible mineral sourcing.

Efforts to improve governance transparency have also been strengthened by sector-wide initiatives such as the SUMEX Project, which has developed a comprehensive analytical framework for improving governance practices in the extractive sector. SUMEX emphasizes the

importance of public reporting, clear regulatory compliance, and improved permitting processes to enhance transparency. The project encourages mining companies to adopt transparent frameworks that allow stakeholders to monitor environmental impacts, social initiatives, and corporate decision-making.

The Finnish Network for Sustainable Mining has further contributed to governance improvements by promoting best practices for ensuring clear, responsible mining activities. The network's guidance encourages mining companies to adopt transparent permitting frameworks that provide the public with access to key information on project timelines, environmental risks, and social engagement strategies.

In addition to regulatory alignment, mining companies are increasingly adopting voluntary standards that reinforce their commitment to transparent governance. The Initiative for Responsible Mining Assurance (IRMA) has become a widely adopted framework, with companies such as Dundee Precious Metals in Bulgaria aligning their operations with IRMA's principles to demonstrate accountability and uphold sustainable mining practices.

These efforts collectively reflect a growing trend within the mining industry to adopt transparent governance frameworks that improve stakeholder trust and ensure responsible decision-making. By actively disclosing environmental, social, and operational data, companies such as Anglo-American, Boliden AB, Outokumpu, and Dundee Precious Metals are reinforcing their commitment to ethical mining practices. These achievements highlight the critical role that governance transparency plays in promoting sustainability, ensuring industry accountability, and aligning mining operations with global best practices.

G. Capacity-Building for ESG Adoption

The findings from the capacity-building initiatives emphasize the importance of workforce training and leadership development in advancing ESG principles. The results highlight that structured training programs focusing on responsible mining practices significantly contribute to the successful adoption of ESG frameworks. Leadership development programs further support ESG-driven decision-making, ensuring that sustainability considerations are embedded into corporate strategies.

Additionally, knowledge-sharing platforms are identified as effective mechanisms for disseminating best practices across the sector. The study suggests that continuous investment in human capital is essential for fostering a culture of sustainability and ensuring the long-term success of ESG integration efforts. Therefore, the SUMEX project team developed MOOC: Sustainable Management in the Extractive Industry (https://www.futurelearn.com/courses/transitioning-towards-sustainable-management-of-mineral-resource-extraction) and it has been part of the EIT Raw Materials Academy (https://eitrawmaterials.eu/rawmaterials-academy) course list since project end.

The results from the SUMEX project reports reinforce the importance of ESG integration in the raw materials sector. The study identifies sustainability frameworks, regulatory mechanisms, real-world case studies, analytical methodologies, and capacity-building initiatives as critical factors in advancing responsible mining practices that is also reflected in numerous studies [5]; [11]; [22]; [23]. The collective findings indicate that while ESG implementation poses certain challenges, such as financial and regulatory hurdles, the long-term benefits—such as improved risk mitigation, stakeholder trust, and financial resilience—outweigh these initial barriers [2]; [3]; [10]; [25].

These results contribute to the growing body of evidence supporting the economic and operational advantages of ESG adoption in the mining industry. They highlight the need for industry-wide collaboration, regulatory support, and continued research to drive sustainable transformation in the extractive sector. For fostering the collaboration LinkedIn Group function has been used. All experts on the field are invited to join with the group: Sustainable Management in the Extractive Sector: Navigating Challenges and Forging New Paths (https://www.linkedin.com/groups/14134912/).

Additionally, continuous research and data-driven assessments will be necessary to refine ESG strategies and ensure their effectiveness in diverse operational contexts. Additionally, the SUMEX Podcast Series (https://www.sumexproject.eu/2023/05/03/sumex-podcast/) serves as a platform for disseminating knowledge and fostering discussions on sustainable raw materials extraction, with a particular focus on Environmental, Social, and Governance (ESG) integration within the mining sector. Through expert interviews, case study analyses, and policy discussions, the series provides insights into the challenges and opportunities associated with responsible resource management in Europe and beyond. By engaging with industry leaders, researchers, and policymakers, the podcast highlights best practices, innovative solutions, and regulatory developments that contribute to sustainable mining operations. The series aims to bridge the gap between theoretical sustainability frameworks and their practical implementation, offering valuable perspectives for professionals, decision-makers, and stakeholders interested in advancing ESG-driven transformation in the extractive industry.

IV. CONCLUSION

The findings of this research highlight the financial and operational advantages of ESG integration in the raw materials sector, particularly within geological exploration and mining. By analyzing sustainability frameworks, regulatory mechanisms, case studies, analytical methodologies, and capacity-building initiatives, the study demonstrates that ESG principles play a crucial role in shaping the future of responsible mining. While challenges such as financial costs, regulatory complexities, and industry-wide inconsistencies persist, the long-term benefits—enhanced risk mitigation, improved stakeholder trust, and financial resilience—far outweigh these initial barriers.

One of the key takeaways from the research is that ESG integration helps mining companies mitigate a wide range

of operational and financial risks. By proactively addressing environmental concerns such as emissions reduction, water resource management, and biodiversity protection, companies can minimize liabilities, regulatory fines, and reputational damage. Furthermore, strong social responsibility initiatives, including transparent stakeholder engagement, fair labor practices, and equitable community benefit-sharing, contribute to securing a social license to operate, which is essential for long-term project stability. Governance improvements, such as ethical leadership and regulatory compliance, further strengthen investor confidence and reduce financial volatility.

The study also reinforces that ESG adoption is not just a compliance requirement but a strategic driver of long-term profitability. Companies that implement ESG frameworks experience greater operational efficiency, lower capital costs, and improved access to investment. Investors and financial institutions are increasingly prioritizing ESG-aligned businesses, recognizing their lower risk exposure and greater potential for sustained growth. As a result, mining firms that embrace ESG principles are better positioned to attract funding, enhance competitiveness, and future-proof their operations in an evolving regulatory and market landscape.

However, realizing the full potential of ESG integration requires a collective effort from industry stakeholders, policymakers, and regulatory bodies. Harmonized policies, clear sustainability guidelines, and financial incentives can accelerate ESG adoption and create a level playing field for all industry participants. Capacity-building initiatives, such as workforce training and leadership development, are equally critical in embedding a culture of sustainability within the sector.

As global demand for raw materials continues to grow, the mining industry faces increasing pressure to balance economic growth with environmental stewardship and social responsibility. The research findings suggest that companies that proactively integrate ESG principles will be better equipped to navigate this evolving landscape, ensuring long-term value creation while minimizing negative impacts. The transition to sustainable mining practices is not just an ethical necessity but an economic and operational imperative that will define the future of the extractive sector.

V. ACKNOWLEDGMENT

SUMEX project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 101003622.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 275-280

Frame Semantics in the Domain of Unmanned Aerial Vehicles for Logistics and Data Transmission

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***Abstract* — With the rapid development of Unmanned Aerial Vehicles (UAVs), the demand for precise documentation has become essential. This evolution has introduced a new layer of terminology into Aviation English, as the communication and operational requirements of UAVs differ significantly from those of traditional manned aircraft, particularly in the context of logistics and data transmission. Recognizing this, ICAO and other aviation bodies are working to standardize UAV-related terminology, as inconsistent interpretations can lead to miscommunication. This article provides an overview of frame semantics theory and explores UAV applications in logistics and data transmission. It addresses the significance of frame-based terminology as an analytical tool for understanding the complexities of UAV discourse. Utilizing Sketch Engine, this study analyzes the frequency and collocation patterns of terms within the UAV field, providing valuable insights into the underlying frames that shape technical English in aviation. This analysis highlights multi-word terms and frames, revealing a significantly higher frequency of nouns compared to verbs, indicating a preference for descriptive terminology within the UAV domain. By studying UAV-related terminology, this research offers valuable insights into how technological advancements influence and expand specialized professional languages like aviation English.**

Keywords—frame-based theory, unmanned aerial vehicles, UAV, logistics.

I. INTRODUCTION

In recent years people have witnessed the emergence of new technologies enabling the autonomous operation of unmanned vehicles—airborne (UAVs - Unmanned Aerial Vehicles), ground-based (UGVs - Unmanned Ground Vehicles), and maritime (USVs - Unmanned Surface Vehicles and UUVs - Unmanned Underwater Vehicles). The rapid advancement of UAVs is transforming multiple industries, particularly in logistics and data transmission, where their autonomous capabilities enable faster, more efficient, and cost-effective operations. Originally developed for defense applications, UAVs have expanded into various military and civilian sectors, including transportation, communication, disaster response, and environmental monitoring. Their ability to navigate complex environments, both natural and man-made, makes them indispensable for data collection, reconnaissance, military or rescue operations, cargo transport, etc. Equipped with AI-driven navigation, GPS, infrared sensors, and decision-making algorithms, UAVs facilitate the movement of goods, rapid stock assessments, and improved situational awareness in high-risk scenarios. Real-time telemetry ensures the transmission of collected data to ground stations or cloud platforms for analysis and decision-making.

Alongside technological innovation, the rise of UAVs has introduced new terminology and communication challenges in aviation. Given the distinct operational and regulatory requirements of UAVs compared to traditional aircraft, organizations such as the International Civil Aviation Organization (ICAO) are working to standardize terminology and regulations [1]. Linguistic clarity is essential for ensuring operational efficiency, regulatory compliance, and safety. Familiarity with terminology and structural patterns can also improve translation practices within the unmanned vehicle industry.

Frame-based theory (FBT) [2], which organizes domain-specific knowledge into structured frameworks, provides an effective approach for facilitating deeper comprehension of aviation terminology, particularly in the context of UAVs. Frame Semantics [3] serves as a valuable framework for understanding and organizing the

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8630
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evolving linguistic landscape of UAV operations in logistics and data transmission. By analyzing the semantic structures underlying UAV-related terminology, it is aimed to contribute to a clearer, more systematic approach to communication in this quickly expanding domain.

One of the primary functions of language is to convey knowledge. The concept of the "frame" was first introduced into linguistics by Fillmore [3] through Frame Semantics, which describes how meanings are structured and linked to words, granting access to our conceptual system. A key principle of this theory is that all concepts belong to broader cognitive structures and are interconnected — activating a single word triggers the entire frame. These frames provide contextual knowledge of words and terms, clarifying both their semantic meanings and syntactic patterns. Additionally, Fillmore [3], and Fillmore and Atkins [4] propose that frames are embedded within texts, shaping discourse and guiding interpretation.

Building on Fillmore's ideas, Faber et al. [2], and Faber [5] [6] developed frame-based terminology, which emphasizes the interconnected nature of concepts within specialized domains. This approach views knowledge acquisition as a gradual process, beginning at the term level, expanding to the phrase level, and ultimately forming a comprehensive conceptual framework. Unlike traditional terminological approaches that consider terms in isolation, frame-based terminology examines their relationships within a structured knowledge system, integrating linguistic, cognitive, and ontological perspectives.

The purpose of this study is to explore frame-based terminology in the domain of unmanned aerial vehicles for logistics and data transmission. By examining linguistic patterns and technical terminology within this field, the research aims to enhance comprehension of UAV-related texts, improve technical communication, and support the accurate interpretation and production of specialized documentation.

II. MATERIALS AND METHODS

In the context of UAVs, terminology is not merely a collection of isolated words but a dynamic system shaped by real-world functions, operational contexts, and technological advancements. Analyzing UAV terminology through a conceptual frame helps identify patterns that enhance both comprehension and practical application. This structured approach ensures greater terminological consistency, facilitating effective communication across disciplines and regulatory environments. Ultimately, integrating contextual and functional knowledge within frame-based terminology leads to more precise and systematic linguistic representations of UAV-related concepts.

Corpus linguistics relies on extensive, machine-readable text collections from specific genres to perform in-depth linguistic analysis. These text databases, known as corpora, enable researchers to systematically examine language patterns, usage, and variations within a given domain, offering insights that traditional linguistic approach may not easily uncover. By studying these large datasets, corpus linguistics facilitates the investigation of syntactic structures, word frequency, and semantic subtleties across various contexts. As a result, it serves as a valuable tool for both theoretical and applied linguistic research [7].

This study investigates the application of frame-based terminology within the specialized domain of unmanned aerial vehicles (UAVs) employed for logistics and data transmission. The research conducts a systematic analysis of linguistic structures and domain-specific lexicon in order to advance the understanding of UAV-related discourse, optimize the clarity and precision of technical communication, and facilitate the accurate interpretation and generation of specialized documents. Applying a frame-based approach allows for a more systematic organization of UAV terminology, and facilitates consistency in training materials and regulatory frameworks. Given the critical role of UAVs in logistics and data transmission, this study also seeks to clarify how terminology reflects operational functions, communication protocols, and technological advancements in these areas. Ultimately, this research contributes to the development of a structured linguistic framework that ensures precise and effective communication in UAV operations. As this is a long-term endeavor, the discussion in this article represents only an initial, exploratory stage of the research.

The UAV domain corpus was designed specifically for the purposes of this study. It was compiled from a regulatory document, academic articles, and technical manuals. Although exact frequencies vary by source, the statistics below capture trends observed across a few datasets. While the general domain is aviation technical English, this corpus is highly focused, specifically addressing the area of UAV terminology and concepts. It includes 6 authentic sources – Unmanned Aircraft Systems (UAS), ICAO Circular 328 [1]; Unmanned Aerial Vehicles and Drones, a collection of articles edited by Gacovski [8]; the books Unmanned Aerial Vehicles Application: Challenges and Trends by Abdelkader and Koubaa (eds) [9], Drone Development from Concept to Flight by Suman [10], and Handbook of Unmanned Aerial Vehicles by Valavanis and Vachtsevanos (eds) [11], and the research article Unmanned Aerial Vehicles (UAVs): Practical Aspects, Applications, Open Challenges, Security Issues, and Future Trends by Mohsan et al. [12]. All texts are authentic, monolingual, and they belong to the academic or scientific genre.

The texts were grouped in a folder named Corpus_UAVs, which was then submitted in Sketch Engine [13]. Sketch Engine is a widely employed corpus management and text analysis tool in linguistic research and language education. It offers access to an extensive repository of corpora spanning multiple languages and genres, enabling researchers and other users to conduct comprehensive investigations into language patterns,

usage, and trends. Additionally, the platform facilitates the construction of custom corpora, allowing researchers to tailor their analyses to specific linguistic domains. Designed with a user-friendly interface, Sketch Engine incorporates a range of practical features, including keyword extraction, word sketches, and collocation analysis, making it particularly beneficial for research in specialized fields such as technical aviation English. The keyword extraction function determines the frequency of words or lemmas within a target text and compares them to their occurrences in a larger reference corpus, thereby providing a broader contextual framework. The "word sketches" feature summarizes a word's grammatical and collocation behavior by presenting the most frequently associated verbs, nouns, adjectives, and adverbs, thereby facilitating a deeper understanding of word usage across various contexts. Furthermore, Sketch Engine enables the identification and examination of collocations—words that commonly co-occur—assisting researchers in exploring linguistic patterns and gaining insights into the subtleties of word combinations within a given corpus.

III. RESULTS AND DISCUSSION

The corpus for the UAV domain was designed and analyzed. The total word count processed in the corpus is 656,859, with a total of 827,033 tokens. In linguistic analysis, a "token" refers to each individual occurrence of a word in a text, meaning that repeated instances of the same word are counted separately. Analyzing the UAV-specific corpus using Sketch Engine has revealed that the most frequently occurring one-word terms (Table I) align closely with the cognitive structures proposed in Frame-Based Theory (FBT). This correlation highlights the key concepts essential for comprehending the study, processes, maintenance, and repair of unmanned aerial vehicles.

The high-frequency words identified in the corpus provide valuable insights for researchers and educators, enabling them to pinpoint the most commonly used terminology within the UAV industry. These terms encompass core concepts related to UAVs and their complete systems, such as *autopilot, payload, telemetry, and navigation; technical and diagnostic vocabulary, including failure, fault, glitch,* and *crash*; and operational terms like *waypoints, hover*, and *return-to-home*.

Additionally, the corpus analysis highlights abbreviations that are new to the aviation field and specific to unmanned aerial systems. Examples include: BVLOS *(Beyond Visual Line of Sight*), RPAS *(Remotely Piloted Aircraft System*), RTH (*Return to Home*), LiDAR (*Light Detection and Ranging*), IMU (*Inertial Measurement Unit*), IoD (*Internet of Drones*), FSO (*Free-Space Optical Communication*), FBWL (*Fly-by-wireless*), etc. These abbreviations are of utmost importance for understanding UAV flight control, performance, and mission planning.

The inclusion of such terms contributes to the development of a specialized lexicon that supports precise descriptions, system operations, and overall UAV functionality, thereby enhancing domain-specific linguistic research and technical education.

TABLE I FREQUENCY OF ITEMS IN A UAV CORPUS

Item	Frequency		Item	Frequency
flight	5,345		fault	1,545
system	4,285		sensor	1,540
drone	3,995		path	1,469
autopilot	3,756		result	1,417
control	3,377		provide	1,333
payload	3,304		glitch	1,308
model	3,144		speed	1,303
failure	2,609		telemetry	1,253
network	2,403		efficiency	1,104
data	2,314		increase	1,028
navigation	2,160		operate	1,019
velocity	1,955		hover	974
algorithm	1,742		waypoint	896

While frequency analysis helps identify the most commonly used terms, it may also obscure important technical vocabulary that is less frequently used but still significant within the domain. Therefore, a comprehensive approach that combines frequency analysis with qualitative assessments is essential for capturing the full scope of UAV-specific terminology.

In aviation technical English, specifically in UAV domain, just like in any other specialized English field, terms can be composed of more than one word. Sketch Engine offers information about two-word terms (*terrain mapping; barometer glitch; signal loss, hover stability, collision avoidance, logistics management*), three-word terms (*return to home, ground control station, high-speed land, fly-by-wireless, remote pilot station*), four-word terms *(high-resolution 3D model; search and rescue operations; real-time sensor streaming*), even, though rarely, five-word terms *(real-time supply chain monitoring; aerial warehouse inventory tracking; unmanned cargo transport operations*). Researchers can examine the frequency and collocation patterns of these terms within the specified corpus, allowing them to uncover significant multi-word expressions and their contextual meanings in language use. This analysis provides insight into how UAV-related terminology is structured and applied in different communicative contexts.

According to Frame-Based Terminology [6], understanding a term's meaning begins with its core concept and expands through its contextual applications. FBT highlights that specialized terms derive meaning from their relationships with other concepts within a domain. In UAV discourse, for example, "*autopilot*" is not an isolated term but part of a broader frame that includes "*navigation*," "*sensor integration,*" and "*flight control*

algorithms." Recognizing these interconnections enhances both terminology comprehension and precise language use in technical and educational contexts.

By applying FBT, researchers can move beyond word frequency analysis to identify semantic frames that structure UAV-related communication. This approach facilitates the development of more accurate terminological resources, benefiting both linguistic research and domain-specific education.

To further enhance this analysis, tools like Sketch Engine generate visual representations of collocation graphs, which are instrumental in illustrating patterns and relationships in language usage. These visualizations provide a clearer understanding of how words function within specific contexts, allowing researchers to identify key associations, terminological clusters, and semantic dependencies within the UAV domain. By integrating FBT with corpus-based tools like Sketch Engine, researchers can gain deeper insights into the structure and evolution of UAV terminology, ultimately improving both technical communication and knowledge dissemination.

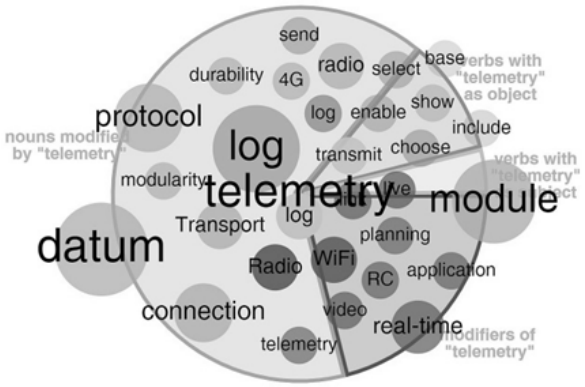

Fig. 1. Visual representations of collocations with “telemetry”.

Fig. 1 shows the collocations of the term telemetry. Telemetry involves sending real-time flight data—such as altitude, speed, GPS coordinates, battery status, and system diagnostics—from the drone to a ground control station. This data helps operators monitor UAV performance, detect potential issues, and make necessary adjustments during a mission.

A Sketch Engine analysis of the UAV corpus revealed a significantly higher occurrence of nouns compared to verbs. For example, the noun *transmission* appeared 612 times, whereas the verb *transmit* was recorded only 54 times. Similarly, the noun *failure* occurred 2,609 times, compared to 45 instances of *fail*. Additionally, *expansion* appeared 96 times, while *expand* was recorded 13 times. This pattern indicates a strong emphasis on describing technical processes and outcomes, particularly in discussions of UAV logistics operations. For instance, in logistics-related contexts, the noun *delivery* is far more frequent than the verb *deliver*, reflecting the focus on describing UAV-based supply chain processes, cargo management, and automated distribution systems. The dominance of nominal forms over verbs is a common characteristic of technical texts within both the UAV and logistics domains, where precise descriptions and categorization of phenomena are crucial for effective communication.

Following Pamela Faber's "event representation" [6], we can create a specific example within the UAV category based on the visual representation in Fig.1. Event Representation Template: *telemetry*. The following modifiers of telemetry are retrieved – *real-time, wifi, radio control (RC),* and *video*, reflecting key aspects of data transmission in UAV systems. Additionally, *telemetry* interacts with various concepts essential to UAV operations. *Telemetry log* refers to recorded flight data for post-mission analysis, while *telemetry datum* highlights individual units of transmitted information. A strong *telemetry connection* ensures uninterrupted data flow between the UAV and the ground control station, contributing to durability in long-range missions. The efficiency of *telemetry* relies on a well-defined *telemetry protocol*, governing data encoding and transmission rules. Furthermore, *telemetry transport* determines how data packets move across networks, impacting reliability and speed. The concept of *telemetry modularity* plays a crucial role in UAV systems, allowing for adaptable and scalable communication setups depending on mission requirements (fig. 1).

For the process template, the following verbs are extracted from the specific corpus: *show, enable, include, choose,* and *select*, emphasizing the functional role of telemetry in UAV monitoring, control, and data analysis.

Based on corpus data extracted from the concordances of "unmanned aerial vehicle (UAV)" — the most frequently used abbreviation in this domain — the following key terms emerge as the most common (Table II). These terms are categorized into several semantic groups, including UAV types, components, logistics and transportation, navigation and control systems, data transmission and communication, sensors and data collection, and security and regulations.

These categories underscore the significant role of UAVs in logistics while offering a structured breakdown of their various aspects. By organizing the information into essential attributes, this classification enhances understanding of UAV functionality and its broader applications within the field.

Understanding words, terms, collocations, and phrases in specialized aviation technical English requires the ability to interpret their meaning within a broader conceptual framework. In the UAV domain, Frame-Based Terminology facilitates knowledge organization by structuring terms and concepts into coherent frameworks or frames, which represent the relationships between specific components and processes.

In the UAV dataset, terms such as *infrared cameras, radar systems,* and *payload sensors* evoke the frame of sensors and data collection. This frame encompasses actions related to environmental scanning, obstacle

detection, terrain mapping, and surveillance. Terms like *LiDAR* (Light Detection and Ranging) and *GPS tracking* also contribute to this frame, highlighting precision navigation, geospatial mapping, and object recognition. These terms collectively provide a conceptual structure that reflects the processes and activities essential for the acquisition, processing, and interpretation of sensor data in UAV operations.

TABLE II SEMANTIC CATEGORIES OF MULTI-WORD TERMS

semantic categories	multi-word terms
types	fixed-wing UAVs, rotary-wing UAVs, hybrid UAVs, AI-powered UAVs, delivery drones, surveillance drones
components	airframe, propulsion system, flight control system, communication & navigation system, ground controlled station
logistics & transportation	cargo delivery, last-mile delivery, route optimization, air freight, supply chain management, warehousing & inventory, package handling
navigation & control systems	GPS navigation, autonomous flight, remote piloting, waypoint tracking obstacle avoidance, flight planning
data transmission & communication	wireless networks, real-time data transfer, IoT integration, telemetry systems, signal processing, cloud computing
sensors & data collection	LiDAR, infrared cameras, radar systems, GPS tracking, environmental monitoring, payload sensors
security & regulations	air traffic management, UAV regulations, cybersecurity in UAVs, no-fly zones, safety protocols, compliance standards

Similarly, in the UAV corpus, terms such as *cargo delivery, last-mile delivery,* and *air freight* evoke the frame of logistics and transportation. This frame encompasses concepts related to automated parcel distribution, route optimization, fleet management, and regulatory compliance. Terms like s*upply chain management, warehousing, inventory,* and *package handling* further reinforce this frame, highlighting the critical procedures and standards necessary to ensure efficiency, security, and real-time tracking in UAV-based logistics.

Together, these terms illustrate the importance of maintaining good coordination, data accuracy, and operational efficiency within the UAV logistics and data transmission domain. By structuring terminology within such frames, FBT enhances understanding, facilitates technical communication, and supports the development of UAV-related lexicons for research and industry applications.

IV. CONCLUSIONS

This article provides an overview of frame semantics and its application to the specialized discourse of unmanned aerial vehicles (UAVs), particularly in the contexts of logistics and data transmission. Grounded in the principles of Frame-Based Terminology (FBT), which posits that language comprehension is shaped by underlying mental frames and contextual associations, the study demonstrates how linguistic meaning in technical domains is structured through recurring conceptual patterns. By employing corpus-linguistic tools such as Sketch Engine [13], the research analyzes the frequency and collocational behavior of terms specific to the UAV domain, offering a practical implementation of FBT in aviation-related technical English. The findings reveal a predominance of multi-word expressions and a significantly higher occurrence of nouns compared to verbs, suggesting a marked preference for descriptive, referential terminology. This approach not only enhances our understanding of the cognitive and linguistic structures underlying UAV discourse but also contributes to the development of specialized educational and communicative resources tailored to the needs of students and professionals operating within this rapidly evolving technological field.

Moreover, this research aids in identifying both emerging and frequently used terms, phrases, and collocations in the UAV domain. The current research may lead to the adaptation of traditional aviation phraseology and the development of situation-specific terminology for mixed airspace environments involving unmanned aircraft. As UAVs become more integral to modern operations, the need for precise language when interfacing with automated systems may drive the evolution of a specialized sublanguage. Additionally, UAV terminology increasingly reflects cross-disciplinary influences from fields like robotics, telecommunications, and data science, presenting both challenges and opportunities for professionals who must navigate these converging areas of expertise.

ACKNOWLEDGMENTS

This work was supported by the NSP SD program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 281-288

Exploring the Impact of Digital Transformation on Business Model Innovation in the Retail Sector

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***Abstract*- There is no surprise that digital technologies have enormously transformed business management in recent decades. Individuals and organizations are at the cutting edge of digital transformation equivalently. Currently, most customers worldwide are digitally literate, have access to mobile devices, and make rational decisions concerning what, where, how to buy, and whom to trust. Therefore, organizations are keen to reshape the customer value requirements and transform their businesses online to compete in the new marketplace. The industrial world is giving way to the digital world. The retail industry is experiencing significant transmogrification as the outcome of digitalization and the glorification of related technologies. Throughout the COVID-19 predicament, the transformation process has accelerated. Marketers essentially pay attention to the reshaping of retail industry strategies in response to market conditions. This paper provides up-to-date literature on digital transformation by reviewing several valid research studies, as well as modern insights on capturing customer value through business strategy upgrades and implementation in the retail industry. This study contributes to a better understanding of how digital transformation is transforming business models in the retail industry, making important contributions. The study emphasizes its significance in driving creativity and adaptation in retail businesses by evaluating the key drivers, obstacles, and opportunities of digital transformation. The findings provide useful recommendations for retail executives looking to handle technological upheaval and capitalize on new business model prospects. Future studies can examine how business model innovation is affected over the long run by pioneering technologies like blockchain, artificial intelligence, and the Internet of Things. Future studies must use mixed-method research, then it will be beneficial for more accurate results, and a more thorough examination of cross-sector comparisons may clarify how digital transformation affects various businesses and their structures. Researchers could also look at how leadership and organizational culture affect the outcome of digital transformation projects.**

Keywords- Information Technology, Digital Transformation, Business Models, and Retail Industry

I. Introduction

Recently, there has been a dramatic advancement in digital technologies, and this alteration in digitalization is a major milestone in contributing to the innovation of the retail industry. The critical state during COVID-19 is instantaneous innovation procedures. For example, during the pandemic, purchase volume has a reasonable increase from 2020 to 21 globally, and the retail industry achieved a 35% share in the capitalization, especially in the marketplace [1]. Thus, customer expectations also escalate

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8640
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as the need to renovate business models in the retail industry will help us to cope with the situation. Similarly, it is necessary to focus on supply chain integration, technology, logistics issues, and the upgrading of digital marketing [2]. The shopkeepers achieved more market share and value during the pandemic, especially those who had adopted digital business models and become more successful, and achieved an advantage [1].

Further, the amelioration of digital technologies that require businesses to identify innovative ways, helps to have a competitive edge over competitors via core competencies, is stated as a digital revolution [3]. In industrial ecosystems, digitalization refers to the "application of digital technologies to revolutionize a company model and generate new income streams and value-producing opportunities" [4]. According to Zhai, et al. [3] if the up-to-date trends of digital transformation have been adopted, then it will be a game-changer situation in business success, especially financial gains and development of business performance.

Similarly, gradually the vision began to study and explore digital platforms, because of their function in generating value through contact between the firm and its consumers or other marketplace ecosystem performers [5]. A recent research study stated that digital platforms are a key component of experiential advertising, an omnipresent and nonlinear strategy that drives value creation processes and marketing that involves customers through communications, interactions, and involvement [6]. Retailers frequently search for new and imaginative methods to maintain relationships with potential consumers. Social networking is becoming one of the most popular platforms for connecting customers with marketers [7]. DT presented several technologies, but some are virtual reality, big data analytics, the Internet of Things (IoT), artificial intelligence, and augmented realities [8].

Furthermore, according to the experts, organizations have to adapt their corporate models in response to advancements in digitalization. In other words, when the parameters of an existing business model change, the latest business model is generated [9]. Some of these elements are exchangeable, activities, participants, transaction methods, and governance structure. By adding more dimensions and clarifying their content, the findings improve on past investigations. Rising innovations in retail business models made possible by digitalization have piqued the interest of innovation management and marketing professionals, leading to notable progress in the academic field [10]. However, other research is scattered and focuses on particular aspects of digitalization advancements in retail business models [11]. The current body of research has taken a broad view of how digitalization affects the innovation of retail business models, but it has not provided any insight into these processes. Both specialists and managers are currently unsure about the future of retailing. Many studies disregard the value of 4.0 technologies, failing to investigate the key factors that are particularly advantageous for current retail business models [12, 13].

This paper has identified contemporary literature on digital transformation and how it transforms the retail industry, as well as modern insights on capturing customer value through business strategy improvements and implementation in the retail industry. The significance of the paper is high as it states the latest knowledge about the new trends of digital customers and also the conduct that is essential to attain a competitive edge over others. The paper describes the business models and the limitations of digital technologies in the retail industry.

A. Digital Transformation (DT)

DT is a vital concept in the business setting that is set to capture more value from consumers as it digitalizes procedures and innovates strategies in business. DT is characterized as the application of cutting-edge digital technology (such as social media, mobile, analytics, or embedded devices) to provide substantial business benefits (e.g., new business model development, process optimization, or customer experience improvement) [14]. McKinney also describes DT in three different domains. Firstly, it introduces new boundaries of the business setting, secondly, it identifies new processes to diversify visions about experiences of customers, and thirdly, it speeds up the digital proficiencies of business.

DT is also listed as "the use of technology to dramatically improve the performance or reach of organizations" [15]. DT was defined as "digital transformation is the deliberate and continuing digital evolution of a firm, business model, idea, process, or approach, both strategically and tactically" [16]. Loonam, et al. [17] specified that Businesses that are digitally oriented can profit from substantial growth opportunities by implementing ICT technologies like social media, digital gadgets, big data, AI, IoT, virtual reality, and augmented reality, and so on, benefit digitally enabled businesses [17]. According to the concept, businesses that combine their procedures with technology will enjoy more benefits and reimbursements [17].

DT revolutionizes patterns between workplaces as it improves the business's financial condition and performance by rearranging and lower down the costs of several actions due to the emergence of digital technologies [3]. DT has improved the decision-making method as information from consumers is analyzed more conveniently for human minds, and it suggested the newest business models that added value [18]. DT has a role in constructing up-to-date business, better data handling, efficient management, effective supply chains, customer retention, and satisfaction. It facilitates the dissemination of information about the product’s features conveniently [19]

B. Retail Industry Revolution

History has modernized many times, and the improvements in procedures, working conditions, and business models concerning time. The retail industry has also reformed as per the requirements of the existing and potential consumers, there are four revolutions taking place from Industry 1.0 to 4.0 [20]. These changes were

important and had noteworthy powers to govern the business sector; however, they also had an impact on economic trends, labor conditions, technological advancements, and living standards. Comparatively, the revolution also transformed the retail sector into a digital one, making it more in line with the modern world.

Starting from Retail 1.0 was initiated in the middle eighteenth century and lasted till the middle nineteenth century, this change was also named mechanization [21]. According to Meyer [21], the terms mass production and electrification were presented after the 2nd resolution started. According to the history of mankind, humans utilized their hands to produce and create various goods such as handicrafts, musical instruments, weaponry, and culinary tools. After the introduction of the steam engine in the late seventeenth century, this tendency would give way to mass production [20]. Local merchants still controlled the retail industry in the middle of the 19th century, offering consumers full-service benefits like credit, repairs, and in-person help to explain the benefits and characteristics of products. To maintain the flow of trade, people had to carry cash, and businesses had to physically deposit currency. However, because of technological breakthroughs, the Industrial Revolution significantly expanded the supply of reasonably priced, high-quality goods [19].

Further, low cost and mass production were the main causes for the evolution of Retail 2.0. It is known that the electrification duration of Retail 4.0 was from the early 20th century to the late 20th century [22]. Automation of production will enhance consumption patterns; automotive availability has widened dramatically, which is why people have relocated to cities to meet requirements, resulting in the creation of plazas, shopping malls, and industries, among other items [22]. Furthermore, in the late 20th century to early 21st century, retail 3.0 was started and named Automation. The appearance of extensive online shopping, online payments, e-commerce platforms (Alibaba, Amazon, eBay), and social media was an important decisive moment in the former times of the retail industry. These events corresponded with the opportune discovery of the internet and contemporary computers [20]. Globalization advances product consumption and convenience, along with worldwide marketing and manufacturing, and the development of electronic products would be the essential cause of DT.

Currently, Retail 4.0 is utilized to suit multiple demands; digital transformation has offered several technologies that are dubbed Technologies 4.0, such as AI, big data analytics, virtual reality, cloud computing, IoT, and augmented reality [8]. The sales made via the internet in the digital commerce industry have increased by 45.8% globally over the previous two years. It is expected that online retail will increase from 13.6% in 2019 to 19.5% in 2021. Smartphone e-commerce sales increased from 52.4% to 72.9% of all e-commerce transactions in only four years [23]. The COVID-19 pandemic has fastened the transition process toward online shopping by about five years [19]. Target and Walmart have both benefited from omni-channel fulfillment by offering grocery pickup and delivery options, which has improved sales for both companies [24].

C. Modern Technologies in Retail

The consumer-centric organizations are upgrading their supply chains by quickening the flow of information and products, and on condition that modified services as per the consumer's needs. Market intelligence is the most recent marketing technology that determines consumers' value preferences about purchases and post-purchase behavior [25]. Retailing is occasionally referred to as omni-channel, which is the fusion of different technologies to provide a satisfying and cutting-edge experience for customers. With the usage of 4.0 Retail technologies, we may have a simpler and more readily available way of living. For instance, if a TV ad viewer is curious about a product, he may scan a QR code with his smartphone, view the item's description, and put it in his shopping cart. He could pick it up again tomorrow, but he hasn't completed the purchase yet. The item is simple to order online and pick up at the store after work. He may easily travel between mobile applications and websites while employing IoT, cloud computing, and QR code scanning to collect and retain his data [19].

Further, the Retail industry utilized technologies that are IoT and AI in outlets, improving the shopping experience. AI support refers to retailers now having a chance to go storefronts unmanned without hesitation, it saves large amounts of money in labor costs [26]. Furthermore, cloud computing and BDA analyze consumer data, enabling retailers to forecast customer predilections and provide personalized services. The technologies also improve the value chain distribution's effectiveness, adaptability, and competitiveness.

D. Big Data Analytics (BDA)

Nowadays in the contemporary world, competition and complexities are unlimited to deal with ambiguous circumstances, and big data analytics is highly beneficial for data handling. BDA is just a method for evaluating the enormous amount of data in any specific company. The utilization of data-driven practices enables organizations to make decisions effectively and is beneficial for creating interactions with clients. It also aids in guessing the corporate income, and it also gives more advantages [27]. BDA has a great influence on handling the data of customers. Consumers' expectations have changed in the age of digital devices, and there is now a need to fulfill their requirements as per digital demands. It is now time to apply digital marketing and BDA to ordinary business practices and satisfy the desires of digital consumers to generate advantageous consequences [28].

Similarly, digital transformation has been accountable for supplying a large amount of data that generates a range of information with diverse authenticity and accelerates the process by allowing firms to build accurate data-driven strategies [29]. BDA is a key technique for delivering comprehensive information regarding the consumer. It permits business enterprises to comprehend various customer preferences, investigate sales trends, and

determine acceptable marketing policies, and it additionally encourages enduring connections with consumers by illuminating consumer loyalty [30]. There is an extra benefit that will support businesses to make fruitful decisions in complex circumstances by providing valid data for decision-making [19]. However, acquiring data is essential before organizations can benefit from the results. Performing so provides advantages in many ways, including leveraging the data to draw in new clients. Then, with the help of BDA, businesses will be able to anticipate customer loyalty, which will improve business turnover.

At the moment, technologies are expanding at an impressive rate, and the retail business needs innovation. It is now also necessary to use the most recent retail business trends. [7]. For example, Happy Fresh is a grocery store that employs innovative technologies and sells its items on Amazon. They designate specific staff to manage the process, promote their products, and capture 80% of potential consumers.

E. Artificial Intelligence (AI)

Essentially, artificial intelligence refers to "the agents that get percepts from the environment, which permit such agents to map percept structures to complete certain operations" [31]. AI discusses a machine's capability to exhibit intelligence as compared to an animal or a person. AI system enhancements assist risk management and decrease real-time fraud [32]. Similarly, AI refers to a machine's memory, recognition, learning, and the creation of unique visions via data mining. When performing routine operations, intelligent automation enabled by artificial intelligence systems requires little operator intervention [33]. The retail industry refers that it governs the methods required to improve the settlement of inventories, it also reduces labor costs as it disregards the need for people to execute various tasks in the business atmosphere [34]. AI is emerging daily; this shift in organizations enables digital operations and innovations while improving and expanding human capabilities, decreasing human error, and boosting productivity. AI is quite helpful in the retail industry since it can quickly analyze a lot of data and present alternative client choices [35]. AI empowered the retail industry with effective inventory handling, and it also provides prognostication of the future trends of the business environment.

F. Internet of Things (IoT)

The Internet of Things is a system of physical devices that is used to create a link between applications and the Internet, such as products, computers, sensors, machines, and properties [36]. It is a system that enables these gadgets to establish a connection to the internet via specific information protocols and sensing objects to process data and communicate [37]. Similarly, IoT has distinct purposes such as monitoring and tracking, and it also allows users to access various real-time locations and other critical information [38]. IoT also helps the customer in distinctive ways as they browse and monitor the data of suppliers, and also allows tracking.

The fact that connection is already a need for all current products on the market shows that the IoT is not only a theory but a reality. The data is extremely useful since businesses require it to make critical choices. Modernizing sensor technologies is crucial since they play a crucial role in the collection, processing, and exchange of data [39]. Similarly, IoT is fantastic; for example, if retailers enter the location of their store into a database, virtual assistants such as Google Assistant, Siri, and Alexa would give customers information about nearby retailers as well as the items that the consumer desires [19]. Nowadays, businesses utilize smart gadgets with Bluetooth and radio transmitters to notify customers who enter stores about the newest promotions, discount vouchers, and discounts provided on various products. This method improves the interaction between customers and retailers [20].

This approach promotes communication "between things and other things, as well as between things and humans." These gadgets, which might include everything from washing machines, lighting, water meters, and RFID tags to actuators, sensors, pumps, and weighbridges, connect tangible objects to the digital world [40]. IoT is predicted to have a big influence on future supply chains as more and more objects, containers, and vehicles are outfitted with sensors that allow for more exact monitoring and measurement [41, 42]. IoT has contributed to many benefits, including advancements in the detection of counterfeit goods, predictive maintenance, real-time tracking, accurate sales data, lowering the likelihood of under- and overproduction, customized marketing, more accurate carbon monitoring, biometric payments, increased competition, and the accomplishment of sustainable goals [34].

G. Virtual Reality (VR)

Virtual Reality (VR) permits persons to participate in realistic three-dimensional environment simulations digitally or through the consumption of head-mounted spectacles and sensor-equipped clothes [43]. This assists users in understanding circumstances and making decisions by providing a realistic experience of visual graphics without interaction with the actual situation [44]. The capacity to incorporate computer-generated three-dimensional objects into a real-world setting is known as augmented reality, or AR. As technology advances, the potential of AR to provide improved experiences becomes more apparent [45]. These technologies' potential uses in product visualization, education and training, and better picking and inventory management have been well documented. They are also being studied more and more for their capacity to create virtual workplaces that enable meaningful interactions between partners, coworkers, and customers wherever they may be in the world [34].

Nike, a manufacturer of athletic shoes, clothes, and equipment, has created a system that allows customers to design their own sneakers and purchase them in a retail store. Customers will enjoy the pleasure of shoe modification by customizing their own Nike sneakers utilizing the most recent automation service [19]. They put on a pair of plain Nike sneakers and use voice commands

to choose colors and designs. The technology uses augmented reality, projection technologies, and object tracking to display to the customer the designed shoes. Machines print the design on the footwear when the customer makes their selections, and the customer will have the footwear in less than a couple of hours. Regularly, the completion of customization choices may take two weeks [19].

Cloud Computing

A straightforward idea that will assist with data storage on any web platform is cloud computing. The internet's on-demand placement of software, computer power, and other IT and data storage resources across all platforms. It involves combining computer resources to enable their simultaneous usage for multiple tasks. Additionally, the computing cloud makes it possible to combine the company's current assets. Additionally, the administrator can access the system from any location [46]. Consumers can utilize real-time data obtained through virtual alternatives connected to virtual infrastructure and cloud computing to make judgments based on reliable data [47].

Retailers improve their understanding of consumer behavior and preferences by studying transaction data from in-store or online customer behaviors. Retailers must invest in storage because Retail 4.0 generates vast amounts of data that must be processed, stored, and shared throughout supply chains. Because of its low cost and ease of usage, cloud computing is typically considered the most effective technique [48]. BDA and computing cloud are used in a predictive manufacturing system to enable self-aware machines and systems, while CPSs will be used in the future industry to enhance production and efficiency [39].

H. Social Media in the Retail Industry

Nowadays, social media is one of the key segments of digital marketing. Organizations implement different techniques and employ a variety of indicators to determine the efficacy of social media marketing. It is also important to consider how it influences professional outcomes, especially in the expanding database from qualitative research [7]. These range from elevated customer communication through means that include electronic WOM to metrics tracking, campaign formulation, performance, and engagement. The capability to engage with customers and distribute relevant data is a shared benefit of merchants' participation in social media marketing, with numerous networking sites creating the ability to speak with consumers and spread relevant data. Consumer feedback obtained through social networking sites aids a corporation in dispelling myths regarding a brand or product [38].

A report by Data Portal Global (2021) stated that "(a) the world's population stood at 7.83 billion at the start of 2021; (b) 5.22 billion people use a mobile phone today, equating to 66.6 percent of the world's total population; (c) Unique mobile users have grown by 1.8 percent (93 million) since January 2020; (d) the total number of mobile connections has increased by 72 million (0.9 percent) to reach a total of 8.02 billion at the start of 2021; I 4.66 billion people around the used the internet in January 2021, up by 316 million (7.3 percent) since this time last year as global internet penetration now stands at 59.5 percent, and (f) there are more than 4.20 billion social media users around the world". Thus, "the number of social media users is now equivalent to more than 53 percent of the world's total population."

The enormous perfection of social media marketing is that it supports the improvement of brand reputation, which is the term for how customers are involved with one another and publicize a good or service, disseminating both positive and negative information about a corporation. Social media has the potential to increase the geographic and population scope of electronic word of mouth by allowing users to post opinions and ideas that are immediately viewed and shared by other users across the world.

II. Methods and Materials

This study uses a systematic literature review (SLR) to look into the impact of digital transformation on business model innovation in the retail industry. The study adheres to Tranfield and Justine Paul's SLR framework mentioned by [49], beginning with the formulation of particular research questions targeted at understanding how digital transformation affects the evolution of retail business models. A comprehensive search strategy was created using pertinent databases like Scopus, Google Scholar, Science Direct, and Emerald Insight, along with search terms like "business model innovation," "digital transformation," and "retail industry." Studies were chosen based on their relevance to the study goals, and their titles, abstracts, and complete texts were thoroughly reviewed. Data extraction entailed filling out a standard form to collect study information such as research methodologies, sample sizes, and important findings. Only research that satisfied strict methodological requirements was included, thanks to a quality assessment of the chosen studies. After analyzing 150 studies, it became clear that digital transformation is influencing business model innovation in the retail industry. With the help of tables, figures, and in-depth analysis, the results were methodically combined and presented, offering a thorough summary of the main conclusions and their ramifications for the retail sector.

III. Results and Discussion

Technologies 4.0 have a substantial role in the era of digitalization; the usage of these in the corporate model enhances the overall performance of the business and the competitive edge achieved over the competitors. Although the expression "Industry 4.0" has been in use for a decade, "Retail 4.0" is still pretty recent to retailers worldwide. The retail transformation has made our lives much easier. Retail 4.0 provides a chance to aid retailers in surviving the COVID-19 epidemic, which is causing retail stores and outlets to close. Retail 4.0 can handle the new COVID-19 pandemic threshold. This research tried to present contemporary literature on digital transformation and the

evolution of the retail industry, and also stated modern insights on capturing customer value through upgradation and execution in the retail industry. The study conveys future direction for the advancement of the business model and enlightens the concept of capturing co-creation and customer value.

The review of 150 studies will helps us to make the findings of this study focused on the following characteristics of digitalization that facilitated retail business model innovation: first, an inclusive range of communication technology for retail business models; second, digital technologies increased the quantity and quality of data required for decision-making procedures; and third, digitalization reformulated ecosystem partnerships and bilateral agreements. This article proposes resolutions to apply new technologies 4.0 in the retail industry, such as how to employ virtual reality, big data analytics, artificial intelligence, the Internet of Things (IoT), cloud computing, and augmented realities. Similarly, implementing these technologies in the retail industry improves performance, increases potential customers, and satisfies existing customers. Modernizing existing retail business models enables us to provide, capture, and generate value for customers. Future research should focus on e-loyalty and e-engagement, as well as their implications for Retail 4.0. It is encouraged to concentrate on modern methods of customer engagement on Internet platforms.

A. Digitalization and Innovation in Business Models (BM)

Researchers studied the concept of modernization and improvements of existing business structure. according to his definition, the business model outlines the coherence of the strategic choices that help guide the activities and interactions that add value to the company at the tactical, strategic, and operational levels [50]. Therefore, the business model is the framework that integrates resources, processes, and service delivery to provide the long-term profitability of the organization. [51] argued that the improvement of the business model is considered as the restructuring of business strategies to create, capture, and deliver more value, and the ultimate resulting innovation of BM growth and validity [4] stated that Value creation requires taking into account the value proposition and meeting the specific demands of the consumer. There is also an understanding of services as either products, services, or a combination of the two. The primary goal of the research is to identify strategies for digital transformation in business models and the application of contemporary technologies. The methods used by enterprises to capture additional value for their services.

To produce value, retailers execute a wider range of a firm's portfolio, additionally integrating numerous goods and offering customized communication, which has made favorable outcomes while fulfilling client wants, establishing a long-lasting advantage to serving digitally sophisticated consumers [52]. During COVID-19, various retailers provided delivery services instead of traditional transportation, and other intermediaries enticed clients by delivering more rapidly and free-of-cost services. Retailers have recognized that digital services, in addition to a competitive variety of items and traditional services, are essential to supplement current offers and boost consumer value. Retailers implement a variety of methods for customer co-creation since the retail industry today has an abundance of chances to co-create value with customers as a result of digitization [53]. Enterprises are using social media and digital communication platforms to provide feedback, solutions, and proposals that are especially tailored for their geographically scattered, diverse consumer segments.

Value delivery is a method and activities that are applied for the ultimate offerings of a company. Retailers renovate these by using effective customer communications and by building long-term associations with customers. Senior managers in retail firms may more successfully manage client contacts through digitalization since they understand these customer-specific variances to fulfil their new expectations [54],[55]. Retailers can broaden their target markets and connect to new client groups thanks to digitization, which has enabled them to work with other businesses and link to popular platforms like Facebook and Amazon. To deliver particular value, businesses need to enhance their Omni channel experiences for customers, such as through the usage of 4.0 technology. Many technologies have emerged as a result of digital transformation, but the most recent include virtual reality, big data analytics, artificial intelligence, the Internet of Things (IoT), and augmented realities [8]. Researchers stated partnerships, technology in stores, sales acquaintance participation, data analytics, and using a mobile channel are five prospective innovation areas to integrate digital and physical businesses [13]. Customers may now order, pick up, or return items and information from several locations, owing to the omni-channel approach made feasible by digitization. The literature emphasizes the need to synchronize physical and digital media.

An effective BM is responsible for capturing more value and is mostly related to models of revenue and cost structure. Researchers argued that digitization has made it attainable to parallel process data, make data transparent, permanently retain data, and ensure security and privacy. Streamlining procedures and facilitating the collection of knowledge that enhances effective and efficient decision-making [56]. Retailers capture value by practicing digitally oriented models of revenue, by revising the cost structure with the help of retail 4.0 technologies. Hence, BM plays an influential role in creating and generating value, it helps businesses to boost the current growth and ultimately achieve sustained growth.

Industry 4.0 technologies including artificial intelligence (AI), big data, the Internet of Things (IoT), cloud computing, augmented reality (AR), and virtual reality (VR) are driving the shift to Retail 4.0 by changing retail business models, increasing operational efficiency, and boosting customer engagement. Retailers were able to swiftly adjust by switching to digital platforms, contactless payments, and virtual experiences as a result of the

COVID-19 pandemic's acceleration of the adoption of these technologies. According to the main conclusions of a review of 150 studies, digitalization has made it easier to create new ecosystem relationships, improve communication technology, and make decisions based on data. Personalized services are made possible by technologies like AI, immersive shopping experiences are offered by AR and VR, and supply chain optimization is fueled by real-time insights from IoT regarding inventory and customer behavior.

Retailers are now focusing on co-creating value with customers, using digital tools to create personalized and interactive experiences that promote loyalty and pleasure. The emergence of omnichannel strategies assures smooth interactions across online and offline touchpoints, aided by cloud-based tools for efficient operations. Future study should focus on e-loyalty and e-engagement, researching how digital platforms might improve long-term consumer relationships and drive growth in an increasingly digital retail world.

IV. CONCLUSIONS

This study emphasizes the revolutionary role of digital technologies in transforming retail business models, including how virtual reality, big data analytics, AI, IoT, cloud computing, and augmented reality are driving innovation and increasing customer value. The findings show that digitization increases communication, decision-making through enhanced data, and ecosystem linkages. The study provides useful insights into how Retail 4.0 might help organizations address difficulties such as enhancing performance and consumer engagement. Future studies should look into the function of e-loyalty and e-engagement in the digital retail ecosystem, with an emphasis on innovative customer interaction techniques on digital platforms. This research provides a framework for developing retail business strategies and integrating cutting-edge technologies to satisfy changing consumer demands.

V. ACKNOWLEDGMENTS

The research is a very crucial process that needs extreme attention from the researcher. Thus, I would like to thank my mentors for their assistance and support throughout this research, which made me capable of conducting such wonderful research. Special thanks to my friends and colleagues for their collaboration. I also appreciate the participation of everyone in this project. Finally, I want to thank my family for their encouragement.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 289-295

The Social Dimension of Sustainability for the Business Competitiveness

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Abstract*—Sustainability is a critical factor in business competitiveness, shaping corporate strategies and long-term market positioning. While the environmental dimension is well understood and widely adopted, the social dimension remains underexplored, leading to significant challenges. Issues such as employee well-being, diversity and inclusion, stakeholder engagement, fair labour practices, and ethical governance are often inadequately addressed, despite their substantial impact on business resilience and performance. The aim of this study is to examine the role of the social dimension of sustainability in enhancing competitiveness, emphasising its equal importance alongside environmental and economic considerations. Socially responsible practices strengthen brand reputation, foster customer loyalty, drive innovation, and improve employee productivity - factors essential for maintaining a competitive edge in modern markets. The study employs a methodological approach based on primary and secondary data analysis, drawing insights from academic literature, policy documents, corporate sustainability and Environmental, Social, Governance (ESG) reports, and sustainability expert interviews to provide a practical perspective on emerging trends, challenges, and best practices in implementing social sustainability initiatives in a real business environment. This multi-source approach ensures a comprehensive understanding of the current state and future directions of social sustainability of businesses. This study contributes to the growing discourse on sustainable business practices by demonstrating that social sustainability is not merely an ethical consideration but a fundamental element of corporate success. Enterprises face challenges related to defining, quantifying, and operationalising social sustainability. At the same time the results of the study show that European Sustainability Reporting Standards provide a comprehensive framework for corporate social sustainability initiatives of enterprises. The study's results highlight the need for a structured, data-driven approach to defining and measuring the social dimension of sustainability for small and medium enterprises and serve as evidence-based methodological framework for further exploration of social sustainability as a core driver of business competitiveness.

Keywords - business competitiveness, corporate social responsibility, social sustainability, social sustainability standards, large enterprises.

I. INTRODUCTION

The concept of sustainable business emerged in the academic literature as a response to market failures contributing to environmental and social degradation. Dean and McMullen (2007) provided one of the first theoretical frameworks, defining sustainable entrepreneurship as a business activity that simultaneously ensures profitability and addresses environmental and social concerns [1]. Other scholars complement this idea by stressing that sustainable business differs from traditional business in that it prioritises long-term environmental and social benefits alongside economic ones, sustainable business models promote social well-being, inclusion and ethical business practices [2]. Consequently, the essence of sustainable business lies in the pursuit of economic opportunities that also generate positive social and environmental outcomes, making it a key driver of sustainable development and corporate responsibility.

The concept of social sustainability emerged in the broader sustainability discourse at the end of the 20th century as one of the key pillars of sustainable development, alongside environmental and economic sustainability. Initially, discussions on sustainability focused mainly on environmental and economic aspects, but by the early 2000s, social sustainability was becoming increasingly important in corporate governance, policy frameworks and academic research [2]. Colantonio (2009) points out that although social sustainability has been neglected in sustainability discussions, its role in improving quality of life, social equity and community resilience is becoming increasingly important [3]. Kamaludin (2023), exploring

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8661
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social sustainability in the context of social entrepreneurship, highlights its importance in promoting fair labour practices, social inclusion and ethical business models [2]. Social sustainability is multidimensional, encompassing issues such as equitable access to resources, human rights, community development and workplace well-being. It is critical to business sustainability, as companies that integrate social sustainability into their strategies benefit from stronger stakeholder relationships, improved corporate reputation and long-term financial stability [4].

Research shows that labour practices, human rights and decent working conditions are key components of social sustainability and have an impact on business performance. Companies that prioritise ethical labour standards, occupational safety and community engagement tend to experience higher employee satisfaction, higher productivity and lower operational risk, all of which contribute to their long-term market positioning [6]. Social sustainability initiatives contribute to greater transparency in supply chains, which increases consumer confidence and investor interest, ultimately strengthening financial stability. Companies that actively engage in socially responsible practices tend to perform better in competitive industries because they attract talent, build stronger customer relationships and differentiate themselves from less responsible competitors [7]. However, while social sustainability can improve the competitiveness of companies, its implementation requires a strategic approach, as measuring and quantifying the impact of social sustainability remains a challenge for many organisations [8].

Social sustainability risks are a critical factor in assessing the sustainability risks that companies face. Among these, human capital risks are particularly significant, affecting 64% of global market capitalization and 55% in Europe. (See Fig.1.) These risks encompass challenges related to workforce well-being, fair labour practices, and access to skilled employees, all of which influence business resilience and long-term performance. Data security and customer privacy risks impact 36% of global market capitalization, posing increasing challenges for companies in an era of digital transformation [9].

Companies increasingly recognize social sustainability risks as financially material, necessitating proactive strategies to enhance workforce conditions, protect customer data, and uphold human rights in supply chains. The social component of sustainability encompasses key risks that impact companies' financial stability and operational resilience. According to the data, human capital risks—such as employee health and safety (28%) and employee engagement, diversity, and inclusion (35%)—are among the most financially material factors, reflecting the growing importance of workplace well-being and equitable labour practices in business sustainability [9]. Addressing these issues effectively can help businesses mitigate risks and strengthen their long-term competitive advantage in an evolving market landscape.

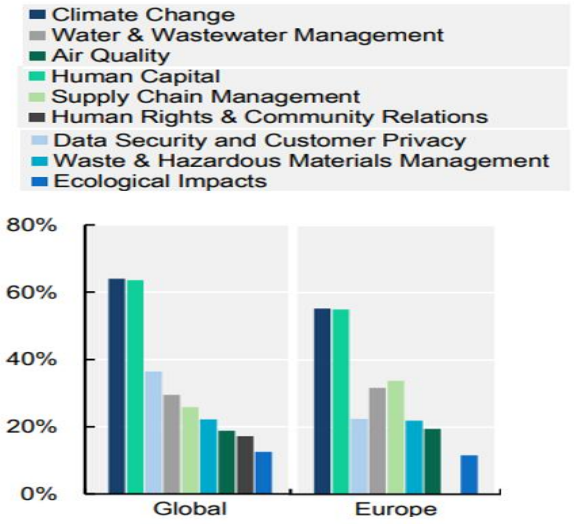

Fig. 1. The share of market capitalisation by selected sustainability risks in 2022 [9].

The European Union (EU) policy framework for the social dimension of sustainability is embedded within several key strategies and legislative frameworks aimed at ensuring sustainable development. The EU's approach integrates economic, social, and environmental concerns, as outlined in the European Green Deal, the 2030 Agenda for Sustainable Development, and sector-specific policies like the European Pillar of Social Rights (EPSR). The Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) further reinforce mandatory disclosures on sustainability aspects, including social criteria [10]. The Europe 2020 Strategy, previously the guiding framework for smart, sustainable, and inclusive growth, introduced ambitious targets such as achieving a 75% employment rate for ages 20-64 and addressing social inclusion and poverty reduction. It has been succeeded by the European Green Deal, which aligns with Sustainable Development Goals (SDGs) and emphasizes social sustainability [11]. The EU Action Plan for the Circular Economy and Sustainable Finance Action Plan support sustainability in business, urging companies to integrate Environmental, Social, Governance (ESG) factors into corporate decision-making [10].

The EU has progressively developed its legal framework to strengthen corporate accountability and promote sustainability, particularly in the social dimension. This evolution reflects a structured approach to integrating sustainability into corporate governance, ensuring that businesses operate responsibly within the broader context of social and environmental sustainability. The legislative milestones over the past decade highlight the EU's increasing commitment to enhancing transparency, promoting social inclusion, and ensuring fair labour practices across Member States. The Non-Financial Reporting Directive (NFRD), adopted in 2014, marked the first major regulatory step toward corporate sustainability reporting. By requiring large

companies to disclose non-financial information, such as environmental, social, and governance (ESG) aspects, this directive laid the foundation for subsequent legislative advancements. Recognizing the need for a stronger social framework, the EU introduced the European Pillar of Social Rights (EPSR) in 2017, reinforcing principles related to fair working conditions, equal opportunities, and social protection. Building upon these initial efforts, the European Green Deal, launched in 2019, established sustainability as a core policy priority, integrating climate action, environmental sustainability, and social equity into the EU's long-term economic strategy [10, 11]. This policy shift underscored the need for more stringent corporate sustainability obligations, culminating in the adoption of the Corporate Sustainability Reporting Directive (CSRD) in 2022 [12]. The CSRD significantly expanded corporate disclosure requirements, making sustainability reporting more comprehensive, standardized, and legally binding for a broader range of companies. To support the effective implementation of the CSRD, the EU developed European Sustainability Reporting Standards (ESRS) in 2023 [13]. These standards standardise the sustainability information provided by companies, ensuring that companies provide consistent, transparent and comparable sustainability data across the EU. This legal framework underscores the EU's long-term commitment to embedding the social dimension into corporate sustainability policies. The transition from the NFRD (2014) to the CSRD (2022) and the implementation of the ESRS (2023–2024) demonstrates a systematic enhancement of sustainability reporting obligations, reinforcing corporate responsibility and aligning with broader EU sustainability objectives, including the European Green Deal and the United Nations Sustainable Development Goals (SDGs). Through these legislative advancements, the EU seeks to promote fair labour conditions, reduce social inequalities, and foster sustainable business practices, ensuring that companies play a central role in achieving a socially responsible and sustainable European economy.

According to the European Union Directive 2014/95/EU [14], large and publicly listed companies in Latvia are required to submit sustainability (non-financial) reports for financial years starting from 1 January 2017. The requirements defined in the ESRS entered into force on 1 January 2024. According to Latvia's Sustainability disclosure law [15], companies that are public interest entities with more than 500 employees will have to report on ESRS for 2024. In 2027, small and medium-sized enterprises will be required to submit sustainability reports for 2026.

The aim of the study is to investigate how the social dimension of sustainability enhances business competitiveness, emphasising the need for structured, data-driven approaches and alignment with European sustainability standards. The authors analyse how the social dimension of sustainability has been covered in corporate sustainability reports to date and the perception of the impact of social sustainability on business competitiveness.

II. MATERIALS AND METHODS

This study employs a qualitative research design drawing on primary and secondary data to ensure a comprehensive understanding of the research subject - the social dimension of sustainability. Guided by established research design literature [16, 17], the methodology integrates qualitative content analysis and thematic analysis of qualitative interviews. The analysis is based on the following data sources – the latest available public sustainability (non-financial) reports from Latvian enterprises published in 2023 and qualitative semi-structured interviews with sustainability and corporate responsibility experts.

The selection of sustainability reports was based on the following criteria: the company's industry to ensure the variety of sectors and businesses, size of the company (large companies were selected as this group is the first to report on the integration of sustainability initiatives under ESRS), and availability of sustainability reports published no later than 2023. A total of 11 sustainability reports [18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28] from companies operating in Latvia in three sectors - transport (n=3), manufacturing (n=4) and services (n=4) - were reviewed. Initially, open coding was carried out using an inductive content analysis approach to identify the main social sustainability themes in the companies' activities. In a next step, using a deductive content analysis approach, the results were analysed by applying the four ESRS Social Dimension Thematic Standards and the 12 corresponding ESRS themes (see Table 1).

TABLE 1 SOCIAL SUSTAINABILITY THEMATIC STANDARDS AND TOPICS COVERED IN THE ESRS

Thematic ESRS	Topics
ESRS1 - Own workforce	● Working conditions ● Equal treatment and opportunities for all ● Other work-related rights
ESRS2 - Workers in the value chain	● Working conditions ● Equal treatment and opportunities for all ● Other work-related rights
ESRS3 - Affected communities	● Communities' economic, social and cultural rights ● Communities' civil and political rights ● Rights of indigenous peoples
ESRS4 - Consumers and end users	● Information-related impacts for consumers and/or end-users ● Personal safety of consumers and/or end users ● Social inclusion of consumers and/or end users

The group of experts interviewed for the study consists of professionals with experience in both sustainability issues and business practice. A total of nine expert interviews were conducted (n=9). The experts were selected using a purposive sampling method, with the main criterion being the expert's knowledge and experience in sustainable and socially responsible business. This selection ensures that the data obtained is both scientifically valid and practically useful, as it reflects real and in-depth subjective

observations on the topic under study. In the case of the companies, the interviews were carried out by the company staff responsible for the preparation of the sustainability reports. The experts interviewed in the study represent the following organisations: private higher education institutions (n=2), a transport company (n=2), a trading company (n=1), a financial services company (n=1), the Latvian Platform for Corporate Social Responsibility (n=1), the Latvian HR Management Association (n=1), the Institute for Corporate Sustainability and Responsibility (InCSR) (n=1). In order to ensure the confidentiality of the experts, their names are not disclosed.

As the qualitative approach allows focusing on individual experiences and interpretations, the data collected provides a better understanding of how the social dimension of sustainability affects the performance and competitiveness of companies. The interview questions covered a number of key themes, which have allowed for a deeper understanding of the role of the social dimension of sustainability in the competitiveness of Latvian companies. Qualitative data collection was carried out using pre-prepared interview guidelines, which included both structured questions with 1-5 scale ratings and open-ended questions. The structured questions allowed for a systematic assessment of the impact of sustainability practices, while the open-ended questions gave experts the freedom to elaborate on their views on the social dimension of sustainability, its manifestations in the practices of Latvian companies and the opportunities to use social initiatives as a competitive advantage. The interviews were conducted in January and February 2025.

The analysis of both the interviews and sustainability reports was conducted using the principles of thematic analysis [29]. This involved systematic coding of interview transcripts and report texts to identify recurring patterns and themes, organising the codes into themes that capture the core elements of sustainability practices and corporate responsibility and interpreting the identified themes within the context of the selected industries and theoretical frameworks on sustainability in entrepreneurship. The triangulation of diverse data sources (policy documents, sustainability reports, interviews) enhances the study's validity and reliability. By comparing and contrasting findings across these sources, the research provides a robust analysis of sustainability practices and their implications for corporate competitiveness in the context of Latvian entrepreneurial environment. The criteria adopted from the ESRS [13] further ensure that the evaluation of sustainability reports is both systematic and rigorous. The qualitative research design, supported by thematic analysis and multi-source triangulation, offers a detailed and nuanced examination of sustainability in entrepreneurship. It not only captures the theoretical underpinnings of sustainable practices but also reflects their practical application across different industries.

III. RESULTS AND DISCUSSION

The discussion of the results of the study first covers the analysis of the sustainability reports of the companies, followed by the results of the analysis of the qualitative interview data.

The content analysis of the 11 sustainability reports revealed that the social dimension covers employee well-being, internal and external social responsibility, social dialogue, ethics and inclusion. The results of the open coding analysis are summarised in Table 2.

TABLE 2 THEMATIC OPEN CODING RESULTS OF THE SOCIAL DIMENSION OF THE SUSTAINABILITY

Social Dimension Theme	**Examples of Social Sustainability Initiatives in the Studied Companies**
Employee engagement, development and well-being	Latvijas Finieris (manufacturing) stands out for its "Knowledge Afternoons" initiative, which promotes employees' lifelong learning and professional development. The company ensures that employees have access to training and a high-quality working environment. Riga Airport (transport) pays special attention to mental health measures, anti-discrimination and safety, which improve employee motivation. Orkla Latvija (manufacturing) emphasises a culture of diversity and inclusion, ensuring gender balance in management and promoting a fair pay policy. Swedbank (services) develops diversity and employee well-being programmes that cover both physical and mental health. CleanR Group (services) focuses on a safe working environment through safety measures and well-being initiatives.
Social dialogue and workers' rights	Latvijas Finieris (manufacturing) emphasises close cooperation with trade unions and regular dialogue between management and employees. Riga Airport (transport) uses employee surveys and internal communication channels to promote engagement and improve working conditions. Latvijas Dzelzcels (transport) regularly conducts social dialogue, analysing employee satisfaction and looking for ways to improve the working environment. Rigas Satiksme (transport) actively uses idea banks and surveys to promote open discussion about the working environment.
Social responsibility and public engagement	Latvijas Finieris (manufacturing) engages in sponsorship and donations to promote social welfare. Riga Airport (transport) works with local communities and promotes education initiatives. Orkla Latvija (manufacturing) supports local communities and educates the public about health issues. Balta (services) offers free insurance for children and provides funding for social projects to support the people of Ukraine. Rigas Siltums (services) engages in an open dialogue with society and offers socially responsible energy solutions.
Ethics, equality and inclusion	Latvijas Finieris (manufacturing) adheres to high moral standards by ensuring a clear code of ethics. Orkla Latvija (manufacturing) focuses on gender equality and equal pay. Swedbank (services) promotes diversity, equality and the Sustainable Development Goals in the social sphere. Schwenk (manufacturing) Latvia creates an inclusive working environment and provides equal opportunities for all employees.

The open coding results revealed that most companies emphasise employee development, motivation and health, which are important for long-term productivity and innovation. Companies actively participate in social projects and contribute to the well-being of society in various ways. Corporate ethics and equal opportunities are important aspects of companies' sustainability strategies. While different companies adapt their approach according to their sector, in general all recognise that sustainable development is not possible without socially responsible behaviour. Developing the social dimension not only helps to improve the working environment but also has a positive impact on society and strengthens companies' reputations.

Applying the four ESRS thematic standards to the findings from open coding shows that, in general, companies' activities fit within the framework of these indicators. A summary of the results obtained by applying the ESRS standards and their corresponding topics as a network of indicators for corporate social sustainability initiatives is presented in Table 3. Overall, these reports demonstrate that, regardless of sector, companies in Latvia are actively working to meet both international and national sustainability standards, creating positive impacts for employees, the value chain, local communities and consumers.

TABLE 3 THEMATIC OPEN CODING RESULTS OF THE SOCIAL DIMENSION OF THE SUSTAINABILITY

ESRS Thematic Standard	**Examples of the Relevant Initiatives Realized by the Companies**
ESRS1 (own workforce)	Enterprises provide a modern and safe working environment, promote employee development and implement equity principles both internally and along the value chain.
ESRS2 (employees in the value chain)	The value chain is managed through responsible procurement policies, cooperation with suppliers and transparent processes that guarantee respect for labour rights at all levels.
ESRS3 (affected communities)	All reports show active community involvement and initiatives that promote economic, social and cultural well-being in local communities, while also ensuring civic and political transparency.
ESRS4 (consumers and end-users)	Information transparency, consumer safety and the provision of inclusive services are key elements in improving the end-user experience and social inclusion.

While the document analysis of 11 sustainability reports suggests that the ESRS framework is broadly appropriate for measuring the social sustainability initiatives of large companies, the expert interviews significantly broaden the perspective on the issue from a practical side.

The experts interviewed for the study believe that the impact of sustainability practices on the competitiveness of Latvian enterprises is significant and increasingly important - especially for companies operating in the international market and looking to attract skilled employees. Businesses that invest resources in employee wellbeing, ethical practices and environmental issues are perceived as more reliable and attractive to potential employees, international partners and investors. Some experts pointed out that the impact of sustainability practices is particularly felt in companies that export or work with international partners, while this impact is less pronounced for domestic companies - which are still often focused on price competitiveness. Such practices enhance a company's reputation and can provide a long-term competitive advantage, but differences between company segments suggest that many local enterprises have yet to achieve a higher level of sustainability integration. While many companies currently choose sustainability as a voluntary practice, it is expected that with increased regulatory requirements (e.g. EU standards) sustainability issues will become a mandatory competitive factor. Overall, experts' ratings on this issue on a five-point scale range from moderate (3) to significant impact (4), with the impact expected to increase further in the future.

Questions on the definition of the social dimension provide an opportunity for a broader interpretation and definition of what exactly falls under the social dimension of sustainability from an expert perspective, thus broadening both the theoretical and practical understanding of the field. According to the experts interviewed for the study, the social dimension is closely linked to human well-being and covers internal employees as well as customers, suppliers' employees and local communities, emphasising fair treatment, equality and ethical practices. Some experts believe that the social dimension of sustainability has two sides: on the one hand, a formal social policy that includes diversity management, improving working conditions, remuneration policies and employee development, and on the other hand, a broader corporate attitude towards society that manifests itself in relations with all stakeholders. The social dimension of sustainability not only seeks to address negative impacts such as discrimination and forced labour but also contributes to positive impacts by investing in the local community, developing the skills potential of employees and improving the work culture. Integration with international standards, such as the sustainability reporting standards set by the EU, helps to define the concept more clearly, covering internal employees as well as supplier employees, affected communities and customers. In addition, the social dimension is also essential for maintaining a company's reputation and ethics, as it ensures the development of stable and sustainable relationships with employees, customers and communities. Overall, the concept is seen as holistic and multifaceted, encompassing both the implementation of formal policies within the company and broader attitudes towards people and society.

According to expert observations, the social dimension of sustainability manifests itself in Latvian companies' practices in a variety of ways, depending on the company's size, sector and strategic priorities. Some companies are proactive in this area, introducing initiatives that improve employee well-being, provide

flexible working conditions and promote an inclusive culture both internally and in their relations with customers and suppliers. Other companies are now introducing social initiatives only formally to meet regulatory requirements, but this approach rarely leads to full inclusion and long-term benefits. In addition, some experts stress the importance of training management teams and defining the concept of social sustainability more broadly, including not only working conditions and employee development, but also the principles of diversity and inclusion, as well as relations with society at large. Increasingly, companies are responding to growing demands from both the market and the regulatory environment - for example in the face of labour shortages and the demands of international markets - which is encouraging the introduction of social initiatives as an important factor for competitiveness. Expert interviews show that the social dimension of sustainability is manifested in Latvian companies' practices through both formal and proactive initiatives. However, there are significant differences between companies and a deeper integration of the social dimension, and a more committed approach are needed to fully exploit this dimension as a competitive advantage.

Overall, experts say the social dimension of sustainability has a significant impact on the competitiveness of Latvian companies. Different companies demonstrate different levels of integration: some implement social practices only formally to comply with regulatory requirements, while others actively use these initiatives as a strategic competitive advantage, creating a positive corporate image and improving the internal working environment. Several experts suggest that companies that actively invest in employee well-being, more flexible working practices and an inclusive company culture can gain a competitive advantage. As increasing demands from both consumers and the global marketplace make companies more accountable for their social impact, this helps to attract skilled employees, increase productivity and enhance corporate reputation. This approach is primarily sensible for companies that are focused on building long-term relationships with society and customers and wish to contribute to the development of an ethical and protective working environment. Some companies tend to see the social dimension as a regulatory requirement and are mainly driven by the tendency to comply with standards at European Union level. Such companies may not realise the full potential of the social dimension, which hinders competitiveness growth. On the other hand, companies that implement social initiatives - such as better working conditions, employee development and an inclusive work culture - gain advantages both in terms of employee motivation and in their relations with investors, partners and customers. The average expert rating of the impact of the social dimension of sustainability on companies' competitiveness ranges from 3 (moderate impact) to 4 (significant impact) on a five-point scale. This indicates that this dimension is an important factor in competitiveness, capable of contributing both to a company's internal development and to improving its position on the external market.

Latvian enterprises can use social sustainability initiatives as a competitive advantage in the long term, creating a stable and positive corporate image in both the domestic and international markets. Experts believe that these initiatives improve employee motivation, promote an inclusive work culture and help companies attract talent, which in the long-term increases productivity and reduces employee turnover. Businesses that embrace social sustainability are also perceived as ethical and responsible, which is essential to attract investment, partners and customers who value sustainable practices. Moreover, companies that implement social initiatives as part of their long-term strategy may see them as a competitive factor, not only for being more responsible towards society and the environment, but also for improving their position in a market where the demand for corporate social responsibility is growing. Active and transparent communication of social initiatives allows companies to demonstrate their compliance with international standards and ethical norms, thereby building credibility in both the domestic and international markets. In addition to these benefits, social sustainability also serves as a differentiator: companies that are able to integrate these initiatives into their strategy stand out among their competitors and are better able to adapt to the changing market and regulatory environment. Such practices can help enterprises to build and maintain loyal relationships with their customers, gain better visibility and ensure their long-term competitiveness.

IV. CONCLUSIONS

The study highlights the growing importance of the social dimension of sustainability in shaping business competitiveness. Through the analysis of corporate sustainability reports and expert interviews, the research provides valuable insights into the extent to which businesses integrate social responsibility into their operations. The findings reinforce that social sustainability is not merely a compliance requirement but a key driver of corporate success in an increasingly sustainability-conscious market.

The content analysis of 11 corporate sustainability reports revealed a strong emphasis on employee well-being, social dialogue, ethics, and community engagement. The application of the ESRS framework provided a structured assessment of corporate social sustainability practices across four key dimensions. The studied Latvian companies are actively aligning with global sustainability standards, contributing positively to employees, supply chains, communities, and consumers.

Expert interviews provided a practical viewpoint on the role of social sustainability in business performance. Businesses investing in employee well-being, ethical labour practices, and community engagement experience higher employee satisfaction, increased productivity, and improved stakeholder trust. With ESRS and EU sustainability reporting requirements becoming more stringent, experts noted that businesses that proactively integrate social sustainability gain a strategic edge over

those that adopt it merely as a compliance measure. At the same time, smaller enterprises still struggle to implement the ESRS framework due to resource constraints. Large companies have made significant progress in meeting these standards, but further regulatory support is needed to assist small and medium enterprises in adopting structured sustainability reporting.

While businesses are making substantial progress in integrating social responsibility, challenges remain in measuring impact, achieving full ESRS compliance, and fostering deeper stakeholder engagement. For businesses to maximize their competitive advantage, they must move beyond regulatory compliance and embrace social sustainability as a long-term investment in corporate resilience and market positioning. Companies that successfully integrate social responsibility into their operational strategies will be better positioned to thrive in an increasingly sustainability-driven global economy.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 297-303

Digitization as a Factor in Lobbying and Public Involvement in the Approval of Legal Acts in Latvia

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***Abstract*— The opportunity for the public to give their opinion and follow the development of legislation is not only a practice of full-fledged democracy and good governance, but also an opportunity for the public administration to obtain information, knowledge and analysis that it did not have access to. The aim of this study is to analyse the impact of digitisation on representation of interests and public involvement in the development of legislation in Latvia. The analysis of quantitative and qualitative data explored 4,943 legislative advancement processes in the Single Portal for Development and Harmonisation of Draft Legal Acts (TAP portal) between 2018 and 2024. Digitization of the final phase of the development of legal acts, i.e. public discussion and coordination in Latvia allows to assess: 1) how actively society is involved; 2) who does it – simple citizens or professional organizations; 3) whether digitization has increased public involvement; 4) whether public involvement significantly slows down decision-making.**

The results show that the infrastructure of the TAP Portal has successfully promoted the involvement of organized interest groups in the process of harmonization of legal acts, mainly in the form of legal entities and associations. The participation of private individuals is small. The original objectives of the TAP Portal have been exceeded as it has been used by more than 600 different types of actors. At the same time, the hypothesis that organised groups significantly slow down decision-making processes was not confirmed; the length of decisions is more influenced by the political agenda and the nature of the legislation.

The study confirms the role of the Single Portal for Development and Harmonisation of Draft Legal Acts as an important platform in promoting transparency and efficiency in the development of legal acts. The authors recommend continuing to promote the use of this portal among interest groups, as this would enhance both transparency of the process and balanced representation of interests in the legislative process.

Keywords*— *digital platforms for public participation, lobbying, legislation development, public governance.

I. Introduction

Many experts in politics point to the contribution of the representative of positive interests to the transfer of information and knowledge to decision-makers [1], [2]. This is also confirmed by the research carried out in Latvia by A. Zanderes as part of his master's thesis, in which the interviewed current and former ministers and high-ranking officials state that "the contributions of lobbyists should be preserved in relation to the provision of information and data in the discussion process and in the course of decision-making." [3]. What decision makers want and also use is analytics, expertise and explanations [4]. Obtaining and processing such information is a resource-intensive process. Therefore, decision-makers are happy to use the support provided by lobbyists, because they not only analyze and synthesize, but also summarize in a user-friendly form [5].

In addition, it is desirable to turn this information into a specific wording, which can also be referred to publicly. For example, in the case of Latvia, it is the Single Portal for Development and Harmonization of Draft Legal Acts (or TAP portal). Even more, it is pointed out that without using the opportunity to post their proposals on the given portal, decision makers may get an idea of the lobby's superficial approach to the issue under consideration [3] or the desire of lobbyists to hide and not publicly defend their interest.

Lobbyists can be conditionally divided into three groups: 1) representatives of individual interests; 2)

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8659
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representatives of group interests representing a "defined area"; 3) representatives of group interests representing a wide range of interests [1]. Examples of the first group include company representatives or natural persons who are directly interested in the specific decision or outcome. The second group includes industry professional organizations, such as the Latvian Forest Industry Federation (mainly specialized in representing the interests of the forest industry) or the Latvian Ornithological Society (mainly specialized in improving the living environment of wild birds). This does not mean that they do not express an opinion or expertise in other issues as well, however, the range of their competences is apparently defined in advance and outside of their competences, they engage in discussions relatively rarely. The third group includes think tanks such as Public policy think tank PROVIDUS and Latvian Formula 2050. Think tanks can also provide expertise or fight for the outcome of a specific issue, however, they cannot be expected to represent years in a specific area.

The less individuals (whether that means a number of companies or individuals) are represented, the more likely it is to express a very selfish view and not take into account the interests of the whole. Even if equally selfish and rational (from the point of view of their interests) individuals form a large group, there is a very high probability that individual interests will conflict with each other and the group's overall group compromise is much closer to the interests of the whole or society. At the same time, a large group may under-represent or even come into conflict with one (or some) individuals of this group [6], which is why a member or members of an organized interest representation organization (for example, an association) expresses a different or even contradictory message than that expressed by the representative organization itself. However, discussions within the group significantly increase the quality of the group's external message and reduce the probability that an ideal but unrealistic solution will be offered, or as defined by Harold Demsetz, the “Nirvana fallacy”. The "Nirvana approach" is significantly different from the "comparison method", because the first tries to prove why any alternative, compared to the "ideal solution", is in some way imperfect and will not achieve the maximum desired result, while in the "comparison method", the one that best achieves the goal is chosen among several imperfect but realistic alternatives [7].

Digitization not only affects formal bureaucratic structures, it creates new forms of accountability in public sector organizations. It creates new ways of traceability and also increases accessibility [8]. Thanks to digitalization, it is also possible to analyze the processes of interest representation or lobbying in the Latvian state administration, which affects the public discussion and coordination of legal acts before viewing in the Saeima or the Cabinet of Ministers.

II. Materials and methods

The study uses both qualitative and quantitative research approaches. Secondary data analysis was used in the quantitative research approach, document analysis was used in the qualitative research approach. The empirical basis of this study is the information on the progress of legal acts available in the Single Portal for Development and Harmonization of Draft Legal Acts (TAP portal). In total, the study analyzed 4,943 legislative processes. Of these, 14 cases refer to the period from 2018 to 2020. On the other hand, 522 legislative acts were initiated in 2021, 1,695 in 2022, and 1,433 legal acts were initiated in 2023. By December 10, 2024, 1,279 legislative developments were recorded. Information on 20 different types of legislation is available on the TAP portal. However, the analysis shows that the four most common types of legislation account for 95% of all registered documents. The most represented are 2,219 draft regulations, including amendments, as well as 1,174 draft orders, incl. 88 their amendments. Also, a significant part is made up of 701 informative reports and 601 initiatives of the Cabinet of Ministers for the Saeima to make changes in laws.

Although legal acts have the opportunity to receive comments, this does not mean that this option is always utilized. Consequently, there are legal acts in which no public comment has been submitted by public comment submitters, as well as those in which the same submitter has provided comments repeatedly during each consultation process. Given that a specific public comment submitter’s objections often recur from one consultation procedure to another, the study assumed that—even if objections are submitted multiple times—they are counted as a single public comment. The same approach applies to positive public comments. However, if in one consultation procedure a public comment submitter expresses an objection and in another procedure the same submitter provides a positive comment, then, within the framework of the study, these are regarded as two distinct public comments. Furthermore, if a public comment submitter has indicated an intention to submit a comment but fails to do so within the designated time period, that instance is automatically considered as implicit approval by default.

Latvian legal acts give the right to participate in the development of legal acts to all its citizens and organizations. For example, the regulations of the Cabinet of Ministers “Procedures for the Public Participation in the Development Planning Process” state that “Public participation shall be implemented by formal (for example, associations, foundations, trade unions, employers' organisations, religious organisations) and informal (unregistered initiative groups, interest associations) groups of the public, as well as individual natural persons.” [9]. State Administration Structure Law also states that “institutions shall involve public representatives (representatives of public organisations and other organised groups, individual competent persons) in their activities by including such persons in working groups, advisory councils or by asking them to provide public comments.” [10].

Of course, the expression of public comments, which is regulated by the above-mentioned regulations of the Cabinet of Ministers, can be distinguished from more regular involvement in the work process, which is regulated by the State Administration Structure Law, however, the authors' empirical observations over many years lead to the assumption that, with the exception of the participation platform ManaBalss.lv, the rest of the infrastructure is basically designed with organized interest representation in mind In order to test the hypothesis that public participation in the development of specific legal acts is basically implemented by organized representation of interest or lobbying, the public project data analysis of the TAP portal will be used.. Two hypotheses are put forward:

(H1) "Infrastructure is built" and it is basically used by organized representations (organizations).

(H2) This organized representation is basically lobbyists or, according to Latvian legislative terminology, interest representation organizations.

Organized representation will be considered the criteria of formal representation in the regulations of the Cabinet of Ministers "Procedures for the Public Participation in the Development Planning Process", namely associations, foundations, trade unions and their associations, religious organizations, residents' councils [9], supplementing them with merchants and other legal entities that are not directly under the ministries. For example, public comments are given by both local governments and law enforcement agencies, but such organizations will not be considered as representatives of society in the context of the study. The opposite interpretation will be given to derived public entities, such as higher education institutions, Bank of Latvia (Latvijas Banka), capital companies owned by the state and municipalities, as well as associations uniting municipalities and cities, because they are not directly subordinate to ministries and act with similar motives as public groups.

On the other hand, the threshold for the representation of interests will be used in accordance with the criteria of the "Law on Transparency of Interest Representation", namely "systemic representation of interests is representation of interests carried out at least three times within 12 months of the representation of the first interest." [11], so that representation of interests is framed as systematic and can therefore be called lobbying. It should be noted that none of the exceptions mentioned in this law, which cannot be considered as the representation of interests, are applicable to communication on the TAP portal.

As one of the goals in the creation of the TAP portal was to transfer the public discussion of legal acts to this website, that is, in three years (from the fall of 2021), to reach the level that at least 85% of all submitted public comments have taken place through the TAP portal [12]. According to the authors, this not only increases productivity by reducing the proportion of technical (non-automated) activities, but it also increases the transparency and traceability of the legislative process. Within the framework of the project, a goal was set that at least 50 non-governmental organizations would use this website [12]. The authors assume that this number was not chosen randomly and describes the number of social partners and representation of interest at that time. Therefore, the hypothesis will be tested:

(H3) The creation of The Single Portal for Development and Harmonization of Draft Legal Acts (TAP portal) has a positive effect on wider public involvement in the development and adoption of legal drafts.

To test this hypothesis, the number of involvement of non-governmental organizations involved in the harmonization process and the development of the extent of involvement over time will be analyzed, assuming that the hypothesis will be confirmed if the involvement exceeds the 50 mark.

In good faith, it should be assumed that the main goal of public participation is to develop the highest possible quality legislation, taking into account all interests, that is, decision-makers gain more knowledge or information that allows them to develop regulation that maximizes the desired benefit and minimizes the undesirable side effects of regulation. It should also be assumed that a draft legal act that has gone through public consultation should be at a high level of readiness, as the various interests have already been evaluated. Therefore, the coordination process should primarily involve government institutions to align terminology, prevent contradictions with other legal acts, and ensure consistency with policy planning documents.

Given the extensive experience and competence of civil servants, this should not have a significant impact on the overall duration of the decision-making process. However, the tactic of interest representatives to strengthen with arguments those decision makers with whom the views or political agenda coincide can lead to the phenomenon: "the equality of interest representation is threatened without even ignoring or rejecting the participation of any interest representative" [5]. Namely, by strengthening the interests of one party, the consideration of other interests, including the right to adopt or change the legal framework in a timely manner, is reduced either unintentionally or with deliberate tactics. Therefore, the hypothesis will be tested:

(H4) The involvement of interest representative organizations in the process of harmonization of legal acts significantly slows down the speed of decision-making.

In order to clarify this, the duration of decision-making between the public consultation and the start of the harmonization process will be analyzed, as well as the regularity of the time that elapses between the conclusion of the harmonization process and the consideration in the Cabinet of Ministers, depending on how the harmonization stage has gone.

III. Results and discussion

The analysis convincingly proves that interest representation groups are basically involved in the harmonization of the legal act. There are also rare cases

when, for example, objections to the "The Fifth National Open Government Partnership Action Plan of Latvia 2022–2025" have been raised by first-year students of the Master's program in Public Administration at the University of Latvia's Faculty of Business, Management, and Economics. However, for the most part, these objections come from associations, foundations, trade unions, or other legally established organizations.

State-based entities, such as the Public Utilities Commission of Latvia, the Bank of Latvia, the National Electronic Mass Media Council (NEPLP) and the Society Integration Foundation, who have issued a total of 471 public comments, are also very active in providing their public comments. Higher education institutions are also active. Among the businessmen, the representatives of the energy industry are the most active, for example JSC "Conexus Baltic Grid", JSC "Gaso", JSC "Latvenergo" and JSC "Sadales tikls" have provided a total of 132 public comments. On the other hand, the involvement of private individuals is very rare, and even then, it should be assessed on whose behalf it is done.

Out of 12 submitted State-based entities, such as the Public Utilities Commission of Latvia, the Bank of Latvia (Latvijas Banka), the National Electronic Mass Media Council (NEPLP) and the Society Integration Foundation, who have issued a total of 471 public comments, are also very active in providing their public comments.

8 were provided by representatives of religious organizations—the Dean of the Aglona Basilica parish and the Bishop of the Rezekne-Aglona Diocese of the Roman Catholic Church. It is very likely that these should be classified as organized representation of interests, which would only further strengthen the evidence that the hypothesis "(H1) "infrastructure is built" and they are based on organized representation (organizations)" has been fully confirmed.

TABLE 1 PUBLIC COMMENTS SUBMITTERS (2018-2024)

Public comment submitters	**Total**		**3 and more public comments have been given**	
	Number of persons	***Number of public comments***	***Number of persons***	***Number of public comments***
Organized representation of interests, mainly associations	387	7257	151	6970
Individual – legal entities	161	909	31	755
Individual – private persons	4	12	2	9

However, looking at Table 1, the hypothesis "(H2) this organized representation is basically lobbyists or, according to Latvian legislative terminology, interest representation organizations" is only partially confirmed. In terms of the number of public comments, the organized representation has given 95% opinions. Even if state derived persons, such as higher education institutions, the Bank of Latvia, the Public Utilities Commission of Latvia, the Bank of Latvia, the National Electronic Mass Media Council and others, are deducted, which might not conform to the legal characteristic that they act "in their own interests or in the interests of other private individuals", similarly, close to 90% of public comments will come from organisations that have issued opinions 3 and more times in a 12-month period. However, in terms of number, such organizations correspond to only 33% of public comments submitters. It is important to note that in the sense of the "Law on Transparency of Interest Representation", providing official public comments is only one of the direct or indirect forms of communication that qualifies someone as a representative of interests. In 2015, the "Dienas Bizness" portal published a list of the most influential lobby organizations representing the interests of merchants [13]. Although some have changed their names and possibly their influence, all are still active. However, a significant part of them would not be classified as an interest representation organization if the only feature were involvement through the TAP portal.

TABLE 2 THE ACTIVITY OF THE "MOST INFLUENTIAL LOBBIES" (2018-2024)

The number of public comments registered in TAP portal per organization	**Number of organizations**	**Total number of public comments in this group**
0-2	6	8
3-9	11	52
10-50	6	149
51+	4	1652

However, empirical observations show that due to working groups and other forms of direct or indirect communication with public officials, they would be unambiguously classified. Most likely, the low activity on the TAP portal is explained by the operating style of these organizations and the widespread belief that the harmonization process is basically meant with ministries and other state institutions. Clause 58 of the Rules of Procedures of the Cabinet stipulates: "Ministries or other authorities shall agree upon the draft by providing an opinion. The opinion shall be provided on each draft individually." The term "institution" is not defined in detail in the Rules of Procedures of the Cabinet, but contextually it covers all public administration units that are responsible for specific areas or policies that the relevant legal act may affect. Therefore, many interest representatives do not consider it a sufficiently effective way of realizing their interests. At the same time, many other influential interest representatives (lobbyists) act in the opposite way, and not only in situations where they oppose a specific legal act. Surprisingly, numerically twice as much support has been given for the progress of the specific legal act than objections have been expressed. Moreover, this practice is not only between state institutions, but also among interest representative organizations.

TABLE 3 BEHAVIOR OF THE MOST ACTIVE PUBLIC COMMENT SUBMITTERS (2018-2024)

Name	Number of public comments	
	Oppose	***Agree***
Latvian Association of Local and Regional Governments (LALRG)	572	1279
Employers' Confederation of Latvia	315	585
Latvian Association of Large Cities	264	455
Latvian Chamber of Commerce and Industry (LCCI)	146	357
Latvian Trade Union of Education and Science Employees (LIZDA)	79	291
Free Trade Union Confederation of Latvia	85	236

The information presented in Table 1 clearly shows that the initial goal of the TAP portal, that this website will be used by at least 50 non-governmental organizations, has been strongly exceeded, therefore the hypothesis "(H3) The creation of The Single Portal for Development and Harmonization of Draft Legal Acts (TAP portal) has a positive effect on wider public involvement in the development and adoption of legal drafts." has been confirmed. During the entire period, more than 600 non-governmental organizations, businessmen and private individuals have used it. In Figure 1, the bars represent the quarterly dynamics, showing how many new public comment submitters have appeared compared to the previous quarter or, conversely, how many did not submit public comments in this quarter compared to the previous one. The broken line describes the total number of public comment submitters, excluding ministries, while the black continuous line describes the cumulative number of unique public comment submitters since the launch of the TAP portal. Given that several influential interest representative organizations have still been relatively inactive on this portal but are gradually increasing their participation, the number of regular users is expected to grow in the future.

In order to test the hypothesis: "(H4) The involvement of interest representative organizations in the process of harmonization of legal acts significantly slows down the speed of decision-making.", only those legislation with a record of decision-making in the government were selected. This was a total of 4043 out of 4943. Another 4 legislation were excluded from the analysis, where it was likely that incorrect information was given either about the time of harmonization or adoption, because the decision was of an earlier date than the harmonization. Following each type of legislation, a correlation was calculated separately between the duration of decision-making (time period between the date of the first coordination and the date of decision-making) and whether at least one interest representative raised an objection. Similarly, the correlation was examined when, instead of public comment submitters providing objections, those providing positive public comments were considered.

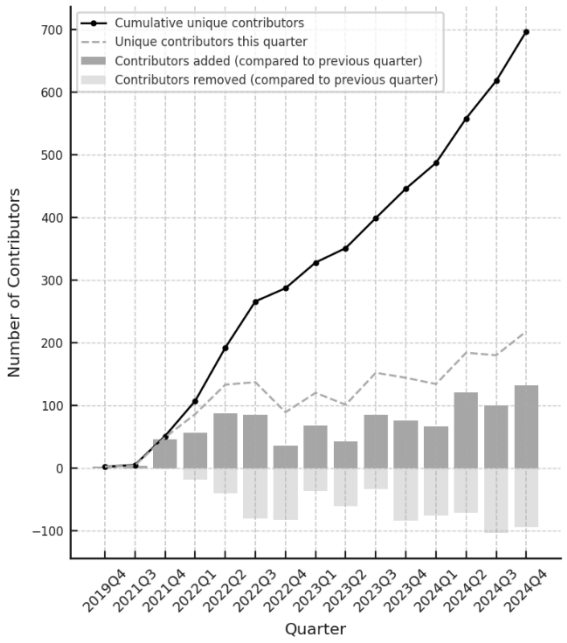

Fig. 1. Dynamics of public comment submitters in TAP portal (2019-2024).

It should be noted that one legal act of the type "Draft protocol decision of the meeting of the CM (Cabinet of Ministers)" had an observable correlation of 0.99, but this does not leave an impact on the hypothesis evaluation, because, firstly, it is numerically underrepresented (n=9), and secondly, it is of a very technical nature. For hypothesis evaluation, types of legal acts, each with a large set (n>100), were selected. In total, there were 4 types of legal acts: 523 informative reports, 428 draft laws, 1902 CM regulations and 917 CM orders. Each of these pieces of legislation had sufficient "no objection" representation. The smallest share, or 52%, was for legal drafts, while the largest share, or 91%, was for draft orders, which progressed through coordination without objections from representatives of "non-ministries". Table 4 shows the obtained correlations, which clearly show that the hypothesis: "(H4) The involvement of interest representative organizations in the process of harmonization of legal acts significantly slows down the speed of decision-making." has not been confirmed.

TABLE 4 CORRELATION BETWEEN DECISION-MAKING DURATION AND TYPE OF PUBLIC COMMENTS

Type of legislation	Correlation between decision-making duration and type of public comments	
	Agreement	***Objection***
Informative report	0,28	0,26
Draft law	0,19	0,16
Draft Rules	0,20	0,25
Draft order	0,21	0,02

The strangest thing about these obtained results is that the presence of agreement, which should have a positive

effect on the speed of decision-making, seems to have worked in the opposite way, and in most cases even more negatively, than objections. It was checked whether the results are not influenced by a third factor, for example, the Ministry of Finance raised an objection, however, the existence of objections from this Ministry also has a statically insignificant effect on the duration of decision making.

TABLE 5 DECISION MAKING SPEED

Type of legislation	**Duration of decision making time (days)**			
	Average	***Median***	***min***	***max***
Informative report	80	57	1	850
Draft law	154	102	0	1776
Draft Rules	107	80	0	1377
Draft order	85	60	0	1783

Other regularities were also looked for, but none showed a significant correlation. Therefore, it can be concluded that the duration of decision-making depends on the political agenda, which has a very large time amplitude.

IV. Conclusions

The Single Portal for Development and Harmonisation of Draft Legal Acts (TAP portal) has become the main platform for public participation, and most of its infrastructure is used to engage organized interest representatives such as associations, foundations and companies. Individual citizen participation in the reconciliation process is rare, indicating the dominance of structured representation.

The research data confirm that the majority of submitted public comments come from organized groups that engage in the coordination process more than three times a year, which is consistent with the lobbying characteristic defined in Latvian legislation. However, it was also observed that less active representatives, although rarely using the platform, still dominate numerically. It is expected that many organizations will increase their activity on the TAP portal in the future, including it as another tool for representing their interests.

The analysis shows that the TAP portal has significantly contributed to wider public involvement, exceeding the initially set goals. In total, the platform has been used by more than 600 different types of actors, and its role as a promoter of transparency and efficiency is unmistakable. This confirms the hypothesis that the TAP portal has a positive effect on public participation.

On the other hand, the hypothesis that the involvement of organized interest groups slows down the decision making process was not confirmed. The duration of the decision is mostly related to the political agenda and the nature of the legislation, not to the objections or support expressed by interest representatives. Furthermore, the study shows that within the alignment process, positive alignments do not reduce decision making time, indicating complex factors influencing these processes.

In conclusion, it should be concluded that the TAP portal has not only improved the transparency and traceability of legal act development processes, but still many groups of interest representatives do not consider it one of the main channels or tools for representing their interests. Therefore, the authors recommend to continue popularizing the use of this portal among groups of interest representatives, as it would promote both the transparency of the process and the balanced representation of interests in the process of drafting legislation.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 305-311

River Networks as Ecological Hotspots and Corridors for Invasive and Aquaculture Species: Long-Term Bioclimatic Modeling in Latvia

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***Abstract*— Climate change significantly affects aquatic biodiversity, particularly through the expansion of invasive species, which pose critical threats to native ecosystems and economic sectors such as aquaculture. This study synthesizes research findings on the impact of climate change-driven species distribution, focusing on three alien thermophilic fish species: silver carp *Hypophthalmichthys molitrix*, bighead carp *Aristichthys nobilis*, and pumpkinseed *Lepomis gibbosus*. The range expansion of this species has continued across the Europe. Using a species distribution modelling approach, predictions are made of the geographic range of the fish based on presence records and environmental variables from the Near-global environmental information for freshwater ecosystems database likely to be associated with habitat suitability and important for the possible further expansion of the species. The results show a possible widespread under the current climate situation and prospects for the future expansion of the species under the influence of climate change in Latvian river networks, identifying ecological hotspots and corridors for these invasive and aquaculture species. In the aquaculture sector, climate change influences the viability of farming conditions and fosters the proliferation of invasive species that compete with or prey upon economically valuable fish stocks. Research on ecological and socioeconomic thresholds in Latvian pond aquaculture underscores the need for adaptive management strategies to mitigate climate-related risks. These findings underscore the necessity for targeted conservation policies, improved invasive species management, and climate-adaptive strategies in aquaculture. Proactive measures, including habitat restoration, stricter biosecurity regulations, and public awareness campaigns, are essential to mitigate the adverse effects of climate change on biodiversity and economic sustainability.**

Keywords*— *bioclimatic long-term modeling, ecological hotspots and corridors, invasive and aquaculture species, river networks

I. Introduction

Species dispersal beyond native ranges drives global change, with globalization accelerating organism translocation [1]. Climate change further influences invasion success by enabling range shifts, allowing non-native species to establish and outcompete natives under new conditions [2] – [4]. Such shifts can disrupt ecosystems, reducing biodiversity and ecosystem services [5], [6].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8703
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Freshwater ecosystems are particularly vulnerable to biological invasions [7], with introduced fish species posing significant threats [8]. In Europe, at least 40 alien fish species have established populations [9]. One such species, the North American sunfish *Lepomis gibbosus*, introduced in the late 19th century, is now widespread across Europe and Asia Minor, with climate change expected to facilitate its northward expansion [10] - [12]. Despite over a century since its introduction, *L.gibbosus* continues to spread [13]. Identifying environmental factors influencing its expansion is crucial for risk assessment and monitoring, particularly in Latvia, where suitable conditions exist but the species is not yet recorded [14].

Species distribution models (SDMs) or ecological niche models (ENMs) predict potential species distributions by correlating presence records with environmental factors [15]. These models, employing statistical and machine learning algorithms, aid in forecasting range expansions under climate change. Similarly, Asian carps pose ecological concerns due to their voracious feeding, which can displace native fish and impact aquatic vegetation. In some areas, they dominate biomass (MICRA 2002), potentially affecting native herpetofauna like the European pond turtle *Emys orbicularis* and amphibians. While some suggest they help control algal blooms, a comprehensive impact assessment is needed [16] – [18].

GIS modeling and ecological niche models are essential for studying fish invasions, yet existing research primarily focuses on other regions or species e.g. *Hypophthalmichthys molitrix* and *Aristichthys nobilis* [19]–[23]. Applying these tools enhances predictions of invasive species spread, informing biodiversity conservation and management strategies.

II. Materials and Methods

A. Occurrence Data Collection

The Ukrainian example was used to obtain data where it was more accessible and then adapted to the Latvian situation. Species occurrence data were sourced from GBIF (2021) [24], FishBase (2022) [25], and social media platforms (Facebook, Twitter, Instagram, Flickr) for Ukraine, utilizing geotagged photos and text-based records [26], [27]. Search queries included Latin and vernacular names in Ukrainian and Russian. Data were compiled for 17 Ukrainian regions, verified using literature sources [28] – [30], and filtered for spatial bias using the 'spThin' R package [31] to maintain a minimum separation distance, reducing autocorrelation [32].

B. Environmental Data

Environmental variables were sourced from Near-global freshwater ecosystem datasets [33] and the CliMond dataset [34]. Highly correlated variables ($|r| > 0.8$, $p < 0.001$) were removed using the 'caret' R package [35], and feature selection was performed with the 'Boruta' algorithm [36]. Pseudo-absence points were generated using the 'dismo' package [37].

C. Model Building

Species distribution models (SDMs) were developed using Maxent [38] and Bayesian additive regression trees (BART) [39]. Response curves were analyzed to assess variable effects on habitat suitability [40]. Maxent models were optimized using the 'SDMtune' package [41], adjusting feature classes and regularization multipliers [42]. The 10th percentile training presence threshold was used for habitat suitability delineation [43]. Considering niche differences between native and invaded ranges [44], we compared bioclimatic niches using ANOSIM [45]. Maps were processed in SAGA GIS [46], and statistical analyses were performed using PAST [47].

This approach integrates GIS modeling and SDMs to assess the feasibility and environmental suitability of invasive species expansion in Latvia, with implications for conservation and aquaculture management.

III. Results and Discussions

When looking at possible future climate scenarios for Latvia, seasonality has great importance. Comparing the average temperatures and precipitation values of the recent past (1961–1990) and the future (2071–2100) months, it can be clearly seen that higher air temperatures are expected in all months in the future than today (see the example of the Latvia town Dobele) (Figure 1). More precipitation is expected in most of the year in the future, only in April and July–September there will be less precipitation. Winter will become three months shorter. Only in one of the coldest months of the year (February) the average air temperature will be below zero. Spring will come in March two weeks earlier than today and will be shorter. In May of the future, the weather conditions will correspond to today's June. Summer will become two months longer, and in addition, temperatures typical of today's hottest months (July, August) are expected in June and September, but July and August in the future will be significantly – on average by four degrees – hotter than today. The summer months of June–August will be the wettest, just like today, while the "new" summer month of September will be dry (like today's May). Weather conditions similar to today's autumn (October–November) will prevail for three months – from November to January. The long autumn will be made particularly unpleasant by a third more frequent rains [23].

These temperature changes create a favorable environment for invasive alien crustacean species, the arrival of which is associated with both deliberate introduction and secondary spread after their invasion into European freshwaters. The alien crustacean species found in Latvian freshwaters are mainly North American and Ponto-Caspian species, whose arrival is associated with both deliberate introduction and secondary spread after their invasion into European freshwaters. The large decapod – the American signal crayfish – was introduced to Latvia for the purpose of scientific experiments in 1983 in one lake [49], but in later years and currently occurs in the Salaca and Gauja river basins [50]. The other North American species – the American spinycheek crayfish

(*Faxonius limosus*) – is a more recent arrival, first detected in the territory of Latvia in 2005 in the Lielupe River [51].

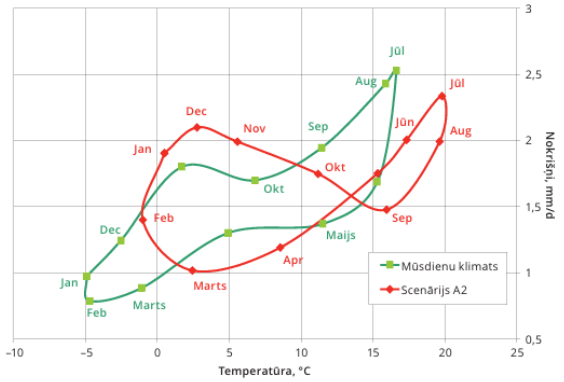

Fig. 1. Temperature-precipitation diagram for current and future climate (IPCC scenario A2) in Dobele [48].

It was first introduced into European freshwaters in Germany in 1890 and has since been introduced into German, Polish and French waters [52]. In Latvia, it is currently found in the Venta, Lielupe and Daugava river basins [50]. The Ponto-Caspian decapod, the narrow-clawed crayfish (*Astacus leptodactylus*), was observed in Latvian freshwaters already at the beginning of the 20th century, and its occurrence is currently associated mainly with the freshwaters of Vidzeme and Zemgale [49]. Representatives of another group of alien crustaceans of the Ponto-Caspian region, Amphipoda, which are widespread in European waters, are found in Latvian freshwaters – mainly *Pontogammaridae* and *Gammaridae* families [53]. Certain amphipods *Obesogammarus crassus* and *Dikerogammarus villosus* are already potential newcomers to Latvian freshwaters, as they have been found in Latvian ports and the Daugava estuary [54]. In turn, *Ponto gammarus robustoides* is much more widely distributed in Latvian freshwaters, as it was purposefully introduced in the 1960s to improve the fish food base in the Great Baltezers and the Kegums Reservoir together with other species of the Ponto-Caspian region – the amphipoda *Chaetogammarus warpachowskyi* and the mysids *Paramysis lacustris*, *Limnomysis benedeni*. Further studies showed that *P. lacustris* has settled best in the new habitats in the near Riga lakes and *P. robustoides* in the Kegums Reservoir [55], [56]. Currently, the amphipoda *P. robustoides* is found in the mouth of the Daugava River and its lower reaches in the Riga, Ķegums and Pļaviņas reservoirs, as well as in the Latvian coastal lakes (Papes, Liepājas, Babītes, Lilastes, etc.), as well as in the tributaries of the large and small rivers of the Baltic Sea and the Gulf of Riga, such as Lielupe, Saka, Venta, Roja, Aģe, Ķīšupe, etc. or in their mouths [57], [58]. This can be explained not only by introduction, but also by the secondary spread of the species in the Baltic Sea after introduction into the freshwaters of Lithuania and/or Latvia [59], [60]. Recent studies have revealed that the alien amphipoda *P. robustoides* is common in the lower reaches of the Daugava and, continuing its spread, has already established itself upstream of the Pļaviņa Reservoir (Figure 2) [58].

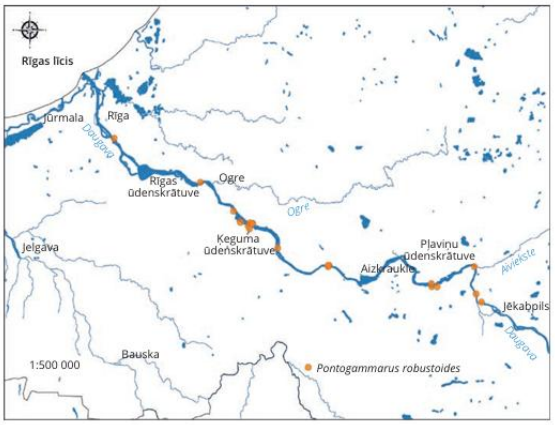

Fig. 2. Occurrence of the alien amphipods *P. robustoides* in the lower reaches of the Daugava River [55],[58].

In the lower reaches of the Daugava, *P. robustoides* has become the dominant amphipod. The native amphipod *Gammarus pulex* was found in the Ķegums Reservoir at the mouth of the Rītupīte stream and upstream of the Pļaviņa Reservoir near Zeļķi between the amphipods *P. robustoides* and *G. varsoviensis*, which according to the latest research data is also considered a Ponto-Caspian amphipod [61]. In fact, *P. robustoides* has outcompeted and replaced the local amphipod *G. pulex* in the lower Daugava, as this species was present in the lower Daugava in studies of the 1960s [62], and has also affected the diversity of invertebrate species. In places with a higher number of *P. robustoides* individuals, a decrease in species diversity is observed (Figure 3).

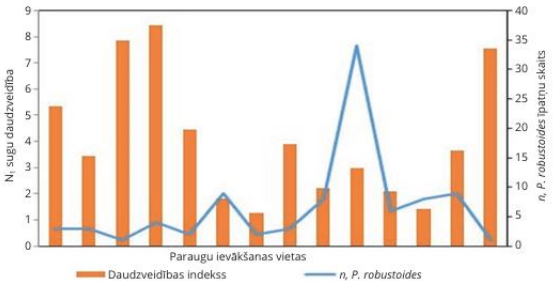

Fig. 3. Number of individuals of the alien side-swimming *P. robustoides* versus species diversity N1 (the value of N1 depends on the number of individuals of the species: the greater the number of individuals of a species, the lower the diversity) [48].

A similar trend is also observed for the previously discussed species *L.gibbosus*, whose distribution map was created in the study conducted. The obtained probability maps were averaged to produce a habitat suitability map for the pumpkinseed corresponding to the current climate in Europe and clipped to and Latvia (Figure 4). Contour lines

distinguishing suitable for the species areas match the 10th percentile training presence threshold value [14].

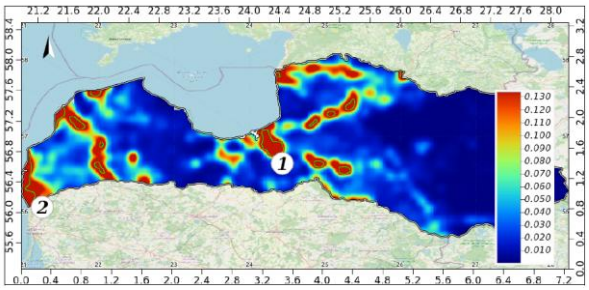

Fig. 4. Map of predicted habitat suitability for the pumpkinseed in Latvia based on the combination of selected predictors from the Near-global environmental information for freshwater ecosystems; the legend shows habitat suitability ranging from relatively high (red) to low (blue); areas suggested for legal introduction: 1 - Lower Daugava, 2 - Kurzeme Province [14].

Also the silver carp *H.molitrix* and bighead carp *A.nobilis* are two species of Asian carps that have become invasive in many parts of the world, including Europe. These fish can have significant negative impacts on native ecosystems. Understanding the factors that affect their distribution is important for managing their spread. Because these species are actively used in aquaculture, particularly in fisheries, it is crucial to investigate the influence of other climatic factors on their distribution in the northern portion of their range [63].

Our results show that the temperature, namely the annual mean temperature, is the main factor affecting the distribution of Asian carps in Europe. Given the critical role of temperature factors in shaping the distribution of these Asian fish species, our analysis suggests that the potential suitable habitat for H. molitrix in Europe currently lies within latitudes between 53 and 55◦ N. However, by 2050, projections indicate a northward shift in its range, extending up to 58–62◦ N (Figure 5). This expansion will encompass Latvia and areas further north of Norway, Sweden, and Finland. Potentially suitable habitats for the more thermophilic species *A. nobilis* are primarily located in the Danube, Dniester, and Seversky Donets basins, spanning up to 48–51◦ N. Forecast projections suggest that by 2050, this species could potentially expand its range northward to 52–55◦ N, reaching up to 58◦ N around the Baltic Sea (Figure 5).

These findings corroborate former studies reporting that most thermophilic freshwater animals are likely to experience range shifts in the future [16], [63], [64]. According to former forecasts, self-reproduction of silver carps will likely occur in the Netherlands by 2050 [23]. While temperature factors play a significant role in determining the distribution of Asian carps, these fish species have demonstrated a remarkable ability to adapt to colder climates. In northern regions, they are more likely to survive in artificially created water systems, such as ponds, reservoirs, and canals. These environments provide a more stable temperature regime compared to natural water bodies, enabling the fish to persist even in colder conditions.

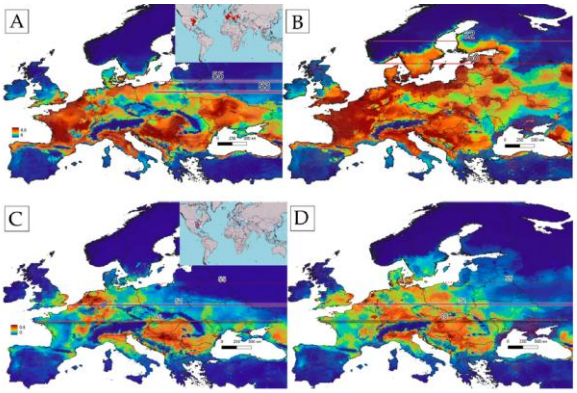

Fig. 5. Potential (probabilistic) model of Asian carp expansion built in the Maxent program in Europe based on CliMond dataset (red color > 0.5). *H.molitrix*: (**A**) current (dotted line marks - 55° N, red line marks – 53° N); (**B**) CliMond dataset 2050 (thin line – 62° N, thick red line – 58° N). *A.nobilis* (dotted line – 55° N; thin line – 51° N, thick red line - 48° N); (**C**) current; (**D**) CliMond dataset 2050 [14].

Adapting to colder temperatures also requires the ability to migrate to wintering areas where there is sufficient oxygen. As water temperatures drop below 10 ℃, the behavior of fish changes. They form schools and prepare for wintering by moving to deeper parts of water bodies, where oxygen levels are typically higher. In the context of aquaculture, maintaining adequate oxygen levels in stagnant water bodies during the winter months is crucial for the successful wintering of the fish population. This may necessitate additional aeration measures, such as the use of air pumps or bubblers. Overall, the adaptability of Asian carps to colder environments poses a significant challenge for managing their spread. Understanding their survival strategies and implementing effective control measures are essential for mitigating the negative impacts of these invasive species. As species cultured in warm waters discharged from power plants, Asian carps have demonstrated an ability to thrive in more northern regions, as documented in open databases (Fishbase.org, FAO.org). This adaptation is partly attributed to their ability to utilize warm water discharges from power plants. Additionally, the widespread distribution of these thermophilic herbivorous Asian fish is facilitated by the stocking of captive-bred fry. For these species to successfully reproduce in the wild, specific conditions are required. Water temperatures between 22 ℃ and 28 ℃, along with suitable water flow and changes in water levels, can stimulate natural fish reproduction and favorably impact the development of benthopelagic fish eggs. While fry growth can occur in stagnant water bodies, these conditions are unsuitable for reaching maturity and triggering reproduction.

IV. Conclusions

Our research highlights river networks as ecological hotspots and corridors for invasive and aquaculture species, emphasizing the northward expansion of Asian carps in response to climate change. By 2050, Northern European

waters will likely provide suitable conditions for these species, necessitating proactive management strategies to mitigate ecological risks while harnessing potential aquaculture benefits.

By analyzing 598 occurrence records in Europe and 873 in North America, we identified 18 key environmental variables influencing species distribution, with temperature playing a critical role. The climatic predictor 'tmin9' (minimum monthly air temperature in September) was particularly significant, closely correlating with temperatures during the growing season [65]. Our models confirm that polycultures of Asian carps can thrive, enhancing their adaptability to extreme conditions, but also posing a significant challenge to native biodiversity. Experimental and field-based studies [66], [67] have shown that species such as *L. gibbosus* require water temperatures above 9.5 ℃ to feed actively, reinforcing the importance of temperature in species distribution.

Effective management requires:

- Impact assessments to evaluate ecological risks, including potential disease spread [68], [69].
- Monitoring and control strategies to prevent uncontrolled expansion [70], [71].
- Collaboration among scientists, policymakers, and stakeholders to balance aquaculture development with biodiversity conservation [72].

Our modelling also indicates that Latvia has a low probability of spontaneous invasion by *L. gibbosus*, with only 3% of the country offering moderate suitability. However, coastal areas and the Lower Daugava could become viable habitats under warming conditions. Historical data show that *L. gibbosus* spread rapidly through Ukrainian river systems, aided by reservoirs and human activities [73], [30]. While GIS-based species distribution models (SDMs) provide valuable insights, ongoing field validation is essential to refine predictions and inform sustainable management policies [75].

V. Acknowledgments

We acknowledge the Emys-R project (https://emysr.cnrs.fr) funded through the 2020–2021 Biodiversa + and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), with the EU and the funding organizations Agence Nationale de la Recherche (ANR, France, grant ANR-21-BIRE-0005), Bundesminis- terium für Bildung und Forschung (BMBF, Germany, grant 16LW015), Latvijas Zinātnes padome, LZP (Latvian Council of Science) (LZP, grant ES RTD/2022/2), and the National Science Center (NSC, Poland, grant 2021/03/Y/NZ8/00101). We are also thankful for the support from the Collège de France and Agence Nationale de la Recherche (ANR) through the PAUSE ANR Ukraine program (Nekrasova O., grant ANR-23-PAUK- 0074), and the project "Ecological and socioeconomic thresholds as a basis for defining adaptive management triggers in Latvian pond aquaculture" (lzp-2021/1–0247), project 16–00-F02201–000002 for the use of the mobile complex of scientific laboratories for research purposes.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 313-317

Biogas Market Research in EU Countries

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***Abstract*—Recently, the development of renewable energy is considered one of the important criteria for energy security in the world. The article examines the potential and possibilities of biogas production in the EU countries due to the available biological waste and agricultural raw materials. The state of technology and development of the biogas market, the dynamics of production and conversion of biogas into electricity are characterized. It is determined that an important reason for the need to increase the use of renewable energy sources is the uncontrolled growth of household and industrial waste, which leads to environmental pollution and requires high costs for disposal. It is studied that modern methods of waste management through the production of biogas and biomethane can not only alleviate the global energy crisis, but also effectively protect the ecology of the environment. It is emphasized that biogas will play a key role in achieving Europe's long-term goals for energy security and mitigating the effects of climate change, as part of a promising and balanced complex of renewable energy sources. It has been proven that the production and use of biogas has a number of justified and confirmed by world practice advantages, since the availability of a wide range of necessary raw materials for the production of biogas and biomethane allows the construction of biogas plants in areas of concentration of agricultural production and technologically related industries. Special attention is paid to the role played by biogas and biomethane in the fight against climate change and the development of sustainable technologies, since sustainable development is the basis of the well-being of EU countries, it is respect for the environment in which the population of European countries lives and their future generations will live. This ideology underlies the development of the biogas industry in Europe. Based on statistical data of past periods and regression analysis, a calculation of the forecast volumes of energy production from biogas and biomethane in EU countries was made using a trend model and Excel spreadsheet editor. Considering the development perspective, it is determined that the transition to sustainable energy remains the most important for the EU economy, where the biogas sector can already provide a competitive and sustainable alternative to imported fossil gas thanks to domestic production.**

Keywords*— *renewable energy, renewable energy sources, biogas, biomethane, biogas plant, energy crisis, sustainable development.

I. Introduction

One of the priority vectors for the development of renewable energy is the production of biogas from organic residues. In achieving Europe's long-term goals for energy security and mitigating the effects of climate change, biogas will play a key role as part of a promising and balanced set of renewable energy sources. Sustainable biogas production in Europe is of strategic importance given the growing dependence on gas imports. A study of the materials of the European Biogas Association showed that biogas and biomethane are becoming increasingly

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8623
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important energy sources in the EU energy mix, and their production has been increasing over the decade. In this study, we were guided by the need to study the European experience in shaping waste management policies and biogas and biomethane production in the context of effective environmental protection and the transition to sustainable energy. That is why the production and use of biogas and biomethane in the EU must comply with a set of sustainability criteria that were proclaimed by the Renewable Energy Directive (RED II) in 2018 [1].

The purpose of the scientific research is to study the experience of developing sustainable technologies in Europe in the context of the ideology that underlies the development of the biogas industry in EU countries.

Recently, renewable energy sources have become one of the important criteria for energy security in the world. An important reason for the increase in the use of renewable energy sources is the uncontrolled growth of household and industrial waste, which leads to environmental pollution and requires high costs for disposal. If they are not treated, they lead to uncontrolled methane emissions. Therefore, the design of biogas plants and installations can contribute to their reduction. Anaerobic digestion (AD) plants are a controlled environment where these emissions are converted into renewable gas. Currently, attention to this energy source and scientific developments in the biogas field are increasing [2].

One of the promising types of raw materials for biogas that does not compete with food and feed crops is cover crops grown between two annual food crops. According to EBA, more than a quarter of the potential for biomethane production can be provided by using cover crops for this purpose. Using the harvested mass of such crops for biogas, with the subsequent return of the digestate to the same fields, allows to significantly expand the potential for attracting arable land resources to the energy sector without harming agricultural production [3]. The use of high-quality compost or digestate to replace mineral nitrogen, phosphorus and potassium fertilizers reduces the impact on the environment as a result of avoiding the production of primary mineral fertilizers [4]. The formation of effective methods of managing agricultural waste and converting it into biomass energy available to people can effectively protect the environment and at the same time make a significant contribution to reducing carbon emissions [5].

II. Materials and Methods

The authors of the article have been conducting scientific research for a long time in the field of optimizing bioeconomic processes and the efficient use of renewable energy sources. In particular, a significant portion of the research has been carried out in the educational and scientific laboratory "DAK GPS" of the Higher Education Institution "Podillia State University" [6-9], which has provided a solid foundation for further work in this direction.

The study employed a comprehensive set of scientific methods to ensure an in-depth analysis of the problem. Theoretical analysis and synthesis of literary sources made it possible to determine the main approaches to studying the issue and to establish the theoretical foundation of the research. Statistical data processing methods ensured the accuracy and reliability of the obtained results, while comparative analysis helped identify patterns and differences between the studied phenomena. Modeling and forecasting methods were used to construct possible development scenarios and assess their consequences. This integrated approach allowed for well-founded conclusions and recommendations.

III. Results and Discussion

The production and use of biogas has a number of justified and confirmed by world practice advantages, since a wide range of necessary raw materials for biogas production allows building biogas plants in areas of concentration of agricultural production and technologically related industries [10]. Biogas will play a key role in achieving Europe's long-term goals of energy security and climate change mitigation [2]. It should be noted that an essential aspect of biogas production is the use of renewable energy sources, which are also waste. The state of technology and development of the biogas market for the period 2009-2022 is evidenced by the increase in the number of biogas plants in Europe by 2.5 times and amounts to 19491 units. (Fig. 1).

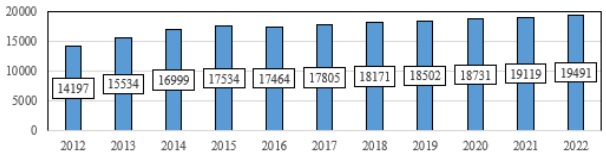

Fig. 1. Number of biogas plants in the EU, units. (Covered by the authors) [11].

Biogas production has been increasing since the 1990s. Market conditions, together with targeted policies, are stimulating the use of biogas. While combined heat and power plants run on biogas, other gas demand markets (gas utilities, industry and transport sectors) require the use of biomethane, a purified biogas with a high methane content, similar in quality to natural gas and therefore capable of replacing it [12].

That is why the production and use of biogas and biomethane in the EU must comply with a set of sustainability criteria, which were announced by the Renewable Energy Directive (RED II) in 2018 [1].

The RED II policy has had a positive impact on the quality of the raw materials used for biogas production. Data show that since the introduction of the regulations, new biomethane plants are increasingly using waste and residues for their operations [13].

The uses of biogas are mainly directed to the production of electricity and heat. There are, however, several cases of conversion of biogas into biomethane injected into the natural gas grids or used as biofuel in vehicles. In this last direction, worthy of note are a few north-central EU countries which have implemented an effective policy to

promote the use of biomethane for public and private transport.

According to the statistical report of the Biogas professional association in 2023, data on combined biogas and biomethane production in 10 European countries in 2022 are presented, among which Germany is the leader (Fig. 2).

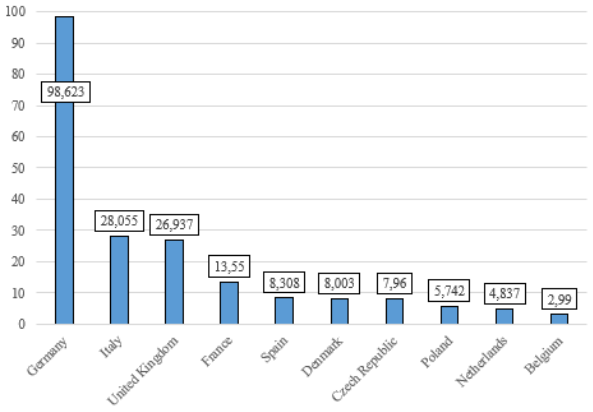

Fig. 2. Energy production in Europe, by country [11].

According to estimates, the prospects for biogas production in Europe indicate a tenfold increase in production by 2030. Currently, it is believed that biogas production is better to focus on less controversial raw materials, such as livestock manure, agricultural waste and residues, which do not compete with agricultural land used for food production. This model is advocated by Denmark, which opened its first biogas plant based on manure in 1975. After the adoption of the national "energy agreement" for 2012-2020, the country began to develop biomethane, which now accounts for about 10% of what is injected into the natural gas network. [13]. According to data from the German Biogas Association, the number of biomethane plants in Europe in 2011 was 182 units. Over an eleven-year period, their number increased to 1,323 units, or almost 7.3 times (Figure 3).

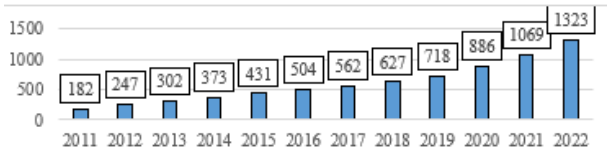

Fig. 3. Number of biomethane plants in the EU, units [7].

A report by the European Biogas Association showed that biogas and biomethane are becoming increasingly important energy sources in the EU energy mix, and their production has been increasing over the decade. In 2022, there were 1,222 biomethane plants in Europe, a 6.7-fold increase compared to 2011 (Table 1). [14].

According to the new edition of the statistical report of the European Biogas Association (EBA), biomethane production in Europe in 2022 increased by almost 20% compared to the previous year, and the combined energy production from biogas and biomethane amounted to 21 billion cubic meters (table 2).

TABLE 1. NUMBER OF BIOMETHANE PLANTS IN THE EU [14]

Years	Existing plants	New plants	Total
2011	182	0	182
2012	182	61	243
2013	243	59	302
2014	302	71	373
2015	373	58	431
2016	431	73	504
2017	504	58	562
2018	562	65	627
2019	627	90	717
2020	717	166	883
2021	883	184	1067
2022	1067	155	1222

The deployment of 35 bcm of sustainable biomethane a year by 2030 proposed by the European Commission in the REPowerEU action plan, will contribute to energy security and climate change mitigation. To reach the 35 bcm target, biomethane must sustain a substantial growth until 2030. The development of the sector will additionally contribute to an integrated net-zero energy system, encompassing the energy and agroecological transitions and helping Europe embrace circular economy [16].

TABLE 2. DYNAMICS OF ENERGY PRODUCTION FROM BIOGAS AND BIOMETHANE IN THE EU BILLION M³/YEAR [15].

Years	Energy from biogas	Energy from biomethane	Total
2011	6.8	0.5	7.3
2012	11.0	0.7	11.7
2013	12.5	0.9	13.4
2014	13.7	1.0	14.7
2015	14.9	1.3	16.2
2016	15.3	1.7	17.0
2017	15.4	1.9	17.3
2018	15.5	2.1	17.6
2019	16.5	2.4	18.9
2020	16.6	3.1	19.6
2021	16.7	3.5	20.2
2022	16.8	4.2	21.0

The Head of the Renewable Energy Division of the International Energy Agency (IEA) highlighted the expected global expansion of biogas in the coming years. The realistic target of producing 35 billion cubic meters of biomethane by 2030 was also confirmed, which will be aimed at building a greener and more energy-efficient EU [17].

According to the European Biomethane Map [18], published in July 2024, Europe has reached an installed capacity of 6.4 billion cubic meters of biomethane per year, of which 81% of the capacity corresponds to plants located in the European Union and amounts to 5.2 billion cubic meters per year.

Of the 1,548 registered biomethane plants, over 80% are connected to the gas grid, with almost half of them (49%) connected to the distribution network and 14% to the transport network. This means that the biomethane sector

is making a major contribution to Europe's long-term energy security and climate mitigation goals, in line with the REPowerEU Plan.

According to a recent analysis by the European Biogas Association (EBA), €25 billion of private investment will be attracted by 2030, leading to the installation of 950 new biomethane plants [18].

The forecast for the development of the biogas industry in European countries was calculated based on statistical data from past periods using regression analysis and the Excel spreadsheet editor. Regression analysis allows you to determine the degree of relationship between variables and predict the value of a certain variable based on known values. The trend line is a geometric representation of the average values of the analyzed indicators. The resulting linear trend graphs illustrate the relationship between periods and volumes of production and the coefficient of determination (R^2). It makes it possible to assess the density of the relationship between the studied phenomena, which is determined by the quantitative value. The closer R^2 is to 1, the more precisely the relationship is determined, which reflects the relationship between the values and the tendency to positive or negative changes (Figure 4).

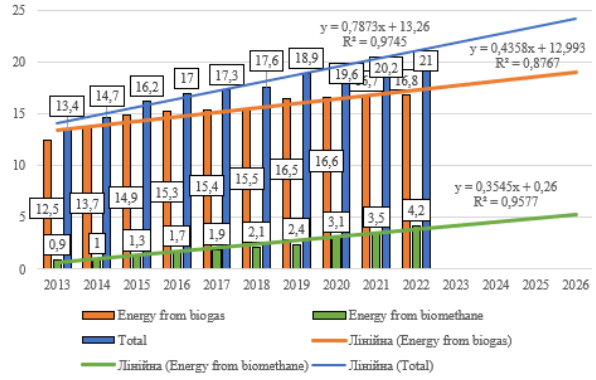

Fig. 4. Trend model for forecasting energy production from biogas and biomethane in Europe, billion m³/year

The calculations showed that for the trend line of energy production from biogas $R^2 = 0.8767$ and determines a high level of density of the relationship between the values. For the trend line of energy production from biomethane $R^2 = 0.9577$, which characterizes a significantly high degree of reliability of the relationship between the values, i.e. the linear regression equations are in good agreement with the sample data. Also, the high density of the relationship between the studied phenomena is illustrated by the trend line of the total energy production from biogas and biomethane, which confirms the obtained coefficient of determination $R^2 = 0.9745$ and predicts an increase in these indicators in the prospective period (Figure 4).

According to the regression analysis indicators, the trend line on the graph was extended beyond the available data in order to predict future values. Statistical data on energy production from biogas and biomethane for the period 2013-2022. made it possible to obtain graphs showing the predicted values of biogas production development for 2023-2026. (Table 3).

TABLE 3. FORECAST OF DEVELOPMENT OF ENERGY PRODUCTION FROM BIOGAS AND BIOMETHANE, BILLION M³/YEAR

Year	Energy from biogas	Energy from biomethane	Total	Linear (Energy from biogas)	Linear (Energy from biomethane)	Linear (Total)
2013	13	1	13	13	1	14
2014	14	1	15	14	1	15
2015	15	1	16	14	1	16
2016	15	2	17	15	2	16
2017	15	2	17	15	2	17
2018	16	2	18	16	2	18
2019	17	2	19	16	3	19
2020	17	3	20	17	3	20
2021	17	4	20	17	4	20
2022	17	4	21	17	4	21
2023	x	x	x	18	4	22
2024	x	x	x	18	5	23
2025	x	x	x	19	5	24
2026	x	x	x	19	5	24

Analyzing the results of the trend model of energy production from biogas and biomethane in the EU countries for 2013-2022, it should be noted that its production during this period is characterized by constant growth. The trend line showed a further growth trend until 2026. In particular, energy production from biogas will increase to 19.1 billion m³/year, energy from bioethanol will increase to 5.2 billion m³/year, which in total will be 24.3 billion m³/year. The results of the research indicate that European countries pay due attention to the development of this industry.

IV. CONCLUSIONS

Summarizing the results of the study, the following key positions in the development of biogas production in the EU countries can be identified:

- analysis of the development of the biogas industry showed that biogas plays a key role in achieving Europe's long-term goals for energy security and climate change mitigation
- highlighted a new trend to focus on biomethane production, since biomethane is a universal energy carrier and is suitable for a number of sectors of the economy, including transport, industry, energy and heat supply
- conducted studies have shown that biogas and biomethane are becoming increasingly important energy sources in the EU energy mix, and their production has been increasing over the decade.
- during the study period, a steady positive trend in the increase in biogas and biomethane production capacities was noted
- the production and use of biogas and biomethane in the EU must meet a set of sustainability criteria that were proclaimed by the Renewable Energy Directive (RED II) in 2018.

Based on the research conducted, it can be stated that the development of renewable energy and sustainable technologies is one of the priority vectors that will contribute to energy security, reduce the burden on the environment, and achieve the main goals of a resource-efficient economy.

V. Acknowledgments

The research was funded partially by the International Visegrad Fund (https://www.visegradfund.org)

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 319-323

Evaluation of UN SDGs Achievements Considering the Eco-Innovations Metrics. Case: European Union Countries

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***Abstract*— The current research paper explores the relationship between eco-innovation metrics and progress towards UN SDGs, contributing to the discussion on sustainable development. To achieve the research goals, the authors use easily interpretable and statistically significant methods to test the hypotheses, like Pearson correlation coefficients, multiple regression analysis. The methods are considered relevant to demonstrate statistical relationships between UN SDGs and the eco-innovation index, to discuss country performance typologies, and to formulate policy implications for future sustainable development. The results demonstrate that EU countries with higher UN SDG performance tend to have higher eco-innovation scores, moreover, eco-innovation capacities of EU nations are more aligned with the performance on environmental sustainability than on any other aspect of sustainable development. The authors conclude that eco-innovation dimensions operate at diverse levels of influence on the performance of UN SDG 12, while resource efficiency outcomes stand out, being the best predictor, so it should be strongly considered in policy recommendations and strategies.**

Keywords*— UN SDGs, eco-innovation index, circular economy, planetary boundaries.*

I. Introduction

Connections between sustainable development and environmental innovation have become a gradually important field of research within modern sustainable development studies. Moreover, the framework of the United Nations Sustainable Development Goals (UN SDGs) is often used as a pattern for sustainable development on the global level, meaningfully interconnects with the eco-innovation metrics and thus develops an interesting area for empirical studies and theoretical advancement in the fields of sustainability.

The relationship between eco-innovation metrics (based on the EU eco-innovation index) and progress towards UN SDGs forms both a complex and multi-dimensional field for research. The authors of the current paper are willing to demonstrate that when the EU eco-innovation index (alongside its composition elements) is viewed alongside UN SDG achievements, they establish a strong analytical framework for understanding how innovative technological solutions serve to achieve sustainable development results and thus this relation should be considered for further analysis.

The current research paper investigates the quantitative relationship of eco-innovation indices with the performance of the UN SDGs. The specific objectives of the research are finding correlation patterns of eco-innovation metrics with specific UN SDG targets and identifying the most important components of eco-innovation indices with strong association with sustainable development outcomes. As a result, this research contributes to the discussion on the field of sustainability and theoretical and practical policy progress

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8704
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as nations across the globe struggle to commit to their UN SDGs while simultaneously innovating new technologies to address environmental challenges.

II. Materials and Methods

Eco-innovation is an indispensable tool for promoting economic growth and protecting the environment. It combines innovation and sustainable development and is essential for achieving sustainable development goals, addressing environmental challenges and promoting economic growth. Eco-innovation has been a key focus of the European Union (EU) policy agenda over the past decades. Eco-innovation is a proactive approach and delivers positive environmental outcomes. The performance of eco-innovation is a factor determining its effectiveness in achieving sustainable development goals. The study [1] examined the average value of eco-innovation performance in EU Member States using data from the Eco-innovation Scoreboard and provided a comparative analysis of eco-innovation performance in EU Member States in two different periods, 2013–2017 and 2018–2022. The study used indicators such as eco-innovation investments, eco-innovation activities, eco-innovation outcomes, resource efficiency outcomes and socio-economic outcomes. The results of the analysis indicate dynamic changes in eco-innovation performance in EU countries.

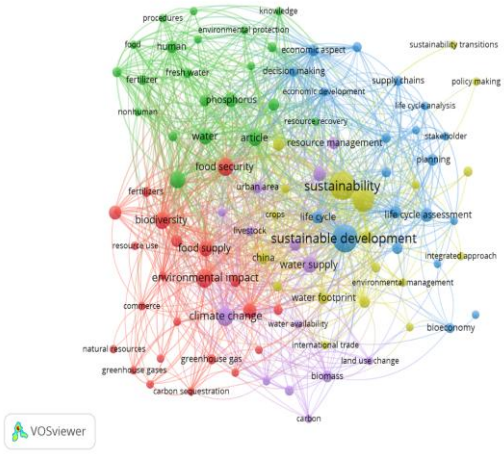

Fig. 1. VOSviewer tool

It is important to assess the differences between countries in terms of the degree to which they have achieved the SDGs related to the levels of innovation they have implemented. The study on innovation drivers and sustainable development [2] used two types of analysis. First, cluster analysis was used to examine changes in regional groups with similar innovation characteristics over the period 2015–2020. Data for 122 countries were collected from the World Bank, the SDG Index and the Global Innovation Index. Second, multiple linear regression analysis was used to assess the ability of the model variables to explain the level of sustainable development. The results reveal four clusters (low, medium, high and very high innovation drivers and sustainable development) as well as movements between these clusters over the period 2015–2020.

The authors performed a literature analysis applying the VOSviewer tool to contribute to understanding the theoretical research topic. The analysis results are shown in the Fig. 1 below and discussed further on. Key-words: “regional development”, “Sustainable development goals”, “circular economy”, “indexes”, “resources scarcity”, “planetary boundaries” In the analyzed papers (developed by the authors via VosViewer based on118 documents found - period 2014-2024 in Europe).

Based on the bibliometric analysis, one can determine several interrelated thematic domains within sustainability studies in European literature for the last ten years (from 2014 to 2024). The central node, positioned as "sustainability", is one of the most important and serves as a conceptual bridge between various research areas, marking its fundamental in modern environmental discussions.

The climate change node shows strong links with environmental impact assessments and greenhouse gas emissions. This cluster stresses anthropogenic drivers responsible for climate change (including carbon sequestration and use of natural resources). The density of connections in this cluster signifies strong attention in research toward climate mitigation and strategies for adaptation. Such a strategy is the development of smart cities [3].

The resource management and water & food security cluster exhibits a strong interconnection with water management and agricultural systems. These two nodes' appearance and connection to sustainability transitions reflect an evolving research focus towards food systems and resource use. Further on, food security appears to be a crucial node in sustainable development discourses.

The life cycle assessment cluster stands for the methodological approaches to sustainability measurement. The connections of this cluster indicate the increasing importance of systematic evaluation methods in sustainability science. The position of the cluster relative to nodes with policy-making implications indicates that this cluster has a major role in informing evidence-based decisions. The policy making implications are in particular important as soon as they are based on empirical findings such as covering waste-to-energy approaches [4] or construction and demolition waste practices [5].

The economic development and sustainable development policy cluster deals with stakeholder engagement and policy implementation frameworks. Its disposition implicates the operational facets of sustainability implementation, governance and strategic planning. The question of assessment and evaluation of sustainable business models is of particular importance within this cluster [6].

It is worth considering that supply chains and resource recovery appear to be bridging concepts among the

clusters and thus imply the cross-cutting nature of sustainability research.

Based on the analysis, the authors can conclude that the current state of the research literature reflects the evolution of sustainability discourse in European research. The network structure suggests some degree of maturity in the field supported by theoretical frameworks and methodological instruments.

The research area related to UN SDGs and eco-innovation indices is an important area of research in sustainable development and environmental economics [7-9]. The implications of this linkage extend across an unusually diverse range of sustainability science and policy implementation domains. Some potential implications are discussed below, and the results based on the data analysis are revealed in the next part. The understanding of connections between eco-innovation metrics and UN SDGs performance metrics could create a valuable perspective to measure the effectiveness of technological and systemic innovations in reaching sustainable development objectives [10].

The eco-innovation index, which measures inputs, activities, and outputs, provides a quantifiable indication of how countries can create eco-innovation [11]. Mapping this against UN SDG progress indicators [12] allows discovering potential synergies between innovative capacity and sustainable development outcomes. The possibility of disaggregating eco-innovation indices into their discrete components [13-14] provides an in-depth analysis that reveals the area within eco-innovation that meaningfully contributes to different UN SDGs. Such granularity should assist policymakers and practitioners in maximizing the allocation of resources while setting approaches for policy design and implementation.

Moreover, such a combination of data allows for an analysis of the geographical and economic context [15] because the effectiveness of eco-innovation in promoting SDGs can differ significantly from one development context to another. Such differences could result in more focused and appropriate context-based recommendations for policymakers and practitioners.

To sum up, understanding the relationship between UN SDGs and the eco-innovation index and its components is fundamental for further understanding how innovation-based approaches can contribute toward sustainable development. The current research paper will cover all the above-mentioned aspects as a whole compared to the majority of the previous research concentrating only on some particular aspects to facilitate evidence-based decision-making and utilization of resources to meet the 2030 Agenda for Sustainable Development.

III. Results and discussion

The current part is devoted to the key findings based on the data analysis mentioned above. The authors have developed three hypotheses to be tested and discussed.

H1: A strong positive correlation exists between overall UN SDG performance and eco-innovation scores.

This hypothesis intends to demonstrate that countries with higher UN SDG performance tend to have higher eco-innovation scores. Overall, SDG performance shows a strong positive correlation with eco-innovation $r = 0.7234$ ($p < 0.001$); environmental SDGs show a strong positive correlation with eco-innovation: $r = 0.7852$ ($p < 0.001$). All the results are statistically significant so they could be accepted.

H2: Environmental SDGs show a stronger positive correlation with eco-innovation than other SDGs.

This hypothesis is also accepted as SDG 7 shows the strongest positive correlation with eco-innovation, while it is worth noticing that there is a relatively strong positive relationship between other environmental SDGs and eco-innovation. The following results are obtained:

- SDG 6 (Clean Water): $r = 0.6234$ ($p < 0.001$);
- SDG 7 (Clean Energy): $r = 0.7124$ ($p < 0.001$);
- SDG 12 (Responsible Consumption): $r = 0.6892$ ($p < 0.001$);
- SDG 13 (Climate Action): $r = 0.6754$ ($p < 0.001$);
- SDG 14 (Life Below Water): $r = 0.5987$ ($p < 0.01$);
- SDG 15 (Life on Land): $r = 0.6123$ ($p < 0.01$).

H3: There is a significant correlation between resource efficiency outcomes and SDG 12 (Responsible Consumption and Production).

The authors expect a strong association between resource efficiency and SDG 12. The analysis demonstrates that the zero-order correlation (without controls) between resource efficiency and SDG 12 is high, standing at 0.6892 ($p<0.001$), while after controlling for other eco-innovation components (like Eco-innovation inputs; Eco-innovation activities; Resource efficiency outcomes), the partial correlation remains still significant at 0.5234 ($p<0.01$). This shows that the relationship persists even when the effects of other factors are removed.

From the analysis results, the authors can conclude that there are considerable insights concerning the links between eco-innovation and sustainable development performance in European countries. It is demonstrated by the analysis that there exists a strong, positive correlation in statistical terms between overall performance in UN SDGs and scores of eco-innovation. Moreover, the results indicate that sustainable development achievements of countries are intrinsically connected with their eco-innovation capabilities.

This research also demonstrates the association of the environmental aspect of the SDGs with eco-innovation

and shows how much stronger the association is than the other categories of SDGs. Such a finding implies that eco-innovation capacities of nations are more aligned with the performance on environmental sustainability than on any other aspect of sustainable development. Among the environmental SDGs, SDG7 (Clean Energy) forms the strongest link with eco-innovation and is followed by SDG12 (Responsible Consumption) and SDG13 (Climate Action. These findings emphasize the indispensable role of eco-innovation in achieving energy transition and climate action targets.

Several insights can be drawn from the analysis regarding the resource efficiency outcomes and their link with SDG 12 (Responsible Consumption and Production). The two-stage analysis demonstrates the strong and independent nature of the association mentioned above: preserving significance when controlling for various other factors provides strong evidence for a fundamental linkage between resource efficiency outcomes and patterns of sustainable consumption and production.

The authors claim that these implications are significant for policy-making on the development and implementation. The strong correlations identified between eco-innovation and environmental SDGs suggest that policies encouraging eco-innovation might be the most effective strategies to pursue multiple objectives of environmental sustainability at the same time. In addition, the sustained significance of the resource efficiency outcomes and SDG 12 indicates that interventions focused on improving resource efficiency might directly support sustainable consumption and production goals.

The research also unveils the interconnectedness of environmental sustainability challenges and solutions. Consistent positive correlations characterized the correlations between the various environmental SDGs, thus, eco-innovation improvements might create positive spillover effects across many environmental dimensions. This demonstrates the need for an integrated approach to environmental policy, wherein eco-innovation is a key driver for all-around environmental improvement.

Moreover, the authors performed the multiple regression analysis to provide better understanding of the H3. This regression model shows that resource efficiency is both statistically significant and significantly more important than any of the other predictors in explaining SDG 12 performance (follow the equation 1).

$$UN\ SDG\ 12 = 0.4856 * Resource\ Efficiency + 0.2234 * Eco\text{-}innovation\ Inputs + 0.1987 * Eco\text{-}innovation\ Activities + 0.2345 * Eco\text{-}Innovation\ Outputs + 0.1876 * Socio\text{-}Economic\ Outcomes + \epsilon \quad (1)$$

The multiple regression analysis offers strong evidence on the determinants of SDG 12 performance, with good modelling properties. The coefficient of determination shows that the included predictors explain around 65.43% of the variance in UN SDG 12 performance ($R^2 = 0.6543$). The adjusted R^2 value of 0.6234 suggests that even with the adjustment for the number of predictors, the model retains its capability of explaining the dependent variable. This is further confirmed by the highly significant F-statistic (standing at 18.76, $p < 0.001$), which guarantees the model's overall statistical validity.

The model demonstrates that among the predictors, resource efficiency stand out, being the best predictor by far with a standardized coefficient (β) of 0.4856 ($p = 0.0023$). This indicates that for an increase of one standard deviation in resource efficiency outcomes, one can expect UN SDG 12 performance to increase by 0.4856 standard deviations while holding other variables constant.

The eco-innovation dimensions operate at diverse levels of influence on the performance of UN SDG 12. At this point, eco-innovation outputs emerge as the second most influential predictor ($\beta = 0.2345$, $p = 0.0178$), followed by eco-innovation inputs ($\beta = 0.2234$, $p = 0.0156$) and eco-innovation activities ($\beta = 0.1987$, $p = 0.0234$). Socio-economic outcomes, while significant, show the least standardized coefficient ($\beta = 0.1876$, $p = 0.0345$) among the predictors.

Diagnostics for the model confirm statistical soundness. The Variance Inflation Factor ranges from 1.23 to 2.45, indicating little multicollinearity among predictors, indicating that the coefficient estimates cannot be seriously distorted by predictor intercorrelation. The Durbin-Watson statistic measures 1.98, indicating negligible autocorrelation in the residuals.

The actual results indicate that while all the predictors significantly contribute to SDG 12 performance, resource efficiency outcomes tend to have an overwhelmingly significant role. This detects the need to optimize resource utilization in making sustainable consumption and production patterns possible. The significant influence of eco-innovation outputs to inputs and activities shows that the results of eco-innovation activities outweigh the working processes that generated them.

To sum up, the authors are able to demonstrate that there are important policy implications emerge concerning the formation of policies and resource allocation, as an essential relationship was found between resource efficiency outcomes and SDG 12 performance which seemed to suggest improvements in resource efficiency initiatives will most likely yield better results on UN SDG performance. However, it was mentioned above that eco-innovation components would still contribute significantly. Combinations of various dimensions of sustainability innovation results would prove valuable.

IV. Conclusions

From the analysis performed in the current research paper, some significant conclusions could be drawn on eco-innovation in relation to sustainable development goals. The study demonstrates the existence of a strong positive correlation between the overall performance of UN SDGs and eco-innovation scores, where a higher correlation is shown among environmental SDGs. As for the UN SDG 12, the relationship with resource efficiency outcomes is remarkably significant. The multiple

regression analysis confirms this result by identifying resource efficiency as the strongest predictor of UN SDG 12 performance within a model.

Considering the paper's findings, it becomes clear that eco-innovation index and its further development should remain a cornerstone of sustainable development policies within the EU. The revealed link between eco-innovation and UN SDG performance, in particular concerning environmental sustainability, underscores the necessity of strategic investments in a range of technological advancements and resource efficiency.

Future research directions must further examine the role of policy instruments in tuning the relationship between eco-innovation and UN SDGs attainment, focusing on the differential effects of various types of policies on this relationship. The authors intend to continue their research to discuss the issue above and contribute to further developing the research topic. Additionally, expanding the scope of future research to include also non-EU countries could provide valuable comparative insights into how diverse regulatory environments impact the relationship between eco-innovation and SDG.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 325-329

Ground Cover Vegetation Diversity of Riparian Forests in Salaca Basin

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***Abstract*—Riparian forests serve as ecotones, marking the transition between terrestrial and aquatic ecosystems and differing from the surrounding landscapes. Managing these forests has been identified as a means to enhance various ecological functions, which play a key role in erosion control, as their vegetation stabilizes soil and reduces nutrient and carbon runoff into rivers. Additionally, riverbank vegetation helps mitigate flooding and improves water quality. Currently in Latvia, the Life project "LIFE IS SALACA" encompasses riverine habitat restoration and management, which demands an assessment of the initial conditions within the study region, necessary for characterising future dynamics of rivers and streams, as well as riparian forests and ground cover vegetation development. Therefore, the aim of this study was to describe and specify the current situation regarding ground cover vegetation diversity in riparian forest habitats in Salaca basin. To assess vegetation composition and structure, permanent 20×20 m (400 m²) sample plot was established in each study area. Vegetation surveys were conducted using the Braun-Banquet method, recording all vascular plant and moss species. The total projected cover (%) was estimated for four vegetation layers: tree layer (E3, trees >7 m), shrub layer (E2, shrubs and young trees 0.5–7 m), herb layer (E1, herbaceous plants, dwarf shrubs, and juvenile trees/shrubs <0.5 m), and moss layer (E0). Additionally, within these layers, the projected cover of each species was determined. The collected data will become an essential basis for monitoring riparian management processes, as well as provide valuable insight into the current vegetation diversity in the Salaca basin.**

***Keywords*— Herbs, Moss, Shrubs, riparian ecotones**

I. Introduction

Riparian zones are essential ecological ecotones that play a crucial role in maintaining water quality, filtering excess nutrients, stabilizing streambanks, and trapping sediments [1]-[3]. These ecosystems support diverse plant and animal communities, provide habitat through deadwood, and contribute organic matter, such as leaf litter and invertebrates, to aquatic ecosystems [4], [5]. Additionally, they regulate light and temperature, influencing primary productivity in both terrestrial and aquatic environments [6], [7]. Positioned at the land-water interface, riparian zones are shaped by river dynamics, such as flooding, while also being highly sensitive to terrestrial disturbances like windthrow [8].

Riparian forests are particularly important for maintaining biodiversity, acting as habitat corridors and influencing key ecological processes such as nutrient cycling, temperature regulation, and organic matter input into aquatic ecosystems [9]-[11]. Riparian vegetation influences soil microbial communities by creating distinct niches that shape fungal and bacterial composition [12]. Riparian vegetation communities form the structural and productive foundation for many other organisms, with high species richness enhancing regional biodiversity [13], [14]. Furthermore, riparian vegetation contributes to ecosystem stability, preventing erosion through extensive root systems [15] and responding dynamically to environmental changes, such as drought or forest management interventions.

Ground cover vegetation, particularly bryophytes, is highly sensitive to alterations in microclimatic conditions

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8684
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and forest structure [16]. Silvicultural treatments, including drainage, fertilization, thinning, and harvesting, can significantly impact species composition and distribution [17], [18]. Expanding large-scale activities, including in-stream interventions like damming and upland practices such as forestry, are having growing impacts on ecological processes at both local and regional scales [19], [20]. Therefore, an assessment of ground cover vegetation composition provides valuable insights into ecosystem health and long-term forest dynamics.

In Latvia, the LIFE project "LIFE IS SALACA" focuses on riverine habitat restoration and management, requiring a thorough assessment of the initial vegetation conditions to monitor future changes. Therefore, this study aims to describe and characterize the current diversity of ground cover vegetation in riparian forest habitats of the Salaca basin, providing a baseline for evaluating ecological shifts following restoration efforts.

II. MATERIALS AND METHODS

The study was conducted in the hemi-boreal forest zone, in the Northern part of Latvia (56°0'–58°0'N and 24°0'–26°0'E), in the river basin area of river Salaca. The mean monthly temperature of the study region ranged from – 4.28 ± 2.8 °C in January to 18.1 ± 1.7 °C in July [21], with the 30-year mean annual temperature of 6.5 ± 0.7 °C and annual precipitation of 687.6 ± 80.4 mm.

The study area encompassed riverine coastal mixed species forests, as well as grey alder *Alnus Incana* and birch *Betula pendula* dominated riparian forest stands, growing alongside Korģe and Sētupe rivers. The study area is characterised by lowland conditions which varied from flat to slope-type topography. Soil conditions varied from mesotrophic mineral soils to eutrophic and drained peat soils.

For vegetation assessment, a total of 85 plots across 24 cadastral units along the banks of the Korģe and Svētupe rivers were established (Fig. 1).

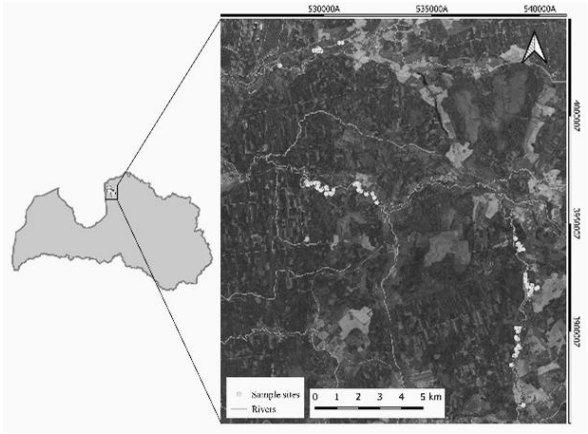

Fig. 1. Location of the study plots.

Each study plot consisted of a single permanent sampling area, measuring 20×20m (400m²), with GPS coordinates recorded for each plot. The plots were identified using cadastral numbers, compartment designations, and distance markers (e.g., 66720050275-5-1). Vegetation surveys followed the Braun-Blanquet method [22], recording all vascular plant and bryophyte species. The percentage cover of each species and vegetation layer was estimated. The vegetation was classified into four layers:

- Tree layer (E3) – trees taller than 7m;
- shrub layer (E2) – shrubs and saplings between 0.5–7m;
- herb layer (E1) – herbs, small shrubs, and young trees/shrubs under 0.5m;
- moss layer (E0) – bryophytes.

To assess vegetation diversity, the total species count and the number of species within each vegetation layer were determined. The average species richness per layer and overall was also calculated. Additionally, the most frequently occurring species and their frequency across plots were identified. To analyse the ground cover vegetation species' abundance in relation to environmental gradients, Detrended Correspondence Analysis (DCA) was applied, generating ordination graphs of species and sample plots. All statistical analysis were performed in the program R Studio version 4.4.1. [23].

III. RESULTS AND DISSCUSION

A total of 238 unique vegetation species were recorded across all plots (one species could have been recorded on several vegetation layers, depending on individual's height). The highest diversity was found in the herb layer (E1) with 200 species, followed by the moss (E0) and shrub (E2) layers, each containing 31 species, which is lower than in other studies from the Baltics, particularly regarding the moss layer [24]. The tree layer (E3) had the lowest diversity, with only 18 species of trees and shrubs taller than 7m. These trends were reflected in the average species count per vegetation layer (Fig. 2): the herb layer had 26.9 ± 8.7 species on average, the shrub layer 6.9 ± 2.6, the tree layer 4.9 ± 1.9, and the moss layer 4.0 ± 1.9 species.

When assessing vegetation cover (Fig. 3), the herb (67.2 ± 40.5%) and tree layers (65.1 ± 27.4%) had the largest coverage, while the shrub layer (43.5 ± 26.8%) and moss layer (22.6 ± 27.4%) were less dominant. The high species diversity in the herb layer can be attributed to the varied environmental conditions present in riparian ecosystems, such as moisture gradients, light availability, and nutrient distribution, which provide a wide range of niches for different plant species. The high standard deviation in the moss layer (Fig. 3) suggests significant variation in its coverage across plots, possibly due to soil conditions (pH) and variation in substrate variability [25]. These findings highlight the complexity of vegetation structure in riparian forests, where each layer contributes differently to biodiversity and ecosystem function [14].

Analysis of the most common species in each vegetation layer (Table 1) revealed that in the moss layer (E0), two species were more frequent: *Eurhynchium angustirete* (Broth.) T. J. Kop. (76.7% of plots) and *Plagiomnium undulatum* (Hedw.) T. J. Kop. (65.1%), species common in riparian forests growing adjacent to

streams [26]. Other frequently found species included *Plagiomnium affine* (Blandow ex Funck) T. J. Kop. (38.4%), *Climacium dendroides* (Hedw.) (29.1%), and *Plagiomnium cuspidatum* (Hedw.) T. J. Kop. (24.4%). In the shrub layer (E2), the dominant species largely overlapped with tree and shrub species found in the herb layer (E1), suggesting a dense understory. The most common species in the shrub layer were *Prunus padus* L. (68%), *Corylus avellana* L. (77.9%), *Sorbus aucuparia* L. (69.8%), and *Acer platanoides* L. (61.6%). In the tree layer (E3), the most frequent species were *Betula pendula* Roth. (67.4%), *Alnus incana* (L.) Moench. (64.0%), *Picea abies* (L.) H. Karst. (62.8%), and *Ulmus glabra* Huds. (54.7%).

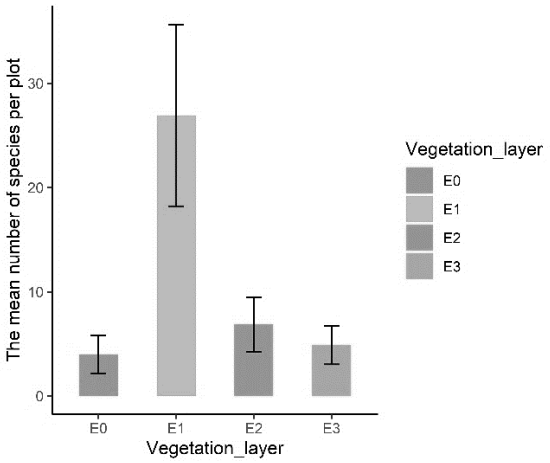

Fig. 2. The mean number of species per sample plot in each vegetation layer. Errorbars represent standard deviation.

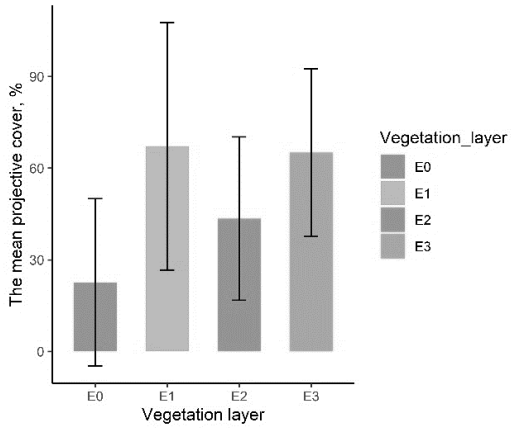

Fig. 3. The mean projective cover of species (%) per sample plot in each vegetation layer. Errorbars represent standard deviation.

Due to the high species count, detrended correspondence analysis (DCA) ordination plots were created separately for species and plots (Fig. 4). The first and second axis gradients were similar in length (DCA1 = 5.7831, DCA2 = 5.3325), with eigenvalues of 0.6543 (DCA1) and 0.4940 (DCA2). The ordination plot showed that most plots formed a single group with two subgroups, indicating a relatively pronounced heterogeneity in composition of species and environmental conditions. Moreover, some outliers had distinct species compositions, particularly in the herb and moss layers. For example, a strongly deviating plot (upper part of Fig. 4., A, B) was characterized by species typical of dry grasslands, such as *Achillea millefolium* L., *Agrostis tenuis* Sibth., *Trifolium repens* L., *Hieracium umbellatum* L., and *Dactylis glomerata* L. (Fig. 4., B).

TABLE 1 THE MOST COMMON VEGETATION SPECIES (NUMBER OF PLOTS WHERE THE SPECIES WAS RECORDED RELATIVE TO THE TOTAL NUMBER OF PLOTS) IN EACH IDENTIFIED VEGETATION LAYER. E0 – MOSS LAYER, E1 – HERB LAYER (≤ 0.5M), E2 – SHRUB LAYER (0.5-7M), E3 – TREE LAYER (≥ 7M)

E0		**E1**		**E2**		**E3**	
Species	***Frequency, %***	***Species***	***Frequency, %***	***Species***	***Frequency, %***	***Species***	***Frequency, %***
Eurhynchium angustirete	76.7	*Paris quadrifolia*	79.1	*Padus avium*	86.0	*Betula pendula*	67.4
Plagiomnium undulatum	65.1	*Acer platanoides*	74.4	*Corylus avellana*	77.9	*Alnus incana*	64.0
Plagiomnium affine	38.4	*Oxalis acetosella*	73.3	*Sorbus aucuparia*	69.8	*Picea abies*	62.8
Climacium dendroides	29.1	*Padus avium*	73.3	*Acer platanoides*	61.6	*Ulmus glabra*	54.7
Plagiomnium cuspidatum	24.4	*Quercus robur*	68.6	*Ulmus glabra*	55.8	*Acer platanoides*	46.5
Hylocomium splendens	22.1	*Athyrium filix-femina*	67.4	*Alnus incana*	52.3	*Tilia cordata*	41.9
Atrichum undulatum	19.8	*Sorbus aucuparia*	60.5	*Picea abies*	46.5	*Padus avium*	29.1
Pleurozium schreberi	17.4	*Dryopteris carthusiana*	53.5	*Tilia cordata*	45.3	*Corylus avellana*	24.4
Rhytidiadelphus triquetrus	15.1	*Geum rivale*	53.5	*Quercus robur*	30.2	*Sorbus aucuparia*	23.3
Dicranum scoparium	9.3	*Alnus incana*	52.3	*Fraxinus excelsior*	27.9	*Quercus robor*	17.4

The variation along the first axis (DCA1) likely reflects a gradient in soil fertility – higher axis values correspond to lower soil fertility. This is supported by species concentrated on the right side of the ordination plot, such as *Vaccinium myrtillus* L., *Vaccinium vitis-idea* L., *Ledum palustre* L., *Calluna vulgaris* (L.) Hull., *Pinus sylvestris* L., and *Hylocomnium splendens* (Hedw.) Schimp., which indicate less nutrient rich soils. Conversely, species associated with more fertile conditions, such as *Urtica dioica* L., *Geum rivale* L., *Lythrum salicaria* L., and *Cirsium oleraceum* (L.) Scop., appeared on the left side of the plot.

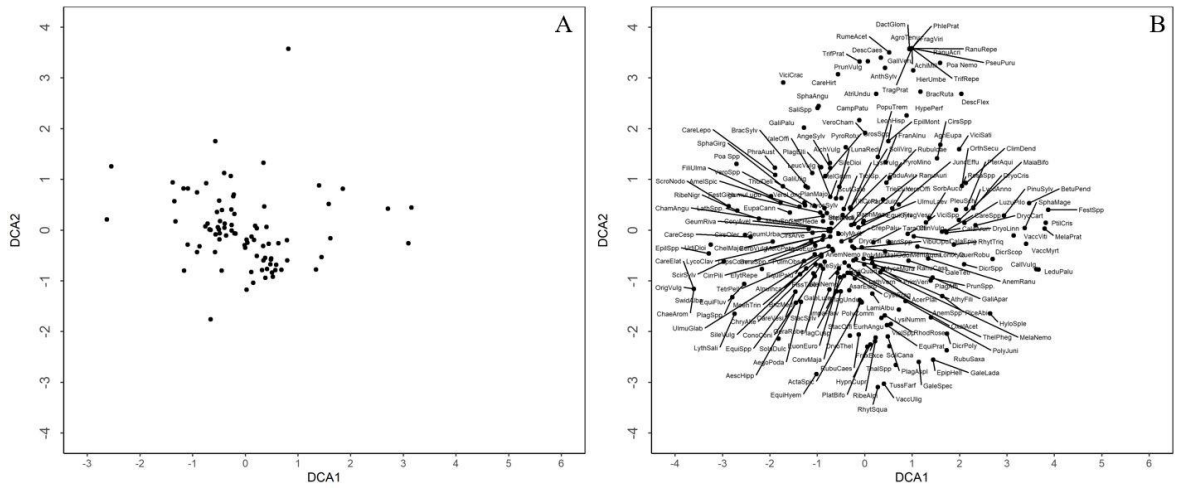

Fig. 4. Distribution of sample plots (A) and herbaceous and moss species (B) in the ordination space of detrended correspondence analysis (DCA).

The second axis gradient was hard to interpret due to the presence of outliers (Fig. 4., B). The vegetation composition in riparian forests can be highly heterogeneous, varying with the distance from the river or stream at which it is characterized, a pattern driven by the distinct physicochemical properties of riparian soils, which tend to differ from the upland soils that dominate the landscape [27]. Moreover, as riparian zones are shaped by river dynamics and terrestrial disturbances [9], river basin forests provide varying conditions suitable for different species communities. Other studies have underscored the importance of considering both climatic gradients and local hydrological conditions when assessing riparian forest responses [28]. Future research should include stand and soil properties for more precise characterisation of vegetation composition and local growing conditions.

IV. CONCLUSIONS

The riparian forests surveyed within the project support a relativly rich diversity of ground vegetation and species communities adapted to various conditions. The study identified 238 plant species, with the highest diversity in the herb layer, suggesting that ground vegetation, particularly herbs, plays a crucial role in overall plant species richness in the riparian forests of the Salaca basin.

The collected data will be useful for monitoring and characterizing the dynamics of riparian forest ecosystems following forestry restoration measures. Additionally, future research practices should focus on expanding the spatial scope to include a wider range of riparian zones with varying hydrological regimes could provide insight into broader-scale patterns and potential climate-related shifts in species composition. Finally, the role of disturbance (natural or anthropogenic) and land-use history should be more closely examined to understand how legacy effects shape current plant community structures.

ACKNOWLEGEMENTS

This study was funded by the LIFE programme as part of the project LIFE IS SALACA—Adaptation of Water Framework Directive and Habitats Directive harmonization and integrated actions for freshwater quality improvement in Salaca river sub catchment No. LIFE22-ENV-LV-LIFE-IS-SALACA/101114155

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Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8684
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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 331-341

Inclusion of Latvian Residents in Local Government Processes

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***Abstract*—Local governments play a very important role in promoting the country's sustainable development, as they greatly influence the country's economic, social and territorial development. In turn, it is important for residents of municipalities to see that changes are taking place as a result of their participation. One of the ways of involving residents is through a participatory budget. Successful cooperation experience could promote greater trust of residents in their local government, better understanding of the activities of the local government. Democratization and decentralization of public administration are currently relevant in Latvia. In 2025, a participatory budget, which is required by law, must be introduced in all local governments in Latvia. In Latvia, less than half of all 43 local governments have tested a participatory budget by 2025. The association "Public Policy Centre PROVIDUS" has been a support and advisor to local governments, encouraging local governments to take steps towards cooperation with residents and to improve this process with each passing year. The aim of this study is to investigate the inclusion of residents in the management of municipal processes through participatory budgeting. Recognizing the importance of residents' involvement in the participatory budgeting process, the study will analyse the awareness, understanding and opinion of residents of all Latvian municipalities about the participatory budgeting process. The theoretical part of the study uses a monographic or descriptive method, but a survey of randomly selected respondents covering all local governments in the country is used to obtain primary data. The results of the study will allow Latvian municipalities to understand the significance and importance of participatory budgeting.**

***Keywords*— residents, municipality, local government, participatory budget**

I. Introduction

This Participation is the foundation of democracy. The history of democracy can be traced back to Ancient Greece, where, with the people's assembly as the highest authority, full citizens decided on administrative, legislative, political and other important issues. Direct democracy means direct and unmediated participation of individuals in society in decision-making on local policy issues. In democratic theory, it is also called participatory democracy [1]. The development of participatory democracy at the local government level is as important as at the national level. This means that residents of local governments are given opportunities to directly influence local government decisions that affect their lives. Often, citizen participation is limited to participation in local elections at a certain frequency, but permanent opportunities for participation in the consideration of various issues should also be ensured. Furthermore, municipalities can in many ways set an example in the development of participatory processes, as the proximity of citizens and their interest in improving the environment affect every member of the community and it can be argued that municipalities have a greater connection with the citizens. The aim of this study is to investigate the inclusion of residents in the management of municipal processes through participatory budgeting. Recognizing the importance of residents' involvement in the participatory budgeting process, the study will analyse the awareness, understanding and opinion of residents of all

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8645
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Latvian municipalities about the participatory budgeting process. The theoretical part of the study uses a monographic or descriptive method, but a survey of randomly selected respondents covering all local governments in the country is used to obtain primary data. The results of the study will allow Latvian municipalities to understand the significance and importance of participatory budgeting.

II. MATERIALS AND METHODS

A. *Situation analysis*

Participatory budgeting (PB) has its roots in a radical democratic project led by the leftist Workers' Party in Porto Alegre, Brazil, in the late 1980s [2]. Radical democracy involves the inclusion of ordinary citizens in the priorities of government decision-making, a revolution that forced governments to allocate public resources to specific areas (shantytowns) and policy issues (such as health care), with a strong emphasis on social justice. PB has largely served as a "school of democracy" where citizens learn to discuss, learn about the functions of government, and begin to engage in democratic practices [3].

Since the late 1980s, PB has spread around the world in a wave-like movement. PB first spread in Brazil and was mainly promoted by non-governmental organizations and the Workers' Party that came to power. Municipalities and society were ready to accept PB because of the positive feedback received: relatively high levels of citizen participation, increased spending on community-related expenses, and the re-election of politicians who supported participatory budgeting [2].

In the late 1990s and early 2000s, Brazil's neighbouring countries also implemented participatory budgeting. For example, the Peruvian constitution was amended to require all local governments to use PB. Municipalities in Argentina, Ecuador, Uruguay, and Venezuela decided to implement PB. Later, the wave of PB spread to countries in Europe - Spain, Italy, Portugal, and the United Kingdom. Then, cities in the United States (Chicago), India (Kerala), Indonesia (Solo City), and Africa (Durban, South Africa) adopted the practice of PB [2]. PB has rapidly expanded worldwide because its basic principles appeal to many audiences. Progressive activists and politicians hope that PB will be a tool to expand the boundaries of representative democracy, mobilize followers, and achieve greater social justice. Participation is also attractive to major international agencies, such as the World Bank and the European Union, as it emphasizes citizen empowerment through participation, improved governance, and better accountability.

One common outcome that emerges from PB processes is changes in attitudes and behaviours at the individual level, including among stakeholders, politicians, and civil servants involved in the process. As Wampler, McNulty, and Touchton (2018) point out, several benefits have been identified because of the WB process: Stronger civil society. WB builds stronger civil society by increasing the number of citizen groups involved, expanding the range of activities, and fostering new partnerships with governments [3], Improved transparency. WB improves transparency by creating greater knowledge among citizens and civil society organizations and allowing for greater oversight and monitoring [2], Increased accountability. WB improves governance and accountability because citizens are more likely to be aware of their rights and government actions through WB. In turn, government officials are more responsive to citizens' demands and work together to pursue shared interests [2], Improved social outcomes. WB improves social outcomes: governance improves, citizens are better informed, and funding is allocated to public projects that focus on community needs [4].

As Touchton and Wampler acknowledge, participatory budgeting as a form of citizen participation cannot replace other, already existing forms of participation (Touchton and Wampler 2014) - in the case of direct participation - public and public consultation, municipal referendum [4]. In any case, a resident of a municipality has the right: to be informed about the content of various administrative documents, to understand the text of administrative documents and the content of decisions, to understand the decision-making process and to criticize or exercise democratic control over the activities of elected officials and their political choices.

Participatory budget supporters [2] argue that direct control of resources is a more effective form of citizen participation compared to other forms of participation. For the LB to give the greatest return, three things are necessary: 1. Strong government support; 2. Sufficient resources; 3. Organized civil society [2].

Not all state and local government officials are willing to experiment with PB - introduce innovations or transfer decision-making powers to PB participants. Therefore, first, support from the state government and support from local government leadership are necessary for the implementation of the PB process to take place. Second, there is a direct connection between available resources and the size of the PB. This is one of the biggest challenges - for local governments to dare to organize PB, even with small funding. With few resources, there will be no grandiose immediate results, but gradual changes will be observed. Researchers have observed that the existence of a strong and organized society is very important for the functioning of PB.

Citizens should cooperate with government officials to ensure project implementation and provide assistance throughout the process. At the same time, citizens should avoid involvement in governance to eliminate the possibility of becoming politically influenced.

The conceptual model of change for the participatory budgeting process (partial scope) includes all the most important factors that participate in and influence the PB process (see Fig. 1).

The model shows that the outcome of the PB can be achieved by involving all parties, with appropriate resources. The government must be involved - it should initiate the process voluntarily or through regulatory acts. Studies show that without government support, the PB works poorly or does not work at all [2]. It is important to

think through and implement the most appropriate PB model, considering financial resources, citizen activity and territorial population. The goal of participatory budgeting is to activate citizens, allow them to make decisions for themselves and experience the benefits of decision-making. Citizens can act individually, they can act in groups - in established non-governmental organizations, communities, but the goal of PB is to bring citizens closer together so that there is a need to communicate and discuss. In this context, advocates of PB argue that PB is a new form of public participation that creates much better results [2] compared to other forms of participation and does not replace them.

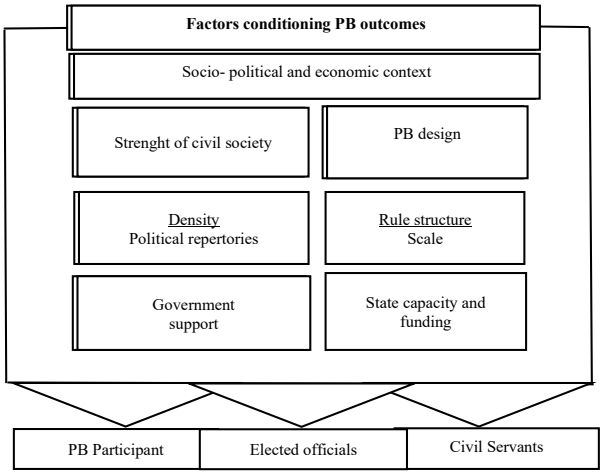

Fig. 1. The part of Participatory Budgeting Conceptual Model of Change (Authors using [2]).

One of the main stakeholders in the PB process is the residents of the respective territory. Observations show [2] that the attitudes and behaviour of residents who engage in the PB process change (see Table 1).

TABLE 1 PARTICIPATORY BUDGET PARTICIPANTS [5]

Nr	PARTICIPATORY BUDGET PARTICIPANTS	
	Changes in attitudes	*Changes in Behavior*
1.	Improved understanding of budget and government Processes	Increased Political Participation
2.	Personal Empowerment	Greater Community Involvement
3.	Support for Democracy	
4	Changes Views of Government	

An understanding of the budget and government processes is formed: by calculating the costs of their own project, communicating with local government representatives about the necessary clarifications, residents see what work needs to be invested in planning the implementation of one small project and can better understand the budget planning of the entire territory. It can be argued that submitting projects gives residents new experience and knowledge, gives self-confidence and a broader perspective on the decisions made by the local government. As a result of the experience of cooperation with the local government, a desire to be active.

B. Participatory budgeting regulatory acts

The European Charter of Local Self-Government, in relation to the importance of citizens' participation, emphasizes in its preamble that the right of citizens to participate in the administration of public affairs is one of the principles of democracy, and this right can be most directly exercised at the local level. The existence of local authorities endowed with real responsibility can ensure administration that is both effective and close to citizens and is based on the principles of democracy and decentralization of power [6].

Article 3, Part 2 of the European Charter of Local Self-Government states that Local self-government means the right and capacity of local authorities to regulate and manage, within the limits set by law, a significant part of public affairs under their own responsibility and in the interests of local residents, without in any way affecting the right to exercise citizens' assemblies, referendums or any other form of direct participation of citizens [6].

Regardless of whether power is shared, applying the principles of direct or representative democracy, citizens must have the opportunity to influence all decisions that affect their lives – all citizens must be politically equal. Going beyond the framework of political theory, ensuring opportunities for participation in practice is also necessary for maintaining and promoting the quality of democracy. Participation helps to make high-quality decisions and identify citizens' wishes, clarify their opinions and obtain feedback on public administration [7]. Ensuring participation is not always easy – it requires time, financial resources and specific skills, especially since different decision-making formats will require different types and opportunities for participation, and each of them differs from each other both in structure and intensity of involvement.

In Latvia, before 2025, several municipalities - the City of Riga, Adazi Municipality, Cesis Municipality, Gulbene Municipality and others - voluntarily organized the municipal participatory budgeting process. The process began at the national level in 2020, when the conceptual report "On the Implementation of Participatory Budgeting in Latvia" was published by order of the Cabinet of Ministers [8], which shows in detail the experience of other countries and the benefits of implementing LB in municipalities. Further, in the newly adopted Local Government Law [9] in 2022, in Sections 59-62 of Chapter 6 "Public Involvement in Local Government Work", the conditions for a participatory budget were stipulated, which must be implemented in local governments by 2025 - for example: the local government budget provides for financing for the participatory budget in the amount of at least 0.5 percent of the municipality's average annual personal income tax and real estate tax actual revenues, which are calculated for the last three years; the project applicant is a natural person who has reached the age of 16, or an association or foundation in which there is no local

government participation; the participatory budget regulations are binding regulations that determine the procedure for using the participatory budget; the project is implemented by the local government, etc. [9].

When approving the state budget for 2025, local governments face the challenge of including funding for LB projects in the planned financial budget. Understanding that local governments have different financial capabilities, the law "On the State Budget for 2025 and the Budget Framework for 2025, 2026 and 2027" was approved, which allows local governments to allocate smaller amounts to finance LB projects: in the annual local government budget for 2025, providing for funding for the participatory budget of no less than 0.1 percent, in 2026 no less than 0.2 percent, in 2027 no less than 0.3 percent and in 2028 no less than 0.4 percent of the local government's average annual personal income tax and real estate tax actual revenues, which are calculated for the last three years [10].

A serious problem, why municipalities did not organize the PB before 2025, was the absence of a voting system, each municipality had to buy its own. The Ministry of Smart Administration and Regional Development promised to create one and it has been done - a unified voting system has been developed and the participatory budget platform GeoLatvija.lv has been created, where each voter, after authentication, can vote for their municipality's projects [11].

C. Research conducted in Latvia

The report "Good Governance in Local Governments" published in 2023 by the Public Centre Providus [12] analysed 12 principles of good governance according to the Council of Europe methodology, which is based on the approach that local governments themselves assess the compliance of their local government with the 12 principles of good governance. For the use of this methodology in Latvia, the association "Public Policy Centre Providus" obtained accreditation from the Council of Europe and led the self-assessment process of local governments. In the study, six local governments provided self-assessments - Bauska, Cesis, Jelgava, Liepaja, Preili and Valmiera counties. In addition, three separate surveys were completed by 1,552 local government residents, 63 local government deputies and 935 local government employees. From the results of the above-mentioned survey, the author of the article has attributed eight principles to public participation and its promotion, therefore they are combined in a table (see Table 2).

The data in the table shows that the highest rating is given to informing local governments about current issues (55.5%), but the lowest rating is given to making local government decisions for the benefit of common interests (30.5%). Two questions were most closely related to public involvement - question 7 and question 8, which reveal that less than half (45.9%) of the surveyed residents are satisfied with the opportunities provided by local governments to express their opinions, submit proposals and participate in meetings.

Approximately only one third (34.4%) of residents believe that their complaints and suggestions regarding the services and activities provided by local governments are professionally examined and considered.

TABLE 2 PRINCIPLES OF GOOD GOVERNANCE FROM THE PERSPECTIVE OF RESIDENTS OF LATVIAN MUNICIPALITIES [12]

Nr.	**PRINCIPLES OF GOOD GOVERNANCE FROM THE PERSPECTIVE OF RESIDENTS OF LATVIAN MUNICIPALITIES**	
	Claims	*Municipality residents (%) who answered affirmatively*
1.	The municipality explains its decisions well and clearly	41.0
2.	The municipality is well accountable to residents about the use of the municipal budget.	38.1
3.	The municipality listens to residents' suggestions and improves the quality of services	34.9
4.	The municipality listens and improves the quality of services	36.9
5.	The local government is guided in its decisions by the common interests of all residents, not the personal interests of individual people	30.5
6.	The municipality informs residents well about current issues	55.5
7.	The municipality professionally examines and considers residents' complaints about the municipality's activities and the services provided.	34.4
8.	I am satisfied with the opportunities provided by the municipality to participate in the work of the municipality (to express an opinion, participate in meetings, submit proposals)	45.9

Research on participation conducted regularly since 2006 can be found on the website of the Cabinet of Ministers of the Republic of Latvia. The study commissioned by the State Chancellery (researcher Indra Mangule) "Participation in Latvia", published in January 2023. The results of these studies and surveys point to a kind of paradox – on the one hand, residents agree that the quality of decisions improves because of participation and recognize that their voice matters. At the same time, both participation and belief in the impact of participation are at a low level [7]. Therefore, as the author of the study I.Mangule points out, it is important to examine and measure not only the level of participation itself, but also the motivation of residents to participate and identify obstacles that discourage residents from participation. The aim of this survey was to understand the motivation of residents to participate, as well as to identify obstacles that, in the opinion of the participants, hinder wider participation of residents in Latvia. In the survey, 427 participants shared their participation experiences that the participants have experienced themselves or observed in society. The participants provided answers, thinking about their personal experience in participation and the general situation in Latvia.

When asked about the participation experience, the respondents mentioned: participation in elections and referendums; ManaBalss initiatives and signature collection; support for Ukraine; participation in groups; participation and active activity: in societies, NGOs, associations; participation in public consultations; working commissions, committees, meetings; preparation of decisions/opinions; participation in protests/organization of protests; writing applications; participation in charity events and donations; participation in forums, discussions, advisory councils; work in communities/regional associations and organizations; participation in youth groups/organizations; commenting and discussions on social networks; volunteer work.

Interestingly, none of the study participants mentioned participating in the participatory budgeting process, but the opinion was also expressed that participation makes no sense.

In Latvia, the activities of the "Public Policy Center Providus" are of great importance, which studies public participation, develops methodological materials and recommendations for improving public participation.

In the study "Public Participation in Public Administration: Analysis of Good and Bad Cases" conducted in 2022, three of the five main findings related to the involvement of citizens can be highlighted:

1. Transparency of the decision-making process, including feedback, is an essential prerequisite for the public to be able to effectively engage in the consultation process. If the process is not understandable, it creates distrust in both the process and the result [13].

2. Planning is important in public participation - planning of time, human and financial resources. Often, planning problems are a significant limitation to implementing sufficiently broad consultations with the public [13].

3. A successful public participation process allows you to expand the circle of cooperation partners. Each successful consultation case allows you to get to know new public partners - new non-governmental organizations, new activists, with whom to build cooperation in the future [13].

These recommendations should be considered by municipalities, which are required to implement participatory budgeting by 2025. In this regard, the "Public Policy Center Providus" offers "Guidelines. Implementation of participatory budgeting in municipalities" [13].

The stages of the participatory budgeting process can be conditionally divided into five stages (see Fig. 3) and citizen participation is certainly necessary in submitting ideas and voting. But do citizens think the same way?

To find out, a study was conducted - to find out the opinion of residents on the participatory budget process.

III. RESULTS AND DISSCUSSION

The aim of the study is to study the inclusion of residents in the management of municipal processes using participatory budget planning.

Research tasks:

- To obtain information about residents' knowledge and previous experience of the municipal participatory budget
- To find out whether residents are ready to participate in the municipal participatory budget process
- To study the experience of residents-participatory budget project submitters
- To study the experience of residents who voted on participatory budget projects
- To analyse the connections and residents' recommendations for improving the participatory budget process

The hypothesis of the study is that most Latvian residents do not know what participatory budgeting in local governments is and have not participated in voluntary activities before 2025.

Cross-sectional descriptive design was chosen to achieve the goal and characterize residents in relation to participatory budgeting in local governments. Data were collected on several variables to create a description of the population [14].

The study was conducted using a survey method. An electronic survey was chosen for several reasons: to avoid the interviewer's influence on the respondent; such a survey is not expensive; a summary of current data is available on a computer; the number of people can follow the survey process; the results can be compiled and analysed faster, since data transfer is not required. The data entered by the respondent is of high quality, because the entry is possible only in accordance with the setting [15]. The authors of the study are aware that with this survey it is possible to ask relatively simple questions and there is a high risk of an unrepresentative sample, and the invitation to participate in the survey can also be perceived as Spam. However, it is precisely a quantitative study in this situation that would be most appropriate to cover the required sample size and to establish the knowledge and opinion of the most important stakeholders about the process, which is determined in the country as mandatory and has the force of law.

The survey received 394 responses, which is sufficient to form a representative sample. According to the Statistical Office, the population of Latvia in 2024 was 2,187,170. However, the entire population does not need to be included in the study, as residents from the age of 16 can participate in the participatory budgeting process. The population under the age of 16 was 314,928, so the population size was 1,872,242. [15]. This means that the representative sample size for this population is 385 respondents, if the sampling error is 5% [14]. When using non-probability samples, it should be recognized that some members of the population have a higher probability of

being included in the sample than other members of the population, this method is used because: the study is to determine whether the problem exists at all, the research resources are limited [16].

The study was conducted from January 19, 2025, to February 19, 2025. Survey responses were expected from residents of all 36 Latvian counties and 7 cities in the country. Analysing the responses received, it was concluded that no questionnaires were received from residents of Dienvidkurzeme countie and Varakļani countie.

The questionnaire contained a total of 48 structured and unstructured response questions. Not all respondents were required to answer them. Depending on the respondent's answer, the next question was asked. Those respondents who had no experience in the participatory budgeting process were not required to analyse project submission or voting. Those respondents who had previous experience in the participatory budgeting process were asked to analyse their observations as project submitters or as voters. At the end of the questionnaire, all respondents were asked to rate the influence factors of all the main parties involved in the process on a scale from 0 to 5 (the last four survey questions), but this article will not analyse the assessment of the main parties involved in the participatory budgeting process.

A. Respondent characteristics

Five questions were asked to characterize the respondents. First, it was important that the answers cover as many municipalities as possible - 36 counties and 7 cities. The largest number of respondents - 43.7% indicated Cesis county as their declared place of residence, followed by Riga city (12.9%) and Valmiera county (7.6%). From the above, it can be concluded that the survey largely reflected the opinions of the residents of Cesis county and the opinions of those living in the Vidzeme region.

It seemed important to find out whether the respondent lives in a city or in the countryside. 43.8% of respondents indicated their place of residence in a rural area and 56.2% - in a city. This leads to the conclusion that the opinions of urban and rural residents are represented relatively similarly.

Analysing the age of the respondents, it should be said that different age groups are represented (see Table 3).

TABLE 3 PERCENTAGE DISTRIBUTION OF RESPONDENTS BY AGE GROUP (%)

Nr.	PERCENTAGE DISTRIBUTION OF RESPONDENTS BY AGE GROUP	
	Age groups of respondents	*Respondents (%)*
1.	up to 16 years	0.3
2.	from 17 to 19 years	4.3
3.	from 20 to 30 years	10.7
4.	from 31 to 40 years	17.5
5.	from 41 to 50 years	22.3
6.	from 51 to 64 years	35.3
7.	from 65 years and older	9.6

The largest proportion of respondents (35.3%) was aged 51-64, followed by the group aged 41-50 (22.3%) and the third largest group (17.5%) was aged 31-40. The largest number of respondents were people with higher education (79.2%) and secondary education (19.3%), while 6 people (1.5%) responded with primary education. This educational structure of respondents clearly demonstrates the consequences of non-probability sampling methods - convenience sample and snowball sample. As in this case, when a researcher with higher education finds others in his circle of acquaintances - with similar education.

B. Summary of questionnaire responses

At the beginning of the survey, general questions were asked about the possibilities of residents to influence local government decisions. When asked whether residents could influence the use of their local government's budget funds, 42.6% (168 responses) answered that they can, but 57.4% (226 responses) do not believe that they can. Respondents believe that they can influence the use of budget funds in their local government in various ways: By submitting written proposals to their local government; By establishing a Residents' Council in the local government and using it to express proposals; By participating in council meetings and committees and expressing proposals; By deciding on the use of a certain amount of financial resources; By participating in project competitions initiated by the local government and voting for them.

When analysing the reasons why residents cannot influence the use of their local government budget funds, the majority of the offered answers - 35.4% - answered that politicians decide on this; 29.6% of respondents answered that there are no open discussions about the local government budget; 19.5% believe that the budget is planned by local government financial specialists; 7.5% believe that the local government does not consider residents to be knowledgeable about local government budget financial issues. Respondents had the opportunity to write their answer option, and the following options were written there: The existing regulatory framework does not allow residents to participate in the distribution of finances; The opportunity exists, but residents have to find time, make efforts and often enthusiasm wanes; There are no open discussions about the local government budget.

Half of the respondents (50.3%) were informed about the existence of a participatory budget in local governments. 84.0% agree with the statement that participatory budgeting is one of the methods that can reduce the gap between the people and the local government (state) administration, allowing residents to express ideas about the investments they think are necessary. 16.0% of the respondents think that residents should be given the opportunity to decide directly, themselves, and not indirectly (through delegated representatives - deputies) on the use of their local government budget funds.

72.8% of respondents know that by 2025, participatory budgeting must be organized in local governments in Latvia, and 22.3% of respondents (88 out of 394) know that

participation in the participatory budgeting process is possible from the age of 16.

The majority of respondents (83.0%) believe that residents should be invited to develop the municipal participatory budgeting regulations, the reasons for which were given: To create mutual communication and understanding between the municipality and residents; So that residents can include their opinion on the participatory budgeting process; Agree with both of the above-mentioned answer options; To express the painful problems that deputies have never known about.

Any activities for the benefit of society usually require voluntary consent without compensation. Therefore, to the next question - whether residents would voluntarily participate in their free time without compensation in any of the stages of the participatory budget - 64.2% answered in the affirmative, but 35.8% are not ready to devote their free time to the preparation of the LB regulations without compensation.

Similarly, respondents answered the question - whether residents should be given the opportunity to directly, themselves, and not indirectly (through delegated representatives - deputies) to decide on the use of their local government budget funds, 60.9% answered yes, but 39.1% answered no, thus indicating that not everyone is ready to actively participate in deciding on finance-related issues.

When clarifying why citizens should not be invited to participate in the development of the budget regulation, it was mentioned that: Municipalities will not take into account the opinion of citizens anyway; Citizens are not knowledgeable enough to be able to contribute; I believe that this is not necessary; Citizens' suggestions should be taken into account; This is the duty of municipal employees for which they are paid; Citizens expect someone else to do it for them; Citizens act recklessly; Only citizens who have practice and experience are knowledgeable.

The stages of the participatory budgeting process can be roughly divided into five stages (see Figure 2), and citizen participation is certainly necessary in submitting ideas and voting. But do citizens think the same way?

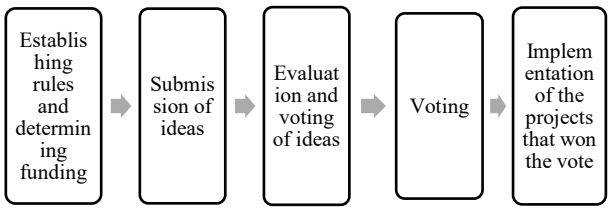

Fig. 2. Phases of one cycle of participatory budgeting [5].

When asked to mark the stages of the PB process in which citizens should participate, in 1st place is the submission of ideas (332 responses) and in 2nd place is voting on projects (310 responses), which is a logical conclusion, because without the participation of citizens these stages cannot exist. Interestingly, 220 respondents indicated that citizens should also participate in the selection of projects for voting, and 156 responses indicate that there should also be citizen participation in the implementation of projects.

The LB needs funding. The Law on Local Governments of the Republic of Latvia states that for this purpose, funding must be provided for the participatory budget in the amount of at least 0.5 percent of the municipality's average one-year actual revenue from personal income tax and real estate tax, calculated for the last three years [10].

Therefore, residents were asked - in their opinion - whether local governments are wealthy enough to be able to allocate 0.5% (in accordance with the Local Government Law) or at least 0.1% (as stipulated in the Law on the State Budget for 2025) of their annual budget for the implementation of initiatives proposed by residents.

Many respondents answered that it is difficult to say (50.5%), 33.2% believe that the funds are sufficient and 10.9% believe that there is not enough money. This question has caused reflection among residents, because the answers contain the following conclusions: The bureaucratic apparatus needs to be reduced and there will be enough money; Local governments must definitely support residents' initiatives; Local governments must work more efficiently; If the PB will be a priority, there will be enough money; More money must be allocated, this process must be initiated by residents; Each local government may have a different hand - some can allocate more, others - less to the PB.

As we have already established, there are different stages of the process in the PB and not all of them are ready for residents to participate. When asked what role you would like to play in your municipality's participatory budgeting process in 2025, the audience splits into 3 different parts (see Fig 3).

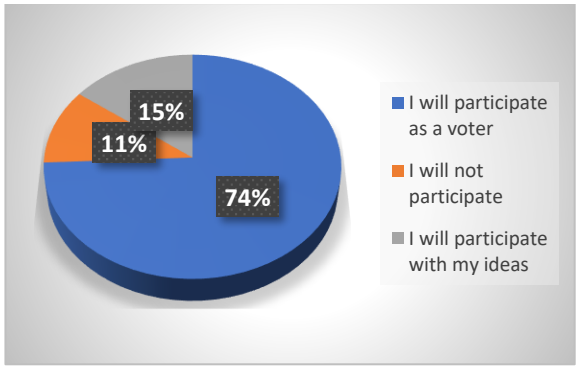

Fig. 3. The role of citizens in the future of municipal participatory budgeting (Created by authors).

It seems obvious that the numerical majority of the PB are voters (74%) and a surprisingly large number - 15% - are ready to enrich the PB initiatives with their own ideas. 11% of those surveyed decided not to participate, citing the following reasons: No faith in the municipality; No ideas

what could be done in the municipality; Don't want to do anything; There is an age limit; No free time.

It should be noted that the "age restriction" clause could apply to those under 16, but often it is precisely young people of primary school age who have good ideas.

Before 2025, the implementation of the PB in municipalities was voluntary and of all 394 respondents, the majority - 67.9% (195 people) - did not participate in the PB, citing the following reasons: I did not know that there was a participatory budget project competition 68.9%; I did not want to get involved 14.3%; There was no participatory budget project competition in my municipality 8.7%; I did not know how to vote; The proposed projects were not relevant to me; I did not know about such an opportunity; There were no clearly understandable rules; Other life priorities and busyness at work.

The answers of the project submitters to the questions will be discussed below. 22 persons or 6.5% of all respondents have such experience. The aim of participatory projects is usually to promote public involvement, initiative and participation in the development of the relevant administrative territory and the use of allocated financial resources, promoting the participation of residents in municipal budget planning, improvement of cities and parishes, strengthening and growth of the community. In this question, the project initiators indicated the goals of their submitted projects: improvement and arrangement of the environment; to draw attention to their sparsely populated territory and awaken the locals; to take care of the development of babies by offering "Baby Schools" classes for 1-2 year old children; to create walking trails with benches, a boardwalk along the lake, a children's playground; in the future, some sports opportunities; improvement of the playground; development of public infrastructure and creation of new leisure opportunities; financial support for the restoration of the church; improvement of the neighbours; organization of events; youth initiatives; improve the infrastructure of the municipal institution; change the road surface from gravel to asphalt; week-long events for seniors, compiling history in a book; innovative services in the municipality and the development of sports and playgrounds, green areas.

After the 2021 Latvian regional reform, the territory of local governments has become larger and more difficult to manage. Therefore, local governments have often already incorporated the regional planning units into their regional bylaws, based on city and parish associations, for example, the Limbazi county participatory budget bylaw [17], the Cesis county participatory budget bylaw [18]. Of all project applicants, 50% (11 project applicants) indicated that the project is related to an activity in the local parish, 27.3% - activities in the local city, 18.2% link their project to the county, and 4.5% to the county centre.

Of all project applicants, the majority (36.4% or 8 people) learned about the PB competition from the municipality's website, 18.2% (4 people) from an acquaintance; 13.6% (3 people) - in a local newspaper and 13.6% - from advertising on social networks. The rest have mentioned - from a social service worker, from neighbours, at the Democracy School and I initiated such a competition for young people, so I knew. It must be concluded that there could have been a larger number of project applicants who learned about this activity from the municipality's website. Therefore, the next question is what the municipality should improve or do differently when providing information to residents about participatory budget projects.

The answers could be written in free form and included ideas: send an invitation to participate to each organization, institution, company; it would be valuable to individually address the head of each organization, company - perhaps in parishes, small towns; communicate more with residents; organize information days, but information in general is sufficiently accessible; expand the range of topics and questions; encourage that any resident can do this, regardless of their level of knowledge, because it often seems that only lawyers, landscape architects, etc. can do this; place more advertisements in newspapers; we need a person in the municipality who works with communities, helps establish residents' councils, creates a closer connection between communities and the municipality, informing about the work of the municipality, employees, etc.

The municipality approves the conditions for submitting participatory budget projects in the Regulations. Most of the regulations were obtained from the municipality's website (86.4% or 19 people out of 22). The rest mentioned the portal www.likumi.lv, the Social Service and the fact that they themselves worked on the preparation of the regulations.

All the conditions for submitting projects in the municipality's participatory budget regulations were understandable to 72.7% or 16 respondents, 6 respondents had to seek clarification. According to the assessment of project submitters, the municipality should improve the following in relation to the PB: Feedback with project submitters; Voting procedure; Explanations for the project; The application submission and reporting processes should be simplified as much as possible.

There are also suggestions to definitely indicate in the regulations the phone number of the employee to whom to contact with questions, to ensure that the project application preparation expenses are paid from the project funds, because associations, etc. do not have free funds for prepayment, it is necessary to take into account that local projects cannot compete between more populated and less populated territories and the amount of funding for projects should be increased.

When asked to project initiators - has at least one of your projects won and was or will be implemented - the majority answered in the affirmative - 72.7% or 16 respondents.

Voting for projects is a special stage of the process and it is difficult to win without special marketing activities of the project submitter. Of the project submitters themselves, 68.2% have voted for some participatory budget project,

but 31.8% or 7 respondents have not voted. The question arises - why not vote for your own project?

During the voluntary PB, some Latvian municipalities have not organized a vote of residents, but a special commission has determined the winners of the projects.

Other municipalities have tried a vote of resident's system. What did the project applicants do to attract as many voters as possible? Answer options: I addressed them personally, waited at the village library with coffee and home-baked buns, invited them to vote on social networks, wrote in WhatsApp groups, posted invitations in the local store, addressed teachers, involved the active part of society to live with the vote; I did nothing special, - I clearly described the idea, the steps of its implementation and the benefits; We sent information to various information sources; I sent private messages to friends and acquaintances with a request to vote; Social networks, posters, flyers, a presentation at the event, involvement of all friends of acquaintances; I definitely approached very well-known people to vote in person; I communicated with residents in my free time; Repeated advertising on social networks, involvement of relatives, friends, informing various groups about the goal of the project, voting strategy - we vote in the last hours of voting (during the period when most people are already sleeping and the project submitters are "relaxed") - in our case, it worked; I went to the residents explaining my goal and vision in simple sentences; We created a residents' chat and asked them to vote in the last hours before the end of voting, we united 2 parishes, because the initiative was binding on both parishes.

It must be concluded that to obtain a better result-voting, mutual communication between residents is necessary, which is also the goal of the participatory budget.

Not all projects that are submitted for voting win and are implemented. How many of the respondents we addressed answered in the affirmative? 68.2% or 15 respondents' projects have won, but 7 respondents' projects (31.8%) have not won yet.

Returning to the residents who have ever voted for a project (100 affirmative answers), to the question - how did you find out about the project you voted for, the answers are ranked as follows: from the information posted on the municipality's website- 40 answers; from an acquaintance who asked to vote for the specific project -32 answers; from the information posted in the municipality's local newspaper -8 answers.

There were also answer options - I developed the project myself, I found out from the information posted on the municipality's Facebook account, I found out from the information posted on the Instagram account.

So, most people learn about PB projects from information on social networks. Many respondents (72%) believe that the information provided by the municipality about all participatory budget projects was sufficient.

Representatives of local governments have stated that it is not always good for residents to see the number of votes cast, as a low voter turnout negatively affects potential voters, as the desire to vote for the winning project. The survey showed that 84% (84 respondents out of 100) are satisfied with the fact that the number of votes cast for projects submitted by residents can be seen online, but in the notes on the voting process it was noted that "you could see the number of votes - therefore, you can immediately conclude which projects will not be implemented and that maybe there is no point in voting for these projects anymore, but to support someone who is not personally relevant, but has received more votes and has a chance of being implemented."

It is not uncommon for voters to have to choose between several projects, as there are at least twenty PB initiatives and several projects seem to be supportable. 81% of voters have had to think twice when choosing between several participatory budget projects, but 19% knew which project to vote for.

The PB voting system is often not simple - sometimes voters, depending on the region, are given one or several votes. This is done so that PB activities are not concentrated in one place but are used in different participatory budget planning units.

46% of voters in the survey could not say how many votes were allocated in the PB vote according to the regulations of the respective region, 32% voted with one vote, 13% voted with two votes and 3 voters – with three votes. Respondents also answered that projects were combined and there was an opportunity to vote on them several times, others do not remember the number of votes cast. Voting experience and this study show that it is possible to organize your own, different voting system in each region.

Voters overwhelmingly (95%) voted electronically and only 5 people out of 100 signed in person. Most respondents admitted that voting was easy and only 7 respondents found it difficult.

It must be admitted that most of the population in the PB process are and will be voters, so it was important to find out their opinion about the voting process. The answers expressed opinions that were summarized from the statements of several respondents:

- There is no possibility for a parish with a small population to gain enough votes to win; disproportionate voting, - a small parish has fewer opportunities to gain votes; it is difficult for less populated areas to compete with large ones.
- Voting is a slow process; it was difficult to vote for rural people without an electronic signature.
- It was not possible to vote for all the projects, because there was a restriction; it should be possible to vote for several projects, there was no clear position on the second vote: whether

one could vote in one's own association or another, it was not clear whether those declared elsewhere could vote.
- Only declared residents could vote; often they could not vote on the website; only users of the municipal application could vote.

At the end, a question was asked about suggestions for improving the voting system, but the answers received can be applied not only to voting, but to the entire PB process.

Residents' suggestions for improving voting are: Counties should also organize written voting so that older people can vote and create more accessible voting for those who cannot vote electronically, for example, by creating voting opportunities in the city's largest stores, where people of different ages shop every day; Organize voting so that you can vote by email; I would like the county's website to work flawlessly and you can vote. Voting should be freely available on multiple platforms, not just the application; Ensure voting for projects in all settlements, not just customer service centres; Create the opportunity to vote for multiple projects; Do not show the votes obtained during the voting process; Show the votes obtained during the voting process; Organize voting so that not only residents declared in the county can vote, but also those who own real estate but live in another county; Provide clear and understandable information - who can vote, how many times, etc. No one reads the long regulations anyway and then misunderstandings arise; Inform residents more about voting options; Convert the votes received for the project into a percentage of the number of residents entitled to vote in the specific parish to which the submitted project applies and then evaluate the winner. For example: In Cesis there are 100 eligible voters, but 10 vote, then 10 percent voted for the project. There are 50 eligible voters in the position, but 10 vote, then 20 percent voted for the project.

Residents' suggestions for improving the PB process are Work on advertising and updating the PB. There is a desire to talk more about the PB opportunities, on television - in current affairs, in the news, so that people see that they can vote; More clarity about the process and fairer rules, so that small parishes also have a chance to win; Create a video recording and show how easy it is to write a project; The usefulness of the project should be assessed by a professional commission before voting with a coefficient of the project's necessity or usefulness: the higher, the more valuable in terms of nature and application; Make the PB process more visible to the public: announce the submission of project applications more loudly, report on the voting and announce the winners.

IV. CONCLUSIONS

- The study has practical significance, which will allow Latvian municipalities to understand the importance of participatory budgeting and develop prerequisites for its implementation.
- The hypothesis that many Latvian residents do not know what participatory budgeting is in local governments has not been confirmed, as 72.8% or 287 respondents out of 394 respondents claim that they know what participatory budgeting is in local governments and their answers to the questionnaire confirm this.
- The hypothesis that residents have not participated in voluntarily organized activities before 2025 has been confirmed by the study, as 72.8% or 287 respondents out of 394 respondents have not participated in participatory budgeting in local governments by the mentioned period.
- When developing participatory budgeting regulations, local governments should consider residents' recommendations on the possibility of voting with multiple votes on projects in different settlements with different population densities.
- Improvements to the voting system cannot be demanded from municipalities, because the Ministry of Smart Administration and Regional Development has led the development of a unified voting system and a participatory budget platform GeoLatvija.lv has been created, where each voter, after authentication, can vote for their municipality's projects.
- In general, residents positively perceive the opportunity to participate in participatory budget projects and in a process based on voluntary principles, the proportion of the most active project submitters among the respondents was 5.6% or 22 respondents, which is promising.
- Looking to the future, we want to believe that all 74.9% of respondents (295 respondents) who promised to be voters in the survey will vote for one of the participatory budget projects this year, and 59 respondents (or 15% of respondents) will present their ideas for improving the standard of living in municipalities.
- Having received feedback from respondents, the authors acknowledge that this survey was not only used to obtain information for the study, but also to educate the public. From the questions in this questionnaire, respondents were able to learn more about the participatory budgeting of municipalities and be inspired to actively participate in this process in the future.
- The study was exploratory and should be repeated annually. It would be necessary to present the results of the study to local government leaders and specialists working on participatory budgeting.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 343-348

Consumer Statisaction and the Principles of its Formation in the Latvia Health Care Market

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***Abstract*—Consumer satisfaction is a key aspect of business success, as it directly affects consumer loyalty, promotion of cooperation, as well as company recommendations and positive feedback. It refers to the extent to which the products, services and experiences offered by a company meet or exceed consumer expectations and needs. Consumer satisfaction is influenced by various factors, which can mostly be considered subjective. Researchers have developed several customer satisfaction metrics that can help companies improve and promote successful business. The aim of the study is to assess consumer satisfaction with the Latvian healthcare system. To achieve the set research objective, the theoretical part was analysed using the monographic or descriptive method, while the primary data was obtained through a survey. The study provides an understanding of the feasibility of medical tourism in the Latvian economy. The results of the study will provide an opportunity to understand the feasibility of medical tourism in Latvia.**

***Keywords*—Medical tourism, customer satisfaction, customer satisfaction measurement, business.**

I. Introduction

Medical tourism has become a global pillar of healthcare, with an estimated value exceeding US$100 billion and growing by 15% to 25% per year [1]. The medical tourism industry was valued at US$47 billion in 2024 and is projected to reach over US$111 billion by 2029 [2]. The World Tourism Organization defines medical tourism as a type of tourism activity that involves the use of evidence-based medical resources and services (both invasive and non-invasive), including diagnosis, treatment, prevention and rehabilitation [3].

Medical or health tourists are those who travel to a country other than their home country for medical or health-related purposes. To improve the accessibility of health tourism services, the Latvian Ministry of Health has developed an action plan aimed at promoting the export of health services. This specific plan was drawn up for the period from 2024 to 2027, and includes as its main basic directions: promoting the country's economic growth; promoting the growth of health care services exports; improving the quality of health care services; promoting the recognition of Latvia's image in the field of health care services exports; promoting the return of medical professionals to Latvia; promoting the retention of medical professionals in the country in the field of health care; promoting a regulatory ecosystem favourable to the export of health care services [4].

Like Latvia, both neighbouring countries are also working diligently on medical tourism export promotion services. Popularizing this sector can provide significant improvements in the growth of the country's overall economy, as well as ensure the growth of the specific area. In the Republic of Lithuania, the Ministry of Economy and Innovation is the state institution responsible for formulating state policy in the field of tourism, resort development, as well as resort areas. This institution also implements international cooperation functions in the field of tourism. The Ministry defines the following as its main objectives: identification of tourism development

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8646
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priorities; development of competitive tourism products; reduction of tourism seasonality; increase in the total number of tourists [5].

The Estonian national tourism policy is managed by the Ministry of Economy and Communications. The Estonian tourism policy defines the following as its main objectives: increasing the international competitiveness of Estonian tourism; increasing the export of tourism services; strengthening the added value of tourism enterprises [6].

The study is conducted with the aim of comparing health tourism trends in the Baltic States in order to find out whether this service is positioned as available to any medical tourist who plans to come to a particular country to receive healthcare or wellness services of interest to them. The countries included in the scientific article are analysed considering economic factors, tourism statistical data, as well as previously conducted research in the specific sector.

Research objective: to assess the advantages of the Latvian medical tourism sector compared to other Baltic countries. To achieve the goal, the following tasks were set: 1) to characterize the theoretical aspects of medical tourism services and the Baltic States; 2) to evaluate the services of the medical tourism sector in the Baltic States; 3) to conduct a comparative analysis of the advantages of the medical tourism sector in Latvia compared to the other Baltic countries. To implement the goal, the available theoretical basis on medical tourism was analysed using the monographic or descriptive method, as well as data from official statistical databases were compared using secondary data analysis. Research period: The study covers the period from 2021 to 2024. The study will provide an understanding of the opportunities and prospects of Latvian medical tourism.

II. MATERIALS AND METODS

Medical tourism is one of the tourism trends, the main goal of which is to provide a person, considering medical indications, with qualified full-fledged treatment outside the country of residence [7]. The authors distinguish three groups of medical tourism, namely, domestic tourism, outbound tourism and inbound tourism (see Figure 1).

In the classification of medical tourism offered by certain authors (see Figure 1), domestic medical tourism is mentioned as one of the types of medical tourism. Within the framework of this type of tourism, people living in one country travel to another city or region to receive medical services [8]. The reason for this may be the desire to receive the services of more qualified specialists or some specific diagnostic examinations that are not available in the region from which they are traveling – small towns or rural regions. This classification also distinguishes outbound and inbound medical tourism, which is associated with the provision of planned medical and diagnostic services to patients outside their country of residence. Outbound medical tourism is aimed at treating a patient abroad, which may be due to the need for immediate access to medical treatment, wider availability of medical institutions, as well as the lack of medical services or low-quality treatment, as well as less qualified service providers in the patient's country of residence [9]. Inbound medical tourism, on the other hand, is aimed at attracting foreign patients to provide them with medical care [7]. For the most part, the indications for both inbound and outbound medical tourism are practically the same, people travel in search of more affordable, higher-quality or unavailable medical or diagnostic services in their home country.

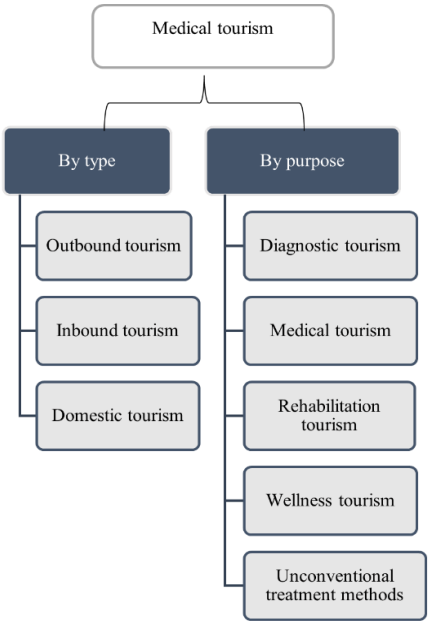

Fig. 1. Classification of medical tourism [7].

Medical tourism is classified according to the purpose of receiving medical services into diagnostic, treatment, rehabilitation, wellness and alternative medicine tourism [7]. Diagnostic medical tourism includes services intended to identify certain diseases, as well as to confirm or deny unclear diagnoses. The most common diagnostic examinations that medical tourists choose to undergo are imaging examinations, such as magnetic resonance imaging, computed tomography examinations, and positron emission tomography. The latest publicly available information from the Health Statistics Database shows that 2,557 medical tourists came to receive diagnostic services in Latvia in 2022 [10]. A type of medical tourism with the aim of receiving treatment is most often carried out by patients who have already been diagnosed with a disease. Such patients travel to another country or region to receive the necessary services related to therapeutic technologies or surgical intervention methods. In contrast, the rehabilitation direction of tourism is aimed at restoring lost body functions that have occurred because of injuries, strokes, paralysis and other pathological processes [7]. Wellness tourism focuses on and generally improving the health and well-being of the body. This type of tourism can include various SPA treatments, massages, healthy eating programs, as well as active leisure activities. The main goal of wellness tourism is to reduce stress and fatigue, as well as promote overall well-being. The final type of medical tourism in this classification is medical tourism for non-traditional

treatment methods. The most common alternative treatment methods include acupuncture or needle therapy, phytotherapy or herbal therapy, homeopathy, as well as chiropractic or manual therapy [11]. It is important to note that non-traditional treatment methods are often not based on scientific evidence and therefore may be associated with certain risks.

A. Characteristics of the Health Tourism Industry in the Baltic States

The medical tourism industry focuses on patients and clients who come from abroad to receive the desired medical and health-improving services.

The Tourism Law of the Republic of Latvia defines health tourism as one of the types of tourism aimed at improving the general condition and well-being of the body, as well as prevention, diagnostics, treatment and rehabilitation, using, among other things, natural healing resources [12]. Latvia as a medical tourism destination is attractive to foreign patients both with the level of modern medical services and with lower prices, compared, for example, with Central Europe - Germany, Switzerland or Austria. Another important advantage is the possibility of relatively quickly making appointments with specialists, as well as for various examinations.

The latest data publicly available in the Health Statistics Database show that in the medical tourism sector in Latvia in 2022, preventive services were provided most often, followed by diagnostic and therapeutic services [10]. The main countries from which medical tourists have travelled have been European Union member states, as it is relatively easier for patients from these countries to arrive in Latvia than for citizens of third countries.

The Latvian medical tourism industry is largely coordinated by the Latvian Health Tourism Cluster, which has been operating since 2012. This association unites both Latvia's leading clinics and hospital professionals to promote the expansion of the medical tourism market by providing high-quality and affordable services to both local and foreign patients [13]. Currently, the organization unites more than 60 members, both from the state and local governments, as well as from the private medical sectors. The main defined goals of the Latvian Health Tourism Organization are:

- to promote the development and adoption of regulatory enactments regulating resorts in the Republic of Latvia.
- to develop and expand the activities of resort towns in the Republic of Latvia.
- to represent and defend the general interests of members in the public and private sector institutions of Latvia, as well as in other organizations operating in the tourism, medical, and especially health tourism sectors.
- cooperate with Latvian and foreign partners, as well as participate in the preparation and implementation of international projects.
- promote the export of medical products and health services.
- develop innovative health and health tourism products [14].

Republic of Lithuania Medical tourists are offered services such as plastic surgery, orthopaedics, vascular surgery, dentistry, as well as SPA and rehabilitation. Medical tourism services in Lithuania are offered by 89 companies that provide various types of services, ranging from serious treatment manipulations to wellness-promoting procedures.

The Lithuanian medical tourism cluster LITCARE has been operating in Lithuania since 2013, which, like the Latvian Health Tourism Cluster, unites both private and public organizations that provide medical services, including dentistry services, as well as SPA and wellness services [15]. The organization defines as its main goal the promotion and development of medical tourism exports, as well as strengthening Lithuania's competitiveness in the international market [16]. The cluster also promotes cooperation between Latvian and Estonian medical tourism professionals by jointly organizing conferences and exhibitions of both international and local importance. The Republic of Estonia has become an important medical tourism destination, especially in the neighbouring countries of the Baltic region, as well as in Scandinavia and the Nordic countries. Foreign patients have been coming to Estonia since the 1980s to receive various types of medical and wellness services [17]. The Estonian healthcare system is well regulated, and its medical institutions are equipped with modern technology. Competitive prices for medical procedures, as well as high standards of care, have attracted international patients looking for affordable and high-quality healthcare services. The Estonian medical tourism cluster Medicine Estonia supports its members in promoting the export of medical services [17]. The organization's main strategic goals include:

- promoting international recognition and the number of medical tourists.
- improving the diversity and quality of health tourism products and services.
- improving the professionalism and qualifications of medical workers.
- positioning health tourism companies, as well as taking a leading role in the Estonian healthcare system.
- sustainable development of the efficiency of health tourism companies [18].

All Baltic States have established medical tourism clusters, which aim to promote the industry, strengthen cooperation between industry players and attract foreign patients. The Baltic States offer a wide range of medical services, from diagnostic and preventive services to complex surgical operations, however, patients should carefully compare various factors, including service prices, when choosing a place to be treated, to make an informed decision.

B. Research Results

Medical tourists choose to receive medical services outside their home country mostly because of more affordable prices and shorter lines. The author compares

the availability of medical tourism in the Baltic States according to three different aspects: physical accessibility, economic accessibility, and availability of specialists.

Physical accessibility (transport). Although the Baltic States are in the northern part of Europe, air traffic to these countries is well developed. The main airports are in the capitals, namely Riga, Tallinn and Vilnius, but smaller airports are also located in Palanga and Kaunas in Lithuania, as well as Tartu in Estonia. Riga Airport is considered the main air traffic hub in the Baltics [19]. This is also evidenced by the data published by the World Economic Forum (WEF) in 2024, which indicates that in the analysis of the Travel and Tourism Development Index, Latvia was awarded 3.08 out of 7 points, which is the highest result, precisely in the air transport infrastructure sector, ranking it in first place among the Baltic countries [20]. Lithuania received 2.94 out of 7 points in the same sector, while Estonia only 2.83 out of 7 [20]. The 20 airlines operating at Riga Airport provide connections to more than 100 European and Asian destinations [19]. In total, Riga Airport served 6.63 million passengers in 2023, Vilnius Airport also served around 6 million passengers, and Tallinn Airport served a total of 8,764 passengers.

By train from Riga, you can go to Vilnius in Lithuania, as well as to the border town of Valga in Estonia. Trains run from Vilnius to Warsaw in Poland, as well as to Riga in Latvia. From Tallinn, you can go by train to Valga, then change trains to go further to Latvia. At the level of the Baltic States, bus transport is much more accessible, as well as cheaper, compared to train transport. Data published by the World Economic Forum in 2024 indicate that in the analysis of the Travel and Tourism Development Index, Latvia was awarded 3.75 out of 7 points, Lithuania received 4.47 out of 7 points in the same sector, while Estonia received the highest rating of 4.63 out of 7, specifically in the land and port infrastructure sector [20]. Estonia is the only one of the Baltic countries with well-developed sea transport, namely, it is possible to reach Helsinki in Finland, Stockholm in Sweden, as well as the Aland Islands by ferry from Tallinn.

The number of incoming tourists in 2021, which is the latest publicly available data, was twice as high in Lithuania as in Latvia (see Table 1). In this particular year, 948,000 international tourists arrived in Lithuania, bringing in 585 million USD in tourism spending. In 2021, only 478,000 international tourists arrived in Latvia, generating a total of 751 million USD in revenue, while in Estonia, 808,000 tourists arrived in this particular year, contributing 901 million USD to the economy. According to this summary, tourists who arrived in Latvia spent more money on tourism spending than tourists who arrived in Lithuania.

The target markets for Latvian medical tourism are the United Kingdom, Ireland, Norway, Sweden and Germany. Most often, medical tourists from these countries choose Latvia as a medical tourism destination, as it is easily accessible by air. On average, the flight duration from these countries to Latvia is no longer than 2.5 to 3 hours. Statistical data show that in 2022, 2,811 patients from the United Kingdom, 1,659 patients from Germany, and 390 patients from Sweden chose Latvia as a medical tourism destination [10]. Lithuania defines Germany, Poland, the United Kingdom, and the Scandinavian countries as its target market countries. Medical tourists from Poland and Germany can easily reach Lithuania both by air and by traveling by land by bus or their own private car. The flight duration from Poland, Germany, as well as from the United Kingdom and Sweden, does not take longer than 1.5 to 2 hours. However, Estonia, which is located further north than the other Baltic states, is defined as a medical tourism destination by the Scandinavian countries. It is easy to get to Estonia from the Scandinavian countries by air or water. The average travel time by air is 1 hour and 20 minutes, but by ferry the travel time can be up to 15 hours.

TABLE 1 COMPARISON OF DESCRIPTIVE ECONOMIC ACTIVITY DATA IN THE BALTIC STATES [1]

Indicator	Baltic States		
	Latvia	***Lithuania***	***Estonia***
Population, 2023	1 883 008	2 857 279	1 365884
GDP per capita, 2023 (EUR)	26 600	32 500	30 700
International tourist arrivals 2021	478 000	948 000	808 000
Tourist expenditure 2021 (EUR million)	751	585	901
Competitiveness index - GCI (2024)	59.13	69,89	68.17
Global competitiveness rank (2024) *	45	30	33
Travel and tourism development index rank (2024) **	65	44	36
Current health expenditure per capita, 2021 USD, PPP Total	3153	3432	3258,78
Government	2 186,00	2 305,00	2 481,98
Private (out-of-pocket)	851.00	1035	719,34
Standard VAT rates (%)	21	21	22
Medicines and medical equipment for personal use (%)	12	5	9
Transport (passenger transport) (%)	12	9	9
Hotel accommodation (%)	12	9	9
Restaurants and food services (%)	21	9	9
Number of doctors per 10,000 population, 2022	34	51	34
Gross monthly salary of a doctor	1 619	1 466	2 709

*Rating out of 67 countries in 2023
**Rating out of 119 countries in 2023

Economic accessibility. It is known that most people choose to go for medical services abroad, because it is often possible to save costs in this way, as well as to get to certain specialists faster. This choice is influenced by both the country's total income per capita and how much the country spends on health in general. If a country has lower wages and less is spent on health, then medical services are also cheaper. Lower health expenditures per capita in the target country can be a significant factor influencing patient choice. Low medical care costs, which are usually associated with a lower gross domestic product, as well as low administrative costs, increase the availability of

medical care. Of the Baltic countries, Latvia is characterized by a lower GDP per capita than the other two Baltic countries, as evidenced by data from 2023. Estonia is in second place with a GDP per capita of 30,700 EUR, however, Lithuania is in the lead among the Baltic countries with a GDP per capita of 32,500 EUR. Part of the price of medical tourism services is made up of value added tax (VAT), which is the highest in Estonia at 22% according to the standard rate, however, if we apply it to tourism-related services, such as accommodation, restaurant and catering services, as well as transport services, then in these sectors the VAT is lower for both Estonia and Lithuania compared to Latvia (see Table 1).

In the medical tourism sector, the author analysed the prices of five services – breast implants, tummy tuck, bariatric surgery, hip replacement, and rhinoplasty (see Table 2). The prices of the most popular surgical services in the Baltic region do not differ significantly, however, it should be noted that the costs of hip replacement surgery in Latvia are cheaper compared to the other Baltic countries. However, the costs of rhinoplasty or nose surgery are cheaper in Lithuania. Comparing the prices of these specific services, it can be concluded that the costs of these services in Estonia are slightly more expensive compared to the other Baltic countries, but still relatively lower, such as in other Scandinavian countries.

TABLE 2 AVERAGE PRICES FOR THE SERVICE IN THE BALTIC STATES [1]

Service (EUR)	Latvia	Lithuania	Estonia
Breast implants	3 800/ 4 600	3 050/3 895	4 290/5 290
Abdominoplasty	4 000/5 600	3 100/3 958	3 690/ 4 590
Bariatrics	3 380/ 4 980	5 450/6 960	3 500/ 6 150
Hip replacement	2 812/ 3 500	6 340/8 098	5 600/ 6 400
Rhinoplasty	3 400/4 500	2 050/3 767	3 500/ 5 500

For Availability and quality of specialists. Comparing all three Baltic countries, the largest population in 2023 was in Lithuania, Latvia is in second place, but Estonia has the lowest population level. Accordingly, the number of doctors per 10,000 inhabitants is also the largest in Lithuania – 51 (see Table 1). Studies show that Estonia, Latvia and Lithuania have consistently been among the leaders of the European Union countries in terms of the number of doctors per 10,000 inhabitants, however, over 30 years, the number of doctors in Latvia decreased by 1.65 doctors, while in Estonia the number increased by 3.63 doctors, in Lithuania by 5.34 doctors per 10,000 inhabitants, this is associated with a decrease in the population in all three countries [21].

Medical tourists, when choosing a country to go to receive a service, highly value quality service. When choosing to receive treatment abroad, the patient is looking not only for more favourable prices, but also for high professional standards, as well as safe and reliable services. A quality service includes not only a successful treatment outcome, but also a kind attitude, clearly understandable information about the treatment process and possible risks, as well as support after treatment. A study conducted by the Medical Tourism Association in 2024 emphasizes the quality and standards of medical safety for foreign patients. In the survey conducted, more than half of the participants indicated that they were worried about traveling to another country due to factors such as quality of care, safety, and distance [1]. All three Baltic countries position themselves in the medical tourism market as safe and offer high-quality standards for treatment and wellness procedures.

For the convenience of medical tourists, medical tourism clusters operate in each of the Baltic countries, which provide patients with more convenient communication with both the chosen clinic and specialists. The Latvian Health Tourism Cluster unites more than 60 members, which are state, municipal and regional hospitals, as well as private clinics, rehabilitation centres, resort hotels, as well as travel agencies and educational and research institutions [13]. The main area of activity of the cluster is the promotion of cooperation between industry specialists and organisations to make medical tourism services more accessible to both the residents of their own country and foreign tourists. The Lithuanian medical tourism cluster LITCARE has become a well-known partner among health tourism professionals in countries such as Latvia, Estonia, Ukraine, Azerbaijan and Kazakhstan. It is also reported that the cluster is entering the markets of countries such as the UK, Israel, Norway, Sweden, Germany and the USA [16]. The Estonian medical tourism cluster The Medicine Estonia cluster, like the other medical tourism clusters in the Baltic States, unites industry companies and specialists that provide services in treatment, diagnostics, research and further education. The cluster also takes care of advertising its services and various marketing activities to attract medical tourists.

The Baltic States are positioned as an attractive and accessible destination for medical tourists, offering a wide range of high-quality medical services. The region's attractiveness is promoted by a good geographical location, which ensures easy accessibility, as well as experienced specialists working with the most modern technologies. Medical tourism clusters, in close cooperation with healthcare institutions and representatives of the tourism industry, provide integrated solutions that simplify the receipt of medical services and improve the overall patient experience.

III. CONCLUSIONS

- Health tourism is a growing industry worldwide, including in the Baltic States, which can be attributed to competitive prices compared to Western European countries.
- By promoting closer cooperation between the Baltic States, it is possible to attract new, qualified specialists in the field of health tourism, thus increasing the overall quality of services.
- The study has practical significance, which will allow Latvian medical organizations to understand the prerequisites and development prospects necessary for starting medical tourism.

- The average costs of surgical services in the Baltic States do not differ much, therefore, medical tourists have equal opportunities in all the Baltic States.
- Changes in the number of doctors may be related to the financing of the healthcare system, physician migration, demographic changes, as well as other socio-economic trends.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 349-353

Bark Abrasion Evaluation on Birch (Betula Spp.) Round Timber by Using Machine Learning Algorithm

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***Abstract*— Birch has an exceedingly high potential from the point of view of cultivation, respectively, now in Latvia more and more new factories are being opened that produce birch plywood and the demand for birch round timber is increasing every year. Latvian legislation, as well as business relations between different trading parties, require accurate determination of the volume of round timber without bark. Automatic measuring devices mainly determine the diameter with bark and then reduce it using bark algorithms. Machine learning has great potential in labour shortage. During machine learning, a computerized system could analyse large amounts of data and diverse properties [1]. Convolutional neural network can ensure the system's resistance to image defects due to various types of lighting conditions, image shifts and changes in their shapes, which can be caused by the characteristics of the camera lens [2]. One of the tasks of timber measurement process is to assess the amount of bark abrasion, as well as the thickness of the bark. Within the framework of the project, we have investigated the possibilities of determining the area of bark abrasion of round timber using machine learning algorithms. To assess the accuracy of the model, we have randomly selected 90 round timber samples from the system, which have been marked by a timber scaler in a computer program, as well as the computer program itself. On software with image processing and analysis capabilities, visual data of the side surface of round timber were evaluated, manually assessing the areas of bark abrasion. The obtained results were compared with the bark mass obtained using the prepared computer vision algorithm. Machine learning algorithm, on average, calculates smaller bark mass – 76 %, compared to the manually obtained results – 84 %. Bark abrasions and most of the remaining bark can be assessed without difficulty for round timber with a darker and more crusty bark, for example, for cuts prepared from the thick end of the trunk. For birch round timber with a white colour, in some cases, part of the white colour is perceived as bark abrasion and, therefore, a smaller majority of remaining bark is assessed. To assess the volume of round timber without bark, the proportion of bark must be assessed, which must be calculated from the total volume of the measured diameter with bark. When assessing the coincidence of the determined bark types, it can be observed that the bark type according to the computer vision algorithm coincides in 79 % of cases with the bark type obtained after manual processing of visual data.**

***Keywords*— Birch, bark detection, machine learning.**

I. INTRODUCTION

In many European countries, the price for each log is determined based on log volume and quality. Reason for retaining the bark until the moment before sawing is improved log properties with respect to preservation and processing efficiency [3]. Latvian legislation, as well as business relations between different trading parties, require accurate determination of the volume of round timber without bark [4].

The log price depends on log volume and log quality. Both for log quality (which is not discussed any further here), and for log volume, there are different assessment methods, depending on the targeted use and on country specific regulations. Therefore, the determination of the log volume for sawlogs is often based on individual log diameter and length measurements [5]. In some countries, the top diameter is used (e.g. in Sweden) [5], while in other countries, the middle diameter is the basis for calculating the log volume [6].

In Latvia both methods are used, additionally with section wise method - when diameter is measured in every section, starting from 1 cm length [7]. For harvested timber, bark is a good insulating or wrapping material and the most

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8685
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important feature in determining the tree species, which preserves the moisture of freshly harvested wood, prevents the occurrence of lateral drying cracks and the development of fungi for a limited time [8].

Mostly, bark is excluded from the diameter or volume or weight measurement, either by removing the bark prior to the measurement, or by reducing the measured values according to some estimate of the involved bark. For sawlogs, roundwood diameter measurement usually is done in the sawmill, directly after log delivery. The logs are loaded onto a conveyor, where one by one they are singled out. If the bark is to be removed before log measurement, it is usually done at this point [9]. There are several approaches for determining the diameter (or the volume) under bark if the measurement has been done on bark. One common method is to infer bark thickness from the log diameter, based on tabled values or formulas [5].

Other way is bay using X-ray computer tomography. If there are fresh round timber it is possible to determine log diameter with and without bark [10], [11]. There is also possibility to use convolutional neural networks for image recognition. Convolutional neural networks are widely used in image and pattern recognition as they have several advantages compared to other techniques. A neural network is a system of interconnected artificial "neurons" that exchange messages between each other. The connections have numeric weights that are tuned during the training process, so that a properly trained network will respond correctly when presented with an image or pattern to recognize [2]. Assessing the quality of round timber by measuring with automatic measuring devices and using artificial intelligence technologies includes a variety of approaches, including deep learning algorithms and computer vision systems. Deep learning algorithms enable wood defects to subtly segment and acquire various characteristics, as well as create a resource collection with wood defect features for large amounts of data. Deep learning algorithms usually require a relatively large amount of data, but it is also possible to apply them to small amounts of data by training algorithms [12], [13].

Bark detection algorithms can be based on colour, texture, and a combination of colour/texture. Natural colour variations of the bark can negatively affect the pixel colour algorithm, which in turn negatively affects the bark detection algorithm [10].

II. MATERIALS AND METHODS

To assess the possibilities of evaluating bark abrasion, 90 birch veneer log samples were selected at random sampling method from timber sorting line from production environment in JSC "Latvijas Finieris" log yard "Bolderāja" in Riga, Latvia. Samples were collected from 23rd of October till 13th of November year 2024. In this research all taken samples were clean from ice, mud or any other impurity which could affect bark recognition. Top diameter distribution is shown in Table 1.

TABLE 1 TOP DIAMETER DISTRIBUTION OF VENEER LOG SAMPLE SET

Top diameter, mm		Amount, pieces
From	*Till*	
160	179	12
180	209	30
210	249	33
250	299	12

This particular plywood factory in using individual measurement method by measuring the diameter at small intervals. For this method it is necessary to obtain results for bark abrasion on all assortment side surface for under bark diameter calculation. In the same location special camera setup were created to record data on timber sorting line and by using the computer program developed within the framework of the project, birch round timber was processed automatically using the developed bark assessment machine learning service. The following raw and unprocessed images were obtained and shown in Fig. 1. This type of pictures was obtained for all sample set.

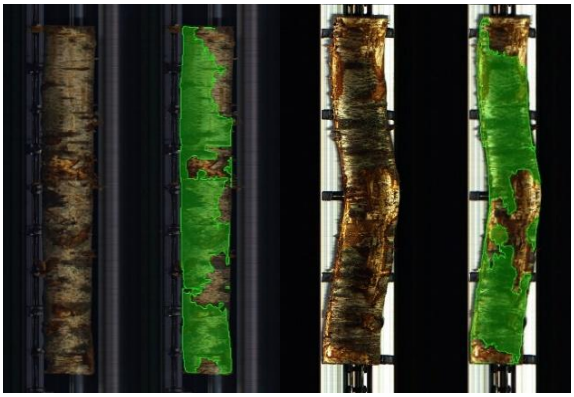

Fig. 1. Samples of birch round timber without bark filters on the left and automatically recognized bark amount on the right.

In this type of image processing, it is possible to obtain the exact volume of the remaining bark, which is applicable in the further calculations of the bark thickness. In this study main task is to understand precision for bark abrasion amount. In Fig. 1 it is possible to see also difficulties on the left side of the figure where part of the bark is marked as debarked. White colour pattern for birch in some cases is giving difficulties to correctly recognize the amount of bark abrasion. Images of birch round timber logs are obtained in motion on the conveyor of the sorting line, without stopping the conveyor. Same birch round timber logs were measured manually by using ImageJ program for computer vision precision comparison (see Fig. 2 and Fig. 3).

To understand machine learning service capabilities to assess bark abrasion, the amount of the bark abrasion on round timber were compared to bark type codes which are used in Latvia. Bark type 0 is used when bark abrasion is 0 %, bark type 1 is used when bark abrasion is 50 %, bark

type 2 is used when bark abrasion is 75 %, Bark type 3 is used when bark abrasion is 100 % [14].

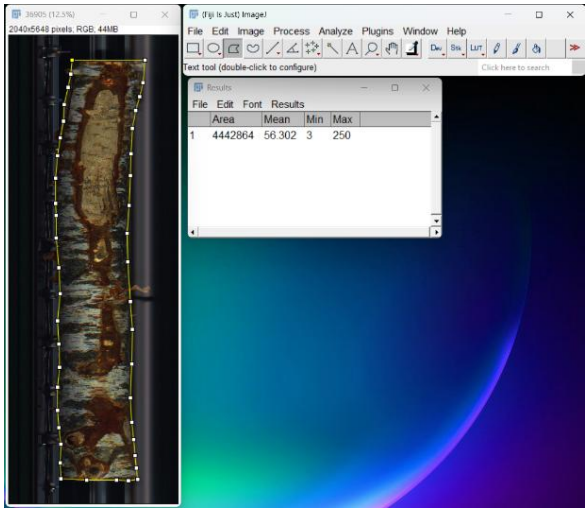

Fig. 2. Full surface area detection manually by using ImageJ program.

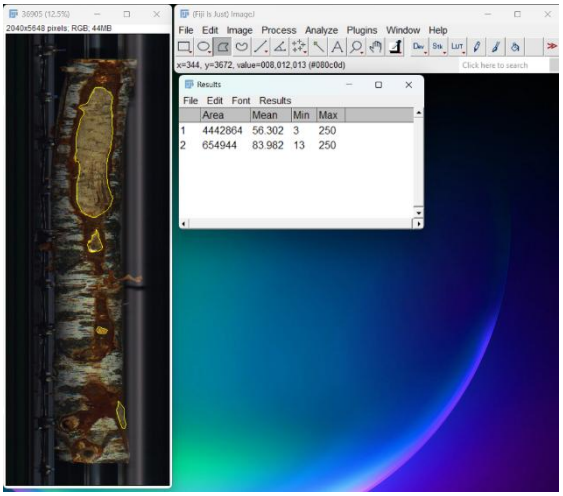

Fig. 3. Bark abrasion area detection manually by using ImageJ program.

In determining the volume of round timber, only the volume of wood is considered, so the proportion of bark should be calculated from the total volume or the measured average with the bark [7]. Since the thickness of the bark varies widely, and in the process of logging it is partially abraded in each working operation, significant difficulties arise in assessing the correct volume of timber. The deduction of bark in further calculation shall be made by applying a particular type of abrasion [15].

III. RESULTS AND DISCUSSION

To correctly determine the volume under the bark using the bark algorithms, it is important to know the actual abrasion of the bark for each cut-off, in cases where the individual measurement method is used. To improve the accuracy of determining the volume of round timber using computer vision technologies, the amount of the bark is also evaluated. Using the visual data of cameras with the help of computer vision technology, it is possible to evaluate bark abrasion on the side surface of the round timber.

On software with imaging and analysis capabilities, visual data of the side planes of round timber is evaluated, manually evaluating the abrasion areas of the bark are determined. The results obtained manually with ImageJ are compared with the amount of the bark, obtained using the prepared computer vision algorithm developed in project framework. Without difficulty, bark abrasions and most of the remaining bark are appreciable round timbers dominated by darker and more crested bark, such as cutoffs prepared from the butt part of the trunk. For birch round timber, where white colour predominates, in some cases, part of the white colour is perceived as an abrasion of the bark and, as a result, a smaller majority of the remaining bark is valued. For this purpose, according to the estimated proportion of the bark, certain types of bark are used (Table 2).

TABLE 2 COMPARISON OF MANUALLY DETECTED BARK AND BARK DETECTED BY COMPUTER VISION

Parameter	Bark amount, % (manual measurement)	Bark amount, % (computer vision)
Total		
Average	84,0	76,2
Standard error	1,8	2,0
Standard deviation	16,7	19,3
Minimum	25,0	18,0
Maximum	100,0	100,0
Samples	90,0	90,0
Bark type 0		
Average	27,0	20,0
Standard error	2,0	2,0
Standard deviation	2,8	2,8
Minimum	25,0	18,0
Maximum	29,0	22,0
Samples	2,0	2,0
Bark type 1		
Average	52,5	45,5
Standard error	3,6	3,8
Standard deviation	8,8	9,3
Minimum	38,0	29,0

Parameter	Bark amount, % (manual measurement)	Bark amount, % (computer vision)
Maximum	60,0	53,0
Samples	6,0	6,0
Bark type 2		
Average	78,2	68,6
Standard error	1,1	1,5
Standard deviation	7,1	10,1
Minimum	65,0	48,0
Maximum	90,0	85,0
Samples	44,0	44,0
Bark type 3		
Average	98,7	92,7
Standard error	0,4	1,6
Standard deviation	2,3	9,6
Minimum	92,0	63,0
Maximum	100,0	100,0
Samples	38,0	38,0

Bark abrasion level in Latvia in autumn is quite low, so most of the data is bark type 2 or bark type 3. The difference for bark type 2 is 10 %. Computer vision is giving slightly smaller bark abrasion value. In bark type 3 the difference is around 8 % and the same pattern that computer vison algorithm gives smaller abrasion value.

In Fig. 4 it is possible to analyse that correlation between actual bark and bark amount determines by computer vision has close correlation ($R^2 = 0,8475$).

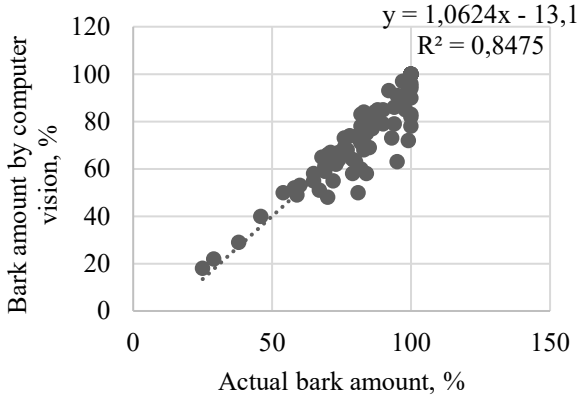

Fig. 4. Actual and computer vision calculated bark amount, %.

In production environment timber scaler is choosing bark type by visual so in this research we wanted to evaluate precision of coincidence of bark types has also been assessed based on manually processed visual data, in the actual assessment of bark abrasion. When comparing the coincidence of bark types according to most bark evaluated by the actual and computer vision algorithm, the type of bark determined by timber scalers is also considered.

When evaluating the coincidence of the identified bark types, it can be observed that the type of bark according to the prepared computer vision algorithm in 79 % of cases coincides with the type of bark obtained after manual processing of visual data. On the other hand, the type of bark determined by the scaler in 62 % of cases coincides with the type of bark after manual processing of visual data (Fig. 5).

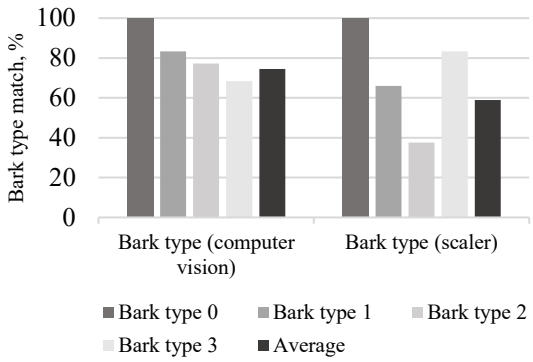

Fig. 5. Bark type match in comparison of computer vison and timber scaler.

When evaluating the coincidence of bark types separately for each type, according to the prepared computer vision algorithm, a trend is observed – as the majority of bark increases, the mismatch of bark types also increases. On the other hand, according to the bark type recorded by the scaler, it can be concluded that the highest coincidence is for bark type 3 (most bark above 90 %) and bark type 0 (most bark below 30 %).

When assessing the coincidence of bark types, scalers should take into account that in the performance of their duties it is possible to see the side surface of the round timber at a rate of 100 %, but using visual data from cameras it is possible to see a maximum of up to 75 % of the side surface, which may contribute to the mismatch of bark types.

In order to improve the coincidence of the bark type according to the computer vision model, it is necessary to improve the recognition of bark abrasion on birch round timber, which is strongly dominated by white colour, but in general if we analyse the bark type match, the results are promising for testing the bark recognition service in production environment.

IV. CONCLUSIONS

Using the prepared computer vision algorithm, on average, a smaller majority of bark is systematically determined in the assessment of most bark – 76%, compared to manually obtained results – most bark – 84%. The reason for this trend is the analysis of the images of the bulk of the prepared bark evaluation algorithm, in which the colour of the peel is evaluated first, and then the texture. To improve the coincidence of the bark type recognition the bark according to the computer vision algorithm, it is necessary to improve the recognition of bark abrasion on birch round timber, which is mostly dominated by white colour.

When evaluating the coincidence of the identified bark types, it can be observed that the type of bark according to the computer vision algorithm in 79 % of cases coincides with the type of bark obtained after manual processing of visual data. On the other hand, the type of bark determined by the scaler in 62 % of cases coincides with the type of bark after manual processing of visual data. Here, however, it should be noted that scalers have the opportunity to see the side surface of the round timber at 100% when performing their duties but using visual data from cameras it is possible to see a maximum of up to 75 % of the side surface, which can contribute to the mismatch of bark types.

The precision of bark type match for computer vision in comparison to timber scaler gives average is 15 % better results.

V. ACKNOWLEDGEMENTS

Forest Sector Competence Centre of Latvia project "Determining the quality of round timber using machine learning algorithms, measured individually with an automatic measuring device" (Recovery and Resilience Facility, 5.1.1.2.i.0/1/22/A/CFLA/007).

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 355-362

Green Transition and Circular Economy Practices: Unlocking Africa's Potential for Sustainable Growth

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***Abstract*- This paper addresses the urgent need for sustainable development in Africa amid the increasing environmental challenges posed by climate change. Despite accounting for less than 4% of global greenhouse gas emissions, the continent faces critical issues such as droughts and limited energy access, threatening economic stability and growth. The research focuses on the interplay between sustainability initiatives and economic growth, arguing that the adoption of renewable energy and circular economy (CE) practices can serve as catalysts for industrial expansion and job creation. To explore this relationship, the study employs a SWOT analysis to evaluate the strengths, weaknesses, opportunities, and threats associated with Africa's green transition. The analysis reveals both the advantages of adopting sustainable practices and the significant obstacles hindering progress, such as inadequate infrastructure and funding shortfalls. Additionally, the paper highlights how circular economy approaches can enhance the continent's sustainable development efforts by promoting resource efficiency and reducing waste. In conclusion, the article underscores the necessity of integrating sustainable and circular practices within national development strategies to achieve resilience and sustainability in Africa. The recommendations include prioritizing investments in renewable energy infrastructure, fostering collaboration among stakeholders, and promoting policies that facilitate access to funding for CE initiatives to support economic growth. By addressing these challenges, Africa can move towards a more sustainable future that balances economic growth with environmental stewardship.**

Keywords*- *circular economy, climate change, green transition, sustainability

I. Introduction

As the impacts of climate change intensify worldwide, the pursuit of sustainable development has become a pressing concern for nations, particularly in Africa, which remains one of the most vulnerable regions to climate-related threats. Despite representing less than 4% of global greenhouse gas emissions [1], Africa is confronted with significant environmental challenges, including rising temperatures, extreme weather events, and a decline in agricultural productivity. These challenges have the potential to jeopardise the continent's ecological health, economic growth and social stability, with the result that millions of people are pushed further into poverty.

In the context of these pressing issues, African nations are confronted with the dual imperative of fostering economic growth while embracing sustainability. This balancing act is complex; traditional models of development often rely on the extraction of natural resources, which may prove detrimental to long-term sustainability goals. Nevertheless, a transition towards more environmentally-friendly practices and renewable energy sources could facilitate new avenues for economic growth, generate employment opportunities and enhance resilience against climate change.

To explore this critical intersection, this article investigates the relationship between Africa's sustainability goals and economic growth, arguing that both can be mutually supportive rather than mutually exclusive. It employs a SWOT analysis to assess Africa's green transition. Additionally, the article highlights the importance of circular economy practices as a means to optimize resource use and promote sustainability across various sectors. Practical examples of circular economy

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8648
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initiatives in agriculture, e-waste management, water supply, construction, and fashion illustrate how these principles can unlock Africa's potential for sustainable growth. Ultimately, the article emphasizes the necessity of harmonizing sustainability and economic development to pave the way for a more resilient and prosperous future for African nations.

II. Materials and methods

A SWOT analysis is employed in the article to identify the strengths, weaknesses, opportunities and threats associated with the green transition in Africa. Furthermore, the analysis examines the current status of Africa's sustainability journey, the potential for future growth, and the implications of these transitions for local communities and global stakeholders. The study also employs a descriptive analysis of various circular economy initiatives across different sectors in Africa, highlighting practical examples that illustrate how circularity can enhance sustainable development and contribute to the continent's green transition.

By investigating these dynamics, the study aims to provide a comprehensive understanding of the opportunities and challenges that lie ahead for Africa in navigating its path toward a sustainable and economically viable future. The analysis is based on a comprehensive review of existing literature, policies, and reports related to Africa's sustainability efforts. It synthesises insights and evidence regarding the current state of sustainability challenges on the continent. This comprehensive perspective will facilitate a balanced discussion of the inherent opportunities and challenges associated with Africa's pursuit of sustainable development and economic resilience.

III. Results and discussion

A. Literature Insights: Sustainability and circularity as determinants of structural change in global economy

In order to gain insight into the particular dynamics at play in Africa, it is first necessary to examine the broader context of sustainability and environmental challenges as determinants of structural change in the global economy.

The growing awareness of the importance of environmental sustainability is exerting an influence on the structure of world trade. The adoption of sustainable practices is becoming a pivotal consideration for both businesses and consumers [2]. Environmental sustainability is emerging as a significant factor influencing the configuration of trade patterns.

The ascendance of green trade policies and regulations reflects a global commitment to addressing climate change and advancing sustainable development [3]. Adoption of environmentally responsible practices confers a competitive advantage on countries and businesses in the international marketplace [4, 5]. An analysis of the nexus between environmental considerations and trade structures offers insight into the evolving landscape of global trade, where sustainable practices are becoming an integral part of decision-making processes by businesses and policymakers [6].

The global supply chain is becoming increasingly susceptible to environmental challenges, including climate change, extreme weather events and resource scarcity. In order to enhance resilience and offset the effects of environmental uncertainty, businesses and nations are modifying their strategies for engaging in supply chains. The development of the circular economy, responsible sourcing practices and green logistics solutions represent measures taken to address environmental risks in global supply chains [7].

Global awareness related to environmental sustainability is increasingly influencing the structure of international trade. Businesses and nations are coming to recognise the need to adopt sustainable practices that minimise environmental impacts [8]. The term "sustainable practices" encompasses a range of activities, including the utilisation of environmentally friendly production methods, the implementation of energy-efficient transportation solutions, and compliance with rigorous environmental regulations. The concept of sustainability is becoming an increasingly significant factor in the development of trade policy models.

The adoption of sustainable practices is becoming a strategic imperative for businesses seeking to align themselves with consumer preferences and meet evolving regulatory standards [9]. The integration of sustainability into production processes and supply chains represents not only a response to market demands, but also a proactive measure to mitigate environmental risks.

The global supply chains, which function as the primary conduits of international trade, are becoming increasingly vulnerable to environmental challenges. The occurrence of climate change, extreme weather events and resource scarcity creates a risk of disruption to the flow of goods across borders.

Sustainability strategies encompass the development of green and circular business models, responsible sourcing practices, and the implementation of environmentally friendly logistics solutions [10]. A circular economy is one which prioritises the reduction of waste and the maximisation of product life cycles. This contributes to a more sustainable and resource-efficient approach to both production and consumption. Responsible sourcing practices are associated with ethical and environmentally conscious sourcing decisions, thereby ensuring that supply chains adhere to high sustainability standards.

The significance of integrating sustainability into business strategic planning and national policy formulation is growing. By promoting sustainable supply chains that address environmental risks, stakeholders can contribute to the development of a more sustainable and resilient global trading system. In an era characterised by heightened environmental awareness, integrating these considerations not only confers a competitive advantage but also

constitutes an indispensable aspect of responsible and forward-thinking production and trade practices [11].

Having established the role of sustainability in global trade as a foundational concept, we now direct our attention to Africa. In this region, the interplay between economic growth and sustainability reveals both unique challenges and opportunities.

B. Between economic growth and sustainability: Current state of play

Despite Africa contributing less than 4% of global greenhouse gas emissions [1], the continent faces climate change challenges, including droughts, floods, and potential crop failures [12]. The financial impact of these changes is estimated at USD 5 to 7 billion annually, potentially rising to USD 50 billion by 2030 [13]. Climate change could push 50 million Africans below the poverty line and risk displacing 100 million. Simultaneously, around 600 million people lack energy access, a crucial factor for economic growth [14].

Addressing the dual challenges of sustainable development and economic growth is vital. This theme was central to the inaugural Africa Climate Summit in Nairobi in September 2023. However, sustainable development and economic growth are often seen as mutually exclusive; a transformation in this discourse is needed to recognize their interconnectedness [12].

Africa relies heavily on natural resource extraction, including oil, gas, and minerals, with 45 countries dependent on commodity exports [15]. Many African nations seek to replicate the economic development models of wealthier nations by exploiting untapped natural resources to improve their economies.

Africa holds potential as a major contributor to global decarbonization, leveraging renewable resources for a green industrial hub [16]. Achieving this vision depends on sustainable resource extraction methods. Companies like KoBold Metals are utilizing AI to improve resource discovery while minimizing environmental impacts, and exploring keyhole mining to mitigate the need for damaging open-pit mines [12].

Context also matters; for a successful green revolution, financial resources and cutting-edge technology are essential. However, the majority of green technologies have been developed in the Global North, complicating their deployment in African nations. Innovative projects such as wind farms and geothermal plants often struggle due to the immediate need for energy solutions at the local level.

At the Africa Climate Summit, stakeholders recognized the importance of engaging local stakeholders in developing environmentally-friendly initiatives. Although governments are expected to lead these efforts, companies must understand local contexts and needs.

Energy access exemplifies the challenges faced: over 600 million Africans lack electricity, and those who do consume less energy than the entire population of Spain [17]. This lack of access hinders economic growth and exacerbates challenges compared to other developing regions. As Africa's population grows, the demand for reliable energy and sustainable futures becomes increasingly urgent.

The United Nations Economic Commission for Africa (UNECA) emphasizes establishing a Just and Sustainable Transition (JST) in Africa, proposing an investment framework to leverage the continent's natural resources while transitioning to renewable energy [18]. The report highlights the potential of Africa's youth, arable land, and strategic resources to drive this energy transition but notes that realizing these opportunities requires significant investment and infrastructure development.

Moving forward, the strategies adopted now will profoundly influence Africa's future growth, energy access, and sustainability, highlighting the need to balance resource dependence, climate challenges, and aspirations for a resilient and sustainable economic future.

C. What to expect: Africa's energy transition potential

The International Energy Agency (IEA) identifies energy access as essential for economic growth. IEA Executive Director Fatih Birol points out that the lack of energy access is a significant hurdle for Africa's development [19]. The COVID-19 pandemic has exacerbated existing energy service deficiencies, causing a 4% decline in modern energy services between 2019 and 2021, hindering progress toward UN Sustainable Development Goal 7.

International institutions have committed to divesting from fossil fuel projects, raising concerns about the feasibility of an immediate transition to renewables in energy-poor sub-Saharan nations, which face challenges in baseload generation and infrastructure. Households are the largest electricity consumers in Africa, where off-grid renewable solutions, particularly distributed solar, show promise. Countries like Kenya and Ethiopia, however, benefit from abundant geothermal and hydroelectric resources.

While solar and wind resources are increasingly cost-competitive, their intermittency remains a challenge. Without substantial investments in baseload generation and enabling technologies, renewables cannot reliably meet energy demands. The IEA's Sustainable Africa Scenario (SAS) suggests that Africa can utilize natural gas to fuel growth while transitioning towards renewables [19].

However, reliance solely on renewable energy without gas presents challenges, especially considering the "green premium" that developed nations can afford.

The discovery of gas in Africa between 2010 and 2020 represented 40% of all global gas discoveries, raising the continent's undeveloped reserves to over 5 trillion cubic metres (tcm) and placing several African nations among the top 15 in terms of proven reserves. It is also noteworthy that the development of all of Africa's untapped gas resources would result in a marginal increase in the continent's

emissions, raising them from less than 3% to just 3.5% of global energy-related CO2 emissions since 1890 [19]. Natural gas is crucial for producing industrial heat and fertilizers, fostering an industrial sector vital for Africa's economic development. Projects in Mozambique, the Democratic Republic of the Congo, and beyond could yield substantial gas supplies, ultimately supporting governments burdened by debt [17].

Despite the potential of natural gas, further measures are needed to achieve climate and development goals. Utilizing renewables to expand energy access is crucial, with 80% of Africa's primary energy generation ideally derived from renewable sources. Although Africa has 60% of the world's most favorable solar resources, it currently holds only 1% of global installed solar capacity [19].

A major obstacle remains the lack of capital for necessary infrastructure. Prioritizing industrial growth and enhanced electricity access will create the infrastructure needed for demand and economies of scale while emphasizing low-carbon sources. Natural gas can serve as baseload generation, providing a chance for Africa to grow economically and attract international investment in renewable systems.

The private sector is increasingly involved in deploying renewable energy, with initiatives like South Africa's Renewable Energy Independent Power Producer Procurement (REIPPP) program launching 95 projects with 3.27 GW capacity. Other large projects, including the Batoka Gorge hydroelectric project and the Grand Ethiopian Renaissance Dam, also exemplify progress.

However, these successes depend on financial resources. Currently, private sector infrastructure financing stands at only 12%. Expanding confidence in African markets is essential for attracting international capital. An estimated annual increase of USD 190 billion from 2026 to 2030 would allow Africa to achieve an energy mix of at least 80% renewables, with gas supporting industry, amid rising primary energy demand expected to increase fivefold by 2050 [20].

D. Assessing Africa's Green Transition Potential: A SWOT Analysis

As we consider the future of Africa's economic landscape, it is crucial to weigh the pros and cons of the green transition, which presents a complex range of opportunities and challenges that must be navigated thoughtfully. The green transition in Africa presents both opportunities and challenges that must be navigated thoughtfully to ensure sustainable economic growth and environmental protection. An analysis of these pros and cons (Table 1) provides a clearer view of the implications for the continent.

The green transition offers Africa a substantial economic opportunity through the advancement of renewable energy resources, which can stimulate industrial expansion, generate employment, and align with global sustainability goals:

- The transition towards renewable energy sources presents Africa with a significant opportunity to utilise its abundant solar, wind and hydro resources. With 60 percent of the world's most favourable solar resources, Africa has the potential to significantly transform its energy sector into a low-emissions and dependable system [1]. Furthermore, this transition could result in a reduction in dependence on fossil fuels, thereby creating an environment conducive to investment in renewable energy infrastructure, which can support industrial growth and job creation.

TABLE 1 THE PROS AND CONS OF THE GREEN TRANSITION FOR AFRICA

Pros of the Green Transition	Cons of the Green Transition
Economic Opportunities	Inadequate Infrastructure
Alignment with Global Goals	Rising Energy Access Inequality
Resilience Against Climate Change	Reliance on Resource Extraction
Diverse Employment Opportunities	Contextual Challenges

- The green transition enables African countries to align with global sustainability objectives and climate change agreements, thereby enhancing international cooperation and support. By committing to sustainable practices, African nations may potentially gain access to climate finance and technology transfer agreements that facilitate their development goals [18].
- The implementation of renewable energy technologies serves to mitigate the risks posed by climate change, which has a disproportionate impact on Africa despite its relatively low contribution to global emissions [1]. As evidenced in the discussions around climate vulnerability, green transitions can serve to enhance resilience against extreme weather events, such as droughts and floods, which have the potential to threaten agricultural productivity and economic stability [13].
- A shift towards a greener economy has the potential to create a significant number of employment opportunities in new sectors, including renewable energy, sustainable agriculture and green technologies. For instance, independent power producers in South Africa have initiated numerous projects under the Renewable Energy Independent Power Producer Procurement (REIPPP) programme, resulting in substantial advances in renewable energy capacity [17].

Nevertheless, obstacles such as insufficient infrastructure, financial limitations, growing disparities in energy access, and the dependence on resource extraction for renewable technology present considerable threats to the successful realisation of a sustainable green transition in Africa:

- One of the most significant challenges to the green transition is the lack of adequate infrastructure and financing mechanisms. It is not yet feasible to make

large-scale investments in renewable energy systems in all African markets due to the lack of adequate infrastructure. The estimated annual investment requirement of USD190 billion for the period 2026 to 2030 underscores the financial gap that must be bridged to support this transition [20].

- While the objective is to achieve a green energy future, there is a risk that energy access may become more unequal. It is estimated that over 600 million people in Africa currently lack access to electricity. Without careful planning, the push towards large-scale renewable projects may exacerbate existing inequalities, particularly in rural and underserved communities [17].
- It is possible that the green transition may necessitate the continued reliance on the extraction of critical minerals, which are required for the construction of renewable energy technologies, including batteries and solar panels. Those countries that are highly dependent on the extraction of oil, gas and minerals may be required to balance economic growth against environmental sustainability, which could result in conflicts between their development paths and green commitments [12].
- The transition to green technologies frequently necessitates the development of sophisticated infrastructure and the expansion of human capital, which can impose considerable pressure on economies that are already contending with a multitude of developmental challenges. Green technologies are frequently designed and tested in developed nations and may not align adequately with the specific contexts of Africa, potentially leading to implementation failures [21].

In order to provide a comprehensive overview of the potential implications of the green transition for Africa, an attempt has been made to summarise these implications in the form of a SWOT analysis (Table 2).

This framework offers a comprehensive overview of the internal capabilities and external challenges that Africa is confronted with as it strives to align its sustainability endeavours with economic growth. By identifying the pivotal factors that shape the transition to renewable energy, stakeholders can gain a deeper understanding of how to harness Africa's abundant resources and innovative potential, while addressing critical barriers such as inadequate infrastructure and energy access disparities. The SWOT table encapsulates these dynamics, offering insights that can inform policymakers, businesses, and the global community in fostering a sustainable future for Africa.

The SWOT analysis illuminates the complex and multifaceted landscape of Africa's green transition, elucidating both significant potential and notable challenges. On a positive note, Africa's rich natural resources, particularly those related to renewable energy, such as solar, wind, and hydro, provide a robust foundation for economic growth and an opportunity to align with global sustainability goals. This presents an opportunity for the creation of new employment opportunities and the development of industrial capacity, which could play a pivotal role in addressing the continent's high unemployment rates. Moreover, the growing global focus on climate change has opened up avenues for international collaboration and financial assistance, thereby strengthening local initiatives to adopt sustainable practices.

TABLE 2 SWOT ANALYSIS ON AFRICA'S GREEN TRANSITION

Strengths	Weaknesses
Potential for Economic Growth: The green transition promises substantial job creation and industrial growth through renewable energy initiatives **Alignment with Global Climate Goals:** Commitment to sustainability can enhance international cooperation and access to climate finance **Diverse Resource Availability:** Abundant natural resources, especially solar, wind, and hydro power, position Africa favorably for renewable energy development	**Inadequate Infrastructure:** Many African countries lack the necessary infrastructure for large-scale renewable energy investments, hindering progress **Energy Access Inequality:** Over 600 million people still lack electricity, which raises concerns about equity in energy access during the transition **Implementation Risks:** Green technologies often require advanced infrastructure and may not be suitable for local contexts, leading to potential failures
Opportunities	**Threats**
Technological Advancements: Innovations in renewable technologies present opportunities for sustainable practices to be implemented effectively across the continent **Global Support:** Enhanced international focus on climate change can lead to increased funding and technological assistance for African nations **Capacity Building:** There is an opportunity to develop local expertise and infrastructure for sustainable energy systems, fostering economic self-reliance	**Resource Dependence:** Continued reliance on natural resource extraction raises environmental sustainability concerns and may lead to conflicts over resource use **Global Economic Pressures:** Fluctuating global energy markets and the withdrawal of financial support for fossil fuel projects could impact economic stability **Climate Vulnerability:** Africa remains highly vulnerable to climate change impacts, which can undermine development gains and hinder the transition to greener practices

Conversely, the analysis identifies several weaknesses and threats that must be addressed in order to ensure the success of the transition. Inadequate infrastructure and disparities in energy access present substantial obstacles to the implementation of large-scale renewable energy projects. The risk of exacerbating existing inequalities is heightened by the fact that over 600 million people lack access to electricity, and the transition must therefore be carefully managed. Furthermore, the dependence on natural resource exploitation gives rise to concerns regarding environmental sustainability and may give rise to potential conflicts over the allocation of resources. The susceptibility to climate impacts serves to further complicate the landscape, with the potential to undermine development efforts. It is therefore imperative to address these weaknesses while leveraging the continent's strengths and opportunities in order to foster a resilient and economically viable green transition.

In conclusion, while the green transition offers significant potential for economic growth, environmental sustainability, and alignment with global climate goals in Africa, it also presents considerable challenges that must be

addressed. It is therefore essential to strike a balance between these pros and cons in order to maximise the benefits of a green transition while minimising adverse impacts on the continent's development trajectory.

E. Can circularity contribute to Africa's Green Transition: Some practical examples

The adoption and implementation of policies that can accelerate the transition to a circular economy are still in their early stages in African countries but momentum is growing [22]. Africa's development has historically focused on conventional industrialization, leading to a reliance on high-value product imports and weak connections to advanced technology and R&D [23]. In response, several African nations are pivoting towards greener economies, emphasizing local product design, reuse practices, and reducing environmental impacts. Although the conversation around circular economy principles is emerging, Africa has practiced CE implicitly through repair, reuse, and sustainable practices.

The CE is viewed as a framework that can enhance resource value, drive economic growth, and create jobs, rather than merely addressing waste management. Given the few existing CE policies on the continent, it raises the question of whether existing approaches can be supported by policy or if alternative strategies are necessary to avoid merely replicating more advanced economies' models [23].

Global trade significantly influences Africa's integration into the CE; the continent, rich in resources, has traditionally supplied raw materials, perpetuating a linear economic model. However, embracing CE principles could enhance Africa's trade dynamics by maximizing resource value, fostering local manufacturing, and lessening reliance on imports. The anticipated demand for critical metals for renewable energy may necessitate a 500% increase in mineral extraction [24]. Efforts such as investigating materials extraction linked to blockchain offer opportunities for African economies to retain more benefits from their resources.

Additionally, the CE can address trade imbalances by promoting intra-African trade and regional integration, creating sustainable supply chains, and developing local CE ecosystems. Collaboration with international partners can further facilitate this transition through technology transfer and investment support, enabling Africa to become a key player in the global CE movement.

While Africa lacks comprehensive continent-wide CE policies, initiatives such as the African Circular Economy Alliance (ACEA) exemplify rising political will to implement CE strategies. The Durban Declaration, endorsed by the African Ministerial Conference on Environment, acknowledges CE's role in economic growth, job creation, and environmental sustainability, while advocating for increased awareness and investment.

Research by ACEA highlights five sectors with immediate circularity opportunities: food systems, packaging, built environment, electronics, and fashion. These sectors present paths to improve efficiency and sustainability, but the lack of systematic CE policy studies underscores the need for comprehensive approaches to promote circular practices.

The transition to a CE in Africa is largely driven by SMEs and local innovators, supported by initiatives like the Switch Africa Green Programme. Cooperation among stakeholders – including governments, businesses, and civil society – is essential for success. Critical enablers for this transition include political commitment, stakeholder engagement, supportive policy frameworks, access to finance, and capacity building [23].

However, over 100 examples exist that highlight the importance of circular economy practices for Africa's green transition and growth [25]. We will just mention five, which illustrate the diverse applications of circular economy principles across different sectors in Africa, showcasing potential paths toward sustainability and economic resilience:

- Agriculture: LONO (Côte d'Ivoire) is a community-driven initiative that transforms agricultural waste into compost, biogas, and animal feed. By collaborating with agro-industrial companies, LONO helps local farmers convert their waste into valuable resources, promoting sustainable agricultural practices while reducing greenhouse gas emissions from waste incineration (https://www.lonoci.com/).
- E-Waste Management: WEEE Centre (Kenya) specializes in collecting and recycling electronic waste, aiming to safely manage the e-waste crisis in Kenya. By dismantling and processing electronic devices, they recover precious metals and recyclable materials, contributing to environmental protection while providing second-hand products to underserved communities (https://www.weeecentre.com/).
- Water Supply Sector: Maji Jibu Company Ltd (Tanzania) - Maji Jibu provides safe, affordable drinking water through a decentralized franchise model, equipping Tanzanian entrepreneurs to manufacture and distribute water while keeping durable plastic in circulation. Their approach focuses on minimizing plastic waste by using refillable containers, thus improving access to clean water while promoting sustainability (https://jibuco.com/).
- Construction Sector: Eco Brixs (Uganda) - Eco Brixs is a closed-loop recycling system that turns plastic waste into construction materials, addressing both environmental waste and Uganda's housing deficit. By producing innovative plastic-sand composite pavers, Eco Brixs provides an alternative to traditional materials while simultaneously creating jobs for local communities (https://www.ecobrixs.org/).
- Fashion Sector: Koliko Company Limited (Ghana) produces hand-made shoes from repurposed materials such as second-hand jeans, flour sacks, and waste car tires. This initiative not only reduces textile waste destined for landfills but also provides affordable, sustainable footwear while creating job opportunities within local communities (https://kolikowear.com/).

Africa's rich resource base and the potential for circular economy practices can significantly contribute to a green transition. The continent boasts of many skilled scholars, policymakers, and indigenous communities that can engage in a participatory approach to design effective policies and innovations that integrate circular economy practices that uphold the principles of sustainable development [26]. Emphasizing collaboration, inclusive policies, and a commitment to local contexts will help optimize economic opportunities and address environmental challenges, fostering sustainability across the continent.

IV. Conclusions

In conclusion, an objective assessment of the merits and disadvantages of the green transition reveals a broader insight into the future of Africa's pursuit of sustainable economic growth. The exploration of Africa's green transition reveals both significant potential and notable challenges in achieving sustainable economic growth. The continent, despite its minimal contribution to global greenhouse gas emissions, remains disproportionately vulnerable to climate change, facing severe environmental degradation and economic instability. This article underscores the interdependence of sustainability and economic growth, highlighting the necessity for African nations to strive for sustainable development and embrace circular economy principles as a pathway to optimize resource utilization and enhance resilience.

To maximize the benefits of this green transition, several policy recommendations emerge. Firstly, governments should prioritize investments in renewable energy infrastructure and technologies that promote sustainability, ensuring that these initiatives are integrated into national economic development plans. Legislative frameworks that encourage private sector participation, such as tax incentives and funding for renewable projects, will be essential in fostering an environment conducive to growth.

For businesses, adopting circular economy practices should become a strategic imperative. Companies can integrate sustainability into their operations by focusing on waste reduction, resource efficiency, and innovation in product design. Moreover, collaboration with local communities and other stakeholders can amplify the impact of sustainable initiatives and enhance supply chain resilience.

At the continental level, it is imperative to strengthen regional cooperation and frameworks that support a unified approach to sustainable development. The establishment of a platform for knowledge sharing among African nations can facilitate the exchange of best practices, stimulate investment, and harness the collective potential for addressing climate challenges. By aligning sustainability goals with economic policies, Africa can not only safeguard its natural resources but also position itself as a leader in the global transition to a circular economy.

In the face of climate change and resource scarcity, the imperative for Africa is clear: it must harness its vast natural resources and innovative potential to drive sustainable growth. By adopting and implementing circular economy practices, the continent can develop a more resilient economic model that prioritizes environmental responsibility. As Africa embarks on this transformative journey, fostering collaboration between governments, businesses, and local communities will be essential. Enhanced investments in sustainability, combined with a commitment to circularity, can enable Africa to not only meet its own needs but also serve as a beacon for sustainable practices globally.

Acknowledgments

This research is done within the collective research project "Circular Economy in the European Union and Its Implementation in Bulgaria", part of the scientific research program of the Economic Research Institute at the Bulgarian Academy of Sciences.

This paper is developed is with the support of the Central Strategic Development Fund at the New Bulgarian University.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 363-369

The Importance of Winter Wheat Varieties for Sustainable Cultivation under Changing Weather Conditions

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***Abstract*—The aim of this study is to assess the adaptability and productivity of winter wheat varieties under variable weather conditions by analysing grain yield, 1000-grain weight (TGW), and protein content through long-term trials, as well as evaluating the impact of nitrogen fertilisation in short-term case studies. A field trials study assesses the performance of long-established (over 13 growing seasons) and newly introduced wheat varieties (one growing season at two locations). Seven significant correlations between weather conditions and grain yield, TGW, and protein content were recorded for the varieties 'Skagen' and 'Brons' over a long-term period. 'Skagen' and 'Brons' are well-adapted to the local conditions in Latvia. Negative correlations were observed between grain yield and mean temperatures in July at Vilani ($r = -0.60$; $r = -0.73$ for both varieties), as well as between total precipitation in September ($r_{Skagen} = -0.73$) at Stende. Additionally, negative correlations were found between TGW and mean temperatures in June ($r_{Skagen} = -0.72$; $r_{Skagen} = -0.64$) at both locations, while a positive correlation was observed between total precipitation in June ($r_{Skagen} = 0.73$) at Stende. Positive correlations were also recorded between protein content and total precipitation in May and June at Vilani ($r = 0.59$; $r = 0.71$) for both varieties. Negative correlation was identified between protein contents and total precipitation in April ($r = -0.68$; $r = -0.69$) for both varieties and positive correlation mean temperatures in June ($r_{Skagen} = 0.57$) at Stende. One growing season compared the effects of nitrogen fertilisation N0, N120, N180 treatments on wheat varieties 'Bright', 'Brigens', 'KWS Ahoi', and 'KWS Imperium' at two locations. At N180, the mean values for the four varieties were significant higher at Vilani and Stende compared to the control. The highest grain yield was recorded for the variety 'Bright' at Stende and for 'KWS Ahoi' at Vilani. The variety 'Brigens' was**

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8662
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identified as having the high protein content and TGW at both locations. These findings provide insights into sustainable wheat cultivation, with a short-term study ongoing to further develop resilient growing systems.

Keywords— correlation, long-term and short-term trial, nitrogen fertilisation, varieties, weather.

I. INTRODUCTION

In Latvia, wheat has been cultivated for centuries, and the sown area of winter wheat is larger almost each year compared to spring wheat. In recent years, winter wheat has been sown on an average of over 400 thousand hectares per year. The average yield obtained is 4–5.5 t ha^{-1}. According to official statistics, the sown area of winter wheat in Latvia has significantly increased over the past 10 years – from 164.0 thousand hectares to 438.1 thousand hectares [1]. Global wheat yields and sown area are projected to increase by 2033, with the European Union expected to become the largest wheat producer [2].

The diversity of winter wheat varieties is dynamic and constantly evolving, driven by the introduction of new varieties each year aimed at enhancing yield and adaptability. Some varieties offer more stable yields and consistent quality, demonstrating less susceptibility to environmental fluctuations. In Latvia, there is an ongoing effort to develop new winter wheat varieties that are specifically adapted to the unique Baltic conditions, ensuring improved resilience and productivity in the region [3], [4]. In Nordic-Baltic conditions it is important to use varieties which are well adapted to marginal environments in order to reduce the influence of the environment on yield and grain quality parameters [5]. As new high-yielding varieties have been developed over the last few decades, their nutrient requirements have also increased [6].

Annual variations in wheat grain yield across varieties can be primarily influenced by meteorological conditions [7] – [9]. Studying the relationship between weather conditions in a specific month and crop yields is crucial due to the ongoing global warming phenomenon. Highlights that climate change leads to increased weather variability. Analysing weather patterns and their effects on yields helps predict future trends and assess the risks or benefits of global warming, enabling informed decision-making and proactive measures [10].

Wheat yield is a complex trait influenced by the genetic composition of the plant, the environmental conditions, and the interaction between genotype and environment [11]. The prevailing view that winter wheat in the northeastern part of Europe will benefit from climate change is largely based on the assumption that rising average air temperatures will be accompanied by an increase in total annual precipitation [12]. However, with more variable rainfall, droughts could occur more often in Latvia. Modelling weather changes in the UK would have little impact on wheat yield, although drier years could reduce yields, particularly in soils with lower water-holding capacity, where drought-induced yield loss could exceed 50% [13]. Increasing heat stress around anthesis is expected to cause significant yield losses in heat-sensitive wheat cultivars in Northern Europe. The crop scientists and breeders should focus on developing wheat varieties resistant to high temperatures during flowering [14]. However, due to climate warming, favourable factors such as warmer winters are also influencing yields. Nonetheless, the potential benefits of a longer thermal growing season in Northern Europe are often limited by the risk of late frosts and early spring and summer heatwaves [15].

The effect of mineral fertilizers also depends on weather conditions [10]. The fertile soils with high water retention enable nitrogen to play a key role in maintaining wheat yields, even under dry conditions. Model simulations suggest that under low or moderate input, nitrogen will remain a major limiting factor for increasing winter wheat yield potential in the coming decades [12]. Therefore, efforts should focus on improving nitrogen efficiency, considering both nitrogen and climatic factors [16].

Overall, the study in Latvia suggests that winter wheat yield was influenced by 34% by cultivar, 33% by weather conditions, and 13% by the crop-year cultivar, with a small effect of nitrogen fertiliser at 3% [17].

This field study focuses on the most widely grown varieties over the long-term, as well as those with the greatest potential in recent years. The aim is to evaluate the adaptability of winter wheat varieties under variable meteorological conditions by analysing grain yield, 1000-grain weight, and protein content through a long-term trial. Additionally, a short-term case study assesses the productivity of different varieties and the impact of nitrogen fertilisation, contributing to the development of resilient and sustainable wheat cultivation practices.

II. MATERIALS AND METHODS

A. Experimental place

Field trials were conducted over 13 growing seasons (from September 2011 to August 2024) at the Agricultural Scientific Centre of Latgale, Vilani and the Institute of Agricultural Resources and Economics (AREI), Stende. This study evaluates the performance of long-term trials for the wheat varieties 'Skagen' and 'Brons'. The objective of the trial was to analyze the impact of weather conditions on the variability of grain yield, 1000-grain weight (TGW), and protein content in winter wheat. Winter wheat varieties were sown at a rate of 450–500 germinable seeds m^{-2}. The main agrochemical parameters are presented in Table 1.

Over the long term, complex mineral fertiliser NPK was applied annually at various ratios, with a rate of 300 kg ha^{-1}. Additional fertilisation was carried out with ammonium nitrate (34N + S) at an N rate of 150 kg ha^{-1} at Vilani. At Stende, either ammonium nitrate (34N + S) or N27-S4 was applied at an N rate of 120–150 kg ha^{-1}, depending on spring climatic conditions. Nitrogen fertilisers were applied twice during the wheat growing season: in spring (BBCH 22–23) and a second during stem elongation (BBCH 32).

Additional results from the 2023/2024 season compare the performance of prospective wheat varieties 'Bright', 'Brigens', 'KWS Ahoi', and 'KWS Imperium' at two locations: AREI in Vilani and Stende. This study examines the effects of nitrogen fertilisation treatments (control - N0, N120, N180) on grain yield, TGW, and protein content in winter wheat varieties. Both locations applied N at rates of 120 kg ha^{-1} and 180 kg ha^{-1}, with ammonium nitrate (34N + S) used at Vilani and N27-S4 at Stende. Nitrogen fertilisers were applied three times during the wheat growing season: in spring (BBCH 22–23), during stem elongation (BBCH 32), and at the beginning of heading (BBCH 51).

In both long-term and short-term field trials, plant protection measures are organized taking into account the situation in the field, following the generally accepted integrated pest management practice for weed and disease control in wheat growing technologies. Except for the short-term trials, the N0 control variant was not treated with any plant protection products.

Grain yield was recalculated to 100% purity and a base moisture content of 14%. Grain quality indicators, protein content, were analysed using the express method (Infratec Nova 6). The thousand-grain weight (TGW) was determined according to the ISTA (International Seed Testing Association) methodology.

TABLE 1 THE MAIN AGROCHEMICAL PARAMETERS OF THE ARABLE SOIL LAYER DURING 13 GROWING SEASONS

Location	***Organic matter contents, %***	***Soil acidity (pH_{KCl})***	***Available P_2O_5, mg kg^{-1}***	***Available K_2O, mg kg^{-1}***
Stende	2.0±0.3	5.7±0.1	161.0±18.4	151.2±20.8
Vilani	4.2±2.5	6.7±0.3	117.2±42.9	125.2±20.1

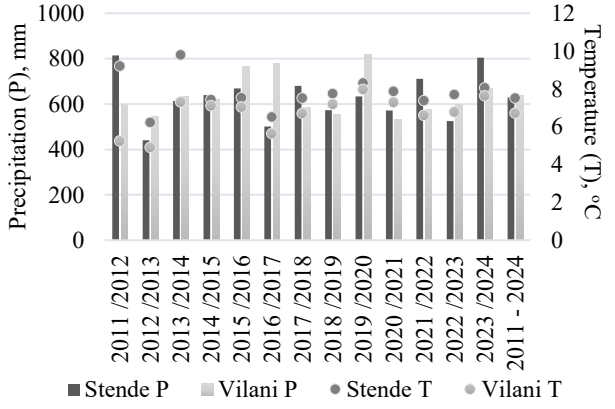

Fig. 1. Meteorological conditions from September 2011 to August 2024.

B. Meteorological conditions

Agro-meteorological conditions for Vilani were characterised using data from the Rezekne station, and for Stende, data from the Stende hydrometeorological station (Fig. 1).

C. Statistical analysis

Software JASP was used for data statistical analysis. The difference between the yields properties were determined using analysis of variance (ANOVA). Significant differences among the measured characteristics of wheat varieties were compared by Fisher's protected least significant difference (LSD) tests ($p \leq 0.05$). The Pearson correlation coefficient was used to analyse the relationships between grain yield, TGW, and protein content with daily mean temperature and precipitation during the vegetation period with significant difference $p < 0.05$ and $p < 0.01$.

III. RESULTS AND DISCUSSION

The results indicate variations in yield, protein content, and 1000-grain weight (TGW) over a 13-year period. The average yield exhibited a wider range, varying from 5.61 to 12.78 t ha^{-1} for the variety 'Skagen' at Vilani and from 6.01 to 12.84 t ha^{-1} for 'Brons' at Stende (Table 2). The variety 'Skagen' has been cultivated in Latvia for a longer period, whereas 'Brons' was introduced in later years. The varieties at both locations demonstrate the potential to achieve yields exceeding 12 t ha^{-1}. These results suggest that both 'Skagen' and 'Brons' are adaptable to local growing conditions and can achieve high yields under favourable conditions. Yield variation reflects the influence of factors such as weather, soil quality, and agronomic practices, highlighting the need for further research to optimise and ensure stable yield performance.

TABLE 2 WINTER WHEAT YIELD BY VARIETY AND LOCATION OVER MULTIPLE YEARS

Variety	***Location (Years)***	***Yield, t ha^{-1}***		
		mean ± SD	***min.***	***max.***
Skagen	Vilani (2012-2024)	9.38 ± 1.93	5.61	12.78
	Stende (2012-2024)	9.25 ± 2.18	6.23	12.28
Brons	Vilani (2013 – 2023)	10.03 ± 1.24	8.78	12.40
	Stende (2015-2024)	8.59 ± 2.21	6.02	12.84

The average 1000-grain weight of winter wheat was higher for the variety 'Skagen' at both locations, with a range from 29.03 to 58.90 g (Table 3). TGW was determined primarily by the variety.

TABLE 3 WINTER WHEAT 1000-GRAIN WEIGHT BY VARIETY AND LOCATION OVER MULTIPLE YEARS

Variety	***Location (Years)***	***TGW, g***		
		mean ± SD	***min.***	***max.***
Skagen	Vilani (2012-2024)	44.73 ± 6.83	29.03	53.20
	Stende (2012-2024)	47.39 ± 6.20	38.55	58.90
Brons	Vilani (2013 – 2023)	41.26 ± 5.48	31.06	47.70
	Stende (2015-2024)	39.79 ± 5.32	32.11	45.80

The protein content was higher for 'Skagen' at both locations, with a wider range from 10.54% to 15.33% at Stende (Table 4). The variety 'Skagen' is more suitable in certain years for food quality, reaching 12%.

TABLE 4 WINTER WHEAT PROTEIN CONTENT BY VARIETY AND LOCATION OVER MULTIPLE YEARS

Variety	*Location (Years)*	*Protein content, %*		
		mean ± SD	*min.*	*max.*
Skagen	Vilani (2012-2024)	13.03 ± 1.01	11.40	15.20
	Stende (2012-2024)	12.93 ± 1.71	10.54	15.33
Brons	Vilani (2013 – 2023)	12.36 ± 0.71	11.30	13.70
	Stende (2015-2024)	11.97 ± 1.08	10.39	13.23

A correlation analysis was conducted to assess the relationship between weather conditions in specific months and yield, 1000-grain weight (TGW), and protein content. Seven relationships were found to be statistically significant.

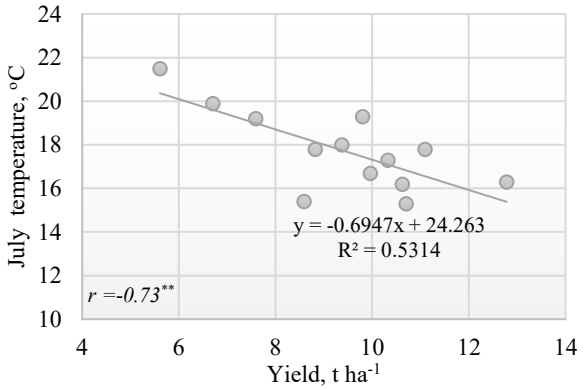

Fig. 2. Correlation of winter wheat 'Skagen' yield with July average temperature at Vilani.

Negative correlations were observed between grain yield and mean temperatures in July at Vilani (r = −0.60; r = −0.73 for both varieties), as well as between total precipitation in September during the sowing period (r = −0.73 for 'Skagen') at Stende (Figs. 2., 3., 4.). These results suggest that higher temperatures in July during the grain-filling period may negatively impact grain yield, potentially through increased evaporation or heat stress, which can limit the plant's ability to accumulate dry matter. Similar results [18] were found in another modelling study in Latvia, showing a negative correlation between July temperatures and winter wheat yield. In Stende, the negative correlation with July temperature is weaker. Observing higher average July temperatures in Vilani in certain years may indicate regional differences in variety adaptability. In this study lowest grain yield was observed at a critical average daily temperature of 21.5°C in July for both varieties at Vilani. The study by [19] indicates that the optimum temperature for wheat growth is between 15 °C and 20 °C. It is estimated that for every 1°C increase in temperature, the duration of grain filling in wheat decreases by 2.8 days [20], which results in a yield reduction of approximately 6% [21]. An increase in the average ambient temperature is not only due to rising maximum temperatures but also growing minimum temperatures [22]. In this study [23] found a stronger correlation between wheat grain yield and minimum temperature than with maximum temperature, estimating a 10% yield decrease for every 1°C rise in night temperature.

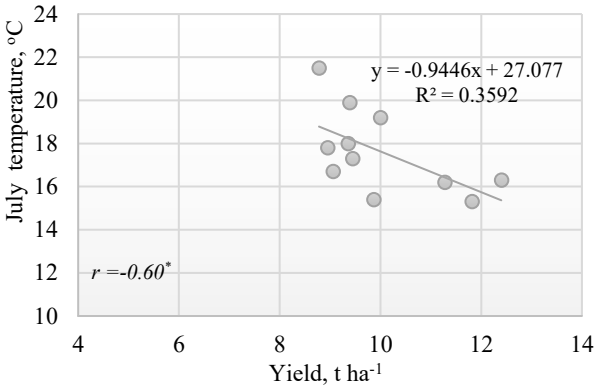

Fig. 3. Correlation of winter wheat 'Brons' yield with July average temperature at Vilani.

The strong negative correlation between September precipitation and yield in 'Skagen' at Stende suggests that excessive moisture during the sowing period can interfere with crop establishment. Lower grain yields were identified with September precipitation ranging from 134.10 to 152.40 mm, which had a negative impact over two years. This could result in poor germination, uneven emergence, or waterlogging, all of which can hinder early growth.

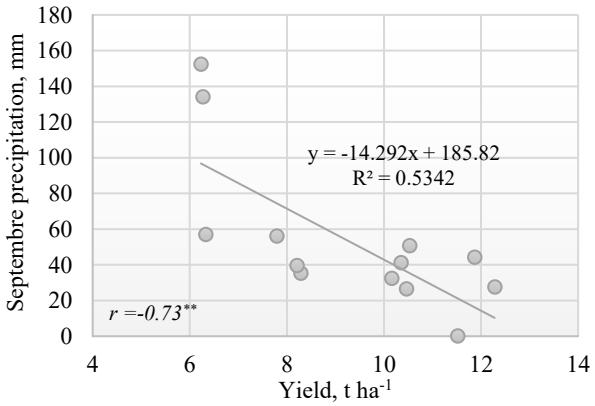

Fig. 4. Correlation of winter wheat 'Skagen' yield with September total precipitation at Stende.

Protein content and TGW interaction with weather conditions across different Latvian regions have not been extensively studied. However, the results indicate regional differences and varietal adaptability. Additionally, negative correlations were found between TGW and mean temperatures in June ($r_{Skagen} = -0.72$; $r_{Skagen} = -0.64$) at both locations, while a positive correlation was observed between total precipitation in June ($r_{Skagen} = 0.73$) at Stende (Table 5). These results indicate that higher mean temperatures in June negatively affect TGW, while increased precipitation in June positively influences TGW at Stende. This suggests that warmer conditions may reduce grain weight, possibly due to heat stress, while higher moisture availability supports grain development and yield productivity.

TABLE 5 CORRELATION OF WINTER WHEAT TGW AND PROTEIN CONTENT WITH MONTHLY TEMPERATURE AND PRECIPITATION

Variety	*Location*	$r_{April\ P}$	$r_{May\ P}$	$r_{Jun\ P}$	$r_{Jun\ T}$
TGW					
Skagen	Vilani			0.06	-0.71**
	Stende			0.73**	-0.64*
Brons	Vilani			0.42	-0.12
	Stende			-0.33	-0.46
Protein content					
Skagen	Vilani	-0.16	0.47	0.59*	-0.09
	Stende	-0.68*	-0.43	-0.43	0.57*
Brons	Vilani	0.10	0.71**	0.42	-0.12
	Stende	-0.69**	-0.26	0.40	0.45

* $p < 0.05$, ** $p < 0.01$

Positive correlations were observed between protein content and total precipitation in May and June at Vilani ($r = 0.59$; $r = 0.71$) for both varieties (Table 5). Increased precipitation in May and June positively affects protein content. A negative correlation was found between protein content and total precipitation at Stende in April ($r = -0.68$; $r = -0.69$) for both varieties, while a positive correlation was identified between protein content and mean temperatures in June ($r_{Skagen} = 0.57$). This suggests that higher precipitation in April may reduce protein content, while warmer temperatures in June may have a greater impact on protein synthesis for wheats variety at Stende. According to [24], [25] protein content increases under drought and heat stress during grain formation and filling, and decreases under optimal weather conditions. Studies [26], [27] reveal that weather interactions during anthesis and mid-grain filling influence TGW and protein content, depending on the variety.

TABLE 6 YIELD (T HA^{-1}) OF WINTER WHEAT VARIETIES BY LOCATION AND VARIETY DURING THE 2023/2024 GROWING PERIOD

N, kg ha^{-1}	*Bright*	*Brigens*	*Ahoi*	*Imperium*	*Mean* ^{A}
Vilani					
0	5.23	5.27	5.23	4.37	5.02
120	6.64	6.31	6.72	4.58	**6.06**
180	7.36	7.39	7.52	5.51	**6.95**
Mean ^{B}	**6.41**	**6.32**	**6.49**	4.82	
A factor $LSD_{0.05} = 0.30$; B factor $LSD_{0.05} = 0.35$					
Stende					
0	1.54	1.27	1.24	1.43	1.37
120	3.89	3.95	3.72	3.55	**3.78**
180	5.83	5.28	5.48	5.48	**5.51**
Mean ^{B}	3.75	3.50	3.48	3.49	
A factor $LSD_{0.05} = 0.34$; B factor $LSD_{0.05} = 0.40$					

$^{A, B}$ with bold significant difference ($p < 0.05$)

This study compared long-term and short-term results, indicating that the climatic conditions during the 2023/2024 growing period affected lower grain yield, protein content, and 1000-grain weight for all prospective varieties at both locations.

Grain yield was comparable across all varieties, with the exception of variety 'Imperium', which exhibited a significantly lower yield at Vilani (Table 6). The highest grain yield was recorded for the variety 'Bright' at Stende (5.25 t ha^{-1}) and for 'Ahoi' at Vilani (7.52 t ha^{-1}) under the N180 rate. Due to high soil organic matter at Vilani, relatively high yields were observed even at N0, and the effect of nitrogen was less pronounced than at Stende. N treatment had a significant impact on yield, with the highest yield observed at N180, particularly in Stende. Several studies in Latvia have shown that grain yield increases when nitrogen rates are raised to 180 kg ha^{-1} N. Beyond this point, further increases in nitrogen application do not result in significant yield growth, but grain quality indicators continue to improve [6].

TABLE 7 PROTEIN CONTENT (%) OF WINTER WHEAT VARIETIES BY LOCATION AND VARIETY DURING THE 2023/2024 GROWING PERIOD

N, kg ha^{-1}	*Bright*	*Brigens*	*Ahoi*	*Imperium*	*Mean* ^{A}
Vilani					
0	10.02	9.95	9.50	9.83	9.83
120	10.82	10.91	10.19	11.59	**10.87**
180	11.72	11.66	11.10	12.29	**11.69**
Mean ^{B}	**10.85**	**10.84**	10.26	**11.24**	
A factor $LSD_{0.05} = 0.50$; B factor $LSD_{0.05} = 0.54$					
Stende					
0	9.18	10.18	9.18	9.13	9.41
120	10.16	10.85	10.02	10.52	**10.38**
180	12.69	13.06	12.92	12.25	**12.73**
Mean ^{B}	10.68	**11.36**	10.71	10.63	
A factor $LSD_{0.05} = 0.26$; B factor $LSD_{0.05} = 0.31$					

$^{A, B}$ with bold significant difference ($p < 0.05$)

Protein content was more variety-specific, with significantly higher levels for 'Brigen' at both locations, as well as for 'Imperium' and 'Bright' at Vilani (Table 7). N treatment had a significant impact at both N120 and N180 compared to the control. The highest protein content was observed with the N180 treatment at both locations, indicating a strong positive effect of higher nitrogen application on protein accumulation. The standard protein content for food-quality wheat grain is 12%. This quality was achieved by almost all varieties under the N180 rate, except for the variety 'Ahoi' at Vilani. A study in Latvia [16] and research in Germany [28] both found that an N rate of 180 kg ha^{-1} is crucial for achieving protein content suitable for bread baking, highlighting the importance of optimal fertilisation for wheat quality.

TABLE 8 1000-GRAIN WEIGHT (G) OF WINTER WHEAT VARIETIES BY LOCATION AND VARIETY DURING THE 2023/2024 GROWING PERIOD

N	*Bright*	*Brigens*	*Ahoi*	*Imperium*	*Mean* ^{A}
Vilani					
0	39.28	35.27	35.69	36.59	36.71
120	39.79	35.49	33.93	35.25	36.11
180	43.18	40.68	37.83	39.64	**40.33**
Mean ^{B}	**40.75**	**37.15**	35.81	**37.16**	
A factor $LSD_{0.05} = 1.08$; B factor $LSD_{0.05} = 0.94$					
Stende					
0	27.44	30.61	28.14	28.83	28.75
120	28.91	29.23	27.92	30.11	29.04
180	33.15	34.56	29.79	34.07	**32.89**
Mean ^{B}	29.84	**31.47**	28.62	**31.00**	
A factor $LSD_{0.05} = 1.26$; B factor $LSD_{0.05} = 1.09$					

$^{A, B}$ with bold significant difference ($p < 0.05$)

The results for the 1000-grain weight of winter wheat varieties showed that 'Brigens' and 'Imperium' had higher potential at both locations, while 'Bright' also had a higher weight at Vilani. Coarser grains were observed at Vilani (Table 8). The N180 treatment had a higher impact on

thousand-grain weight for all varieties and locations compared to the control, highlighting the positive effect of higher nitrogen application on grain size. Effect of N-rate on TGW is also shown by [16], [17].

At N180, the mean values for the four varieties were higher at Vilani, with yield increasing average by 130%, protein content by 16%, and TGW by 6% and at Stende, yield increased by 241%, protein content by 23%, and TGW by 8% compared to the control (Fig. 5). These results confirm that higher N treatment significantly impacted grain yield across all varieties. The findings suggest that the effect of nitrogen is more pronounced at Stende, likely due to differing soil and environmental conditions between the two locations.

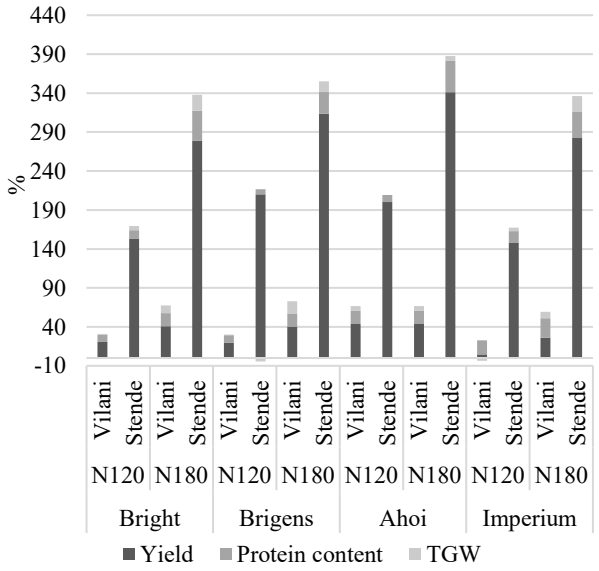

Fig. 5. Yield, protein, and TGW changes by N treatment compared to control during the 2023/2024 growing period.

IV. Conclusions

'Skagen' and 'Brons' are well-adapted to local conditions and can achieve yields exceeding 12 t ha^{-1}, with protein content ranging from 10.54% to 15.33% and TGW ranging from 29.03 to 58.90 g under Latvian climatic conditions.

Analysis of the interaction with weather conditions identified seven significant correlations, providing further insights due to future climatic and agronomic challenges. Negative correlations were observed between grain yield and mean temperatures in July at Vilani ($r = -0.60$; $r = -0.73$ for both varieties), as well as between total precipitation in September ($r_{Skagen} = -0.73$) at Stende. Additionally, negative correlations were found between TGW and mean temperatures in June ($r_{Skagen} = -0.72$; $r_{Skagen} = -0.64$) at both locations, while a positive correlation was observed between total precipitation in June ($r_{Skagen} = 0.73$) at Stende. Positive correlations were also recorded between protein content and total precipitation in May and June at Vilani ($r = 0.59$; $r = 0.71$) for both varieties. Negative correlation was identified between protein contents and total precipitation in April ($r = -0.68$; $r = -0.69$) for both varieties and positive correlation mean temperatures in June ($r_{Skagen} = 0.57$) at Stende.

One growing season compared the effects of nitrogen fertilisation treatments on wheat varieties 'Bright', 'Brigens', 'KWS Ahoi', and 'KWS Imperium' at two locations. The application of N180 significantly increased yield, protein content, and TGW at both Vilani and Stende. Results highlight the positive effects of N180 on crop performance, with particularly strong benefits observed at Stende. The highest grain yield was recorded for the variety 'Bright' at Stende (5.25 t ha^{-1}) and for 'KWS Ahoi' at Vilani (7.52 t ha^{-1}). The variety 'Brigens' was identified as having the highest protein content and TGW at both locations. These findings provide insights into sustainable wheat cultivation, with a short-term study ongoing to further develop resilient growing systems.

Acknowledgments

State Research Programme Project: "Research-based solutions for sustainable agri-food system addressed to the European Green Deal objectives" (GreenAgroRes). Nr. VPP-ZM-VRIIILA-2024/1-0002.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 371-375

Development of an Autonomous System for Control of the Irrigation Regime of Agricultural Production in a Greenhouse

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***Abstract*— Water is known to be a chemical compound and plays an essential role in sustaining life on our planet. Fresh water on earth is only 2.5% and the problems with the drought of the regions are known. Therefore, its sparing use will contribute to reducing this effect. This requires the revision of some of the policies of the agricultural sector and the implementation of new and innovative irrigation solutions. Through irrigation and their root system, plants grow and develop. The application of a proper irrigation regime will contribute to a reduction in water use. In this study, an attempt has been made to create an autonomous system for determining and applying the irrigation regime of plants. For this purpose, a greenhouse was used for the industrial production of cucumbers. A soil moisture sensor is used, and the signal is processed by software developed for this purpose, which produces a control signal for the beginning and end of the irrigation process. The process is controlled autonomously, depending on the current state of humidity and when a certain value is reached, the process is terminated. The sensor part is made of standard soil moisture sensors, and the control part is entrusted to a single-board computer with the ability to control via a wireless network.**

Keywords — automatic control, irrigation mode, sensors, agricultural production, greenhouse.

I. INTRODUCTION

Climate change is having a serious impact on freshwater systems. Rising sea levels will increase areas of saline groundwater, and this will lead to a decrease in fresh water. An increase in rainfall intensity will lead to flood and drought risks in many areas [1,2,3,4].

Water is an extremely important chemical compound for all forms of life on our planet. It is necessary for the implementation of a number of human activities. Water losses occur in any system and it is necessary to limit them by maintaining their good technical condition. Due to the optimization of the costs of water production and the need to protect water resources, rational reduction of water losses should be a priority [5].

In modern society, one of the tasks of greenhouse vegetable production is related to the performance of social functions aimed at year-round supply of the population with fresh vegetables as a rich source of nutrients necessary to maintain the health and viability of the human body [6,7].

Greenhouse farming has become popular over the past three decades. The controlled environment in greenhouses is an ideal place to grow crops in the off-season and increase their productivity. Greenhouse automation is the appropriate tool for full monitoring and control of the

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8667
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environment and has a dramatic, social and economic impact. Greenhouses are translucent glass or plastic structures for accelerated cultivation of crops. They allow for more efficient use of water and daylight [8,9,10]. Proper irrigation is key to improving the quality and productivity of crops grown in greenhouses. The time, duration, type and quantity of irrigation are essential to optimize water use. Various irrigation systems can be used, such as: manual watering, top sprinkler system, mobile irrigation boom, flooded floor, drip irrigation, capillary pad and hydroponics. However, drip irrigation is best suited for greenhouses in terms of efficient use of available water. The moisture content of the soil determines the timing of irrigation and therefore continuous monitoring is necessary to decide exactly when irrigation should begin [11,12].

Precise control of the greenhouse environment is crucial to achieving the best and most efficient environment and cultivation efficiency. In the beginning, operating greenhouses was as simple as pulling a circuit to open or close a vent, turning a valve to control heating or irrigation, or pressing a switch to activate a pump or fan. Over the years, this has evolved as greenhouse systems themselves have become more complex and more reliable [9,10].

II. MATERIALS AND METHODS

The development of the modernization system is carried out on the farm of ZP Katya Popova.

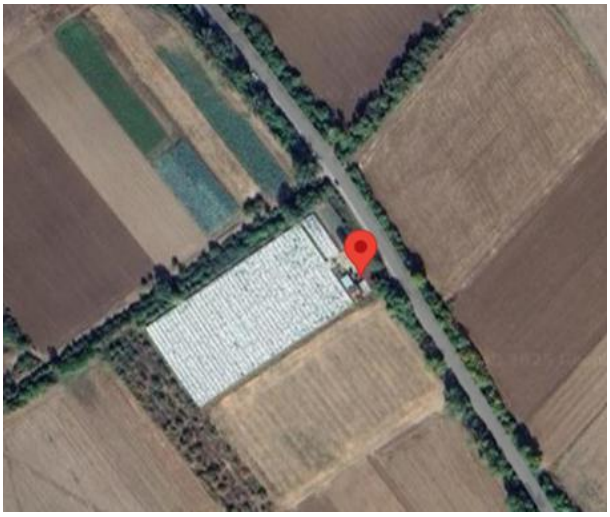

Fig. 1. Satellite photo of the location of the greenhouse.

It is located in the village of Bolyartsi, Plovdiv region, Bulgaria. An old available greenhouse with a drip installation for irrigation is used. The location of the greenhouse is 42°04'24.5"N 24°56'46.5"E (Fig. 1). The automation is done on a glass greenhouse, which is located on an area of 0.72 ha (Fig. 2).

The dimensions of the greenhouse are 60 x 120 m. The structure of the greenhouse is glass with a metal frame. It is divided into two blocks with a path of 2 m between them for loading and unloading activities. The height of the greenhouse to the eaves is 4 m. The volume of the greenhouse is 28,800 m3. Plant production is grown directly into the soil.

Fig. 2. General view of the greenhouse.

The irrigation system consists of a pump group with suction part 1, safety valve 2, check valve 3, filter group 4, detergent application equipment 5, pressure regulator 10, contact pressure gauge 11, pipe mesh 6-9 (Fig. 3) [12]. Water is extracted from a borehole, through the pumping group. The control of the pumping group is entrusted to the programmer "CEPEX" [13]. It can be used to program the switching on and off of the pumping group in a certain time range, but it cannot control the irrigation regime when the microclimate in the greenhouse changes.

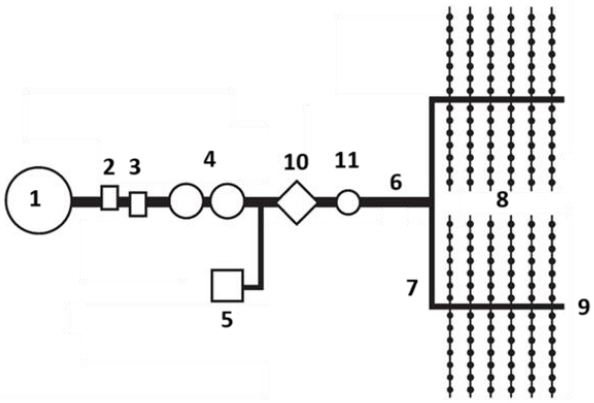

Fig. 3. Scheme of the irrigation installation.

1-pump with suction; 2-safety valve; 3-check valve; 4-filter group; 5-equipment for the application of preparations; 6-transport pipeline; 7-distribution pipeline; 8-drip pipeline; 9-irrigation battery, 10-pressure regulator, 11-pressure gauge

The electrical part of the system is secured by appropriate fuses. The pipe part is secured by the contact pressure gauge 11, the pressure regulator 10, the safety valve 2 and the check valve 3, connected to the outlet pipe of the pump group. It turns on and off the power supply to the pump group when the pressure in the pipe part is exceeded.

The outlet system works when the pump is turned on, the pressure in the irrigation battery 9 is increased and from there it is supplied directly to the drip pipeline 8. If necessary, each battery can be manually stopped.

The culture grown in the greenhouse is cucumbers.

III. Results and Discussion

According to what has been said so far, it is necessary to approach it in a way with minimal changes to the installation. In accordance with the above, the implementation of automated control of the irrigation regime and water fog for plants in order to obtain sufficient air humidity has been chosen.

The flowchart of operation of the automated system is shown in Fig. 4.

The system relies on two circles. The first round serves to start the irrigation regime from the pipelines for the drops, and the second circle serves for additional dew of the air in the microclimate of the greenhouse. An innovative solution is the installation of a second controllable circuit for the water fog system with humidity control.

The logical part of the automated system is implemented by the single-board controller ESP 32 [14]. Each controller is equipped with the separate air humidity and soil moisture sensors for each row. Each controller produces a control signal to the executive units.

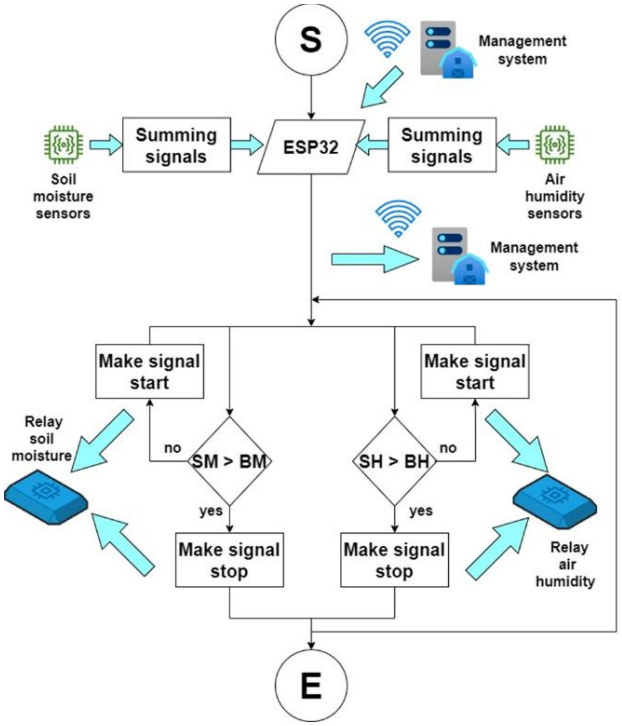

Fig. 4. Flowchart of the operation of the automated system.

Fig. 5. Data from analog inputs.

The ESP 32 receives instructions for the values of the monitored parameters via wifi and a special data transfer protocol. Through the ESP 32 protocol, it communicates with a central computer with user software installed. A request for the required soil moisture and air humidity is sent. The current values measured by the sensors are sent to the user software. They can serve to analyze the veracity of the decisions made. The computer and ESP 32 can work on different networks. The data refresh is every minute.

At the length of each row of the greenhouse of 29 m, four HD-38 sensors were used for two rows to determine soil moisture, located at an even distance from each other [15,16]. According to the design of the greenhouse and the heating installation, the rows are paired. In the greenhouse, there are 40 paired rows in each field. The staggered arrangement of the sensors in both rows is appropriate, thus shortening the number of sensors. The distance between two sensors varies between 7 and 8 m. Three DHT-22 sensors are used to determine the air humidity for every two rows [17]. They are located evenly from each other and in a checkerboard pattern in the space above the plants (Fig. 5), with a distance between them in the range of 9 to 15 m.

With these sensors, the irrigation regime and water fog of each individual row can be controlled. Depending on its distance, a transmitter is installed to each sensor. It prevents signal attenuation.

The actuator in the system is a controllable relay through ESP 32, which turns on or off the power supply to the MV07 solenoid valve (Fig. 6) mounted on the drip pipeline immediately after the irrigation battery [18]. The valve stops and releases water from the irrigation battery to the drip line. For the current development, two valves are needed every two rows - one for the drip pipeline and one for air dew. The drip pipeline has been redesigned, and a triple distributor is connected to the outlet of the solenoid valve, supplying both rows at the same time. Unused outlets from the irrigation battery are closed. For reliable operation of the controller, it is

necessary to use additional power relays to control the valves.

Fig. 6. Sample version of a solenoid valve.

The use of a wifi connection for communication between the individual ESP 32 and the control computer is a suitable option due to the large volume of communication devices and reduced the cable installation. Additional amplification of the network signal is required due to its attenuation in the greenhouse. A router with appropriate parameters is also needed. It is important to note that the exposed elements of the system operate in high humidity and must be provided with an appropriate degree of protection.

The control software has the ability to turn the system on or off entirely. This is achieved by additional controllable relays via wifi. One relay controls the switching on and off of the power supply to the pump group, and the other relay supplies supply voltage to the ESP modules. They are powered via a wired network from the controlled wifi relay. When the system is initialized, a control signal is generated to turn on the two relays.

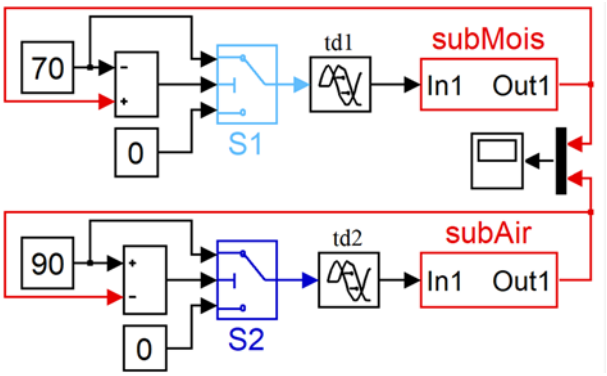

Fig. 7. Logic Element Simulation Model for Each Row.

According to the scheme of work from Fig. 4 ESP32 collects data from soil moisture and air humidity sensors. Because the sensors are located along the entire length of the row, they feed information at the same time. ESP 32 processes the information and creates average values for soil moisture SM and air humidity separately SH. At the same time, information about the desired values of these parameters BM and BH is received via wifi via wifi. In a constant cycle, the control algorithm in ESP 32 compares the two values SM to BM, as well as SH to BH. The logic conditions are SM>BM and SH>BM. In case of failure to meet any of the logical conditions, a control signal is generated to connect the corresponding command relay connected to ESP 32 and the cycle is repeated. The repetition of the cycle continues until the logical condition is positively met, after which a control signal is generated to turn off the corresponding command relay. The two cycles run in parallel and independently of each other. After either of the two cycles is exited, the ESP 32 system returns to the beginning of the logical conditions and the comparison of values begins again. The process is continuous until the power supply to the system is interrupted by the signal of the control computer for the system. Before starting a comparison of the average value with the baseline, ESP 32 returns to the control computer the corresponding current average value. In the user software, it is possible to monitor each value of the respective ESP 32 and set its threshold values. Thus, it is possible to autonomously adjust the parameters of each of the rows of the greenhouse.

The logical part itself is executed according to the simulation model shown in Fig. 7. It is implemented in the memory of ESP 32.

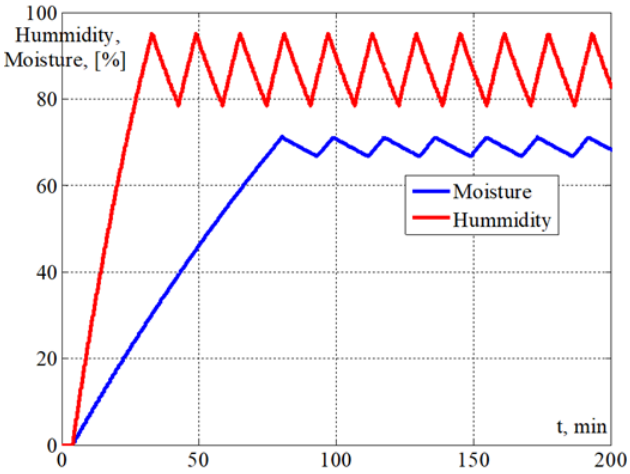

Fig. 8. Sample time diagram of the simulated controlled process.

With the blocks td1=4min and td2=4min, the transport delay from the moment of switching the relay to the flow of the drop or the mist is obtained. The blocks S1 (u2>threshold=2) and S2 (u2>threshold=5) are the logical keys that switch. S1 is responsible for soil moisture, and S1 is responsible for air humidity. The hysteresis for soil moisture is 2, and for air humidity 5. The system is closed with feedback. The signal from the average value of the respective SM or SH sensors of the ESP 32 is fed at the feedbacks. At position 70, the base values BM for soil moisture are set and for air humidity BH is given to position 90. The object of control soil or

air is generated by the two blocks sub. During the recalculation in them, the volume of air in the greenhouse and the area of the surface layer of the soil are taken into account. The control generating signal is taken from the oscilloscope.

In figure 8 shows an example of the simulated process of regulating air and soil humidity for a time of 200 minutes.

IV. CONCLUSIONS

An existing irrigation installation has been converted into a greenhouse with elements of automatic control of the irrigation regime depending on the humidity. The rework includes the replacement of the control relay of the pump group, the rework of the irrigation batteries and the installation of an additional pipe mesh for water fog.

The addition of a sensor network to the existing ESP 32 controller system helps to accurately determine the humidity in different areas of the greenhouse. In addition to soil moisture sensors, air humidity sensors are also used. Through them, the necessary microclimatic conditions for growing plants are achieved.

The simulation of the control algorithm shows the stability and autonomy of the controlled process. An opportunity has been created for the integration of additional control processes. They are not part of the object of current development, but can be used in future developments. Such are control of ventilation in the greenhouse, lowering the temperature of the surface of plants through water fog, etc.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 377-382

Technology and Community Engagement in Sensitive Contexts: Reflections on Two Site-Specific Sámi Art Projects

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Abstract—Aligned with Sami Center for Contemporary Art (SDG)'s vision to foster cultural and artistic engagement within and beyond the Sámi community, it is important to explore the role of technology applied in the center. This research examines two cases: within an artist talk, and in the form of 3D printing and interactive DIY electronics within the Techno-Lab project, which included a virtual reality (VR) application as part of the installation. As the only place in Karasjok where visitors could experience VR or create prototypes, the center became a meeting point for those interested in art and technology. This study focuses on the authors' experiences as facilitators in these projects. The research question asks: How can non-Sámi facilitators critically engage with and interpret the dynamic interactions between technology and the local Sámi community in the context of two artistic projects involving trauma-related content? Arts-based research was adopted as the research strategy. The data include field notes, drawings, and photos from the two cases, which were analyzed using a general inductive analysis approach by both authors. The results broadened the authors' understanding of the Sámi community's needs from both physical and emotional perspectives. They also propose a new conceptualization of technology, considering the perspectives of the Indigenous community—particularly marginalized Sámi women—as well as historical contexts. The results highlight the importance of both language and cultural translation within and beyond the Sámi community. Additionally, the authors' reflections on their positionality emphasize the value of fostering an equitable environment where community members, as relative outsiders to different experiences, can learn from one another and share their knowledge. The research provides recommendations on facilitating technology-based community engagement in artistic institutions working with sensitive topics. These findings are valuable for fostering Indigenous autonomy and supporting practitioners at the intersection of technology and facilitation.

Keywords—Technology, Sami, Community Engagement, Arts-based Research

I. INTRODUCTION

This study explores technology-based interactions and audience communications at an art center in the Indigenous Sami community, building on two cases. The study uses the following terms: Technology refers to the site-specific technology used during an artist talk, such as microphones, as well as technology used in a Techno-Lab project, such as three-dimensional (3D) printers and virtual reality (VR) experiences, in the case of Silja Somby. Facilitation means creating a meeting space between artists, audiences, and creative processes. Sensitive content refers to the Sámi context of projects in this community and artistic projects addressing themes of violence in close relationships and historical trauma.

The artist talk was conducted at the Sami Center for Contemporary Art (SDG) based on an exhibition created by artist Marte Lill Somby. The curator was Marija Griniuk, and the moderator was Shasha Mi. The exhibition consisted of two projects. One, a collective project called Skrevet i Stein (Written in Stone), was created by artists and "Sámi women who have experienced violence in close relationships in Sápmi" [1]. The other focused on the artist's self-exploration, her identity, and reflections on her life experiences, which addressed "themes such as abuse, mental health, and death" [2]. The purpose of the artist talk was to tell the stories behind the exhibition, focusing on the art-making process and facilitation—for instance, how the artist approached and interacted with other participants, fostered dialogue with the local audience, and exchanged

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8702
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cultural perspectives with the moderator, who has similar artistic and practical experience working with gender-based violence survivors in Fukuoka, Japan. During the artist talk, microphones and lighting were used to engage the audience (Figure 1).

Fig. 1. Spatial arrangement of the artist talk. Photo: Marija Griniuk..

As the second case, we explore the Techno-Lab project staged at the SDG in 2023, which involved a VR experience arranged by the artist Silja Somby. One of this paper's authors, Griniuk, served as the project manager and developer for Techno-Lab and the curator for the VR experience. The Techno-Lab project focused on making the technology and do-it-yourself (DIY) culture of Karasjok known to a broad range of visitors. Techno-Lab was supported by Sparebank Nord-Norge as a pilot project to test whether such a workshop space could potentially be converted to a FabLab format. The attendees were invited to try 3D printing, learn about 3D modeling or DIY electronics, create experimental sound instruments, and reconfigure electronic equipment—such as toys—into new instruments. The local facilitator and teacher at Techno-Lab had a background in computer science and could guide the participants in realizing their ideas for prototypes or projects. Techno-Lab was also used to produce ornaments, such as a 3D print expressive of or inspired by traditional Sami ornaments and applied to clothes or textile designs. The DIY sound instruments could be used for workshops and attractions for youth and children (see Figure 2).

The VR experience presented by Silja Somby was designed to expand the interconnections between SDG and technology, transforming an art center into a space for technological exploration. Somby presented a video themed around historical drums in the Sami community that were taken by the authorities. The visitors, while excited about this one-person VR experience, also needed guidance on, for example, where to stand and how to use the equipment. Visitors mentioned that they got dizzy after the video and that the experience was emotionally powerful.

To develop further strategies for applying technology at the SDG, it is important to examine the role of non-Sámi facilitators in engaging with the community. Therefore, the research question in this study is, how can non-Sámi facilitators critically interpret the dynamic interactions between technology and the Sámi community within the context of two artistic projects in sensitive settings?

Fig. 2. A DIY sound instrument: Creating sound by touching bread. Used during workshops by Marija Griniuk. Photo: Johanna Sims.

This article includes an explanation of key terms, concepts, and methods, along with a presentation of the cases involved. A reflection and the main findings follow, which prompt recommendations for using technology in similar contexts—that is, in small communities and projects addressing complex and sensitive topics.

II. Materials and Methods

This section presents the concepts used in this article. Since both projects took place in Sapmi, in the Arctic North, the site-specificity of the projects also highlights their context [3]. In the Finnmark region, there is currently only one FabLab, and the Techno-Lab project was the only place in Karasjok to host experimental technology. This is why the audience members were less accustomed to technological interaction and experimentation than, for example, visitors to universities or art academies. Situated digital communication refers to the site specificity and importance of the local context in creating spaces for technology-based learning or technological interactions in exhibition spaces [4].

The definition of technology has been widely discussed by scholars. Axell [5], who researches technology education in Swedish Sámi schools, defines technology as "more than modern high-tech; it is an age-old tradition of problem-solving, modification, and adaptation to fulfill human needs". Similarly, Cavalcante [6] emphasizes that technology extends beyond machines and computers, highlighting its role in facilitating computational thinking—a cognitive process that "involves the ability to solve problems, think logically and creatively, and communicate ideas clearly and concisely". Technology is inherently flexible, requiring individuals to actively develop strategies for navigating different contexts. As Löfmarck and Lidskog [7] argue, "Each technique can provide different forms of coping, depending on the circumstances". In this

conceptual framework, the application of technology in artistic activities at the SDG is understood as a dynamic interaction between technological tools and the specific needs of the local Sami community in each case. Rather than viewing technology as a fixed entity, we emphasize its adaptability and actively seek strategies that respond to this dynamic interaction. All the cases are discussed in the local context of Karasjok and of the Sami Center for Contemporary Art as the site for technology application for exhibitions and education.

It is essential to consider the broader impact of technology. In the context of technology education, Axell [5] argues that technology transcends its practical applications and carries symbolic value, influencing "children's cultural identity". While technology creates opportunities for positive change, it also raises risks. Technology "not only serves as a catalyst for social and cultural transformations but also causes a number of social challenges, including resource imbalance, risks of dehumanization, and new forms of inequality" [8]. Therefore, we examine the impact of technological applications on specific groups and sociocultural contexts.

Another key concept in this study is facilitation. The authors aimed to fulfill the role of facilitators by fostering colearning relationships with other participants. They explored the definition of facilitation to develop a mindset that would guide their reflections. Drawing on research in education and the arts, the authors conceptualized the facilitator as one who "empowers the autonomy and holism of the learner" [13]. Heron's [13] interpretation of holism suggests that facilitation should simultaneously address "the domains of body awareness, emotions and attitudes, interpersonal relations, social and political processes, psychic and spiritual awareness". A crucial aspect of facilitation is sensitivity to context, which involves helping to "create an emotionally safe, trusting landscape" that encourages "honest, brave exchange" [9]. Facilitators must open their minds and embrace "the immersive, situated, subjective nature of the researcher and the research process. It often leads to a fertile, messy mix of resonance, new understanding, multiple meanings, and further questions" [9].

Kuokkanen [10], a scholar of political science and Indigenous studies, notes that some Indigenous women conceptualize sovereignty and autonomy not in terms of power, authority, and domination, as in European traditions, but rather as practices embedded in everyday activities and ceremonies. Accordingly, we emphasize the importance of defining technology and facilitation practices from Indigenous perspectives.

Arts-based research (ABR) is the method adopted for this article. ABR allows for a holistic approach to inquiry by integrating the perspectives of the researchers, who are artist-practitioners, and by highlighting themes interpretable from the multiperspective of the involved actors [11]. ABR enables new dialogues and participatory experiences to emerge and makes new expressions possible by cocreating with the participants, coexperiencing the art—as in the case of Somby's VR experience—or codiscussing with the audience members, as in the example of the artist talk.

Data Gathering

Data on the Techno-Lab project and VR experiences were collected using observation notes, journaling, and conversations with users, which later were archived by the method of art journaling. Photos were taken of the Techno-Lab workshops with the participants' consent. Based on field notes which include interactions with the artist, and questions and comments from the audiences following the artist talk, one author, Mi, used art journaling [12] (See Figure 3). It was a method combining texts, charts, and sketches—to document reflections on the artist talk. The author adopted this arts-based practice because she experienced intense and complex emotions while reflecting on the talk. Moreover, the context of the talk encompassed layers of sensitivity. By combining text and images, art journaling enabled the author to delve into her complex emotions, visualize the relationships between multiple sensitivities, and share and discuss her reflections with the coauthor in a more comprehensible way.

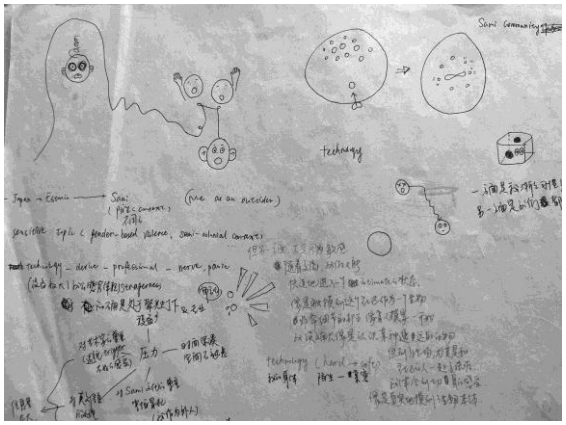

Fig. 3. An example of art journaling: drawing and reflection text. Developed by the author.

Data Analysis

Based on the previous definitions of technology and facilitation, to explore the dynamic relationship between technology and the local Sámi community from a richer perspective, the authors need to reflect on the specific projects to analyze the concrete context. Therefore, the authors chose the general inductive analysis approach as the analytical method [14].

The authors shared textual and visual data through a shared Miro board and Google Document. Based on individual reflections on their respective cases, they read each other's data and provided comments. Furthermore, the authors conducted two online Zoom discussions to analyze the raw data derived from their reflections and to synthesize key themes.

All reflections on the research data related to the artist talk were consolidated into the chart of figure 4 on

Miro. The authors compared these results with the data on the Techno-Lab and cross-checked the key themes.

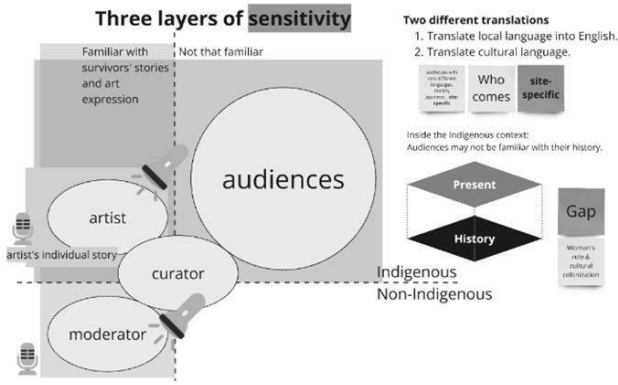

Fig. 4. Different aspects of reflection and relationships between attendees at the artist talk. Developed by the authors.

III. RESULTS AND DISCUSSION

Accessibility

Accessibility serves as a key perspective for understanding technology, but its definition varies in each case. The projects examined in this study were site specific in their connection to the Indigenous Sami community in Karasjok. The availability and usability of the tools, such as VR and 3D printing, varied among audience members with different degrees of experience; this was some users' first VR experience. The Techno-Lab project, as the only experimental technology space in Karasjok and one of very few such places in Finnmark (the county currently has only one other project with a similar format, i.e., FabLab), addressed the need for increased access to digital tools in the local community and became a center for creative coproduction as well as a repair station, where people could come to repair plastic of other material parts for their items.

In the context of the artist talk, accessibility meant not only using technology to convey Sámi women's lived experiences but also reimagining and redefining the role of technology. Microphones and spotlights amplified the voices of the artists and other participants, conveying their trauma-related life experiences to a broader audience, evoking resonances and responses. However, as one attendee noted, some girls lack the language to express themselves because they are too young to even understand their experiences. The findings highlight the need to consider the amplification and visualization of silenced voices when designing technology.

Multidimensional Sensitivity

This theme highlights the sensitive content presented in the projects—content inspired by multidimensional trauma and cross-cultural dialogue. Sensitive content in this study includes projects addressing historical trauma, such as the reference to the historical confiscation of traditional Sami drums by the authorities documented in Somby's VR experience. Similarly, the artist talk with Marte Lill Somby examined themes of identity, personal history, and collective trauma. The moderator of the discussion was a researcher with similar experience working on the topic of gender-based violence within the Japanese community. This cross-cultural dialogue provided a meaningful opportunity to explore how different communities navigate and express histories of trauma through art and storytelling in the artist talk. However, in the reflection, the moderator wrote about the anxiety experienced in the sensitive context of conducting the artist talk: "I felt like I was sitting on the edge of a volcano, as there were so many things to consider. The pressure came from my desire to create a safe environment for both the artist and the audience. I didn't want to trigger any negative feelings in them. I was also concerned about not offending Sami culture as a non-Sami outsider." The reflection also indicated that the anxiety was influenced by the use of the device and the layout of the space. The reflection was further developed into figure 4, showing different layers of sensitivities, the relationship between device use and attendees.

Site Specificity

Karasjok is in a remote area. In such a context, technology is not a neutral tool but is rather shaped by the environment, the experiences of the community in which it is implemented, and traditional practices of creativity and making. For example, the Techno-Lab project introduced 3D printing, DIY electronics, and interactive media to a community where such resources had been largely unavailable. It was important to highlight the usability and usefulness of such technology. For example there was a comment from a resident of Karasjok, that she had previously attempted to set up a technology learning meeting place in Karasjok, but they lacked equipment. Another comment from the user was that repairing a camera by ordering a new detail would be quite expensive, but at Techno-Lab he could just 3D print the missing detail for his camera. From these comments its evident that Techno-Lab could solve some practical issues within the local community. This is why the laboratory also became a station for repairing, for example, the broken plastic camera elements. The introduction of these technologies was not designed merely to provide access, that is, a physical location in which users could receive guidance and accessible tools, but also to adapt them to local cultural and artistic practices. For example, one user stated that DIY electronic instruments could be interesting to implement in her practice as a DJ.

In the artist talk, site specificity was primarily reflected in the translation of languages and cultural backgrounds. This necessitated translating English into the local language, as well as translating different cultural contexts.The translation was canceled due to an unexpected occurrence; however, the audience strongly insisted that the talk be translated from English into the local language. When discussing cultural specificity of gender-based violence occurring within the Sámi community, even though the moderator had read some research materials before the talk, many challenges were

not covered in previous studies and still require further discussion. For example, as the artist noted during the talk, there is no self-help group or similar institution in the Sámi community.

The Gap between History and the Present

The gap between history and the present concerns how historical events, cultural heritages, and past traumas are reflected in contemporary society. The traumatic experiences, artistic expressions, and technological engagements were those of the younger generations of artists, who do not have direct experience of the historical events but know the narratives retold by their grandparents, who experienced, for example, relocations and the introduction of borders in Sápmi.

Discussion

The findings helped the authors better understand the needs of the Sámi community from both physical and emotional perspectives. Physically, due to the location of SDG in Karasjok, technology is not often applied as part of artistic creation. Therefore, there is a need to expand opportunities for people to engage with new technology by integrating it into the daily lives and needs of the local community. Emotionally, for historical and cultural reasons, exhibitions at SDG sometimes involve trauma-related content. Technology should be employed to create an emotionally safe environment, amplify survivors' voices, encourage others to witness artists' stories, and promote public discussions on related issues.

The findings reinforce the need for a new conceptualization of technology. Within the Sámi community, some individuals who have experienced gender-based violence struggle to find the language to understand and express themselves, and some community members have lost direct connections to Sámi history. These challenges prompted the authors to consider whether technology could serve as a bridge to reconnect these missing links—whether in the language used to communicate life experiences or in historical continuity. This perspective transcends the practical application of technology and aligns more closely with what Axell [5] describes as its symbolic value. Within the SDG's arts-based environment, technology has the potential to creatively merge with artistic practices to challenge and realize this symbolic value. A new conceptualization can also encourage people to question contemporary conceptions of technology, shape technology in an Indigenous way, and foster Indigenous autonomy.

The findings of this research are connected to a specific community where the cases originate, but they can also be applied to other Indigenous communities where technology can positively impact art communication. Additionally, technology within an art institution can serve as a platform for enhancing the technological experience.

Finally, the authors reflected on their own positions as non-Sámi facilitators and found that the role of an outsider is not set in stone. Through an analysis of different dimensions of the key theme, sensitivity, they identified various indicators that also capture the relative nature of being an outsider. For instance, in the artist talk, the moderator was an outsider to Indigenous culture compared to the audience, whereas audience members may have been outsiders to the stories and artistic expressions of gender-based violence survivors. Each individual has different knowledge shaped by their unique experiences. Additionally, device use and space layout should be taken into consideration when building a more equitable environment. In this light, key questions arise when thinking about technology: How can the local community be engaged and brought into the spotlight to express their knowledge? How can an equitable environment be established to encourage individuals to adopt an outsider's mindset and learn from those with different identities? How can cross-cultural translation be facilitated? These questions could be examined in further explorations of these topics.

The limitations of this study are related to the scope of the research. The cases are specific to a single community and one art center, with a timeframe of approximately one and a half years. The authors approach the study from the perspective of non-Indigenous representatives working within an Indigenous community context. Additionally, feedback from the local community is primarily conveyed through verbal expression, which may limit their ability to articulate complex emotions. Future research will involve more voices from the local community and explore different methods to facilitate emotional expression. More venues, such as museums and art galleries, in global Indigenous communities can be involved in the future research.

IV. CONCLUSIONS

This research opens up an understanding of the dynamic relationship between the application of technology and the needs of local communities from multiple perspectives, such as the site specificity of SDG and the overlooked perspectives of Sámi women. Based on a deeper understanding of the needs of the Sámi community, this study proposes a new conceptualization of the design and application of technology.

While this study focuses on two specific projects, the insights gained could help other artistic practitioners better understand and engage with the Sámi community. This reimagining of technology may inspire artistic practitioners to explore new and significant themes related to the use of technology in artistic and community-based contexts.

ACKNOWLEDGEMENT

Marija Griniuk received funding from the Research Council of Lithuania (LMTLT), agreement No S-PD-24-49, for her postdoctoral research.

Shasha Mi was supported by the research funding of JST SPRING, Grant Number JPMJSP2136.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 383-390

Analysis of the Evaluation of Utena District Tourism Resources from the Visitors' Perspective in Terms of Attractiveness

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***Abstract*—In the article, the authors analyse the evaluation of Utena district tourist resources from the perspective of visitors in terms of attractiveness. The purpose of the article is analyse the evaluation of the Utena district tourist resources from the visitors' perspective in terms of attractiveness. The research was carried out by means of a quantitative survey (questionnaire). Data collection methods - analysis of scientific literature and sources and questionnaire survey. The article analyses the evaluation of tourist resources from the perspective of visitors in terms of attractiveness from a theoretical point of view and presents the results of the research conducted. It is concluded that the Utena district, as a tourist destination, is associated with such characteristics that shape the value of tourist services as Lithuanian, quiet, natural, clean, and safe. The attractiveness of Utena district's tourist resources is rated on average - 3.4 points out of 5. Natural tourist resources are rated the highest - 3.8 points. The most attractive natural resources of Utena district are Dauniškis park, Triušiukai valley, Alaušas lake shore, Tauragnas lake shore, the Šeimyniškės outcrop and conglomerate rocks, and the Krokulė spring in Užpaliai, etc. The most visited cultural objects in the Utena district are the Wedding Hill, the galleries of the Utena Cultural Centre, the glass galleries of the Utena Square, the Utena Museum of Local Lore, the Narkūnai mound, the Angels Square in Utena, etc. The main problems of the Utena district, identified by respondents, are: lack of entertainment, catering services, and it is very difficult to find information about tourist attractions in the Utena district.**

Keywords*— *evaluation of tourist resources, visitor's perspective, attractiveness, Utena district.

I. Introduction

*Relevance of the topic***.** The attractiveness of a tourist destination is generally determined by a set of multidimensional attributes that may attract visitors to travel to a particular place and depends on visitors' interpretation of a destination's ability to satisfy personal needs. This ability to satisfy visitors' needs determines the attractiveness of a destination and the likelihood of it being chosen. Therefore, understanding the attractiveness of a destination is of paramount importance when analysing visitors' choice of destination. The attractiveness of a tourist destination is crucial as it plays a major role in the success of a tourism site, as it serves as the main motivator for frequent visits and thus also acts as a resource for local communities.

The scientific problem of this research is formulated as a question – what is the attractiveness of the Utena district tourist resources from the point of view of visitors?

The service design research analysis in tourist attractions was analyzed by Lithuanian and foreign researchers, as : Havryliuk, S., Melko, L., Uvarova, G., Karyuk, V. & Mihus, I. (2021); Mitra, S. K. (2019); Labanauskaitė, D., (2020); Labanauskaitė, D., and Jonuškienė, E. (2015); Žuromskaitė, B. (2012); Andriulienė, R., et al. (2011); Lee, C.F., Huang, H.I., Yeh, H.R. (2010); Cooper C., Hall M.C. (2008); Das, D., Sharma, S. K., Mohapatra, P. J., & Sarkar, A. (2007);

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8631
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Dwyer, L., Kim, C. (2003); Vengesayi, S. (2003) and others.

The object of the research is the evaluation of the of the Utena district tourist resources from the point of view of visitors in terms of attractiveness.

The purpose of the research is to carry out an analysis of the evaluation of the of the Utena district tourist resources the visitors' perspective in terms of attractiveness.

Research tasks are:

1. To carry out an analysis of the evaluation of tourism resources from the visitors' perspective in terms of attractiveness from a theoretical point of view.
2. To carry out an analysis of the evaluation of the tourist resources of the Utena district from the visitors' perspective in terms of attractiveness.

Methodology. During the research a quantitative survey (questionnaire survey) was carried out. Methods of data collection - analysis of scientific literature and sources (carried out in order to carry out an analysis of the evaluation of tourism resources from the point of view of visitors in terms of attractiveness from a theoretical point of view) and questionnaire survey. The most recent scientific literature and the most recent scientific articles in Lithuanian and foreign languages were analysed.

The survey sample. The questionnaire survey was conducted in 2024, in the months of October-November, among residents and guests of Utena, distributing the survey link on the portal www.apklausa.lt and social networks, among travellers. 209 people were interviewed. The research is considered exploratory.

II. MATERIALS AND METHODS

The concept of tourist destination attractiveness. In order to assess the attractiveness of a given destination, it is essential to operationalise the concept of destination attractiveness by identifying and characterising the factors that contribute to its attractiveness to tourists.

The potential for tourism development in a given area is determined by its natural, cultural and social resources - climatic conditions, water bodies, forests, architectural, historical and cultural monuments, ethnographic, religious and other objects used for tourism services. The attractiveness of a given area for tourists is assessed on the basis of the condition of these resources.

The concept of attractiveness can be defined as the property of arousing admiration and attracting special qualities and characteristics. The scientific literature on tourism often uses the concept of "attractiveness" (from the Latin attrahere - attraction), which defines such important characteristics of tourist resources as their recreational value. According to this concept, the tourist attractiveness of a territory is formed by a combination of natural, historical and cultural tourist resources and is determined by the presence of attractions (historical and cultural monuments, natural heritage, etc.), developed tourist infrastructure (enterprises in the hotel industry, restaurants, transport, sightseeing services, information services, etc.), the level of safety and law and order, social trends (fashion for a certain type of recreation) and the like, Havryliuk et al. [6]. Destination attractiveness and competitiveness are interchangeable. Destination competitiveness is related to the ability of a tourist destination to offer competitive and better products and services to visiting tourists compared to other destinations, Dwyer, Kim [5]. Destination attractiveness is considered in terms of the feelings and opinions of tourists about the ability of the destination to meet their needs, Vengesayi [11].

The attractiveness of a tourist destination is a positive evaluation of that destination when a tourist experiences positive emotions and develops both physical and emotional attachment to a specific tourist destination, Andriulienė [1]. The attractiveness of a destination has an important influence on a person's expectations, satisfaction, intention to return, choice of destination, perception of motivations and benefits, positive perception of opinion leaders, length of stay and amount spent during a tourism experience, Lee et al [9].

Therefore, it can be concluded that the attractiveness of a tourist destination is a result of well-developed tourism resources and services that are positively evaluated by each visitor due to the positive emotions, feelings, experiences and memories they acquire.

Influencing tourist destination attractiveness and evaluation. Cooper, Hall [3] identify four key aspects that contribute to a destination's attractiveness for tourists:

- *Resources:* Physical and cultural assets that attract and motivate tourists to visit specific locations.
- *Accessibility:* Resources that provide accommodation, services, and human resources, enabling tourists to stay in a particular area.
- *Infrastructure and Services:* The infrastructure and services that improve a destination's accessibility and enhance the overall tourist experience through various attractions, opportunities, and services.
- *Information:* The provision of information about the destination and its resources, which is essential for tourists.

Therefore, resources play a critical role in evaluating the attractiveness of a tourist destination.

According to the classification proposed by the UNWTO Annual Report [12], the attractiveness of destinations has been divided into the following categories: 1) natural tourist resources; 2) cultural and historical tourism heritage; 3) climatic conditions; 4) infrastructure; 5) tourist services and facilities.

Tourism resources are therefore a key determinant of the attractiveness of a destination. Both the natural and built environment influence the attractiveness of a destination. The uniqueness of a place's natural environment, geographical location, climate and landscape has a significant impact on tourists' willingness to visit. Consequently, destinations with a greater abundance of unique and authentic tourism resources are more likely to attract a greater number of visitors. The built environment, including tourism infrastructure, transport, attractions, activities, accommodation, and food services, serves as a complementary factor in attracting and retaining tourists.

However, the evaluation of a tourist destination's attractiveness is influenced by a broader range of factors. Before assessing a tourist destination, it is recommended to answer the following questions, Žuromskaitė [2]: What are the accessibility options for tourist sites? How is the infrastructure developed? These questions relate to the accessibility of a tourist destination by car, bicycle, bus, public transport, or on foot. Communication refers to connections, certain relations, and interaction. There are two types of communication - direct and indirect. Both types of communication are important for the traveller, as various signs, online information and communication with a representative of the destination provide certain benefits to the tourist. Therefore, well-developed communication tools contribute to the attractiveness of a tourist destination, as the traveller feels more confident about his chosen route.

Various researchers have identified primary and secondary features of attractiveness of a destination. Primary features of attractiveness comprise culture, nature, and traditional architecture. Secondary features encompass transport, tourism facilities and services, and accommodation Mitra [10].

Other authors identify key factors influencing the attractiveness of a tourist destination, namely attractions, amenities, and accessibility. Attractions are the primary reason for a destination's appeal and attract the largest number of tourists. Amenities are supplementary elements that, on their own, may not be the primary motivation for tourists to travel. Accessibility relates to transportation to a specific tourist destination, Das et al. [4].

The attractiveness of a tourist destination significantly influences the choice of tourist destinations. Consequently, each region cultivates its tourism resources, enhances them, creates new products, and implements various projects to ensure that the number of tourists in a particular destination does not decrease but increases year after year.

In summary, the following key factors determine the attractiveness of a tourist destination: the attractiveness of tourism resources and attractions, accessibility, development of tourism infrastructure, diversity and quality of services, marketing activities, destination image, cultural distinctiveness, and the activity of local people/communities. Tourist destinations and attractions must be maintained, constantly updated, and their condition improved, with resources adapted to meet the needs of diverse individuals.

Methodology of the survey

The purpose of the research: To conduct a research analysis of the evaluation of the Utena district tourist resources from the perspective in terms of attractiveness.

Research objectives:

1. To determine how respondents evaluate the natural, cultural and other tourism resources of the Utena district.
2. To identify the most attractive tourist attractions of the Utena district and the factors determining attractiveness.
3. To identify the most visited attractions of the Utena district.
4. To identify the main problems faced by respondents.

Research sample. Respondents to the questionnaire survey are residents of the Utena district or those who came from another city. The survey was conducted in October - November 2024. A total of 209 respondents were surveyed. According to the data of the Lithuanian Department of Statistics, in 2023, the Utena district had 37,555 thousand residents. The research sample can be calculated according to the Paniotto formula: $n=1/(\Delta^2+1/N)$, where: n - sample size; Δ - permissible error; N - population size. The research sample was calculated according to the Paniotto formula. According to the Paniotto formula, a sufficient size to ensure the representativeness of the research sample is n = 204.

Research methodology and tools. The quantitative method chosen for the research was a questionnaire survey. A questionnaire consisting of 21 questions was designed. The introductory part of the questionnaire presented the purpose of the study, indicated the purpose for which the collected data would be used and ensured anonymity. The questionnaire consisted of the following blocks of questions: a block of questions related to the purpose and frequency of visiting the Utena district, a block of questions related to the evaluation of the natural and cultural resources and historical objects of the Utena district, a block of questions related to the attractiveness of the visited tourist objects and the factors of attractiveness, and a block of demographic questions. The

results of the questionnaires of the participants of the quantitative study were processed and analysed using the Excel software package.

Research ethics. The distribution of the questionnaires was carried out in accordance with ethical principles (privacy, confidentiality, free choice, etc.). Each respondent was free to decide whether or not to participate in the study. The data will be used to summarise the results, while maintaining the anonymity of the respondents.

III. RESULTS AND DISCUSSION

Demographic and social characteristics of the respondents. 209 respondents took part in the survey, of whom 13% were men and 87% were women. Four out of ten respondents (41%) belonged to the 18-25 age group, 9% of respondents belonged to the 26-35 age group, 11 % of respondents belonged to the 36-45 age group, 17% of respondents belonged to the 46-55 age group, 13% of respondents belonged to the 56-65 age group and 7 % of respondents belonged to the over-65 age group. A significant proportion of the respondents (37%) had higher university education, 17% had higher non-university education, 21% had secondary education, 17% had basic education and 9% had vocational education. The vast majority of respondents (82%) live in Utena district, 18% of respondents come from another district (Vilnius district, Kaunas district, Panevėžys district, etc.). 23% of the respondents who answered the questionnaire are pupils, 21% are students and employees, 13% are civil servants, 9% are senior citizens, 6% of the respondents identify themselves as entrepreneurs, 2% are housewives and civil servants, 2% of the respondents chose the answer "other".

When asked how often respondents visit Utena district for educational or recreational (tourist) purposes, the following answers were received: almost half of the respondents live in Utena district (47%), 16% of respondents visit Utena district several times a year, 13% of respondents visit Utena district several times a year, 5% of respondents visit Utena district at least once a year, 4% of respondents visit Utena district several times a month, 3% of respondents visit Utena district more than several times a month, 4% of respondents visit Utena district once, and 7% of respondents do not visit Utena district.

When asked what prompted the respondents to visit the Utena district, the following results were obtained: 21% of respondents were prompted by entertainment/recreation near lakes and other water bodies, 20% of respondents were prompted by cultural (museums, galleries, expositions, cultural heritage, art objects) and entertainment events, festivals held in the district, 14% of respondents were prompted by visiting relatives and friends, 10% of respondents were prompted by cultural and architectural, historical objects, 8% of respondents were prompted by other reasons (studying at the Utena College, having a farm in the Utena district, it is a way to relax after a hard day's work, it allows you to be close to Utena in the summer, going to see the dancing fountains, etc.). 7% of the respondents were encouraged by the educational events that take place, 6% of the respondents were encouraged by the active leisure and sports events that take place in the district, 5% of the respondents were encouraged by the information provided on the website of the Utena Tourist Information Centre and social networks, 4% of the respondents were encouraged by advertising, recommendations, information at tourist fairs and the opportunity to relax and have fun with children. *Summarising the answers of the respondents, it can be concluded that the respondents were most encouraged to visit the Utena district by entertainment/relaxation near lakes and other water bodies, cultural (museums, galleries, expositions, cultural heritage, art objects) and entertainment events taking place in the district, holidays, visiting relatives and friends, cultural and architectural-historical objects. The least encouraging factors were information on the website of the Utena Tourist Information Centre and on social networks, advertising, recommendations, information at tourist fairs and the opportunity to relax and have fun with children.*

When asked what they most associate with the Utena district, respondents gave the following answers: three out of ten respondents (28%) consider the town of Utena to be a 5 - minute town (everything is close, easily accessible), 25% of respondents associate the Utena region with the lakes region, 22% of respondents associate it with very beautiful nature, a green town, 10% of respondents - with strong industry and quality brands, 6% of respondents - with quality events, entertainment, 5% of respondents - with rural tourism/recreation in the countryside, 1% of respondents - with sport and wellness. 3 percent of respondents chose the answer "other" (with Utena College, studies, the company "Švyturys - Utenos alus", childhood memories, the car market, the LKL basketball club, the homeland, etc.). *Summarising the answers of the respondents, it can be concluded that the Utena region is most associated with natural resources: a region of lakes, very beautiful nature, a green town, while the town of Utena is treated as a 5-minute town (everything is close, easily accessible).*

The answers to the question of how respondents evaluate the listed natural resources of the Utena district are presented in Figure 1.

Respondents mention Dauniškis Park (50.2% of respondents), Rabbit Valley (48.3% of respondents), the shore of Lake Alaušas (47.4% of respondents), the shore of Lake Tauragnas (43.5% of respondents), Šeimyniškės outcrop and conglomerate rock (35% of respondents), Krokulė spring (32.5 % of respondents), etc. as the most attractive natural resources in the Utena district.

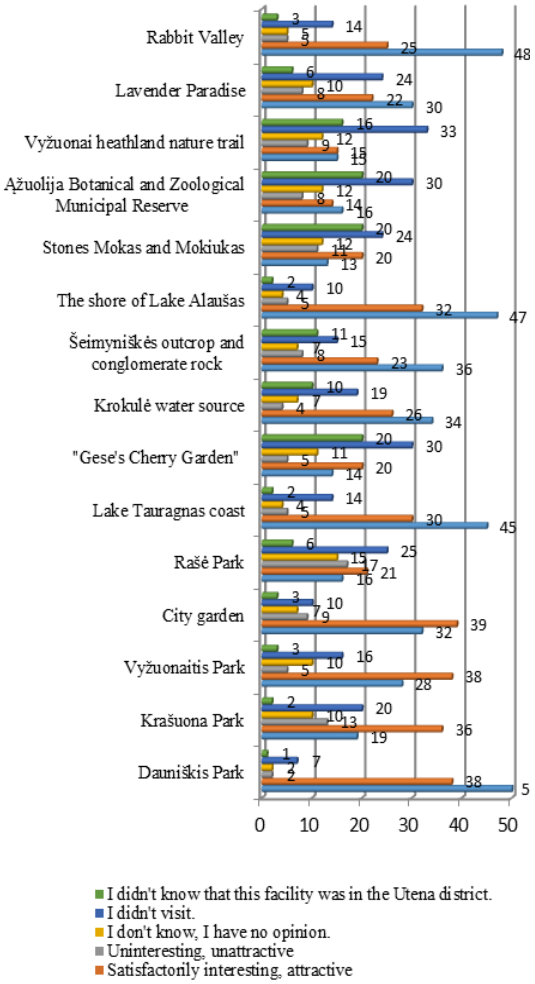

Fig. 1. Assessment of natural resources of Utena district, % (compiled by the authors based on the results of the research

When asked to name an additional natural resource of Utena district not mentioned in Figure 1, respondents named the following natural resources Narkūnai Mound (15 respondents), Vestuvių hill (15 respondents), Klovinių dam (13 respondents) and the nearby footpath, Taurapilis Mound (8 respondents), Nemeikščiai dam (2 respondents), Vyžuonaitis lake (2 respondents), Malūnas Lake (2 respondents), Dauniškis Lake and its springs (3 respondents), Klykiai Recreation Area and Lake (2 respondents), Utena Stud Farm (2 respondents), Ąžuolijos Alkas, Utena Manor, Utena Park, Rašė Stream, Smėlynė Park, Maxima Park, Pakalniai Mound, Biliakiemis Puntukas, Jonas Šimonėlis open-air stone sculpture park (3 respondents), Alaušas deer park, Pakalniai hillforests, Sirutėnai lake, Laumės akys spring (3 respondents), Aliai path (5 respondents), Šeimyniškės hillfort, Pakalniai, Biliakiemis Puntukas stone, Rašės park footpath, Antalgė lake shore, Užpaliai Mound, Pakalniai Mound, Sudeikiai lake shore, Vyžuonai ozas.

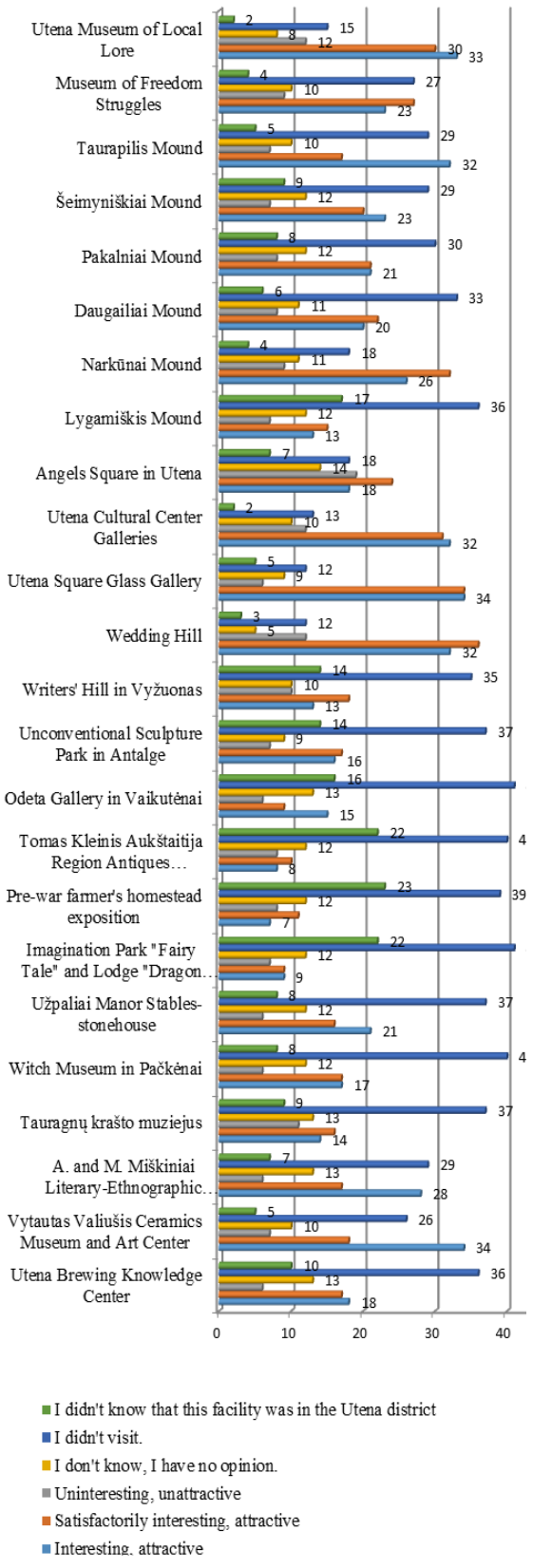

Fig. 2. Evaluation of cultural objects in Utena district, % (compiled by the authors based on the results of the research)

Indubakiai geological reserve (the nearby lake is on the watershed, which is extremely rare), Minčia burial mounds and watermill, Šuminai ethnographic village, Artmaniškis hillfort, A. Smetona oak, Vidinkstas lake and cross, Baltis lake, Antilgė / Untilgė Mound, Aukštaitija ecological monitoring station, Vosgėliai stone, Lygamiškis Mound, etc.

The respondents evaluated the cultural objects of the Utena district (see Figure 2). *Summarising the respondents' answers, it can be concluded that the most interesting and attractive cultural objects are the following Utena Square Glass Gallery, Vytautas Valiušis Ceramics Museum and Art Centre, Utena Local History Museum, Wedding Hill, Utena Cultural Centre Galleries and Taurapilis Hill*. It is noteworthy that respondents have not visited many of the listed cultural sites or do not even know that they exist. Approximately 40% of all respondents have not visited the Pačkėnai Witch Museum, Imagination Park, the Pre-War Farmers' Homestead Exposition, the Tomas Kleinis Aukštaitija Regional Antiques Museum, the Odeta Gallery in Vaikutėnai. Imagination Park, Pre-war Farmers' Homestead Exposition, Tomas Kleinis Aukštaitija Regional Antiques Museum are the least known cultural objects, Ąžuolijos Alkas, Utena Manor House, Utena Park, Rašė Stream, Smėlynė Park, Maxima Park, Pakalniai Hill, Biliakiemis Puntukas, Jonas Šimonėlis Stone Sculpture Park, Alaušas Deer Park, Pakalniai Hillforests, Sirutėnai lake, Laumės akys spring, Aliai trail, Šeimyniškės hillfort, Pakalniai, Biliakiemis Puntukas stone, Rašės park pedestrian trail, Antalgė lake shore, Užpaliai hillfort, Pakalniai hillfort, Sudeikiai lake shore, Vyžuonai ozas. Indubakiai geological reserve (the nearby lake is on the watershed, which is extremely rare), Minčia burial mounds and watermill, Šuminai ethnographic village, Artmaniškis hillfort, A. Smetona oak, Vidinkstas lake and cross, Baltis lake, Antilgė / Untilgė hillfort, Aukštaitija ecological monitoring station, Vosgėliai stone, Lygamiškis hillfort, etc.

The following question was designed to find out about visits to cultural sites in the Utena district. After subtracting from the total number of respondents those who stated that they had not visited a particular cultural site in the Utena district or did not know about it, the number of respondents who had visited the sites was determined, i.e. the attendance of the sites. It turned out that the most visited cultural objects in the Utena district among the respondents were the following Wedding Hill (visited by 84.8% of respondents), Utena Cultural Centre Galleries (84.2%), Utena Square Glass Galleries (83.2%), Utena Local Lore Museum (82.7%), Narkūnai Hill (78%), Angels' Square in Utena (75.1%) (Figure 3), Imagination Park (visited by 36.8% of respondents), Pre-war Farmers' Homestead Exposition (37.3%), Tomas Kleinis Aukštaitija Regional Antiques Museum (37.8%) are the least known and least visited cultural objects in Utena district.

Another question aimed to evaluate the historical and cultural objects of Utena district (see Figure 3).

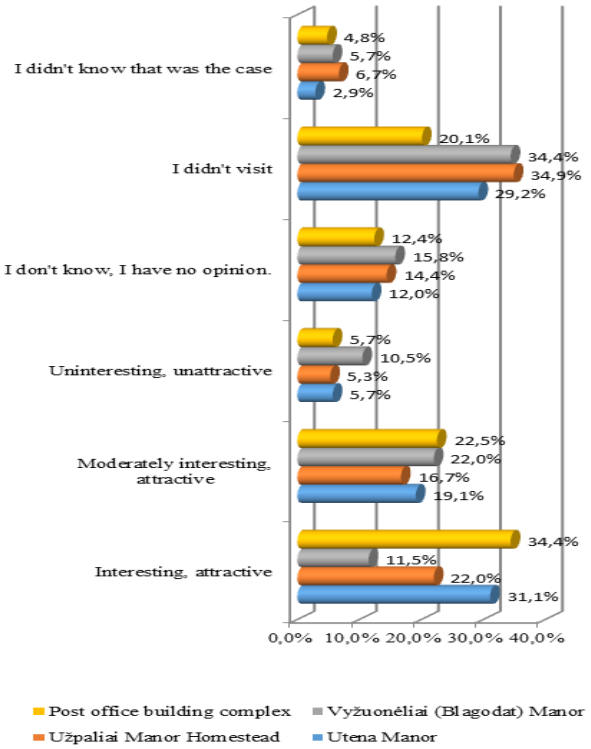

Fig. 3. Evaluation of historical and cultural objects in the Utena district, % (compiled by the authors based on the results of the research)

According to the respondents, the most interesting and attractive historical and cultural objects of the Utena district are the Post Station Complex and the Utena Manor (see Figure 3). Užpaliai Manor and Vyžuonaičiai (Blagodat) Manor are moderately interesting and attractive. The historical and cultural objects of Utena district are known to the respondents, as only a few percent (3% -7%) of the respondents did not know about them. On average, 35% of respondents, have not visited these sites. The most visited site is the Post Station Building Complex - visited by 75% of all respondents.

The next question asked respondents to rate the attractiveness of tourism resources in Utena district (see Table1).

Respondents rated the overall attractiveness of Utena district's tourism resources on a scale of 1 to 5, with 1 being very poor and 5 being very good. The research showed that the respondents rated Utena district's tourism resources on average - 3.4 points out of 5. Natural tourism resources are rated the best: 26 per cent of respondents rate them as very good, 36% as good; the overall score is 3.8 out of 5 (see Table 1).

TABLE 1. ASSESSMENT OF THE ATTRACTIVENESS OF THE TOURIST RESOURCES OF THE UTENA DISTRICT

Factors	1 (very bad)	2 (bad)	3 (on average)	4 (good)	5 (very good)	Average score
Attractiveness of natural tourism resources	2.4	2.9	33	35.9	25.9	3.8
Attractiveness of cultural tourism resources	1.9	11.5	41.1	33	12.4	3.4
Attractiveness of historical and architectural resources	3.8	13.9	41.1	28.2	12.9	3.3
General tourist attractiveness of the district	4.3	10.5	39.7	30.6	14.8	3.4

Source: compiled by the authors on the basis of the results of the research

The next question aimed to identify the factors that determine the attractiveness of the tourist attractions visited.

TABLE 2. FACTORS THAT, ACCORDING TO THE RESPONDENTS, DETERMINE THE ATTRACTIVENESS OF THE TOURIST ATTRACTIONS VISITED

Factors	I agree	I partially agree	I neither agree nor disagree	I strongly disagree	I disagree
Beautiful object	62.2	24.9	10	1.4	1.4
Beautiful and well-maintained environment	71.8	20.1	6.2	1	1
Well-organized infrastructure	71.8	15.3	10.5	1.4	1
Convenient access	69.9	18.2	10	1.4	0.5
Interesting, attractive object	62.2	17.7	17.2	1.4	1.9
Constantly updated object	48.3	30.1	16.3	3.3	1.9
Suitable for visitors of all ages	64.6	21.1	11.5	1.9	1
Variety of services provided	62.2	20.1	13.9	2.4	1.4
Quality of services provided	67.9	16.7	11.5	2.4	1.4

Source: compiled by the authors based on the results of the research

A beautiful and well-maintained environment, well-maintained infrastructure, easy access, quality of the services provided and the facility's adaptability to visitors of all ages are the most important factors determining the attractiveness of the visited tourist facility (see Table 2). The least important is that the facility is constantly updated.

The research aimed to find out what difficulties/problems/disruptions respondents encountered when visiting tourist attractions in the Utena district. The answers of the respondents were fairly evenly distributed (12% - 13%) stating that the most lacking were entertainment and catering services. 65 respondents (13%) answered that it was very difficult to find information about tourist attractions in Utena district, as well as to get to some of the attractions. Some of the respondents, i.e. 5% to 7 %, said that there was a lack of camping sites, recreation areas, tourist attractions were old and not renovated, tourist attractions were far apart from each other, there was a lack of accommodation services, and the attractions were not adapted to visitors of all ages. A few respondents (2% - 4%) said that the opening hours were inappropriate and the price was too high. 3% of respondents said that the infrastructure was untidy, the environment was untidy, some facilities were not adapted for the disabled and staff were rude and unhelpful. It should also be noted that there was a lack of toilets for children. 8 per cent of respondents said that they had no problems. Respondents listed many problems and difficulties related to tourist attractions, but the main ones were the lack of entertainment, catering services and that it is very difficult to find information about tourist attractions in the Utena district. Respondents were asked what could improve the tourist attractiveness of the district. Approximately half of the respondents stated that a better flow of information, more catering facilities, more active entertainment, events such as performances, concerts, etc., and a wider range and supply of tourist services would increase the attractiveness of the area for tourists.

IV. CONCLUCIONS

1. The following key factors determine the attractiveness of a tourist destination: the attractiveness of tourism resources and attractions, accessibility, development of tourism infrastructure, diversity and quality of services, marketing activities, destination image, cultural distinctiveness, and the activity of local people/communities. Tourist destinations and attractions must be maintained, constantly updated, and their condition improved, with resources adapted to meet the needs of diverse individuals.

2. The most attractive natural resources In Utena district are Dauniškis Park, Triušiukai Valley, Alaušas Lake shore, Tauragnas Lake shore, Šeimyniškės outcrop and conglomerate rocks, Krokulė spring in Užpaliai, etc. The most interesting and attractive cultural objects are the Glass Gallery on Utena Square, the Vytautas Valiušis Ceramics Museum and Art Centre, the Utena Museum of Local History, the Wedding Hill, the galleries of the

Utena Cultural Centre and the Taurapilis mound. The most visited cultural objects in Utena district are Wedding Hill, Utena Cultural Centre Galleries, Utena Square Glass Galleries, Utena Museum of Local Lore, Narkūnai mound, Angels Square in Utena. Thus, the most interesting and attractive objects are the most visited. The Imagination Park, the Pre-war Farmers' Homestead Exposition and the Tomas Kleinis Aukštaitija Regional Antiques Museum are the least known and least visited cultural objects in Utena district. The most interesting and attractive historical and cultural objects in Utena district are the Post Station Complex and Utena Manor. The most visited is the Post Station Complex. The attractiveness of the Utena district's tourist resources is rated on average - 3.4 points out of 5. Natural tourist resources are rated the highest - 3.8 points. Utena district, as a tourist area, is associated with such characteristics that form the value of tourist services: Lithuanian, quiet, natural, clean, safe. Beautiful and well-kept environment, well-maintained infrastructure, convenient access, quality of provided services, adaptation to visitors of different ages - are the most important factors determining the attractiveness of visited tourist objects. Most of the respondents mentioned the Utena Manor, the Post Station Complex, the V. Valiušis Ceramics Museum as attractive cultural objects and recommended them to others, and the Dauniškis Park, the Tauragnas Lake and a recreational area as natural objects. The main problems of Utena district identified by respondents: lack of entertainment, catering services and etc.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 391-397

Analysis of the Attitudes of Lithuanian Academic Youth Towards Environmentally Responsible Behaviour when Travelling

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***Abstract*— In the article, the authors analyse the attitudes of Lithuanian academic youth towards environmentally responsible behaviour when travelling. The purpose of the article is to analyse the attitudes of Lithuanian academic youth towards environmentally responsible behaviour when travelling. The research was carried out by means of a quantitative survey (questionnaire). Data collection methods - analysis of scientific literature and sources and questionnaire survey. The article analyses the attitudes of Lithuanian academic youth towards environmentally responsible behaviour when travelling and presents the results of the research conducted. It is concluded that all respondents have heard more or less about the principles of environmentally responsible travel. Most respondents, depending on the situation or the purpose of the trip, try to choose environmentally friendly and sustainable means of transport, and apply various sustainable actions when traveling: avoid plastic, try to support local businesses and culture, etc. When staying in accommodation facilities, respondents also try to behave responsibly and sustainably: save water and electricity, use room heating and cooling services sustainably, etc. Most respondents positively evaluate environmentally responsible behavior when traveling, but even half of the respondents are not ready to pay more for a sustainable trip. In summary, young people's attitudes towards travel and its impact on environmental responsibility are dynamic and constantly changing. These trends show that young people are ready to seek sustainable solutions and take responsibility for their actions to protect the planet for future generations.**

Keywords - academic youth, environmentally responsible behaviour, attitudes of academic youth, travels, future generation.

I. INTRODUCTION

Young people's attitudes to travel and their impact on environmental responsibility is an important issue that encompasses both cultural and social aspects. Today's young people are increasingly confronted with environmental problems and want to actively contribute to solving them. In this article, we will discuss how travel can influence young people's attitudes towards the environment and environmental responsibility. Young people are traveling more than ever before, using easily accessible transportation such as airplanes, trains, and rental cars, but these trips often have a negative impact on the environment - increasing carbon emissions, consuming resources, and contributing to biodiversity loss. As a result, young people are increasingly starting to value sustainable travel alternatives such as ecotourism, traveling by public transport or walking.

Social networking and the Internet allow young people to share their travel experiences and discoveries. This promotes awareness of environmental issues, as most young people are interested not only in the pleasures of travel, but also in its impact on the environment. Youth blogs, Instagram and YouTube channels often highlight the values of a responsible traveler and encourage them to choose sustainable and environmentally friendly forms of travel. Young people are also increasingly involved in initiatives that promote environmental responsibility. These can include various campaigns aimed at reducing the use of plastic, preserving nature, and promoting sustainable tourism. Such initiatives not only help young people understand their impact on the environment, but also inspire them to become active problem solvers.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8694
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Topic relevance. The issue of responsible consumption is relevant nationally and internationally. The issue of responsible consumption is particularly relevant for EU countries in the transition to a circular economy. The global public interest in responsible consumption is demonstrated by the ratification of the Paris Agreement (adopted in 2016) and the development of the United Nations (hereinafter - UN) Sustainable Development Goals (hereinafter - SDGs, adopted in 2015), which aim to balance the environmental, social and economic aspects of development with the help of 17 sustainable development goals and strive not only to reduce, but also to eradicate global poverty (UN WTO, 2015). The 12th Sustainable Development Goal is "Responsible Consumption and Production" - promoting resource and energy efficiency, sustainable infrastructure and access to basic services, green and decent jobs, and a better quality of life for all. UNESCO defines responsible consumption as the use of services and products that meet basic needs and ensure a better quality of life for people. Choosing to consume responsibly reduces the use of natural resources, reduces pollution, saves energy and protects workers and consumers. On 25 March, 2021, the European Parliament adopted the EU Sustainable Tourism Strategy [14], which sets out the principles for the development of a sustainable and responsible tourism sector. One of the objectives of the National Progress Plan 2021-2030 [15] is to better exploit the potential of the tourism sector for the country's progress - in accordance with the principles of sustainability and by applying innovative solutions, digitalization opportunities and specialized services for specific markets and target groups. This study aims to reveal the attitudes of academic youth towards responsible consumption while traveling.

Our quality of life, well-being and economic growth depend on our ability to live ecologically. Every year, responsible consumption and sustainability are increasingly promoted and the damage caused to nature and people by irresponsible consumption is highlighted. Residents of European countries are trying to contribute to various initiatives and are becoming more aware of environmental and ecological issues. People are increasingly choosing services and goods that are sustainable and nature-friendly. The scientific problem of this study is formulated as a question - what is the attitude of Lithuanian academic youth towards environmentally responsible behavior when traveling? Responsible consumers and users not only understand their rights, but also follow social and environmental standards, aiming to create an environment that is favorable for everyone and to ensure consumption with minimal impact on the environment. The goal of environmentally responsible consumption is to improve life on the planet, contribute to the quality of life of people around the world and future generations, therefore it is very important to analyze the attitude of academic youth towards responsible consumption when traveling, because travelers are most often a more consuming part of society.

The object of the study is the attitude of Lithuanian academic youth towards environmentally responsible behavior while traveling.

The aim of the study is to conduct an analysis of the attitude of Lithuanian academic youth towards environmentally responsible behavior while traveling.

Research objectives:

- To conduct an analysis of the attitude of academic youth towards environmentally responsible behaviour while traveling from a theoretical perspective.
- To conduct a study of the attitude of Lithuanian academic youth towards environmentally responsible behaviour while traveling.

Methodology. The study conducted a quantitative study (questionnaire). Data collection methods - analysis of scientific literature and sources (carried out in order to reveal the theoretical aspect of the attitude of academic youth to environmentally responsible behavior while traveling), document analysis, questionnaire survey and interview methods. The aim of the scientific literature analysis is to reveal the theoretical aspect of the attitude of academic youth to environmentally responsible behavior while traveling. The questionnaire survey was conducted in order to reveal the attitude of Lithuanian academic youth to environmentally responsible behavior while traveling. The questionnaire survey is used to survey Lithuanian academic youth and was carried out by placing the survey questionnaire on the Internet space www.apklausa.lt, distributing the questionnaire in higher education institutions. 209 respondents were surveyed.

II. MATERIALS AND METHODS

Due to the influence of economic, social and political globalization processes, the tourism sector has become the leading economic sector in many countries around the world. According to the United Nations World Tourism Organization, tourism generates 9 percent of GDP, one in ten jobs and 6 percent of global exports worldwide through direct and indirect effects. However, tourism's impact on the environment can be both positive and negative. On a global scale, tourism has a serious negative impact on the environment: Flights to tourist destinations cause more CO2 emissions than all local activities combined, with serious consequences for climate change. In its report on air traffic, the German Institute of Air Transport and Airport Research shows that global passenger traffic will increase by one third between 2009 and 2014, from 2.5 billion to almost 3.3 billion per year [14]. Aviation currently accounts for five percent of global CO2 emissions. Without significant action, its contribution will rise to 22 percent by 2050, according to calculations recently published in a study for the European Parliament (Transforming Tourism: The 2030 Agenda for Sustainable Development, 2016) [16]. For these and similar reasons,

there is a growing focus on green consumption, including green travel behaviour.

Ecologically responsible consumption is a broad concept that many people associate with protecting the environment. However, we consume responsibly not only when we make conscious choices to reduce harmful effects on the environment and ourselves, e.g. not buying unnecessary things, sorting waste, etc. We also consume responsibly when we take into account the behaviour of the company producing the goods we buy, e.g. how the company produced the goods we buy, how the company produced the goods we buy, etc. We also consume ecologically responsibly when we take into account the behaviour of the company that produces the goods we buy, for example, how the company that produced the desired product behaves toward its employees, or when we choose an accommodation facility that is certified and pays attention to sustainability. Ecologically responsible consumption is the desire not only to reduce all areas of consumption, but also to consider each choice. Ecologically responsible consumption can also be defined as fair, green, sustainable, rational, ethical consumption. Fair consumption is related to the impact of consumption; green consumption is related to the desire to protect nature; sustainable consumption is related to the conservation of resources; rational consumption is related to the minimum amount of consumption; responsible consumption is related to the avoidance of harm and includes all the above categories" (Fontenelle) [1]. Smith also identifies conscious, ethical, green consumption (Smith) [9]. Although socially responsible and ethical consumption are not completely identical, they overlap to some extent (Francois-Lecompte, Roberts) [2]. Ecotourism is one of the most popular forms of sustainable tourism and a model of responsible consumption. For ecotourists, their habits and behaviour are mainly influenced by education, knowledge and awareness, love of nature and desire for new health benefits (Negacz) [6].

Eco-responsible and sustainable consumption by travellers is defined as "consumption that is environmentally friendly, that is, purchasing environmentally friendly products or services while traveling" (Lee & Lee) [5]. Nowadays, travellers are increasingly demanding environmentally friendly products (e.g., eco-friendly hotels, restaurants, cruise ships, airlines, destinations, resorts, and casinos) and expressing their desire to engage in responsible and sustainable consumption (Hall [3]; Ramkissoon, Graham Smith, & Weiler [7]; Wang, Wang, Wang, Yan, & Li [12]). Responsible and sustainable consumption by travellers toward products and services, purchasing and consuming them in an environmentally friendly manner is a necessary condition for promoting sustainable development (Han [4]; Ramkissoon, Weiler, & Smith [7]; Ramkissoon, Graham Smith, & Weiler [8]; Wang, Shen, Amy, Song, & Phau [11]).

Traveling youth seek to discover new cultures, are more interested in and interact with local cultures, are more responsible in their travel, and better understand the principles of sustainability (D,Šaparnienė et al. [10]; United Nations World Tourism Organization, 2008, 2016 [17]). Thus, young people become a demographic indicator that contributes to the creation of "responsible tourism". Therefore, today it is increasingly relevant in the study of behavioural models, motivation, attitudes and sensitivity in behavioural models, attitudes and sensitivity studies and it acquires new scientific and practical importance (D. Šaparnienė et al.) [10].

Lithuania is also promoting youth involvement in sustainable tourism and looking for ways to involve and encourage young people. For example, the Lithuanian association "Active Youth" [13] aims to create opportunities for youth and promote positive and sustainable changes in society's relationship with ecology, health, vulnerable groups and the Internet. Its vision is to become a leading organization in creating a socially integrated and harmonious world. This association provides opportunities for young people to travel more actively and contribute to the development of sustainable tourism (Active Youth, 2021) [13]. In order to promote sustainable tourism, the association provides young people with recommendations both before and during the trip. It is recommended to choose bus or train, take less luggage, choose longer trips with fewer flights, do not print a ticket, travel with greener airlines, choose direct flights and make sure to turn off electrical appliances at home before leaving. When traveling, it is recommended to use reusable or larger water bottles, avoid plastic bags, avoid buying take-out coffee and instead drink it on site, rent a bicycle or use public transportation, rent a hybrid or electric car, use hotel towels and bedding for more than one day, and turn off lights and electrical appliances when leaving the room (Active Youth, 2021) [13].

In conclusion, young people are an important driving force in the development of sustainable tourism. They can make a maximum contribution to increasing the positive impacts of tourism and reducing its negative impacts. Youth is a valuable target group in the tourism industry, therefore, models are being developed around the world to involve youth in solving tourism problems, organizing seminars, discussions and sharing experiences among community members. Lithuania also seeks to promote youth involvement in sustainable tourism by spreading ideas and finding various ways for youth to get involved.

III. Results and Discussion

Research objective: To conduct a research analysis of the attitudes of Lithuanian academic youth towards environmentally responsible behavior when traveling.

Research sample. Respondents of the survey - Lithuanian academic youth. The survey was conducted in January-February 2025. A total of 209 respondents were interviewed. The age group of young people selected for the study was from 18 to 35 years. According to the Law on the Fundamentals of Youth Policy of the Republic of Lithuania, "a young person is a person between the ages of 14 and 29 (inclusive)"; however, due to changes in

public life, it is already planned to increase the age to 35. Therefore, the authors chose this age limit for the survey. According to the data of the Statistical Office of Lithuania, in the academic year 2022-2023, 102.4 thousand students studied in higher education institutions of the country, 71.5 thousand of them in universities and 30.9 thousand in colleges. The research sample can be calculated according to the Paniotto formula: $n=1/(\Delta^2+1/N)$, where: n - sample size; Δ - permissible error; N - population size. The research sample was calculated using the Paniotto formula. According to the Paniotto formula, a sufficient size to ensure the representativeness of the research sample is n = 204.

Therefore, according to the Paniotto formula, the sufficient size to ensure the representativeness of the research sample is n = 204. Responses were received from 209 individuals - young academics aged 18-35 and over - so the survey can be said to be representative. All respondents answered the same set of questions. They were also given multiple-choice answers from which they could choose an acceptable answer or write their comments and suggestions.

Research Methodology and Instrument. The quantitative method chosen for the study was a questionnaire survey. A questionnaire consisting of 23 questions was prepared. The introductory part of the questionnaire presented the purpose of the study, indicated the purpose for which the collected data would be used, and ensured anonymity. When compiling the questionnaire, the following groups / blocks of questions were used: a block of questions related to the principles and choice of environmentally friendly travel, another block related to the respondents' attitudes towards environmentally friendly behavior while traveling, when choosing accommodation and transport services, another block of questions related to the respondents' attitudes towards the possibilities of environmentally friendly travel in Lithuania, and a block of demographic questions. The results of the questionnaires of the participants of the quantitative study were processed and analyzed using the Excel software package.

Research ethics. When distributing the questionnaires, ethical principles (privacy, confidentiality, voluntary decision making, etc.) were observed. Each respondent was free to decide whether or not to participate in the study. The data will be used for summary purposes, while maintaining the anonymity of the respondents.

Demographic and social characteristics of the respondents. 209 respondents participated in the survey, of whom 87% were women and 17% were men. 73% of respondents study at a non-university institution and 27% at a university institution. 83% of respondents are part-time students and 38 percent are full-time students. 85% of respondents are studying and working, and 15% are studying only. 27% of respondents are in the 18-25 age group, 25% of respondents are in the 26-30 age group, 23% of respondents are in the 31-35 age group, and the remaining 25% of respondents are in the 30+ age group.

The vast majority of respondents (97%) like to travel, only 3% of respondents do not like to travel. More than half of the respondents (52%) travel several times a year, three out of ten respondents (32%) travel once a year, 7% of the respondents travel once a month, 2% of the respondents travel once a week, 3% of the respondents do not travel at all, 5% of the respondents chose the answer "other" (travel once every few years; travel when opportunities allow, etc.). The majority of respondents (65%) travel in Lithuania and abroad, two out of ten respondents (23%) travel in Lithuania, 9% of respondents travel abroad, and 3% of respondents chose "other" (travel from abroad to Lithuania, all of the above, etc.).

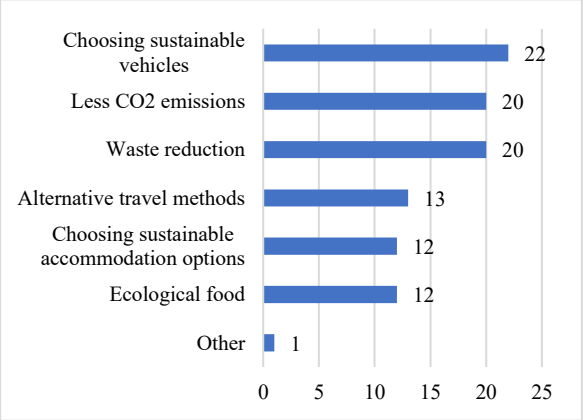

Fig. 1. Results of respondents' awareness of the principles of environmentally responsible travel, % (compiled by the authors based on the results of the study).

Figure 1 shows the respondents' awareness of the principles of environmentally responsible travel. 22% of respondents have heard about the principles of choosing sustainable vehicles, 20% of respondents respectively have heard about reducing CO2 emissions and waste, 13% of respondents have heard about alternative travel methods, 12% of respondents respectively have heard about choosing sustainable accommodation and ecological food. It can be concluded that academic youth are quite sufficiently informed about the principles of environmentally responsible travel.

Respondents use the following modes of transportation when traveling 32% of respondents choose to travel by car, 24% by plane, 14% by foot, 13% by public transport, 10% by bicycle, 7% by train. It can be concluded that slightly more than a third of respondents choose environmentally friendly means of transport (public transport, walking, cycling). Respondents choose the same means of transportation each time they travel, depending on the situation or destination (4%), usually use the same means of transportation, but sometimes change (18%). 14% of respondents choose the most comfortable means of transportation, 13% choose the cheapest means of transportation, choose a means of

transportation taking into account the weather and other factors (11%), and only 2% of respondents choose the most environmentally friendly means of transportation. It can be concluded that the attitude of respondents in choosing a vehicle is not yet environmentally responsible. Most respondents (67%) said that they choose sustainable vehicles when traveling for the following reasons: because of climate change, want to reduce air pollution, care about nature conservation, less environmental pollution, savings, etc.) 18% of respondents said that they do not choose sustainable vehicles for the following reasons: they think more about convenience than about sustainability, they choose what is most convenient, they use their own vehicle, there is not always an opportunity to choose an environmentally friendly vehicle, etc.).

TABLE 1. RESPONDENTS' BEHAVIOR AFTER STAYING AT AN ACCOMMODATION FACILITY, %

Statement	Always	Never	Sometimes
I choose an accommodation that is environmentally and sustainably friendly	8.3	20	71.7
I save electricity in accommodation facilities	50	23.3	26.7
I save water in accommodation enterprise	48.3	21.7	30
I use the towel more than once	70	5	25
I refuse the offer to clean the room every day	45	13.3	41.7
I refuse the offer to clean my room every day. I turn off the heating or cooling of the room when there is no need	66.7	8.3	25
If the accommodation provides catering services, I choose dishes made from local products	25	11.7	63.3
I put in as much food as I can eat	75	5	20

(Source: compiled by the authors based on the results of the study)

Table 1 shows the results of the survey of respondents on environmentally responsible behavior when staying in an accommodation facility (see Table 1). Summarizing the information presented in Table 1, it can be said that most respondents try to be responsible consumers during their stays in accommodation establishments. Most respondents save electricity (50%) and water (48.3%), use a towel more than once (70%). When not needed, they turn off the heating or cooling of the room (66.7%), put as much food in the room as they will eat (75%) and refuse the offer to clean the room every day (45%). The opinion of the respondents regarding the choice of an accommodation establishment for which ecology and sustainability are very important differs the most from the other choices, because the majority of the respondents (71.7%) stated that they only sometimes choose an accommodation establishment for which ecology and sustainability are important, and only sometimes choose dishes made of local products (63.3%), if the accommodation establishment offers catering services. In summary, such behavior of the respondents can be considered as only partially environmentally responsible.

When asked to rate their environmental awareness while traveling, respondents gave the following answers: 57% of respondents rated their environmental awareness as average, 25% reported high awareness, 15% reported low awareness, and only 3% of respondents rated their environmental awareness as very high.

Sustainability in travel is an important issue for many respondents. According to the survey results, 47% of respondents said that sustainability is an important consideration for them when traveling. This shows that more and more people are becoming aware and trying to reduce their negative impact on the environment. On the other hand, 28% of respondents chose a different answer option and interpreted sustainability in travel differently. Some respondents pointed out that while sustainability is an important issue, people often just want to relax and focus on rest and travel experiences when they travel. Others felt that excessive consumption should be reduced or expressed concern about the ever-increasing amount of waste. Meanwhile, 15% of respondents said sustainability is important to them, and 7% said sustainability is very important. Finally, 3% of respondents are not at all interested in sustainability issues in travel. This data shows that there is a growing awareness of sustainability in travel, but there are still some people who are not aware of its importance or who are simply not interested in the issue. This indicates that education and dissemination of information about the importance of sustainability can be very important in promoting more responsible travel behavior.

When asked whether young people are becoming more aware of the environmental impact of their travel, the survey shows that opinions on this issue vary widely. 42% of respondents did not respond positively to the question of whether they often think about the environmental impact of their travel, which could mean that these people do not think about environmental issues or do not believe that their travel has a significant impact. On the other hand, 30% of respondents say they do not know if they think about this issue, which may indicate that they lack information or are unsure of their opinion. Finally, 28% of respondents admit that they often think about the environmental aspects of their travel, indicating a growing awareness and responsibility. Based on the data provided (see Figure 2) on travelers' behaviors and choices, several conclusions can be drawn about the environmental actions they take when traveling. 10% of respondents always choose environmentally friendly modes of transportation. Although this percentage seems small, 72% of respondents sometimes use these methods, which show a certain awareness and desire to contribute

to environmental protection. 18% of respondents never choose green transportation. 40% of respondents always try to avoid plastic, but 15% never do, and 45% of respondents sometimes choose to reduce plastic use, which shows that most people tend to be responsible, but not everyone always follows these principles.

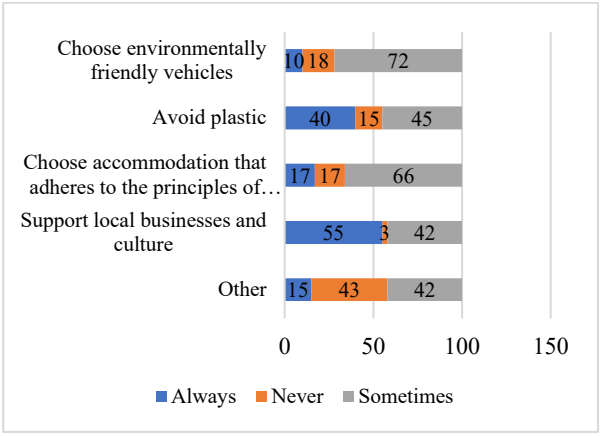

Fig. 2. Actions taken by respondents while traveling, % (compiled by the authors based on the results of the study).

Respondents' attitudes toward sustainable accommodation are quite varied. Only 17% always choose accommodations that follow sustainability principles, 66% sometimes consider these aspects, and the same 17 percent never consider sustainability principles. This shows that sustainability issues are not yet a priority for all travelers. 55% show a strong desire to support local businesses and culture, while only 3% never do, 42% sometimes do, indicating that most travelers value local culture and economy.

When asked what motivates respondents to choose environmentally responsible travel, the responses show that respondents are motivated by a variety of factors. Financial considerations were cited by 32% of respondents, and personal health and environmental principles were cited by 31% of respondents. However, some respondents indicate that environmentally friendly solutions are not sufficiently accessible or affordable, which is why they do not choose sustainability. 5% of respondents say that if green solutions were cheaper, it would motivate them to travel more sustainably. To date, these decisions are often driven by a lack of choice in green options, so many continue to choose traditional travel methods.

As the respondents' answers show, the importance of environmentally responsible travel behavior is particularly important in both academic and everyday life. Of the 209 respondents, 82% have a positive view of this behavior, while 18% have no clear opinion. The positive attitudes toward environmentally responsible travel demonstrate a growing awareness and responsibility for protecting the environment. Environmentally responsible travel among academic youth is an important and relevant issue that requires a comprehensive approach and the active participation of various organizations and institutions. Respondents emphasized that educational institutions and youth organizations should take the initiative to promote such activities. It is important to motivate students to actively participate in Erasmus+ exchanges, which are not only an opportunity to get to know other cultures, but also to get to know sustainability trends and to see good and bad examples. Education, starting from kindergarten, is an essential aspect that allows young people to grow up as conscious and responsible citizens. In conclusion, promoting environmentally responsible travel among academic youth requires a joint effort from educational institutions, youth organizations, and students themselves. Only by working together and investing in education and information dissemination can we create a sustainable and responsible approach to travel.

Based on the results of the survey, it can be concluded that the majority of respondents do not have a clear opinion about the possibilities of environmentally friendly travel in Lithuania. 52% of respondents answered that they do not have an opinion, and 25% of respondents evaluate these opportunities positively. Meanwhile, only 5% of respondents said that they were not satisfied with the existing opportunities. These data show that while some college youth are satisfied with the options available for environmentally responsible travel, the majority of young people are still undecided or uninformed about these options. This may be a sign that there is potential to improve and develop the infrastructure and offer of environmentally friendly travel in Lithuania, aiming at greater public involvement and awareness on this issue.

IV. CONCLUSIONS

1. Young people are an important driving force in the development of sustainable tourism. They can make a significant contribution to increasing the positive impacts of tourism and reducing its negative impacts. Young people are a valuable target group in the tourism industry, which is why models are being developed around the world to involve young people in solving tourism problems by organizing seminars, discussions and sharing experiences among community members. Lithuania is also trying to promote youth involvement in sustainable tourism by disseminating ideas and finding different ways for youth to get involved.

2. All respondents have heard more or less about the principles of environmentally responsible travel. Most respondents, depending on the situation or the purpose of the trip, try to choose environmentally friendly and sustainable means of transport, and apply various sustainable actions when traveling: avoid plastic, try to support local businesses and culture, etc. When staying in accommodation facilities, respondents also try to behave responsibly and sustainably: save water and electricity, use room heating and cooling services sustainably, etc. Most respondents positively evaluate environmentally responsible behavior when traveling, but even half of the

respondents are not ready to pay more for a sustainable trip. In summary, young people's attitudes towards travel and its impact on environmental responsibility are dynamic and constantly changing. These trends show that young people are ready to seek sustainable solutions and take responsibility for their actions to protect the planet for future generations.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 399-410

Features of Attracting Highly Skilled Migrants: a Comparative Analysis of the United States and the United Kingdom

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***Abstract*— Countries are realizing the billion-dollar question regarding innovation and productivity is highly skilled migrants, fuelling the global race for the best in show. The United States and the United Kingdom have been among the top destinations for skilled migrants due to their strong economy world-class research institutions and job opportunities. The paper will be a comparative analysis and literature review of the variables that are attractive to highly skilled migrants in these countries, considering migration trends, policy environments, and economies and outcomes. This refers to using data on human mobility to determine driving forces in migration decisions of where they choose to live, such as economic opportunities, quality of life, and the policy incentives in that location. The research shows that both countries have been effective in attracting highly skilled migrants, although they face continuing obstacles—including visa constraints, credential recognition and integration challenges. The overall conclusion of the study is that the U.S. and the UK's attractiveness to global talent can be enhanced through an appropriate mix of targeted migration policies, effective integration and policy coherence. Overcoming these challenges will enable both countries to maximize the economic and social contributions of skilled migrants, facilitating ongoing growth and innovation in an ever-competitive global environment.**

Keywords*— *Economic Impact, Global Talent, Highly Skilled Migrants, Labor Market Integration, Migration Policies, Skilled Migration, United Kingdom, United States.

I. Introduction

More and more of the world's population is getting educated, and therefore, more and more educated professionals are moving out of their home countries. Referred to as the "global race for talent," this phenomenon has heightened competition among countries to woo and keep highly skilled migrants. They play an important role in their host nations: the enhancement of productivity and accelerated technological development, especially in developing and emerging markets [1, 2].

Immigrants with a high skill level have been targeted for the USA and UK since they have had strong economies, developed infrastructure, and wide-ranging native-friendly migration policies. However, the two countries face questions about their ability to stay competitive as the demand for skilled labour rises. This

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8653
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research looks into the policies, trends, and economic impacts that would make the U.S. and the UK attractive choice destinations for high-quality migrants. By comparing states, this paper identifies lessons and implications for how skilled migration fuels sustained growth and innovation in a modern economy.

A. Background and Rationale

The phenomenon of migration is a policy issue of growing importance in developing countries, and adjustments to policies so they reflect changing global conditions in the labour market have been needed. Talent mobility is a critical driver of economic development in the 21st century, with countries turning to skilled migrants to plug labour shortages, stimulate innovation, and increase productivity. Recently Z. A. Kadirova & Gazieva [3] stated that migration processes can be divided into academic, business, professional and talent migration, depending on their nature and purpose. As countries position themselves as net importers or exporters of human capital, they engage in a wider competition for the same, rife with global friction in the context of skilled migration [2, 4].

The U.S. and the UK, as global drivers of technology, healthcare, and education, influence skilled migration patterns through economic, social, and political policy. Both countries have introduced targeted migration programs targeting top talent. The U.S., for instance, created the H-1B visa program in 1990 to address STEM shortages, while the UK launched the Global Talent Visa in 2020 to attract leaders in academia, science, and technology. Despite all these measures, issues like visa caps, credential recognition, and post-immigration integration continue. These are critical issues that must be addressed in order to establish appropriate public policies that maximize the benefits of skilled migration.

B. Research Problem

Despite the success of the U.S. and the UK in attracting highly skilled migrants, there is now greater competition for global talent than ever before. Other nations, including Canada, Australia, and Germany, are also pursuing aggressive policies to recruit skilled workers. This begs two important questions: What makes the U.S. and the UK attractive for high-performing migrants? How do their policies stack up in relation to effectiveness and inclusivity? What are the biggest frustrations they face with existing skilled migrants, and how can these be overcome? This study tries to answer these queries by doing a comparative analysis of the U.S. and the UK. It focuses in particular on trends in highly skilled migration, effects on labour markets, and policy responses in both destination and source countries. The study aims to help enhance their competitiveness in the market for global talent by identifying their strengths and weaknesses with regard to their approaches.

C. Objectives of the Study

i. To examine the tendencies and outlines of highly skilled migration to the U.S. and the UK.

ii. To compare the strategies and visa programs executed by both countries to attract skilled migrants.

iii. To assess the economic and social impacts of highly skilled migration on the labour markets of the U.S. and the UK.

iv. To identify encounters and blockades faced by highly skilled migrants in both countries.

v. To provide policy endorsements for improving the attraction and retention of skilled migrants.

D. Significance of the Study

The main purpose of the study is to provide a systematic reading of the apparent attraction of part of the phenomena about the reasons generating distinct responses from the US and UK policy systems to the attraction of skilled migrants. This study holds significant value for policymakers, academics, and stakeholders involved in migration and labour market planning. By comparing the U.S. and the UK, the study highlights best practices and lessons learned, which can inform policy decisions in other countries. Additionally, the findings contribute to the academic literature on skilled migration, offering new insights into the factors that influence migration decisions and outcomes.

It is, of course, essential to look beyond the particular dates and periods within a certain time frame to help discern trends and their overall structural significance. It will be demonstrated that the two countries represent two distinct approaches to the attraction of highly skilled migrants. From a practical perspective, the study addresses critical issues such as visa restrictions, credential recognition, and integration barriers, which hinder the full potential of skilled migrants. By proposing solutions to these challenges, the study aims to enhance the economic and social contributions of highly skilled migrants, ultimately benefiting both host countries and the migrants themselves.

E. Literature Review

Current works have essentially covered the discrepant immigration policies that deviate in terms of the proportion of highly skilled migrants. Despite this relative overlap, a reasonable illustration of the similar pattern in attracting HCIs is demonstrated through the use of European colonialism as a method for understanding the different types of ethnic communities in the main developed countries. In doing so, a characteristic array of attractions that countries viewed as attractive is exhibited: namely, first language, income level, insufficient labour in certain sectors, low immigrant welfare dependency, and a large amount of individual social capital. Likewise, distinctions between qualifications that may amount to Eastern and Western

HCIs are constructed. Correspondingly, what is comprehensive is the wide array of studies that support 'self-selection', either of which occurs through educational attainment and occupation, as a result of environmental circumstances, or through further economic, social, and political means, and the narrow interests studies find in the aspiration of some HCIs in wishing to settle permanently overseas. A few additional studies have also focused their analysis on migrants to certain areas while drawing attention to the reasons for immigrants to be able to utilize their class privileges and the options available before and after migration [5].

1) Historical Context of Migration Policies

Migrant admission policy is not primarily the instrument that influences the number and characteristics of immigrants that states receive. Migrant admission policies and the characteristics of migrants that states receive are preconditions for the functioning of other policy areas such as family reunification, multicultural policies, labour market regulations, or social security provisions for immigrants [6, 7]. Despite the large role played by immigration in the population structure of various countries, very little systematic cross-national research exists on the composition of migrant flows. One reason may be that policy debates have centred on very specific groups of migrants such as economic migrants or deceived asylum applicants, with the result that crude distinctions have substituted the systematic study of migrant admission policies. In this paper, I want to focus on highly skilled migrants in the United States and the United Kingdom and analyze the details of international migrant admission policies. Especially, I am especially interested in how highly skilled migrants are classified and what different admission schemes allow highly skilled migrants to enter both countries. I want to address this puzzle by answering my research question: Why do so many highly skilled migrants migrate to the United Kingdom and what are the policy and institutional features of both countries that highly skilled migrants are attracted?

Migration has been a fundamental aspect of human history, evolving from early human movements driven by resource scarcity to modern-day economic, educational, and professional migration. Theories of migration help explain its drivers and impacts, providing a foundation for understanding the dynamics of highly skilled migration.

a) Classical Theories of Migration

Ravenstein's Laws of Migration (1885): Introduced push and pull factors such as economic opportunities and social conditions but do not fully account for modern skilled migration complexities.

Neoclassical Theory: Suggests migration arises due to remuneration differences, with labour moving on or after low-wage to high-wage economies. However, it supervises non-economic aspects like quality of life and career progression.

b) Modern Perspectives on Migration

Human Capital Theory: Migration is determined by individuals looking for better revenues on education and skills, specifically appropriate for highly skilled migrants prioritizing career growth.

New Economics of Labor Migration (NELM): Highlights household choices in migration, bearing in mind risk diversification and income growth, making it suitable for sympathetic family-based migration.

Network and Institutional Theories: Emphasize how social networks and migration rules outline migration tendencies, particularly through diaspora networks as well as regulatory frameworks.

c) Evolution of Skilled Migration Policies

Migration plans have undergone substantial changes over time, adapting to economic requirements and demographic swings. Migration policies have undertaken noteworthy deviations over time, adapting to economic requirements as well as demographic shifts:

Pre-20th Century: Migration is located mainly unregulated, with open borders smoothing labour movement.

Post-World War II: Industrialization directed labour deficiencies in developed countries, instigating the primer of guest worker programs.

Late 20th Century: A modification towards skilled migration strategies appeared, emphasizing talent procurement in knowledge-based economies.

21st Century: Globalization as well as digital transformation have increased the race for high-skilled migrants, leading to policies like the U.S. H-1B visa as well as the UK's Global Talent Visa.

Without getting into a lot of history, one can say that there has been a massive shift in this area from unregulated migration (before the 20th century) to targeted migration policies (in the 21st century) where countries are realizing the worth of attracting skilled migrants. The changes in policies like the U.S. H-1B visa and the UK's Global Talent Visa exemplify this change, with the need for migration frameworks to match economic priorities.

d) Highly Skilled Migration to the United States

Most of the highly educated foreign workers who come to the U.S. do so because they run away from terrible conditions at home and the threat of torture and persecution from authorities because of their sex, religious beliefs, political views, or the fact that they belong to the LGBT community. They may also have moved to the United States for educational and employment reasons. Additionally, migrants feel negatively about the restrictions and the lack of educational and employment opportunities for their children in their home countries. They are repelled by tough immigration laws, corrupt governments, and political instability [8-10].

The least attractive pull factor in the U.S. is negative national conditions and fewer pull factors for students compared to other countries. This is because, in comparison with other countries of residence, national conditions in the United States, such as transportation issues, travel expenses, cultural environment, and language barriers, are less favourable for foreign students. The existence of higher education in the United States and the wide range of specializations are quite interesting to them, which offers many scholarships for attending college. Being one of the biggest world economic powers, the higher salaries employers can pay and living standards are relatively low compared to some European and Asian countries [11, 12].

e) Trends in Highly Educated Migrants

Migrant feminization corresponds to the differences in trends in the migration of women with high and low human capital specifications. Trends in the migration of highly educated migrants in the US and the United Kingdom differ. Migration of highly educated women from the West dramatically increased after the late 1980s and early 1990s, mainly due to the fact that work is the stated reason. The migration of managerial, but not professional occupations, rises for women. Educational qualification accounts for a significant amount of the gender difference. The differences confirm the importance of considering migration by gender and educational characteristics [1].

Highly skilled migrant men and women may or may not always migrate for the same reasons. There is also some evidence that operations managers - jobs held predominantly by women - do not respond to the incentives of the brain drain. The employment decisions of high human capital women and men have many possible causes, including resistance to gender norms, dissatisfaction with lack of opportunity for high-skilled work and use of ability, greater access to migrant networks, and traditional family decisions about who is to migrate and who is to care for children [1, 13].

The United States hosts the largest number of migrants globally, with international migrants comprising approximately 14% of its population. The number of highly educated migrants has grown significantly compared to the local population:

- **1990–2000**: 87% increase in highly educated migrants vs. 38% among natives
- **2000–2010**: 57% increase in highly educated migrants vs. 26% among natives
- **2010–2018**: 38% increase in highly educated migrants vs. 24% among natives

In 2023, 36% of the U.S. population over 25 had a higher education degree, compared to 35% of migrants. However, challenges such as visa restrictions, credential recognition, and integration barriers persist, limiting the full potential of skilled migrants.

f) Educational Attainment and Labor Market Integration

In both countries, graduates of prestigious universities actively pursue careers in banking, investment, and law – as representatives of the most popular professions in the world of business and financial centres. At the same time, in the United States, practitioners of these professions appear in the most diverse sectors of the economy; in the UK, the situation is largely determined by the traditions of British society, customs, and established class distinctions. Different approaches here are determined, because of the complex administrative, organizational, and institutional processes of higher education. Many countries are distinguished by the national characteristics of the functioning of university communities and students that have taken shape for centuries, traditions, and corporate universities, which largely determine the effectiveness of professional socialization and the process of building the identity of alumni from institutions. The reputation of elite universities is reinforced. As a result, highly skilled young people, alumni of distinguished educational institutions, feel more comfortable in the educational systems of their respective countries [14, 15].

Among naturalized citizens in the U.S.:

- 40% hold a bachelor's degree or higher
- 22.1% hold a bachelor's degree
- 17.1% hold a master's or doctorate

Migrant education levels vary significantly by region, with South and Central Asia contributing the highest share of highly educated migrants, while lower educational levels are observed among Mexican and Central American migrants.

g) Sectoral Distribution and Economic Impact

The sectoral distribution of immigrants indicated that immigrant presence represented a large or diminished fraction of workers in different sectors of the economy. Numerous countries have a sector-specific immigration system for high-skilled workers [1].

Highly educated migrants predominantly contribute to:

- **Information** Technology (IT): 4.2 foreign specialists per 10 local personnel
- **Education**: 10:3 migrant-to-native ratio among teachers
- **Healthcare**: 10:2.5 migrant-to-native ratio among doctors and engineers

Migrant labour plays a key role in filling skill gaps, enhancing productivity, and expanding economic output. Notably, migrants account for:

- 18% of healthcare jobs
- 37% of doctors in New Jersey

- 35% of doctors in Florida
- 33% of doctors in New York

By 2034, the U.S. is expected to face a shortage of 124,000 doctors, further highlighting the importance of skilled migrants in the healthcare sector.

h) H-1B Visa and Skilled Immigration

The H-1B program in the US is a temporary work visa that allows employers to hire highly educated foreigners. This program is widely used by the government to recruit temporary workers. The H-1B program is designed to attract and retain highly educated workers who are not American citizens. People who work in this category are specialists in the field of computer and information technology. They do not qualify workers in the US labour market due to the high rates of unemployment in these areas of knowledge. The H-1B visa allows you to legally live and work in the US and is a temporary visa that is issued for a period of up to three years. Given that the visa can be renewed for a period of up to six years, many of these highly skilled foreigners who want to declare permanent residence apply accordingly. However, the number of issued visas is always limited annually, 65,000 for foreign workers and an additional 20,000 for foreigners with master's degrees from US educational institutions [16].

The H-1B visa program remains a critical pathway for skilled migration, particularly in IT and STEM fields:

- 75% of H-1B visa holders work in IT
- 34% hold a bachelor's degree, 22% a master's degree, and 8% a doctorate
- 72% of H-1B visa holders originate from India

However, the visa cap of 85,000 per year remains a limiting factor, restricting potential economic contributions from skilled migrants.

i) Highly Skilled Migration to the United Kingdom

The United Kingdom has a long history of being a host for all kinds of migrants. It has also been a long-time destination for international students to come and get high-quality education. The purpose of this paper is to note more contemporary developments, which have seen the United Kingdom consciously making attempts to attract highly skilled migrants away from their real or perceived competitors, and in terms of being destinations, these have clearly been the United States. Using a varied and mainly targeted approach, the United Kingdom has been successful and can boast the fastest rate of growth of employment in categories requiring high levels of cognitive skills. Only Australia is in a similar second position, yet neither has managed to lessen the United States' commanding share of global high-skill employment [17, 18].

j) Trends and Educational Attainment

While the majority of immigrant college graduates in both the United States and the United Kingdom have a college degree from their country of birth, there are several notable differences in the trends, characteristics, and earnings between college graduates who completed their degrees in their home countries and college graduates who completed part or all of their degrees while living abroad [19, 20]. While the experiences of immigrants in the United Kingdom are somewhat different. Nearly half of all foreign-born college graduates in the United Kingdom completed part or all of their education while living abroad. More foreign-born college graduates in the United Kingdom have a bachelor's as their highest degree compared to foreign-born college graduates in the United States; the opposite is true at the master's degree level. While a non-trivial one-third of all immigrant college graduates in the United Kingdom completed their highest degree in the UK pre-arrival, this is higher for those with African origins.

The UK hosts approximately 10 million migrants, comprising 16% of the population. Among them:

- 38% of EU-born migrants hold higher education degrees
- 44% of non-EU migrants hold higher education degrees
- 34% of UK natives hold higher education degrees

Notably, a significant proportion of highly skilled migrants come from India, Pakistan, and Nigeria. Post-Brexit, the UK has faced challenges in attracting EU talent but has seen an increase in non-EU skilled migration.

k) Sectoral Distribution and Economic Contributions

Half of the non-European countries receive 10,000 or more high-skilled migrants annually, a remarkable though differing level of success when their modest populations are taken into account. These countries may, in search of the global skills they need, benefit both directly from the work of the migrants employed, and indirectly through the benefits of the pool of people resident or transient on which their enterprises can draw, and by their contribution to creative cultural and scientific communities [21].

Key industries employing skilled migrants in the UK include:

Healthcare: 62% of skilled worker visas granted in 2023

Information Technology (ICT): 87% of skilled workers are highly educated

Education: 48% of university engineering and technology faculty are foreigners

Finance and Insurance: 93% of skilled workers are highly educated

Migrants also play a crucial role in entrepreneurship and innovation:

- 39% of the UK's fastest-growing startups have at least one migrant founder
- 40% of Nobel Prize laureates in the UK are migrants
- 1 in 7 UK companies is founded by a migrant

l) Skilled Worker Visas and Policy Changes

As the role of the state in managing these visas has been delegated to firms and educational institutions, the treatment of skilled foreign workers has also become an important aspect of national law [16]. Migration policies have a longer policy history in the United States than in the United Kingdom. In the legislation that remained in effect until the recent administration, a limit on native visas in the US labour market was accompanied by a backlog of potentially skilled foreign workers. In the United Kingdom, the cap on skilled migrant workers is less clearly drawn, and of the visas issued per year, there is a split every month, which has led to a policy innovation almost every month in the areas that the policy is meant to protect. The net migration figures in the United Kingdom are seen to be more important than the wage gap between skilled and low-skilled foreign workers in the domestic labour force.

The UK has multiple visa programs for skilled migration:

i. **Skilled Worker Visa**: Employment-based migration

ii. **Global Talent Visa**: For leaders in academia, science, and technology

iii. **Innovator Visa**: For entrepreneurs with innovative business ideas

iv. **High Potential Individual Visa**: For graduates of top universities

Post-pandemic, skilled worker visas have increased from 137,000 in 2019 to 241,000 in 2022. However, restrictions on international student migration could impact the future talent pipeline.

II. Materials and Methods

This study employs a comparative analysis of the policies and strategies used by the United States and the United Kingdom to attract highly skilled migrants. The research is based on a literature review, drawing data from government reports, academic research, policy briefs, and relevant legislative documents.

To assess the policy frameworks of both countries, key legislative and regulatory measures have been examined. For the United States, the study reviews the USCIS (2022) Immigration and Nationality Act: U.S. immigration law and policy, which governs employment-based immigration, student and work visas, lawful permanent residency, and specialized immigration categories. Ward and Batalova [22] in their research discussed that in the new legislative proposals addressing temporary visa suspensions as well as their potential impression on labour market dynamic forces are also included. For the United Kingdom, the investigation emphasises the Points-Based Immigration System, which controls skilled worker visas, shortage professions lists, and criteria for reimbursement Office [23].

Apart from government policies, previously Skeldon [24] investigates the same concept as the involvement of non-governmental organizations (NGOs), industry associations, and private sector stakeholders in supporting and advocating in favour of highly skilled migrants. These actors determine immigration policy and offer critical services, including legal assistance, job placement, and integration services.

To define highly skilled migrants, the study reflects individuals involved in high-tech and professional occupations, academia, and research. OECD (2020) in their report 'Talent Attractiveness: Keeping highly skilled migrants' addresses that highly skilled migration is progressively predictable as a driver of innovation as well as economic development. Research indicates that countries rank specialists through advanced proficiency due to their part in advancing technological innovation, knowledge transfer, as well as global competitiveness [25].

Furthermore, the study examines the broader economic and social factors influencing skilled migration. The appeal of destination countries is analyzed through criteria such as labour market demand, human capital development opportunities, material and non-material incentives, and long-term settlement prospects [26]. Dustmann [27] investigation shows that the availability of career growth, family support structures, and integration policies significantly affect a migrant's decision to relocate and remain in a host country.

III. Results and Discussion

A. Comparative Analysis of the United States and the United Kingdom

The US and the UK, as the top two immigrant-accepting countries, play a critical part in the recruitment of qualified foreign experts. This paper summarizes the main attractions of these two countries, including the official state strategies and preferences for the immigration of specific individuals. In the US, the main lever used to lure foreign specialists is the opportunity for graduates of American universities to work and live in the country. In the United Kingdom, a number of professional programs have been created specifically for graduates of UK educational institutions. Both countries maintain a demand for high-skilled work, as well as a tolerant attitude towards migrants attracted by tax benefits.

Highly skilled foreign specialists are necessary for further economic growth, international competitiveness, and the level of employment and wages for both indigenous people and immigrants. Graduates from different countries also contribute to the social and cultural diversity of society. If countries strive to attract migrants as a means of stimulating economic growth, it is necessary to study their migration policies, the conditions of their stay in the country, and measures to adapt to the new socio-economic environment. In addition, migrants should be ready to open up and integrate into host organizations.

B. Overview of Migration Policies

Immigration policy regulates the entry, purpose, and duration of foreign citizens in a country, encompassing both migration and immigrant policies. It involves legislative, financial, and organizational measures aimed at four key objectives: admission, rights and status, expulsion conditions, and cooperation with origin countries.

Debates on immigration policies highlight increasing mobility restrictions and selective admission preferences, leading to concerns about exclusionary practices. However, both sending and receiving countries implement measures to manage migration's negative impacts. Finally, immigration policies replicate a balance between restrictive controls as well as economic or social incentives.

C. Labor Market Integration

English-speaking, highly educated migrants tend to integrate quickly into labour markets in the U.S. and the U.K. thanks to effective mechanisms for matching jobs, recognition of qualifications, and markets that are reasonably open to skilled migrants. They also have strong socio-economic outcomes consistent with this trend [28]. These new migrants in the labour market are incredibly flexible, moving where the demand is. And because their skills are applicable in diverse sectors, they will be able to participate in and respond to economic changes in the long term.

D. Clarifying Policy Differences: The Impact on Migrants

The US and UK policies for skilled migrants highlight these countries' different economic and demographic contexts. In contrast to the H-1B program in the U.S. – heavily skewed towards IT – the UK has a competition of its own where it has introduced diversity in the visa mechanism for attracting talent in multiple sectors. Nonetheless, both countries are likely to face issues like visa quotas and hurdles to include migrants in the workforce, which, under consideration, may limit their capacity to realize the full potential of this top-notch migration.

The following table outlines some of the differences in immigration policies and migrant demographics between the United States and the United Kingdom. Although both countries record high talent attraction of educated migrants, the challenges and opportunities presented to skilled workers by their visa policies and integration strategies differ for each state.

TABLE 1 COMPARATIVE ANALYSIS: U.S. VS UK POLICIES

Comparative Analysis: U.S. vs. UK Policies		
Factor	***United States***	***United Kingdom***
Migrant Share in Population	14%	16%
Share of Highly Educated Migrants	35%	44% (non-EU)
Top Source Countries	India, China, Mexico	India, Pakistan, Nigeria
Major Employment Sectors	IT, Healthcare, Education	Healthcare, IT, Finance
Key Visa Programs	H-1B, EB-2, EB-1	Skilled Worker, Global Talent, Innovator
Contribution to GDP	17%	14%

E. Policy Impact on Migrants

a) Ease of Obtaining Visas

- The United States runs on a lottery-based structure (H-1B) for skilled workers, replicating visa acquisition ambiguity. Permanent residency (Green Card) dispensation can take years, specifically for migrants from high-demand countries identical to India and China.
- The United Kingdom, in divergence, has a points-based classification that ranks skilled workers based on mandate. This system provides stronger pathways to gaining work visas as well as residency compared to the U.S. lottery system.

b) Integration Success

- In the United States, the route to permanent residency is lengthy, but migrants can take benefit through strong labour market prospects as well as immigrant communities. However, the deficiency of universal health care can be an encounter for some.
- The United Kingdom delivers clearer visa-to-residency pathways, as well as admittance to healthcare with NHS aids integration. Though, visa fees as well as strict income thresholds intended for family reunification could be barriers.

c) Employment and Economic Contribution

- Migrants in both countries contribute significantly to the economy, with the U.S. seeing a higher GDP contribution (17%) due to its larger economy and strong presence of migrant entrepreneurs in tech and healthcare.

- In the UK, the finance sector also plays a key role, and the post-Brexit shift has increased reliance on non-EU migrants for skilled labour, particularly in healthcare.

By understanding these policy differences, migrants can better navigate their options and governments can refine their strategies to attract and retain skilled workers.

F. Economic Impact and Policy Considerations

The economic impact section could be expanded to include how post-pandemic policies have shifted migration trends in both countries. The impact of high-skilled migration in the UK and US can also be considered from an economic development perspective. Positivist research findings often conclude that high-skilled migrants opt to live and work in areas where productivity is high and, as such, are unlikely to 'redistribute the brain drain,' alleviating the less developed and rural regions. From a policy perspective, such areas may be more inclined to implement policies to support and attract 'new' migrants. Such policies range from police protection for communities thought to be used by migrants to developing community organizations that, among other things, provide information about the locality and specific advice aimed at helping migrants remain in the area and utilize their potential [21].

Post-pandemic migration policies have played a crucial role in shaping these trends. In the UK, the introduction of a points-based immigration system has prioritized high-skilled migrants, leading to a concentration of talent in urban areas with established industries and research hubs. Similarly, in the US, changes to visa policies and work permit regulations have influenced migration patterns, particularly in STEM fields. The tightening of restrictions on international student migration has raised concerns about long-term talent shortages in key industries.

In the UK, evidence to date is weighted primarily in favour of those migrants who are mobile and have above-average education and income. Although much less research has been carried out with highly skilled migrants, the concentrations of skilled migration in particular areas have driven the setting of many policy responses. Such targeted areas include business start-up incentives, help to provide language classes for others, and more diverse and targeted employment services. Clearly, where skilled migrants actually opt to live and where they initially settle has significant implications for policy considerations. To date, knowledge about the location of highly skilled migrants is known through enterprise, workplace surveys, research findings from education research and so on. The development of work spatial geography at the borough level that is standardized across borders would allow the comparison of that knowledge illustrated in relatively more detail and across countries.

Highly skilled migration drives:

Innovation: 23% of U.S. patents are from migrant inventors

Entrepreneurship: 80% more businesses founded by migrants

Labour productivity growth: 1% increase in skilled migration raises productivity by 0.4-0.5%

GDP expansion: $7 billion projected increase in U.S. GDP over the next decade

However, restrictive policies—such as limiting international student migration—could lead to a talent shortage in key industries. To sustain economic growth and innovation, both the U.S. and the UK must adopt forward-looking policies that prioritize skilled migration. Addressing regional disparities in high-skilled migration could further enhance economic benefits by ensuring that talent is distributed more evenly, benefiting both metropolitan hubs and less developed regions.

G. Factors Influencing Highly Skilled Migrants' Decisions

Highly skilled migrants are a diverse group, making relocation decisions based on various factors, including income, family circumstances, professional opportunities, and personal connections. Partners and dependents also influence these choices, considering job prospects, living conditions, and overall attractiveness of destination countries [6].

Key determinants include socio-demographics, qualifications, career progression, prior visits, and familiarity with the destination. Non-financial aspects like job satisfaction, work-life balance, and cultural experiences also play a role. Wage differentials, corporate governance, and startup opportunities further shape decisions, highlighting the complexity of skilled migration choices.

1) Quality of Life and Work-Life Balance

Quality of life and work-life balance are key factors in international mobility, beyond financial incentives. Highly skilled migrants seek good urban environments, secure jobs, shorter work hours, quality schools, healthcare, reputable universities for their children, and well-designed housing [29], [30], [31].

The U.K.'s lack of leisure facilities is a disadvantage, while opportunities for permanent settlement attract migrants. Dual-career partnerships complicate relocation, as spousal employment is a major concern. The U.K. competes for talent not just through financial incentives but by attracting high-tech firms that value both professional and recreational opportunities. Balancing work and family life remains crucial in securing global talent.

2) Education and Skills Recognition

The U.S. and U.K. have similar qualification recognition mechanisms, emphasizing equality and minimal restrictions for skilled migrants. Both countries streamline recognition for professions facing shortages,

reducing costs and effort for applicants. The U.S. faces pressing shortages in medical and social care, prioritizing employment-based recognition. While policies are largely alike, the U.K. requires qualification renewal every three years for shortage occupations, whereas, in the U.S., recognition remains valid for any vacancy [32].

a) Educational and Career Development

The assessment of high-skilled migrants is based on their education and the labour market's recognition of their qualifications. Receiving countries value these migrants for their educational advantage, which contributes to economic growth. Governments subsidize higher education to increase the number of specialists, fostering economic, social, and scientific development [1], [33].

3) Economic Opportunities

Migration's impact on host populations is widely debated, with both positive and negative effects. While concerns exist, skilled migration generally benefits better-educated workers, raising real wages [34].

Highly skilled migrants contribute positively to production, pay more taxes, and use fewer social benefits. Their presence in the labour market tends to increase wages for similarly educated domestic workers, making them valuable to receiving countries seeking economic growth and innovation.

H. Challenges and Opportunities in Attracting Highly Skilled Migrants

The U.S. and U.K. attract highly skilled immigrants due to their liberal immigration policies and strong economies but face challenges in regulating inflows. Increased border scrutiny has led to visa delays, discouraging prospective migrants.

Both nations seek to fill labour shortages quickly with minimal government intervention, aiming to attract top talent not only for immediate job needs but also to counter declining birth rates and drive technological advancements in critical fields. Their leadership recognizes the competitive advantage of securing the best global talent, reinforcing the idea that attracting top-tier migrants benefits their long-term economic and strategic goals.

1) Policy Coherence and Coordination

In both the U.K. and the U.S., multiple government agencies oversee policies to attract and retain highly skilled migrants, leading to coordination challenges. The U.K. divides responsibilities across at least five ministries, likely due to rapid migration growth, while the U.S. splits oversight between federal and state agencies, creating policy inconsistencies and inefficiencies.

Effective policies require cooperation among policymakers, policy actors, and migrants. Policymakers often fail to clearly communicate migration goals, and international cooperation is complicated by diverse stakeholders with conflicting interests. Additionally, better migrant engagement through communication and skill-building could improve integration, but such efforts are largely overlooked in current policies.

2) Social Integration and Inclusion

This article compares the U.S. and U.K. in attracting highly skilled migrants. The U.K.'s points-based system promotes interstate mobility, while the U.S. uses visas to attract talent, strengthening technology hubs. Asian migrants value multicultural learning, enhancing social integration. Future research should explore economic shifts from tech sector growth and land use changes due to immigration policies.

Highly skilled migrants typically earn high incomes, though some face precarious status. Encouraging them to settle in specific areas can boost local economies through increased consumption and housing demand. However, challenges remain in securing immigration status and reducing social integration costs. The study finds that while skilled migration expands labour and consumer markets, it also raises social uncertainty and risks displacement.

3) Brain Drain Concerns

Unskilled migration raises concerns for donor countries due to brain drain, as they invest in education while recipient nations benefit from skilled labour. This depletes the donor country's workforce and disrupts national development plans. While donor countries criticize recipient nations for "poaching" talent, recipient countries argue that migration is an economic choice best left to private negotiations. However, donor countries suffer from "brain drain" as they lose bright people. This study identifies knowledge gaps in the ability and qualification-based classification of migrants by highlighting complex factors such as education, occupation, and economic implications [35].

To address the Brain drain, the U.S. and U.K. have introduced strategies such as the H-1B visa, OPT program, Global Talent Visa, and Shortage Occupation List to retain skilled workers while enabling knowledge transfer. Bilateral agreements and knowledge-sharing partnerships further balance migration benefits.

In the EU, regulatory barriers in licensing still limit cross-border job mobility despite mutual qualification recognition efforts. Public safety concerns have reinforced these restrictions, preventing some skilled workers from working in other member states. Additionally, in the U.K., recent deportations of skilled migrants mainly affected postgraduate students and foreign workers violating immigration rules, rather than European professionals benefiting from exemptions.

I. Best Practices

Best practices for attracting highly skilled international labour fall into four categories:

Qualification Confirmation – Most countries conduct labour market tests to verify the need for highly skilled

migrants, ensuring they do not displace native workers or drive down wages.

Demand Assessment – Migration applications are evaluated based on sector needs. For example, physicians are in high demand due to their societal impact, whereas actors and performers must prove their professional achievements before entering the U.S. or U.K.

Family Inclusion – The U.S. allows a limited number of family members to accompany skilled migrants, while the U.K. offers broader family reunification options.

Employment Monitoring – In the U.S., contracts have expiration periods, and migrants must confirm their continued employment in the permitted profession. The U.K. allows frequent hiring of foreign workers but requires employers to prove the unavailability of local workers before rehiring. Subsidies for worker education aim to reduce reliance on foreign labour, but the costs and risks make such incentives less attractive [36], [37].

1) Innovative Policies in the United States

The US economy relies on its high-tech sector, concentrated in a few coastal regions, driving demand for highly skilled workers. To address shortages, the government has repeatedly advocated for increasing H-1B visas, and in 1991, the TN visa was introduced for Canadian and Mexican professionals [38].

The US requires at least 270,000 IT workers, 100,000 engineers, and over 1.1 million non-IT professionals to maintain productivity. However, domestic tech graduate output is insufficient, making it harder for companies to meet human capital needs. While the US remains a top destination for global talent, recent years have seen a decline in skilled professionals choosing to work there.

2) Successful Strategies in the United Kingdom

The UK has pursued higher education internationalization, expanding fee-based educational exports and publicly funded education for foreigners, educating around 300,000 international students annually. However, two-thirds must leave upon visa expiration [39], [40].

Recently, the government recognized the economic and public drawbacks of losing these graduates, viewing them as valuable taxpayer-funded investments. Their education at top universities, integration into British life, and earning potential made them desirable assets. This shift led to a surge in applications for UK master's and postgraduate programs. While universities welcomed this demand, graduates faced bureaucratic hurdles in securing long-term residency. Acknowledging their role in national interests, policymakers are now working to retain skilled graduates in the UK workforce.

IV. CONCLUSION

The United States and the United Kingdom have elongated been preferred destinations for highly skilled migrants, attracted by strong economies, quality infrastructure, and lenient migration policies. As the global talent race heats up, both countries will need to pivot to remain competitive. The findings aim to provide insights into the appeal of the U.S. and the UK as destinations for high-skilled individuals, offering information on the economic opportunities, quality of life, and opportunities in place that make these locations attractive to migrants. Yet, in spite of these strengths, both countries struggle with major challenges such as visa caps, credential recognition problems, and integration obstacles that limit the full potential of skilled migration.

A. Key Findings and Contributions

Analyzes the factors influencing high-skilled migrants' choice of destination, specifically in the United States and the United Kingdom for higher education as well as professional or scientific work. Using datasets of foreign alumni from 51 U.S. and 30 U.K. universities, the study estimates location probabilities. Findings highlight the significance of both source and host country characteristics. While key factors are similar for both destinations, their impact varies. Studying in the U.S. is more likely for younger individuals, those from federal countries, and those with a Russian legal system. Professional or scientific employment is more probable for younger individuals, Russian-speaking countries, high-income democracies, and EU/OECD members. The study provides insights into migration flows, emphasizing the role of education institutions and destination attributes.

B. Policy Recommendations

Both the U.S. and the UK must therefore implement forward-looking policies that focus on making their respective countries more desirable to global-skilled talent. Concrete recommendations include:

a) Expanding Visa Quotas and Streamlining Application Processes

- To draw in top talent from around the world, the United States should raise the quota on H-1B visas, especially for STEM experts, and implement a more flexible points-based system.
- By streamlining qualifying rules and providing more transparent avenues to permanent residency, the UK should improve its Global Talent Visa program.

b) Improving Credential Recognition and Labor Market Access

- Foreign degrees should be recognized more quickly in both nations, especially in fields with high demand like AI, engineering, and healthcare.
- To provide uniform procedures for evaluating foreign qualifications and work experience, governments should partner with professional associations.

c) Enhancing Retention Through Integration and Inclusion Policies

- The UK ought to enhance post-Brexit outreach initiatives to draw and retain non-EU talent, tackling cultural and professional integration obstacles.
- In order to guarantee that dependents of skilled migrants have access to work and educational opportunities, the United States should improve its family reunification rules.

d) Addressing Socio-Economic Impacts and Mitigating Brain Drain

- In order to mitigate the negative consequences of talent outflows, both countries should have policies in place that encourage partnerships for knowledge sharing with the home countries of migrants.
- Putting money into international talent networks can promote circular migration, in which highly skilled workers support the economies of both their home and host nations.

To remain global leaders in innovation and economic growth, it is crucial for the U.S. and the UK to provide for the diverse wants and needs of highly skilled migrants. That means supporting policies appropriate for different stages of migrants' careers, providing better coordination across government departments, and encouraging greater social inclusion. Deploying these strategies, both countries can not only capture but also keep the best and the brightest in the world and ensure continued success in a more competitive world economy.

Lastly, this study is relevant to the broader discourse on global talent mobility by offering relevant outputs for policymakers, academics, and stakeholders. Moreover, studies on the dynamics of skilled migration should also analyze the long-term consequences of outflows on the destination and origin countries, and how transnational networks influence migration decisions. By tackling these questions, countries around the world can implement global talent mobility appropriately and therefore derive the maximum benefit from migrating talent.

2) Implications for Policy and Practice

The U.S. and U.K. host a growing highly skilled migrant workforce, but attracting these workers is a complex process. This research enhances understanding of destination choice by highlighting the multidimensional nature of influencing factors. It underscores the importance of considering socio-demographic attributes and career stages, rather than viewing high-skilled migrants as a homogeneous group.

The study emphasizes the competition among advanced economies for global talent. To attract and retain top professionals, governments must maximize policy effectiveness and move beyond a one-size-fits-all approach. Tailored initiatives are crucial to address the diverse needs of skilled migrants. This is particularly relevant for the U.S. and U.K., which aim to remain attractive to global talent.

3) Future Research Directions

A broader comparison of short-stay highly skilled migrants across more countries is needed to assess whether an elite group shapes a "new citizenship." Examining salary percentiles and professional opportunities over time can reveal their impact on long-term labour integration. Including short-stay migrants who do not move abroad allows analysis of how national migration policies, labour market flexibility, social benefits, and homeland capital influence future migration decisions.

Highly skilled professionals are key transnational migrants, contributing to both skilled and semi-skilled migration and long-term brain drain. This study highlights key factors in recruitment and selection, including (1) competition among experienced professionals for specific labour cycles, (2) salary and workload incentives that allow the hiring of domestic labour at minimal cost, and (3) external capital inflows via remittances. While advancing the understanding of skilled migration, these findings do not capture the full complexity of migratory cycles.

ACKNOWLEDGEMENTS

I sincerely appreciate the guidance and support of my mentors and colleagues in the completion of this research article, "*Features of Attracting Highly Skilled Migrants: A Comparative Analysis of the United States and the United Kingdom*."

I am grateful to *Tashkent State University of Oriental Studies, Uzbekistan* for fostering an academic environment conducive to research. Special thanks to my peers for their insightful discussions and to the scholars whose work has informed this study.

Lastly, I extend my heartfelt gratitude to my family and friends for their unwavering encouragement.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 411-415

Key Business Priorities and Good Practices of Industrial Management

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***Abstract*— The topicality of the issue under consideration is determined by the need to outline the directions of development of industrial management as a result of the changes that have occurred in a national and global aspect. Good practices for introduction, dissemination and promotion in modern business organizations are presented with the possible approaches and tools for achieving more effective results and sustainable development. They will help employers and top managers to attract and retain the necessary highly qualified specialists in key professions.**

***Keywords*— *business priorities, good practices, industrial management, strategic approaches*.**

I. INTRODUCTION

The relevance of the issue under consideration is determined by the need to outline the directions of development of industrial management as a result of the changes that have occurred in the national and global aspects. Good practices for introduction, dissemination and promotion in modern business organizations are presented with possible approaches and tools for achieving more effective results and sustainable development. They will help employers and top managers to attract and retain the necessary highly qualified specialists in key professions. The dynamic security environment requires a high degree of adaptability and operational flexibility from organizations and individuals. This adaptability must be supported by a strategic focus on continuous learning and improvement to anticipate and effectively manage emerging risks and threats [1, 2].

The purpose of the study is to establish the extent of the relationship between the theoretical foundations of industrial management and its state and development in the Republic of Bulgaria based on a study of practical experience in this area. Factor analysis, SWOT analysis and the "Brainstorming" method with managers from leading industrial companies in the country were used as tools. The study examines the expected business priorities and popularization of good practices in industrial management.

The diagnostic analysis of 28 industrial companies in the districts of the Central Northern region of Bulgaria, conducted in the period March 2023 - August 2024, took into account the role of a set of strategic factors influencing changes in their organizational environment regarding:

- Complexity of the external environment;
- Dynamism and uncertainty;
- Uncertainty and risk;
- Interrelationship between objective circum-stances characterizing changes in the environ-ment and the effectiveness of the applied management methods and mechanisms [3, 4];
- Growing importance of own innovative develop-ments and ensuring their protection as objects of industrial property on the one hand and on the other - recruitment of qualified personnel for their development and subsequent implementa-tion [5, 6, 7].

Within the North Central Region, there are three agglomeration areas that dominate the economy of the region. According to the National Concept for Spatial Development (NCSD), the cities of Ruse, Veliko Tarnovo and Gabrovo form the so-called agglo-meration cores and areas, that is, zones of functional influence. According to NSI data, Gabrovo has the most pronounced industrial profile compared to the other major economies in the North Central Region - industry in Ruse accounts for 35% of the gross added value, and

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8620
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industry in Veliko Tarnovo - 28% during the period under review.

The development of the company's activities, production, operations and people requires compliance of the key organizational parameters with the main business priorities of the Republic of Bulgaria in the 21st century, posing problems whose solution requires the need for effective industrial management.

II. Materials and Methods

To diagnose the changes in the specified characteristics of the environment, the following methods were used in a complex manner:

- Factor analysis;
- SWOT analysis;
- Brainstorming method and its variations.

The object of the study are industrial managers and specialists, as well as representatives of various categories of personnel in the surveyed companies.

Based on in-depth interviews conducted with line and functional managers of units, workshops and departments regarding the expected business priorities, the majority of them share that they should commit to the dissemination and promotion of good practices in the industrial management of Industry 4.0. Almost 70% of the participants indicate that management is strict control over revenues and expenses, as a mechanism for timely diagnosis and prevention of bad business practices.

The big question that arises is the implementation of an integrated approach to achieve higher labor productivity, better customer service and the development of modern entrepreneurial forms.

All managers without exception define the role of entrepreneurship as stimulating improvements and competitiveness of business. In the short term, the change is expressed in reducing the cost of production, and in the long term - in expanding development and design activities.

The analysis confirms the opinion that with the development of new ICT technologies and digitalization, companies are experiencing difficulties with their implementation due to a shortage of sufficiently experienced technical and engineering personnel. Two thirds of the interviewed managers share that they apply outsourcing to varying degrees and in different forms. For nearly 74% of them, the biggest risk is the leakage of internal company information, but a significant part of the managers also report the benefits for companies from the use of outsourcing activities, such as:

- Optimization of the organizational and management structure;
- Cost reduction and predictability;
- Focusing on the core business processes;
- Reducing labor costs;
- Achieving better quality of services;
- Ensuring a workforce with appropriate skills, as well as a cost-effective and reliable telecommunications network and infrastructure.

Full outsourcing of business processes and services (all functions are performed by an external company due to the lack of in-house IT specialists) is gradually becoming a preferred practice for large industrial companies in the globalizing world economy and rapidly developing markets.

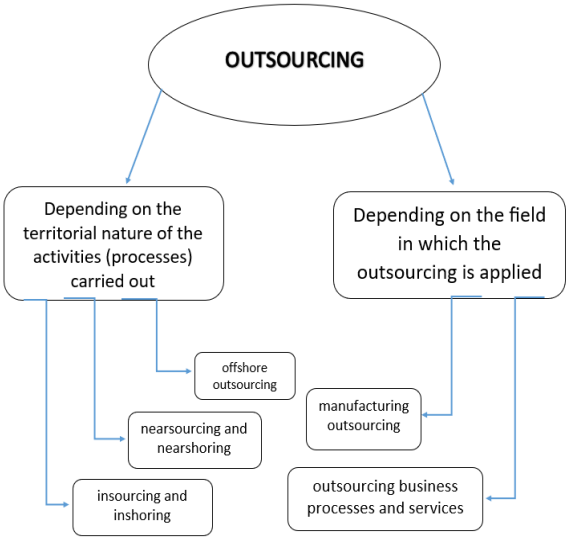

Fig. 1. Models for managing outsourcing processes according to the classification of the consulting company Gartner.

Achieving long-term prosperity requires Bulgarian industrial companies to be adequately adaptable and flexible to the dynamically changing environment. Effective results can be achieved with highly qualified, competent, motivated and committed employees to organizational goals. Success should not be sought only in new technologies and digitalizing processes, but primarily in the human factor and its synergy with the innovative company culture.

From the responses received from managers and representatives of various categories of personnel occupying key positions in the surveyed companies, it becomes clear that the establishment of effective communication is a key competence of modern management and a driver of organizational growth and company culture.

The construction of a modern organizational culture is associated with:

- The return of forgotten values, labor and professional morals;
- The acquisition of new skills and methods for creative and innovative corporate management through the formation of teams;
- The development of analytical thinking and the ability to analyze complex business processes;
- The use of open, transparent and constructive criticism-tolerant management;

- The exchange of information through feedback in the management process;
- The encouragement of entrepreneurial;
- Behavior and leadership.

The standard matrix that actually leads to results is presented in the figure:

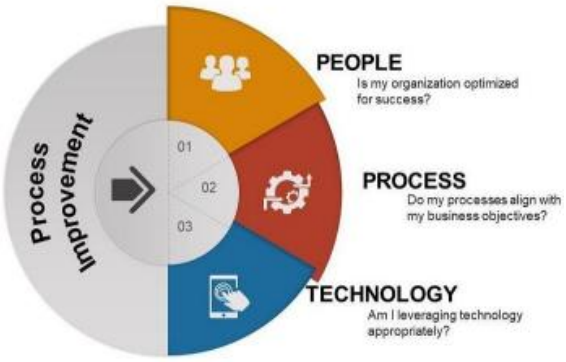

Fig. 2. People, processes, technologies – a process optimization model.

With the emergence of various service industries and the intensification of competition in the manufacturing sector, more and more companies are providing value-added services related to their products (insurance, installations, additional support, training content, etc.). The main factors that help companies navigate the macroeconomic environment are customer experience and operational excellence.

To support the sustainable development and functioning of industrial companies without harming the environment, the participants in the study point to the establishment of the green economy as a socially responsible model of discipline and principles according to which businesses can adapt in order to balance the relationship between economy, people and nature.

Job descriptions should be updated to include requirements for green literacy and workplace behavior. During job interviews, preference should be given to candidates who present environmental initiatives and express willingness to participate in such projects.

The transition to a circular and low-carbon economy requires actions to:

- Increase resource productivity throughout their life cycle and the rate of circular (secondary) use of materials in the economy;
- Extend the life of the product itself;
- Reduce waste and control the need for new resource extraction.

Measures:

- Supporting enterprises in the introduction of waste-free technologies;
- Reducing the amount of waste generated in the production process;
- Implementing green business models that allow interaction between products and services throughout the supply chain;
- Implementing design, reuse and recycling strategies that ensure longer-term use of products.

TABLE 1. MAIN MACROECONOMIC INDICATORS OF THE IMPLEMENTATION OF THE PRIORITY "TRANSITION TO A CIRCULAR ECONOMY"2023/2024

Name	Source	Current VALUE	Target VALUE	EU average VALUE
Environmental innovation index	EK	50	83	100
Share of circular (secondary) of use of materials in the economy, %	EK	4.7	11.7	11.7
Generated waste per unit of GDR, kg/1000 €	Eurostat	418	205	65
Recycling of packaging waste, %	Eurostat	66	70	80
Share of disposed (including landfilled) of the waste submitted for treatment, %	Eurostat	65	35	46

The research we conducted confirms the fact that a prerequisite for higher achievements in the sustainable development of some of the companies is the higher satisfaction and higher motivation of their employees with green human resource management. The biggest challenge facing industrial management in the 21st century, according to the interviewees, is “management in a global environment”. 52% completely agree, 38% rather agree, and a total of 11% disagree, of which only 2% are categorical in their opinion.

The main goal of the priority “technological intensity and innovation environment” of the National Development Program Bulgaria 2030 is to create prerequisites for increasing the technological level of Bulgarian products and exports through technological modernization of enterprises. [8]

As the main advantages of digital transformation, most of the surveyed production managers point out the possibilities for collecting detailed information - "clean data" for the purpose of monitoring, tracking and more effective planning, the significant increase in production capacity and shortening of execution times, the reduction of routine operations, the savings of valuable time, as well as the possibilities for automation, robotization and artificial intelligence as additional production factors to labor.

The use of the possibilities for analysis and processing of large information arrays (Big Data) allows for real-time decision-making. In the field of production, this means more flexible reactions to malfunctions and

optimization that goes beyond the boundaries of the enterprise.

TABLE 2. MAIN MACROECONOMIC INDICATORS OF THE IMPLEMENTATION OF THE "SMART INDUSTRY" PRIORITYINDICATORS 2023/2024

Name	Source	Current value	Target value	EU average value
Share of innovative enterprises, %	Eurostat	27.2	35.0	42.0
Gross fixed capital formation, % of GDP	Eurostat	18.3	21.3	21.3
Entrepreneurship opportunities	EK, EIS	23.9	30.0	122.3
Intellectual assets	EK, EIS	77.9	83.0	82.6
Innovative SMEs in collaboration with others	EK, EIS	29.9	35.0	125.8
Expenditure on R&D by enterprises	EK, EIS	40.9	50.0	79.2

The measures will be aimed at stimulating the development of innovations in enterprises; creating and developing a high-tech industrial base; increasing specialization in products and services that are of high technological intensity and innovation; stimulating research and development activities and cooperation between business and science.

From artificial intelligence and big data to cryptocurrency and blockchain, modern industrial management is constantly faced with inevitable technological challenges and paradigm shifts.

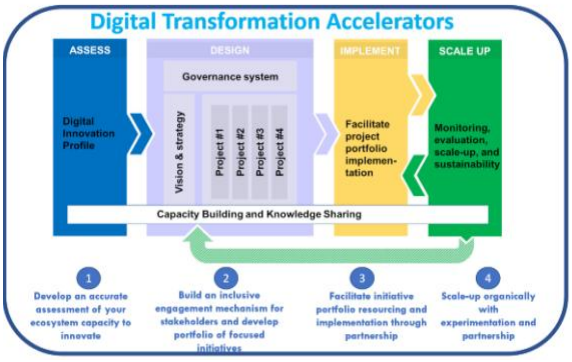

Fig.3. Accelerators for digital transformation.

87% of business leaders believe that digitalization is a company priority, yet only 40% of organizations have undertaken large-scale digital initiatives. The gap between aspiration and achievement is widening for enterprises trying to transform to a digital business. The rapid pace of digitalization is putting the industry under serious pressure and escalating transformation efforts to achieve maximum efficiency and effectiveness, maintain and develop market share, and optimize the generated profits.

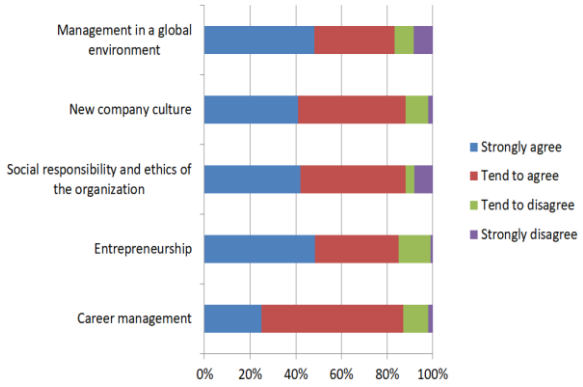

Fig.4..Main challenges facing industrial management in the 21st century (distribution among respondents).

The biggest challenge facing industrial management in the 21st century, according to the interviewees, is "management in a global environment". 53% completely agree, 36% tend to agree, and a total of 11% disagree, of which only 2% are categorical in their opinion. "Social responsibility and ethics of the organization" and "new company culture" have a similar share of supporters (88% in total). Those who disagree with this opinion are 12% each, and with "social responsibility and ethics of the organization" the staunch opponents are more (8% compared to 2% with the new company culture). The presentation of "entrepreneurship" as a challenge gathers the convinced votes of nearly half of the respondents (49%), but also accumulates the largest share of disagreement (15% in total). "Career management" for nearly 3/4 of the respondents does not remain within the framework of categoricality (whether it is firmly "for" or "against"). Only 25% are fully convinced that it will be a challenge for industrial management, and only 2% state with the same categoricalness the opposite.

Fig.5. Monitoring the state of 14 industrial ecosystems.

Expansion, collaboration, and innovation in industrial ecosystems are part of the digital transformation of enterprises and business organizations. Managers recognize the supporting role that industrial ecosystem partners play in ensuring the growth and sustainability of their business activities.

The focus of efforts is on creating an entire ecosystem of industrial zones that meet all international criteria and good practices.

III. Results and Discussion

Regardless of the industry they are in, Bulgarian companies achieve competitive advantages when they develop and adapt. The study proves the need for customer orientation; leadership and employee engagement.

Particularly closely related to industrial management today are the topics related to: entrepreneurship, knowledge economy, network economy, industrial management in the new global environment, career management, corporate social responsibility and ethics and the new corporate culture.

Regional Innovation Center "Ambitious Gabrovo" in partnership with universities, local authorities and industry and non-governmental organizations has launched a project aimed at accelerating the digital transformation of small and medium-sized enterprises (SMEs) in the North Central region of Bulgaria with a focus on artificial intelligence. The project is part of a larger European initiative to create a network of European Digital Innovation Hubs (EDIH), designed to support local enterprises in their digital transformation. [9]

The project budget exceeds 3 million euros and lasts for three years, focusing on increasing regional digital maturity through the use of cutting-edge technologies such as artificial intelligence, the Internet of Things, sensor systems, cyber-physical systems, etc. The hub in the North Central region will provide core services such as training programs to improve the qualifications of human resources, access to innovative technological solutions and foster cooperation between local enterprises.

The main goal is to enable SMEs in the region to gain access to essential resources to help them develop in the context of the ever-increasing digitalization of the economy.

IV. Conclusions

Summarizing the results of the study, we can conclude that modern industrial management needs to accelerate the transfer of innovative ideas and practices to increase the attractiveness of the country as an investment destination in high-tech production and services.

Sustainable development and successful European integration are impossible without flexible and effective adaptation of industrial managers and their organizations to the requirements of the global environment and the main business priorities of the century. The great challenge facing industrial management in the 21st century is management in the modern global environment. Corporate social responsibility and ethics, as well as the new corporate culture of the organization, are coming to the fore. Among them, the expected problems in the process of functioning of organizations in the 21st century are increased competition and increasing resource prices. Others are bank loans and the globalization of business, as well as unfair competition.

V. Acknowledgments

The report was funded by a project of the Scientific Research Fund at the Technical University of Gabrovo.

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Biological and Morphological Characteristics of Vendace (Coregonus albula (L.)) from the Latvian Deepest Lake Drīdzis

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***Abstract*— The vendace (*Coregonus albula* (L.)) is a representative of the genus Coregonus, found in many lakes in Latvia. Although its share in the fishery is small, catches are insignificant and unstable. This species is included in the list of specially protected species with limited use in Latvia. Vendace is common in both large and relatively small lakes with favourable oxygen conditions. It requires high oxygen content in water and is very sensitive to eutrophication and water pollution. Therefore, in this study, the main biological characteristics of the vendace population from the deepest lake in Latvia were assessed. Lake Drīdzis has the most favourable ecological conditions for the existence of this species. The lack of precise scientific data on local vendace populations and their biology hinders the rational exploitation of this fish and does not allow for its reproduction in Latvian lakes. Biological properties were determined for 234 vendace specimens from Lake Drīdzis, caught in autumn during four years. In this study, statistical analysis of biological and morphological characteristics was performed. Von Bertalanffy equations describing theoretical growth of the studied fish in length and weight were calculated. The average condition value was quite high. According to generally accepted criteria for the growth rate of vendace, individuals from Lake Drīdzis showed quite good growth, exceeding that recorded in some other populations inhabiting other whitefish lakes in Latvia, which indicates the presence of suitable food resources for vendace in Lake Drīdzis.**

Keywords*— *Coregonus albula (L.), morphometric and meristic characteristics, adaptation, environmental conditions.

I. INTRODUCTION

European vendace *Coregonus albula* (L.) is a widespread species in northern Europe. It appeared in North–eastern Europe after the last glacial period and is often regarded as an example of a glacial relict [1], [2] and together with other whitefish and salmonids, it is considered an economically valuable fish.

Due to its economic importance, European vendace has been artificially propagated in Latvia since 1900. The vendace (*Coregonus albula* L.) was introduced into more than 30 lakes of Latvia from Peipus (Estonia) and (Russia) lakes. In the 1930s commercial catch of vendace reached 13 tons per lake. However, in the 1990s the vendace was observed only in five Latvian lakes [3]. Presently it can be found in no more than 15 Latvian lakes. Furthermore, its share in the Latvian fishery is small, with rather insignificant and unstable catches [4], [5], [6].

Vendace, *Coregonus albula* (L.), is a species that exhibits considerable phenotypic variation, which is an intermediate reflection of particular environmental conditions that it inhabits. Vendace is common in large and relatively small lakes with favourable oxygen conditions. It requires high oxygen content in water and is very sensitive to eutrophication and water pollution.

Vendace is a polymorphic species of circumpolar distribution composed of several intraspecific forms.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8639
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Coregoninae subfamily group is known as phylogenetically young; therefore, variations in the growth rate and morphological characters of individuals are common within populations. It is said that morphological variations depend more on the hydrological and hydrobiological parameters of the lake where vendace live than on the genetic heredity. Thus when parameters in the lake are changing, there is a possibility that morphologic parameters of vendace are changing too. So Lake Drīdzis has the most favourable ecological conditions for the existence of this species. The lack of precise scientific data on local vendace populations and their biology hinders the rational exploitation of this fish and does not allow for opportunities of its reproduction in Latvian lakes.

The aim of present study is to evaluate the main biological characteristics and its changes in time in the vendace population from the deepest lake in Latvia.

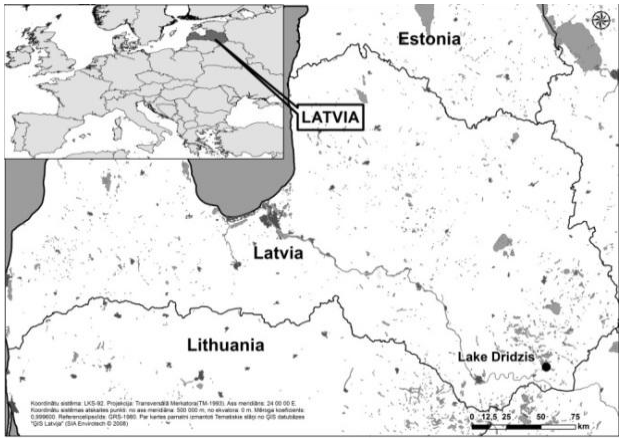

Fig. 1. Location of the Lake Drīdzis in Latvia where vendace were sampled.

II. Material and Methods

A. Study sites and sample collection

Vendace samples, in total 234 individuals, were collected in the autumn of 2015, 2017-2019 from Latvian Lake Drīdzis. Lake Drīdzis is located in Skaista and Kombuļi rural municipalities of Krāslava District in Latvia. Lake Drīdzis is part of Baltic Lakeland (see location of the lake in Fig. 1). Area of Lake Drīdzis is 753.2 ha; the maximal depth is 66.2 m (12.8 m on average). Lake is located in a post-glacial recess and is the deepest in Latvia.

Freshly caught vendace individuals were measured by the whitefish measurement methods described by [7], which is commonly used today [8], [9], [10]. The measured morphological features are presented in Table 1; the lateral view of vendace, indicating points used for morphometric measurements, is shown in Fig. 2. Plastic (morphometric) properties are presented as measurement indices expressed in percent of the head and body length.

TABLE 1 MEASURED MORPHOLOGICAL FEATURES OF VENDACE

Abbreviation	Description of morphological features
Morphometric features	
HL	Head length: from the snout end to the farthest gill cover edge
ED	Horizontal diameter of the eye: from the anterior to the posterior edge of the eye
PO	Postorbital length: from the posterior edge of the orbit to the farthest gill cover edge
StL	Snout length: from the snout end to the anterior edge of the eye
Meristic features	
LL	Number of the perforated scales on the lateral line
Sp.br.	Number of gill rakers on the first left gill arch
RA	Number of ray in anal fin

B. Statistical analysis

Head measurement indices (snout length, eye diameter, and postorbital length in relation to the head length and head length in relation to fish length) of the vendace individuals in Lake Drīdzis during four years were compared. Mean values of indices of the above mentioned parameters were considered for each sampling year separately.

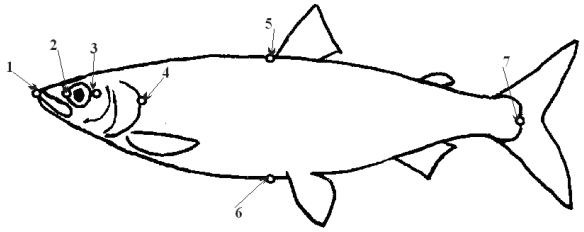

Fig. 2. Lateral view of vendace indicating landmarks used for morphometric measurements.

1 – 2, snout length (StL); 2 – 3, horizontal diameter of the eye (ED); 3 – 4, postorbital length (PO); 1 – 4, head length (HL); 5 – 6, body depth (H); 1 – 7, fish length (SL); 4 – 7, body length (OD).

Since body measurement indices depend on age, Coregonus spp. sexually mature individuals aged 3+ and 4+ were used for the analysis of plastic properties. Scales were taken to determine age of the fish. Age was determined according to Prawdin [7]. Sexual dimorphism in the Coregonus spp. appears only during spawning. Thus, in order to test for significant differences, distinctions in the morphological parameters of males and females aged 3+ and 4+ using Single Factor analysis (ANOVA) were determined. No dependence of morphological properties on gender was discovered. Therefore meristic parameter indices were calculated and pooled in samples from each year.

In order to evaluate variations in vendace meristic properties (number of rays in the anal fin (RA), number of

scales in the lateral line (LL) and number of gill rakers on the gill arch (sp. br.)) of individuals in Lake Drīdzis from different years were compared. It is known that the meristic properties development influence fish egg incubation temperature. Two-Factor analysis Without Replication (ANOVA) ($P < 0.05$) was carried out. No dependence of meristic properties on age and gender was discovered. Proceeding from this, meristic parameter indices were calculated and pooled in samples from each year.

The von Bertalanffy equation that describes theoretical growth of the fish examined in length was calculated for sample from 2015 and 2018 (1) [11].

$$L_t = L_\infty[1 - e^{-k(t-t^0)}] \quad (1),$$

where L_t is fish body length at age t, L_∞ is a theoretical maximum estimated fish length, k is a coefficient of growth rate, t^0 is hypothetical age at which fish length equals 0 cm.

When populations with a short life cycle are studied, a correlation is observed between L∞ and k. In one case, a high L∞ value is combined with a low k value, and in another, a low L∞ value is combined with a high k value, and both cases show the same result. Therefore, the $\emptyset`$ value was calculated for the analyzed samples using the formula (2) [12].

$$\emptyset` = Logk + 2LogL\infty \quad (2)$$

Thus, the resulting single parameter allows comparison of the growth of the same fish species in different lakes and in deferent year [13].

On the basis of morphometric data, fish condition was examined for each individual separately, and an average condition for each sample was worked out. The fish condition was determined using the Fulton condition factor (K) (3) [14].

$$K = \frac{w*100}{L^3} \quad (3),$$

where w is the fish weight in grams, and L the fish length from the snout end to the end of scales layer at the caudal fin base.

The growth rate of the vendace individuals was assessed according to the power function equation (4).

$$W = K * L^n \quad (4),$$

in which W is body weight of the individuals (BH) (g), L is standard body length of the vendace individuals (SL) (mm), K and n – the parameters of the power function [15], [16].

III. Results and Discussion

The assessment of growth rate and morphometric parameters of individuals contributes to the study of fish resources and their successful management [17], since vendace is not only an economically valuable object, but also an important link in the food chain [18]. The assessment of the condition of fish individuals is an important component in the study of various fish populations. According to Bolgier and Connolly [19], the variability of fish condition is often assessed by the ratio of the standard length to body weight of a fish individual, as well as using the mathematical formulas developed by Fulton [19]. Usually, the standard body length and body weight of a fish are closely correlated. However, at different periods of life, the body weight of a fish individual may change without changing its standard length and vice versa. Therefore, the ratio of standard length to body weight is determined for all individuals of the sample (all age groups) together and interpreted as the growth rate of individuals [15].

A. Condition factor

Fulton's condition factor is influenced by several factors, including the age and sex of fish, gut filling, composition of the food consumed, and the fattening level of the fish [20]. In present studies, Fulton's condition factor for both females and males, and for different age groups in the same year's sample sets, did not differ significantly ($p>0.05$). Although Fulton's condition factor values for vendace individuals in samples from different years differed slightly, the differences were not significant ($p>0.05$) (Fig. 3).

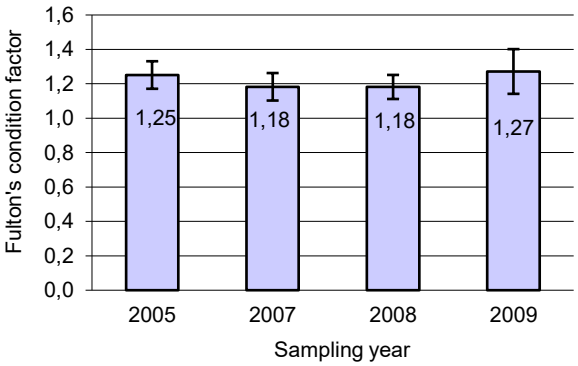

Fig. 3. Mean of Fulton`s condition factor of the vendace individuals from different years in Lake Drīdzis (error bar shows standard deviation).

Fulton condition factor is an indicator of the body condition of a fish. It is considered that individuals with a higher Fulton condition factor are more fattened than individuals with a lower Fulton condition factor [15]. It is also known that the condition of vendace individuals affects spawning. For example, in individuals with a fairly good fattening, the reproductive products mature faster, which in turn accelerates the onset of spawning.

In whitefish, the Fulton condition factor index values in different populations fluctuate within quite wide limits: 0.60-1.9; 0.87-2.08 [21]. For vendace, this indicator is usually around 1.0 [22], [23], [24]. For example, in lakes Drawsko, Kamienny Jaz, Komorze, Pile and Siecino in Poland, this indicator did not exceed 0.84 in the vendace populations [17], in Lake Chłop Fulton's index of fish condition ranged from 0.68 to 1.10 with a mean value of 0.82 [25], but in Lake Miedwie in Poland, the Fulton condition factor for vendace individuals was even lower: 0.69-0.80 [23]. In Latvian lakes the highest Fulton condition factor was detected for vendace in Lake Razna and lake Alūksnes (1.3 and 1.27 accordingly) [24].

In present studied sample sets of vendace individuals, Fulton`s condition factor was relatively high in all sample sets, this exceeded 1.0 (Fig. 3). Therefore, it can be concluded that in our studied sample sets, vendace individuals are in relatively good condition and condition do not changes significantly in time.

It is considered that the growth rate of vendace and the Fulton condition factor are strongly influenced by various lake factors in the summer period: for example, hydrochemical conditions and hydrobiological conditions. Earlier it was noted that the Fulton condition factor is more influenced by the food resources of the water body than other environmental factors [26].

B. The growth rate of vendace individuals

Judging from the ratio of the body weight and standard length of the vendace individuals and the parameters of the power function equation, it is possible to define the growth rate of the individuals.

It is estimated by the power function equation. A constant value of "*n*" significantly greater or less than 3.0 indicates allometric growth of fish individuals. The constant "*n"* of the power function equation also determines the body shape of the fish. For example, it does not exceed 3.0 for fish individuals with a slender body, but for fish individuals with a rounded body shape it is higher than 3.0. [15], [16]. Usually the "*n*" constant varies from 2.5 to 3.5 [22], [27]. For vendace, this parameter is usually around 3.0 [28]. Although in some lakes with insufficient food base this value does not exceed 2.5 [22], [23] and even 2.2 – 2.3 [17].

The ratio of the body weight and standard length of the vendace individuals in the studied vendace samples and its power function equations are shown in Fig. 4. The lowest value of the parameter "n" was in the vendace sample in 2018 (2.75), but the highest value was in the vendace sample in 2019 (3.53). In total, the parameter "n" was above 3.00 in tree from four samples (2015, 2017 and 2019).

It is considered that the growth of individuals is influenced by both abiotic and biotic factors, and fish growth has an adaptive nature, which ensures optimal interaction between the fish population and the environment. In studies of four populations of vendace in the Wielkopolska region in Poland, it was noted that the growth rate of vendace is higher in individuals in water bodies located in the south of the range. The authors noted that such regularity is associated with high productivity of water bodies in the south of the range and low productivity of water bodies in the north of the range [26]. It has also been shown that the rapid growth of vendace is facilitated not only by the productivity of the lake, but also by the low density of the vendace population. However, fast-growing vendace individuals can be overfished already in the first year of life, which can negatively affect the population size [29], [30]. Also it was shown that the growth rate of vendace living in Lithuanian lakes varies from lake to lake [8], [31]. The authors consider that this is the result of adaptation to certain environmental factors. Thus, it is considered that all vendace samples in present study had a quite good degree of fattening. In earlier studies of Latvian vendace populations, the fastest growing vendace individuals were also observed in Lake Drīdzis [24].

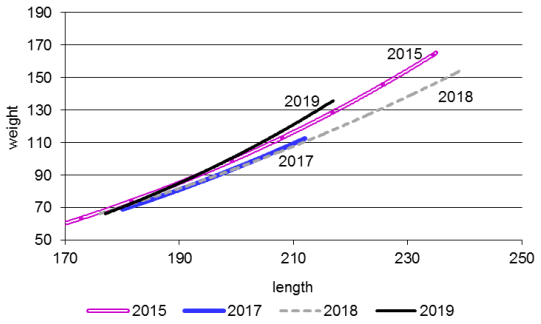

Fig. 4. The ratios of the standard length and body weight of the vendace individuals and their power function equations in the samples from Lake Drīdzis during four years

(Power function equations: 2015: $y = 7E-06x^{3.1166}$, $R^2 = 0.8787$; 2017: $y = 1E-05x^{3.0057}$, $R^2 = 0.6712$; 2018: $y = 4E-05x^{2.7546}$, $R^2 = 0.8723$; 2019: $y = 8E-07x^{3.5321}$, $R^2 = 0.7349$).

The $L\infty$ values for samples from 2015 and 2018 were 251mm and 238 mm accordingly. These are medium length, because $L\infty$ in Lithuanian lakes were the highest 57 cm and 48 cm and, the lowest only 16.4 and 15.5 cm [31]. According to the values of $\emptyset`$ the vendace individuals from 2015 and 2018 years are diveded to fast groving form (4.25 and 4.31 accordingly). These are quite high value comparing with such in Lihuanian lakes (from 2.38 till 2.78) [31].

Same authors noted that the strength of vendace populations varies depending on the spawning conditions of certain year, so it may be that population growth rates should be variable. Populations in the same lake may be assigned to a different group in different years, depending on the nature of growth.

Therefore, it can be assumed that the growth rate of the studied vendace individuals in Lake Drīdzis are relatively high, which is probably influenced not only by the available food resources as noted in our earlier studies

[24]. Although detailed studies of the vendace population density in Lake Dridzis have not been conducted, given the protected status of vendace in Latvian water bodies due to its small numbers, it can be assumed that the growth rate can also be influenced by the vendace population density in this lake, which was noted for small vendace populations in similar studies [30].

C. Morhometric parameters

Various morphological differences in vendace populations are mainly determined by ecological reasons and have the character of adaptation to changing environmental conditions. Thus, in whitefish, body proportions can vary not only in different water bodies, but also in one rather large water body, individuals from different places also have different body proportions [32], [33], [34]. It is known that head parameters are most subject to variability [22]. Significant differences in head parameters were also found in vendace populations in Lithuanian lakes [8], [31]. In present studies, values of this parameter were found from 19.20 to 20.46% in different years (TABLE 2). Studies of the populations of vendace from two Polish lakes (Drawsko and Pelcz) showed similar values of relative head length measurements (19.94-21.33%) [22]. The authors note that when comparing the two lakes, the smallest head parameter was in the deepest lake (max. depth 79.7m), while vendace individuals with longer heads were observed in the medium-deep lake (max. depth 31.0m). A similar trend was observed in present studies, since Lake Drīdzis is a deep lake (max. depth 65.1m).

It is considered that a relatively large head and eyes are characteristic of slow-growing fish, but relatively small eyes are characteristic of fish populations that live in lakes with a good food base [35]. In turn, if the food base of the lake is quite good, then the condition and growth rate of the individuals are also quite high. Comparing the data obtained in present studies, it was found that the average values of relative measurements of head length and eye diameter are not related to the growth rate of vendace individuals. In Lake Drīdzis, the relative eye measurements of vendace vary from 24.47 to 26.32% in different years (TABLE 2).

Earlier, relatively large eyes in fish were found in populations that live in conditions of low light and low water transparency, which in turn are very relevant for plankton-feeding fish (pelede, ripus and vendace) [35], [36]. According to the size of eyes vendace forms that live in the deepest layers of the water body are distinguished from forms that live in the upper layers of the water body [37].

Individuals of vendace living in deeper water bodies have the largest relative eye diameter. According to our data, such regularity cannot be traced, because in the deepest Drīdzis Lake, the relative eye diameter of the individuals of vendace was approximately average compared to previous studies of vendace morphometric parameters in Latvian lakes [24]. Some authors consider that the eye diameter of vendace individuals is most influenced by the food base of the water body [22], because in studies of vendace populations in Drawsko and Pelcz lakes, larger values of eye diameter were found in the shallower Pelcz Lake. Significant differences were observed between the vendace populations of Pleshcheevo Lake and Rybinsk Reservoir (Russia) in terms of the eye diameter parameter, and its values were quite high (27%, 32%) (compared to our data). However, the authors did not try to explain its possible causes [38]. In studies of vendace populations in Lithuanian lakes, significant differentiation of vendace individuals in terms of the eye diameter parameter was observed and a significant correlation was found between this parameter and the area and width of the lakes [31], [39]. It is possible that the size of the eye diameter of vendace individuals in each lake develops as a result of the influence of various factors, and the combination of these factors may be different in each lake.

TABLE 2 HEAD PROPORTIONS OF VENDACE (*COREGONUS ALBULA*) IN LAKE DRĪDZIS DURING FOUR YEARS

(n – number of individuals; mean value ± standart error; *StL; ED; PO* in % of the *HL*; *HL* in % of *SL*; parameters see in TABLE 1)

3+				
PPMI (%)	***2015***	***2017***	***2018***	***2019***
n	20	43	31	26
HL/SL	19.20±0.14	19.56±0.11	20.46±0.12	20.39±0.16
PO/HL	47.38±0.63	49.92±0.25	51.01±0.35	50.51±0.24
StL/HL	26.29±0.46	24.27±0.2	24.12±0.17	24.37±0.17
ED/HL	26.32±0.31	25.91±0.19	24.51±0.16	25.12±0.16
4+				
PPMI (%)	***2015***		***2018***	***2019***
n	9		18	24
HL/SL	19.19±0.2		20.52±0.17	20.45±0.17
PO/HL	48.83±0.72		50.9±0.5	50.62±0.16
StL/HL	25.17±0.44		24.34±0.29	24.23±0.14
ED/HL	26.00±0.39		24.47±0.23	25.15±0.16

As is known, individuals of the vendace from water bodies with a good food base usually have a short and wide head, a small snout and small eyes [40], [41]. In present studies, the features of this complex (short and wide head, small snout and small eyes) were not found in the studied vendace sample groups. However, in Polish lakes, differences in the parameters of snout length and head width were found in vendace individuals in different water bodies [22]. A significant positive correlation was also observed in studies of Lithuanian vendace populations between the length of the pectoral fin and lake depth; between the postorbital head length and lake area;

between the head length, postorbital head length and lake width [8], [39]. The aforementioned studies also found that the populations of the vendace that live in lakes in southern Lithuania differ most from other populations, both in terms of morphometric and meristic parameters.

The basic statistical parameters of the meristic parameters of the studied vendace samples are presented in TABLE 3. In total, three meristic parameters were analysed.

TABLE 3 MERISTIC CHARACTERISTICS OF VENDACE IN LAKE DRĪDZIS DURING FOUR YEARS

(n – number of individuals; mean value ± standard error; parameters see in TABLE 1)

Meristic parameters	2015	2017	2018	2019
n	50	58	66	60
RA	13.06±0.11	13.67±0.1	14.14±0.1	13.94±0.05
LL	83.46±0.7	87.32±0.26	88.43±0.5	86.64±0.51
sp.br	37.26±0.73	40.56±0.32	39.93±0.38	41.62±0.37

The number of rays in the anal fin (RA) of the vendace individuals in the sample sets of different years varied. For example, the highest average values of this parameter (14.14±0.1) were found in the 2018 vendace individuals. In contrast, the lowest (13.06 ±0.11) values of the RA trait were found in the 2015 vendace individuals. The average values of the number of perforated scales in the lateral line (LL) also varied in the vendace individuals of different years. The highest number of perforated scales in the lateral line was found in the 2018 sample set (88.43±0.5). In contrast, the lowest (13.06 ±0.11) values of the LL trait were found in the 2015 vendace individuals (83.46±0.7). The highest average value of the number of gill rakers (sp.br) was observed in vendace individuals in the 2019 (41.62±0.37), while the lowest values of the sp.br. trait (37.26 ±0.73) were found in vendace individuals in the 2015.

Compared to plastic traits, meristic (countable) traits change less; they are even considered as constant parameters that are less exposed to the influence of environmental conditions [39]. However, meristic traits have a different degree of variability, which depends on the time when a final number of countable elements is formed in ontogenesis: the earlier the trait is starting to development, the lower its degree of variability [35].

The number of rays in even and odd fins of whitefish has a relatively small variability. It was noted that the number of lateral line scales varies in different populations depending on living conditions. But the number of gill rakers is considered a particularly valuable feature, since it has no modifications and the functional significance of gill rakers is known. The next generation of whitefish always inherit a moda of the number of gill rakers [42].

Some researchers consider that vendace living in oligotrophic lakes have more gill rakers, while vendace living in eutrophic lakes have fewer gill rakers [22]. It is also considered that, along with the influence of temperature, the number of gill rakers is also affected by the quality of the food of the individuals. For example, Nikanorov [41] notes that in water bodies with weak food resources, vendace have more gill rakers. Comparing the data of vendace populations obtained in present studies with data in previous studies in Latvia, it was found that Lake Drīdzis has average meristic parameter values among six reported vendace populations [24].

It has been determined that the variability of fish is particularly strongly influenced by environmental temperature and lighting during the development of eggs and larvae, especially these factors affect the meristic parameters of fish [40]. This effect is appeared in changes in the number of odd fin rays, the number of vertebrae and the number of perforated scales in the lateral line. That is in lakes where the incubation temperature in the spawning areas is lower. In present studies, higher coefficients of the above parameters were observed. Perhaps this can explain the relatively large number of perforated scales in the Drīdzis Lake vendace individuals. However, a close relationship between the depths of the studied lakes and the variability of meristic parameters in different lakes was not found in present studies. It was also noted that the number of perforated scales in the lateral line is a rather variable parameter. For example, in the summary table of meristic parameters [22], according to the data of the vendace populations from Switzerland, Poland, Belarus and Russia, the maximum amount of this parameter was 91 (in Lake Lanskie in Poland). The maximum indicator of the number of perforated scales of the vendace individuals from Lake Drīdzis found in our studies (97, not shown) has not been noted in any study of vendace populations from the literature sources available to us. In previous studies of vendace populations in Latvia, specimens with the highest number of perforated scales were observed in Lakes Svente and Drīdzis (97, 98 respectively) [43]. According to Nikanorov's data [41], the highest number of perforated scales was found in vendace individuals from Lakes Svente and Drīdzis, but the author associates such differences more with the incubation temperature in the spawning grounds. So, in our studies, the data obtained confirm that the number of perforated scales in the lateral line is a fairly constant parameter in the vendace in Lake Drīdzis. The number of perforated scales in the vendace of Lake Drīdzis is also higher than in the vendace populations of Polish lakes [22].

Considering the obtained results, it is worth talking not about the effect of a certain ecological factor on the development and life of the vendace, but about the adaptation of the vendace populations to the environmental conditions of a particular lake. Thus, in each lake, a set of different ecological factors differently affects the organisms and the variability of their features. This confirms the variability of the morphometric parameters of the vendace and the formation of forms

most suitable for local environmental conditions. In recent research morphological analysis showed that representatives of different genetic lines of *C. albula* within the same lake show minor morphological variations between these lines, which is due to different food preferences and locomotor abilities [9]. Otherwise it was shown that the external appearance of the whitefish is determined more by the environment than by itself. In each lake, the existence of the vendace is influenced by various environmental factors; the interaction of these factors varies in different lakes. As a result, each lake forms its own specific set of ecological factors, in the process of which a specific, characteristic set of morphological factors of vendace individuals is formed in each lake. This set of factors can change over time, also affecting the variability of vendace morphometric characteristics [31]. It has been shown that the increase in the growth rate and fertility of vendace at low population density is a compensatory mechanism for the survival of this species. However, such compensation has its limits, which in turn can increase the risk of local extinctions [44]. Only long-term studies of vendace populations' morphometric parameters and lake environmental factors will allow us to determine the possible regularities of this variability.

IV. Conclusions

In general, the morphological characteristics of the vendace samples of different years in Lake Drīdzis do not exceed the limits of variability of the morphological characteristics of the European vendace (*Coregonus albula* (L.) and changes just slightly during four years. Our present results could be useful in the design and monitoring of conservation programs of vendace populations in Latvian lakes.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 425-432

7-S Challenges in Public Sector Risk Management

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***Abstract*- This paper examines the problems and peculiarities of risk management in the public sector in Bulgaria. Several discussion questions raised: To what extent do public sector administrations have an adequate and working toolkit for risk management? Is the existence of formal tools enough to meet modern challenges? Is there a sufficiently developed organizational culture and knowledge of risk management in the public sector? How does risk management affect network collaboration? How does digital transformation impact the innovation process in the public sector? Can government organizations take the risk of digital transformation? The solution to these questions depends not only on how the evaluation framework will be built, but also on what the design of the risk management system should be, the commitments of the administration to monitor and control it, and the organizational culture and management style. The purpose of the paper is to point out the main deficits in risk management in the Bulgarian public sector from different perspectives and to summarise them in a holistic model - McKinsey's 7-S framework. Data from secondary analyzes of the state of the Bulgarian administration were used, which were triangulated with findings from an empirical study conducted by the authors. The conclusions are that problems are observed in all elements of the risk management framework, although progress is observed over time. From a perspective of the direction of improving the efficiency of the process, the possibility of transferring methodologies and practices to agile risk management is considered. The authors support the view that as an approach, it can solve many of the shortcomings of the traditional bureaucratic model and positively impact network collaboration in the context of digital transformation.**

Keywords-risk management, public sector, McKinsey 7-S Framework

I. INTRODUCTION

In the conditions of a highly variable international, macro and meso environment, risk management is once again the focus of research interest. Whether risk management systems in the public sector manage to catch potential threats in time and ensure reduction of their impact or influence to the maximum extent is a question that hardly has a single and universal answer. The public sector is a particularly important entity that must manage risks with particular care, as its decisions and policies have a huge impact on socio-economic life and can easily change the outlook for certain communities and even entire countries. Despite the high degree of abstraction of this statement, the fact is that the complex situation internationally in the last two years - COVID-19 pandemic, the war in Ukraine, the energy and gas crises, intensive migration processes, and complex interstate relations (including in The Balkans) - pose new challenges to Europe at the geopolitical level. These factors, in combination with the political and al-ready economic instability in Bulgaria, cause serious institutional and administrative difficulties in solving complicated tasks of a strategic nature at different hierarchical levels.

Risk management, as a process and practice, has an essential role in the decisions that are made by the administration. A series of studies by both academics and the executive authority itself, which oversees the process, bring to the fore several discussion questions: To what extent do public administrations have an adequate and workable risk management toolkit? Is the existence of formal tools enough to meet modern challenges? Is there a sufficiently developed organizational culture and knowledge of risk management in the public sector?

Answering these questions for the entire public administration in a country requires a precise monitoring and evaluation toolkit. The solution to this methodological question depends not only on what the framework for identification and assessment will be, but also on what the design of the risk management system should be, respectively the hierarchical commitments to the process of

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8655
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the ad-ministration to monitor and control it, the knowledge and skills of employees, and leadership style.

The purpose of the paper is to point out the main deficits in risk management in Bulgarian public sector from different perspectives and to summarize them in a holistic model - McKinsey's 7-S framework. As a perspective in the direction of improving the efficiency of the process, the possibility of transferring methodologies and practices to agile risk management is considered. The authors support the view that as an approach, it can solve many of the shortcomings of the traditional bureaucratic model and positively impact network collaboration in the context of digital transformation.

II. MATERIALS AND METHODS

A. Context

The development of interpretations regarding the content of the concept of risk goes from a complete lack of possibility to influence risky events [1], through its diagnosis and quantification of the influence and probabilities [2], to the construction of a well-organized management system [3]. There is more and more talk about intelligent risk management and a new approach [4]. In the context of digital transformation and the intensive penetration of artificial intelligence in the public sector, the challenges are related to the implementation of strategic alternatives [5]. They must ensure early diagnosis and adequate response to major risks. Successful risk management is associated with the presence of an appropriate organizational culture [6]. The new risk management paradigm is characterized by a high degree of knowledge and expertise, ensuring the effectiveness of the empowerment and delegation process. Organizations that strive for proactive risk management are characterized by a continuous drive for organizational change, improvement, and reengineering of work processes, investment in staff development and talent retention, working with stakeholders and formal and informal networks.

Intelligent risk management is associated with the understanding that it ensures informed decision making. This implies setting organizational goals at a high hierarchical level and planning and implementing sustainable actions to achieve them. An important aspect is the provision of expert and technological capacity to carry out adequate actions to manage the risks that would threaten the achievement of these goals.

Risk management in the context of financial management and control in the public sector in Bulgaria is perceived as "a process carried out by the management and the entire staff of the organization, which starts with the development of a strategy and covers the overall organizational functioning. It is aimed at identifying those events that may affect the achievement of the organization's objectives, managing the risks associated with those events, and also at controlling that the organization's risk appetite is not exceeded, and providing reasonable assurance, that the goals of the organization will be achieved." [7]. This definition emphasizes several key features that are defining for the process [8]:

- goal setting is the basis of risk management;
- it is a continuous process;
- requires the commitment and participation of all employees in the administration from all hierarchical levels;
- network collaboration is a basis for performance;
- keeps the risk at levels that are within the risk appetite of the organization;
- gives reasonable assurance that the organization's objectives will be achieved.

In recent years, emphasis has increasingly been placed on whether the institutionalization of certain tools in the organization leads to effective risk management and ensures the achievement of its objectives. The relationship between the impact of the environment and intra-organizational dynamics and change is becoming increasingly important to achieve of the intended goals [9], [10]. The researches show [11], [12] that very often the change in the environment and the regulations regarding the risk meet organizational resistance and hardly manage to be imposed in the practice of the administrations.

An interesting study in the public sector outlines some key challenges for it in the context of process management and the implementation of agile approaches [13]. Documentation, or too much documentation, emerged as a significant organizational problem. Insufficient education and experience, low organizational and personal commitment, ineffective communication and limited stakeholder involvement, processes that are not results-oriented, complex or conflicting hierarchical structure and functional interdependence, overly strict internal and external regulatory regulation, complete the list of challenges. The introduction of agile management methodologies in organizations presents new challenges to risk management. Although some of the conventional methods can be applied, it is important to take into account the specifics of flexible methodologies. This implies a more dynamic application of a complex of methods and techniques for risk planning, identification, analysis, assessment and impact.

B. Research approach

The research is based on an established approach, including a review of scientific literature, a situational analysis built on secondary and primary sources of information and a survey, defining conclusions and generalizations.

The review of scientific literature emphasizes the risk management in the public sector as a process, the deficits and the prospects for its improvement. The secondary sources of information include a study of the annual consolidated reports on the state of internal control in the public sector in Bulgaria for the period 2016-2023. They are developed in accordance with the normative regulation of the Law on Financial Management and Control in the Public Sector by filling in a standardized questionnaire for self-assessment approved by the Minister of Finance for each individual year. The consolidated reports cover the self-assessments of the first-level budget managers on the

level of development of financial management and control systems in individual administrations. Reports cover all units of monitored units.

To test hypotheses, the authors also use data from electronic surveys conducted by the team on a defined questionnaire for multi-criteria assessment of administrative capacity. The period of the empirical study covers 2018 - 2023 years, and the sample was formed on a non-random basis and included representatives of all 12 groups of administrations from the executive authority structure - 6 from the central and 6 from the territorial administration. In this sense, the sample reproduces the structure of the general population. The methods used for processing and researching information are statistical methods for analysing structures, one-dimensional distributions, and temporal grouping. Conclusions and recommendations were made through the methods of deduction, induction and translation.

III. Results and discussion

A. Content Analysis

The general assessment made in the consolidated annual reports on internal control in the public sector is that risk management needs improvement. For example, the 2016 report states that "Risk management in public sector organizations still needs consistency of effort, stability and ensuring commitment to identified objectives." [14]. The 2018 report states confirm the findings made in the previous year and it added that it is necessary to "ensure the participation of employees in training related to the introduction and functioning of risk management in public sector organizations, to ensure effective and adequate risk management procedures". [15].

The consolidated report for 2020 notes that risk management continues to be an area in need of improvement in public sector organisations. The identified needs are related to the need for "ongoing review and updating of Risk Management Strategies; preparation and updating of risk registers; engaging managers at all levels in the process; determining risk management coordinating the pro-cess." [16].

The latest public report for 2023 highlights the need to increase the capacity of public organizations in terms of risk management. The weaknesses are again related to the overall process of identifying, assessing, responding to and monitoring risks [17].

Heads of organizations are responsible for building effective risk management mechanisms, as well as implementing tools for ongoing monitoring and updating. A large part of managers indicate that they understand the benefit of risk management for the organization and especially in terms of the process of making a management decision [15]. In the year 2023 again, a large number of government organizations continue to have difficulties, related to the execution of the risk management process, which limits the effectiveness of risk management [17].

From the cited report, it is clear that almost all public sector organizations have risk management strategies in accordance with the provisions of the Law on Financial Management and Control in the Public Sector, Art. 12, para. 3. To what extent the risk management strategies are qualitative, whether they are working documents, is a question that is not yet subject to attention from the control authorities. In 2023, almost 56% of administrations have updated their risk management strategies. Not a small number of organizations, however, do not carry out ongoing monitoring of their strategies, which are a tool for ensuring the risk management process in organizations with rules, procedures and instructions and committed officials.

Another weakness in risk management practice relates to the maintenance of risk registers. In 50% of cases, it is stated that the administrations do not adequately document the risk management process, which is a threat to the achievement of organizational goals. It is extremely worrying to find that only 48% of the administrations, which are budget managers of the first degree, have created bodies, committees, councils, commissions, etc., with a functional specialization in risk management. In the remaining 52% of cases, there are no formal structures charged with administrative-organizational risk management and integration activities [17].

The commitment of management personnel in the administration of risk management and its documentation in the risk register is increasing. In 2018, only 13% actively participate in the process of identification, assessment, targeting and implementation of response, monitoring and reporting, and for 2023 this share is already 48%. A negative indication is that approximately 13% of the heads of organizations report that they partially or do not meet the criterion regarding the commitment of managers at all levels in risk assessment and completion of the risk register. In terms of keeping the risk registers up to date, 60% of organizations conduct an annual review and update of significant risks. All these findings are part of the Consolidated Annual Report on Internal Control in the Public Sector - 2023 [17].

The risk management process in public sector administrations is subject to annual self-assessment and reporting to the Ministry of Finance in Bulgaria. In this regard, it is essential to note that there are drastic differences in the assessments in individual years. For example, if in 2018 72% of administrations rated themselves as good, in 2022 only 34% gave themselves such a rating (see Fig. 1). At the same time, during the period, very good ratings did increase significantly, which shows that the methods of self-assessment through vague criteria, based on several control questions in the questionnaire of the Ministry of Finance, are not sufficiently objective and do not represent the real picture.

The findings that are made in the 2023 report emphasize the need for efforts to ensure the quality of the risk management process and provide an environment for achieving organizational goals. Weaknesses in risk

management negatively impact control mechanisms. In this case, organizational risk levels in a rapidly changing environment increase significantly.

A review of the consolidated reports shows that overall risk management is evolving and more administrations are giving this element higher self-ratings. Despite that, it remains the least developed of the five elements of the financial management and control framework of the COSO model [7].

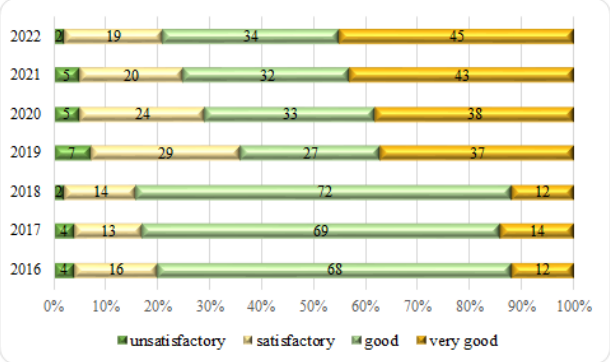

Fig. 1. Self-assessments of the administrations of the risk management process during the period 2016-2022 (authors' calculations based on [14] - [19] and [21] - [22])

The question of how objective these self-assessments are will not be analysed here. It will be mentioned that the self-assessment questionnaires in the last five years are almost identical, with the questions included covering a minimum level of risk management. But the administration in Bulgaria at this stage is not pre-pared to ensure that higher requirements are met, because there are deficits in the risk management expertise in the public sector. That is why it is precisely in this area that the administrations most often indicate that they need training [16], [17].

C. Empirical research

The identified shortcomings of the risk management system are confirmed and supplemented by the empirical study of the administrative capacity of the central and territorial administration in Bulgaria, conducted by the authors.

The research was conducted electronically using a survey card with closed questions in four consecutive years - 2018 - 2023. The sample was formed on a non-random basis and included representatives of 12 groups of administrations - 6 from the central and 6 from the territorial administration. The number of respondents is as follows: 2018 - 142 people; 2019 – 159 people; 2020 – 125 people; 2021 – 119 people; 2022 – 91 people; 2023 - 88 people. The respondents cover all groups of administrations and in this sense, it can be concluded that the sample consists of typical data for the general population and reproduces its structure. Due to the broader scope of the study, only a few descriptive summaries are presented in this article that outline the risk management practice and capacity of the administration.

Each of the questions in the survey has four answers that describe possible states and practices in the administration. The rating direction is from worst to best. The highest grade is awarded when the administration covers the best de-scribed condition. Respondents are the ones who mark the answers on the survey card. The evaluations are made by the researchers according to established author's methodology.

The main assumption in the study was that there are gaps in risk management in several directions described in separate hypotheses.

—The **first hypothesis** is related to the assumption that respondents do not al-ways understand the significance of the administration's strategic and operational goals, and do not realize the relationship between goals and risks.

Therefore, the question was asked whether the organization has set strategic and operational goals for each year with indicators for results, deadlines, re-sources and responsibilities, which are subsequently the starting point for the risk management process.

In general, almost all respondents claim that administrations set annual goals, but some respondents mistakenly equate organizational goals with those of the region or municipality (about 19% with a variation of 11% to 26% in different years). On average, about 16% indicate that such goals are defined, but they are not sufficiently well communicated - they are not published on the website and their monitoring is not arranged. About 2/3 of the respondents indicate that there are organizational goals and their implementation is monitored accordingly.

As noted above, goal setting is at the heart of risk management. There is a need for a more in-depth study of the planning function in administrations and its con-nection with risk management.

—The **second hypothesis** is related to the assumption that the work processes are not always described in the administrations, or if so, the description is partial and the control systems do not always register them. The digitalization of pro-cesses is unsatisfactory.

Respondents were asked to indicate which of the listed situations corresponds to the situation in their administration. Slightly more than 2/3 (70% on average for the period) indicate the best state as relevant to their organization – "All basic work processes are specified with written basic procedures, internal rules, regulations, etc. Employees refer to them and rarely allow deviations that are registered by the control systems." About 14% also indicate that the work processes are scheduled, but at the same time that "Sometimes deviations from the prescriptions are found, but the control systems do not always detect them register". The rest (16% in total) claim that there are no scheduled work processes, and that everything is regulated in the Statute of the administration. In about 9% of the answers, it is indicated that, in addition to the Statute, there are other documents - work maps or technological maps that describe the main steps of a given work process.

This result shows that some of the administrations do not comply with the financial management and control

systems in the public sector. Although they are mandatory, they remain formal.

Over 68% of respondents indicate that work processes are performed predominantly analogically. Automation based on digitalization is rather an exception in their implementation.

—The **third hypothesis** is related to the fact that only some management systems are implemented in the administrations.

Respondents had to choose from a list that included: risk management systems, knowledge management, public procurement, quality management, financialmanagement and control, environmental management, food safety, human resource management, information management, supply management, etc. The majority of administrations indicate up to 5 systems, with half of them even as few as 3 management systems implemented in them. About 10% (average for the period) are the administrations that have implemented more than 8 management systems.

This hypothesis refutes the credibility of the answers in the second hypothesis, where 70% of the respondents note that all the main work processes are specified with written basic procedures, internal rules, regulations, etc. and employees refer to them.

In general, this is also one of the problems of monitoring risk management in the public sector, which is carried out through self-assessment cards without tri-angulating with additional data.

—The **fourth hypothesis** is related to the assumption that not all administrations have developed strategies for risk management, respectively risk registers, or if there are, they are not regularly updated.

About 56% on average (from 48 to 68% in different years) of the respondents indicate that risk management strategies have been developed and implemented in the administrations. However, there are variations in terms of updating strategies and risk assessment. About 14% said their organization's risk management strategy was developed more than three years ago without being updated since then, and the risk assessment was more than a year ago. However, over time this relative share is decreasing, from 23% in 2018 to 7% in 2023. This somewhat contrasts with the responses given in the self-assessment reports and the finding in the consolidated report on the state of internal control, which turns attention to the need to intensify efforts to "ensure ongoing review and update of Risk Management Strategies" [16] and reducing the formality of process execution [17].

About ¼ of the respondents (with a variation of 19% to 32%) also answered that the strategy is long-term (for more than three years), but the risk assessment is done every year. Good practices require more frequent review of risk registers and keeping them up-to-date, as risks are dynamic and must be monitored on an ongoing basis. In this sense, the administrative practice on the matter is rather static.

— The **fifth hypothesis** is complementary, as it concerns the assessment of the risk of political instability. The question concerns the period 2020 - 2023.

TABLE 1. 7-S MCKINSEY FRAMEWORK OF RISK MANAGEMENT IN THE PUBLIC SECTOR
(AUTHORS' CALCULATIONS BASED ON [14]- [19])

Elements	Conclusions
Structure	Weaknesses noted: There are administrations in which there is no structure. "In 49% of cases, there are no formal structures charged with administrative-organizational risk management and integration activities" [16] „…involving managers at all levels in the process…" [17].
Strategy	Weaknesses identified: "Linkage to identified objectives' not always achieved" [14]. "Ongoing review and update of Risk Management Strategies" required [16]. „Changes are needed in almost all stages of the risk management process – preparation, implementation, monitoring and updating of Risk Management Strategies in public sector organizations" [17].
Systems	Weaknesses identified: "Effective risk management mechanisms, implementation of tools for ongoing monitoring and updates" are needed [15]. "Risk registers updated" needed [16] - [17].
Shared values	Contradiction of opinions. On the one hand, "96% of managers understand the benefit of risk management for the organization and especially for the process of making a management decision" [16]. At the same time, the authors' observations show that very often the change in the environment and the regulations in relation to risk meet with organizational resistance and hardly manage to be really imposed in the practice of administrations [18] - [19].
Staff	Weaknesses identified: The lack of structure in small administrations leads to "insufficient functional specialization" [16] of the employees involved, which impairs the quality of risk management [17].
Skills	Weaknesses identified: it is necessary to "ensure the participation of employees in training related to the introduction and operation of risk management" [15], [17].
Style	Weaknesses noted: Insufficient commitment of executives. For example, "engagement of managers at all levels in the process" is considered necessary, as only 13% show commitment [16]. The style is rather traditional and bureaucratic. It is stated that "administrations do not adequately document the risk management process, which is a threat to the achievement of organizational goals" [16]. It is recognized that it is necessary to provide an "environment to achieve organizational goals" [16], but at the same time the administration is not ready for changes in leadership style.

The question was asked whether this risk was included in the risk register at the beginning of the year. 12% of respondents answered negatively to the question. About 1/6 estimated that the risk was identified and assessed as serious at the beginning of the period. In addition, respondents had to assess the measures to address it at the organizational level. Over 78% assessed them as insufficient.

B. Discussion

The conclusions drawn from the analysis of the state of risk management can be summarized by the well-known 7-S McKinsey model (table 1). In general, the identified weaknesses are noticeable in all elements of the model.

These results show that administrations are relatively static structures in terms of identifying and marking responses to significant but unplanned risks. The lack of flexibility, adaptability and proactivity are the main weaknesses in the risk management process in the public sector in Bulgaria.

Successful risk management is associated with the presence of an organizational culture. Culture is defined not only by the risk appetite of the organization, but also by teamwork skills, efficiency, distribution of ownership of work processes and related risks.

The leading motives for risk management, even if normatively regulated, should not be limited methodologically. Agility as a process management practice is increasingly discussed in the context of new public management. Agile tools and approaches improve communication and interaction between stakeholders, support process efficiency and help develop an institutional culture [20].

The existence of normative regulation in a normative and sub-normative act and the presence of numerous methodological developments clearly do not ensure adequate risk management in the public sector. In practice, a situation is reached in which, strictly complying with the requirements of the law, the efforts in the organization are mainly aimed at ensuring formal compliance with it and with the instructions of a higher level. This practice largely stems from the fact that control bodies monitor the availability of rules, procedures and instructions, rather than their applicability and contribution to organizational functioning and achievement of goals. In this way, the bureaucratization of the process is complicated, and its functionality is reduced to the creation of documents, rules, procedures, etc., as a response to external institutional requirements.

The main problems related to building real capacity and culture for risk management, involvement of key stakeholders, early diagnosis and real implementation of management measures are displaced by formal documents that are not working [21] - [22].

The application of strategies that do not cover the generally accepted under-standing of strategy, the reconfirmation of risk registers in years with the same content, the impossibility of indicating potential risks for the administration by the persons in management positions, the lack of a process approach to risk management and its adequate integration into management systems, etc. shows that the normative approach and the strict regulation of this process in the organizations that manage the budget are ineffective. The need to search for working solutions based on the specifics of the organization, the accumulated experience and the possibilities for adequate transfer of good practices is outlined.

It is necessary to intervene on the registered insufficient capacity of public organizations to manage risk. The methodological guidelines and instructions, recommendations, trainings and implemented projects developed so far are insufficient. This requires rethinking the model and applying a specified and individualized approach. External control does not solve the problems with risk management, but only confirms them, since the formal presence of certain documents that are approved in the organization is sought. Trainings on various programs and projects also do not achieve the desired effect. The search for alternative solutions, which are increasingly being imposed in various sectors and functions, is an opportunity to improve the risk management process.

Agile management and adapting its principles to risk management in the public sector is a suitable approach for building a new model. Emphasis can be placed on:

1. Less standardized documentation, written procedures and rules, more visualization and organization-specific ICT-based tools.

2. Less theoretical training, more practical solutions and mentoring.

3. Less regulation external to the organization, more shared experience and lessons learned.

4. Wider participation in the risk management process vertically and horizontally, knowledge sharing, interaction and active communication, fewer regulations.

5. Working in formal and informal networks.

6. Simplified rules, short communication channels, regular monitoring and reporting.

7. Encouraging initiative at all levels, the use of various tools for understanding context and events, strategic and operational analysis of the prerequisites and consequences of risks and implemented responses.

These emphases are in contrast to the widespread practice of ubiquitous documentation, long descriptive procedures, long and complex reporting and communication paths, application of foreign practices with unclear effect in the organization. At the moment, they have not shown a positive effect on their implementation in the public sector in Bulgaria, which is also the reason for the weaknesses in risk management, as well as for the achievement of organizational goals. The concept and model of risk management definitely needs a transformation that integrates this process not only in the management systems, but also in the organizational culture of the public sector.

IV. CONCLUSIONS

Several key conclusions emerge from the study. First of all, there is relative agreement on the need for risk management in the public sector, but the efficient solution for how to conduct it has not yet been found in the Bulgarian administration.

Research into the factors influencing the process can complement monitoring, but government collaboration with relevant higher education institutions is need-ed.

Universities have a lot to say, to help, not only in training the necessary personnel, but also in conducting research.

Serious attention should be paid to the way in which the self-assessment of the administrations is linked. It is obvious why the "One size fits all" strategy is ap-plied, but it is not suitable for such a large variety of structures, scope and tasks of individual administrations. Furthermore, the introduction of more and more working and reporting norms seems inadequate in the context of the increasingly widespread application of agile approaches.

Commitment to the process is weak. There is still no mechanism to ensure ad-equate knowledge transfer to the public sector and network impact in improving risk management.

The problem with the fact that some of the reports have a design that implies formal self-assessment is also significant. The administration prefers to inflate its estimates when there are no mechanisms for data triangulation, evidence, etc.

Last but not least, today's public sector organizations are entering into new and increasingly complex partnerships with companies, some of which have different risk profiles. These circumstances should be taken into account when preparing joint decisions for public private partnerships, etc.

ACKNOWLEDGMENTS

This paper is part of the activities under the project No. КП-06-Н65/10 from 12.12.2022 “Formal and Informal Innovation Networks” implemented with the financial support of the National Science Fund of Bulgaria.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 433-438

The Lack of Competition in the Non-scheduled Public Transport Sector in Italy

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***Abstract*—This paper explores the impact of regulatory constraints on the non-scheduled public transport sector in Italy, focusing on taxi and chauffeur-driven rental services. Despite extensive market liberalization in other industries, this sector remains subject to strict numerical limitations imposed by municipalities under Law No. 21 of 1992. The resulting scarcity of licenses has fostered a secondary market, inflated costs and restricting market access for new entrants. The article examines the economic consequences of this licensing system, highlighting how it distorts competition, raises consumer prices, and reduces service availability, particularly in major urban centres. Attempts at legislative reform have consistently met resistance from industry stakeholders, preventing meaningful liberalization. Moreover, the practice of acquiring licenses in small municipalities, underscores the inefficiencies and complexities within the current regulatory framework. Through an analysis of legal regulation, market data, and policy implications, this paper argues that comprehensive reform is necessary to enhance competition, improve service quality, and ensure fair access to the market. The findings suggest that removing or significantly increasing the cap on taxi and NCC licenses could lead to greater market efficiency, lower consumer costs, and a more dynamic transport sector.**

***Keywords*—"competition", "drivers", "Italy", "non-scheduled public transport", "taxi licenses".**

I. Introduction

Maintaining and creating fair competition is a priority in modern society in the whole the world. The liberalization of entrepreneurial competition in Italy has significantly evolved over the years, particularly since the enactment of Legislative Decree 114/98 [19] (the so-called "Bersani Reform"), which eliminated numerical restrictions on fixed-site retail trade. This reform enabled a more dynamic and competitive environment for businesses, facilitating market entry and expanding consumer choices. However, a notable exception to this liberalization remains within the non-scheduled public transport sector, which comprises two key categories: taxis and chauffeur-driven car rentals (NCC - noleggio con conducente).

Unlike other sectors, non-scheduled public transport remains subject to rigid numerical limitations, governed by Article 5 of Law No. 21 of 1992 [20]. This provision authorizes municipalities to determine the number and type of taxi and NCC licenses issued within their jurisdiction. As municipalities exhaust their allocated quotas, aspiring entrepreneurs are forced to acquire licenses through private transactions rather than public tendering processes. This phenomenon has led to a distortion of market dynamics, restricting free competition and limiting service availability, particularly in major urban centres where demand far exceeds supply.

As an alternative to acquiring licenses in major metropolitan areas, some entrepreneurs have sought licenses in small municipalities where quotas remain unfilled. However, the bureaucratic complexity of cross-provincial registration and the requirement to maintain a physical garage within the issuing municipality add further constraints. Despite these efforts, the fundamental issue remains unresolved: the artificial scarcity of taxi and NCC licenses continues to stifle competition, inhibit service improvements, and burden consumers with excessive costs.

The authors critically examine the impact of regulatory restrictions on non-scheduled public transport in Italy, exploring the economic and social consequences of the existing licensing system. By analyzing legal regulatory tendencies, market distortions, and policy implications, this paper aims to contribute to the ongoing debate on potential reforms and the broader necessity for

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8665
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liberalization in the sector. The following research methods are used in the article: analysis of legal acts and other sources, statistical information, comparative, and logical methods.

There is still a lack of scientific articles on this topic. The following authors have written on the issues of taxi competitiveness in Italy: Vincenzo Visco Comandini Stefano Gori Flaminia Violati "Le licenze dei taxi: abolizione, regolazione o libero scambio di diritti?" (2004) [2]; Chiara Bentivogli, "Taxi regulation and the Bersani reform: a survey of major Italian cities" (2009) [3] – she analyzes the Italian taxi market and its recent changes after the new Bersani law; Laura Chierroni "Deregulation as a Means of Social Policy" (2017) [4] - she analyzes the disputed issue of the effect of liberalization on social welfare in Italy involving the uncompetitive taxi business; Luca Germano, Giuseppe Montelbano, Andrea Pritoni, "Still waiting for the "liberal revolution"? The Italian pro-competition law and the cases of taxi licenses and beach concessions" (2023) [5].

II. MATERIALS AND METHODS

Although over the years, particularly since the distant 1998, with Legislative Decree 114/98 (the so-called "Bersani Reform") for fixed-site trade, the liberalization of entrepreneurial competition in Italy has seen a notable increase, making it possible, for example, to open retail outlets (commonly called shops) without any numerical limit. But there still exists a sector where very strong restrictions on free access remain. This is the non-scheduled public transport sector that is embodied in the two categories that compose it, namely taxis and car rentals with drivers.

Taxi drivers and car rental companies with drivers, while still having the obligation to return at the end of the service (except in special cases) to the garage located in the municipality that issued the authorization, can provide the service to any destination. The rule of return to garage creates not only an economic and logistic burden, but also increases pollution. Taxi drivers have the advantage of having parking areas dedicated to them, which cannot be accessed by car rental companies with drivers, who instead must stop, while waiting for the customer's call, at their own headquarters, their garage.

The peculiarity, the uniqueness in a certain sense, of this category (taxi and car rental with drivers), lies in the provisions of art. 5 of Law no. 21 of 1992 (and subsequent amendments and additions) [20]. This art. 5 establishes, among other things, that the municipalities, in preparing the regulations on the operation of non-scheduled public transport services, establish:

a) the number and type of vehicles and vessels to be used for each individual service.

The word "number" correctly suggests that there is a limit to the number of taxi and chauffeur-driven rental licenses that can be issued. The statistics of 2024 show that there are 28,604 taxi and 127,508 NCC in Italy [6]. Comparing with other cities of Europe (London, Paris), the number of taxis in Milan and Rome is less than half [7]. For example, following the statistics on 2024 in Rome (Lazio region) there were 8171 licenses for taxis and 7998 NCC licenses [8], and comparing to the tourists flow in Rome, this is a very small number. Therefore, the availability of taxis in this city has increased significantly, and the prices for services are high. Similar problems and needs to grow the number of taxi and NCC licenses were expressed in the document "Parere a Roma Capitale sull'incremento del contingente taxi e sull'adeguamento del sistema tariffario, reso dall'Autorità di regolazione dei trasporti ai sensi dell'art. 37, comma 2, lett. m), del decreto-legge 6 dicembre 2011, n. 201, convertito, con modificazioni, dalla legge 22 dicembre 2011, n. 214, e successive modificazioni" [21] by the Transport Regulatory Authority in 2024. There are little towns, for example the Cremona region in Italy, where any taxi licenses do not exist in their territory but only NCC [9]. It could cause problems for disabled people, or in the need for extra cases (because NCC requires advance booking).

Having established a "number" has the consequence that a parallel "market" of licenses has been created over the years, causing their value to increase significantly. In fact, once this "number", calculated by the municipalities (in reality, due to subsequent regulations, compliance is carried out annually by larger local authorities such as the provinces and regions, for example, Lombardy Region, circular no. 13.777 of 12/07/1999 and subsequent Resolution of the Provincial Council of Cremona no. 12/09/2000 with act no. 507 (Regione Lombardia, circolare n. 13.777 del 12/07/1999 and subsequent Deliberazione della Giunta della Provincia di Cremona n 12/09/2000 con atto n. 507) has been exhausted in an "empirical" way on the basis of resident citizens and services present in the territory, other people interested in carrying out this activity no longer have the possibility of obtaining the desired license to be able to practice the profession. In fact, once the "number" has been exhausted, the municipalities will no longer publish public notices for the assignment of new licenses. Only if a municipality had a significant increase in the resident population or the introduction of new services for the community, such as, for example, the construction of a new hospital or a new railway station, could the "number" be revised upwards. It is evident that these situations are infrequent. Noteworthy is that in the autumn of 2024, new licenses were introduced in the Rome municipality in a very strict way (only 1000 licenses, and strict requirements: for example first 200 licenses for vehicles equipped for the transport of disabled persons) [22] - it could be connected also with the Jubilee of Rome and the larger number of tourists.

In order to carry out this activity, interested parties are therefore obliged to turn to the market, purchasing the relevant authorization title from those who already have a license. In this way, the price of individual licenses has grown enormously (for example, the average price for a taxi license in Italy is 100-120 thousand euros. In Rome, it starts from 125 thousand euros; in Milan – from 150 thousand euros, Turin – from 100 thousand euros [1]). Those who sell it consider it a "severance pay", a sort of

final price to be collected usually at the end of their working life, close to retirement, while for those who buy, it is an investment to be made profitable during all the years in which they will carry out the activity of taxi driver or rental company with driver.

The licenses can be inherited also. In fact, Article 9, paragraph 2 of Law no. 21 of 15 January 1992 establishes that in the event of the owner's death, the license or authorization can be transferred to one of the heirs belonging to the owner's family unit, if in possession of the prescribed requirements, or they can be transferred, within a maximum period of two years, to others designated by the heirs belonging to the owner's family unit, provided they are registered in the role held by the provincial chambers of commerce, industry, crafts, and agriculture and in possession of the prescribed requirements. From the literal interpretation of the national law, it would seem that the heir can take over the license from the predecessor (the deceased) only if, at the time of death, he already possesses the required professional requirements, otherwise leaving him the right to sell it to others within two years. But the Article 5 of the same law also attributes to the municipalities, through the preparation of specific regulations, the establishment of the requirements and conditions for issuing the license for the operation of the taxi service and the authorization for the operation of the rental service with driver. Consequently, there has been a flourishing of provisions at the local level that have in a certain sense, made up for the legislative gap by introducing, for example, in one of the municipalities of province of Cremona, the possibility of transferring the license to one of the heirs on the condition that he requests it within 3 months of death and within 1 year of the request, demonstrating that he meets the requirements (returned to the municipality and registration in the provincial register). In the authors' opinion, the inheritance order should be abolished, or at least revised, because it also limits competition by preventing other participants from entering. because these are personal services. It also reduces competition.

Finally, it should be emphasized that the one who pays the price for all bureaucratic rulings is obviously the final consumer, that is, the ordinary citizen or tourist. All of these reasons listed above show that taxis are expensive. For example, in Rome, a standard ride amount of a 5 km route with a 5-minute stop or wait by a user without luggage costs 13.10 euro plus a progressive rate, which also depends on speed and so on [17]. In Bolonia municipality declared this information about prices: if a person leaves from a parking lot, the fixed starting fee is 3.90 euros; if calling radiotaxi or using an app, the taximeter is activated upon call with the fixed starting fee of 3.90 euros and increases based on the distance: the amount cannot exceed 6.80 euros (3.90 euros + 1.45 euros x 2 km) even if the distance is greater than 2 km; to this must be added the radiotaxi/app supplement of 1.35 euros, for a maximum total of 8.15 euros; once the journey has begun, the passenger will pay 1.45 euros for each kilometre travelled in an urban area, but when the taxi travels at a speed of less than 20 km/h the taximeter will apply the rate of 29.30 euros per hour, equal to 49 euro cents per minute (multiple-based rate: journey and time) and so on [18]. Availability of taxi services in Rome has issues also. For example, the Italian Authority on Competition and Market, with the collaboration of the Special Antitrust Unit of the Guardia di Finanza in their research emphasized that the trend of requests for taxi services is growing more than proportionally compared to the requests that the various cooperatives and apps are able to satisfy: over the period January-July 2023, the total requests increased from approximately 985 thousand to approximately 3 million, while the unfulfilled requests increased from approximately 155 thousand to approximately 1.3 million. The percentage of unfulfilled requests, which between January and February was around 14-15%, rose to approximately 45% in June and July [23]. The introduction of a procedure for additional or temporary taxi licenses could improve the situation.

III. RESULTS AND DISCUSSION

Over the years, governments have tried several times to "liberalize" taxi and chauffeur-driven rental licenses with legislative proposals, but they have always clashed with enormous taxi protests from the category, which has staged real civil "riots" or strikes with traffic blocked in the centres of large cities such as Rome, Milan, or Naples [10] [12] [13]. This, together with the inevitable loss of electoral votes in the entire category, has meant that such legislative proposals have remained just proposals and that Art. 5 of Law 15 January 1992, n. 21, is still in force in Italy. For example, the survey "Italians and Taxis 2025" [16] was made intervene with some taxi companies and presented in the press room of the Chamber of Deputies (the event was promoted by Uritaxi with the support of the AppTaxi and Taxi Move apps) to show a positive level of satisfaction among passengers about taxi services: one of the most significant aspects concerns waiting times - 88.5% of Italian users manage to get a taxi within six minutes of calling, a figure that exceeds the European average of 85.1%; 9 out of 10 Italians are satisfied with waiting times under 6 minutes. It seems that the situation is good in the Italian non-scheduled transport services. However, it is worth noting that the survey does not include tourists and it was commissioned by one of the interested parties, for which it is extremely important to maintain a stable market and monopoly in this business. It seems that taxi lobbying organizations have great power to avoid liberalization of this business using different ways and staying in a non-competitive situation. Another issue could be tax-avoidance. The Economic Research Institute shows that the average pay in 2025 for a taxi driver is €24,388 a year and €12 an hour in Italy [15]. The average salary range for a taxi driver is between €18,584 and €28,339, and it is less than the average of Italian salary in total (around 32,450 euros). It seems that their income is low, but some taxi drivers sate that a profit can reach 500-600 euros per day [11].

As an alternative to purchasing taxi and chauffeur-driven rental licenses on the free market, which are now

exhausted in the "numbers" in the main Italian urban centres, some private entrepreneurs, unable to sustain the expense of purchasing such licenses, have begun to turn to small Italian municipalities (another trick), even in possession of their "number" of licenses to be assigned through a tender, very often still available since in small centres there is no need for these transport licenses. Partly because there are no tourist flows comparable to large cities and partly because the use of private/personal cars is very widespread in Italian reality. Therefore, it is not uncommon to see entrepreneurs' residents in Milan looking for these transport licenses in small municipalities even more than 100 km away from their actual interest in carrying out the activity, subjecting themselves to the obligation to have a garage where the car must stop at the end of the day in the territory of the municipality that issued the license. The licenses are provincial, and in order to obtain them, entrepreneurs must be registered in a special register kept by the competent province: Art. 25, comma 2-bis, Regional Law n. 6/2012 [24].

According to Italian law, it is not sufficient, i.e., to be registered in the Register of the province of Milan to request the release through a tender of a license from a municipality located in another provincial area. An excess of bureaucracy, certainly, but the spirit of the law is that these taxi drivers and rental companies with drivers must perform services for the municipalities, even the small ones, that have issued the license. However, not even this limitation is sufficient to prevent people who wish to undertake this profession from requesting the publication of a tender for the assignment of a taxi and rental company with a driver's license in small municipalities. These entrepreneurs also take exams to register in the register of the province where the small municipality is located (we would like to mention that in Italy the administrative division starts from the region, followed by the provinces contained in the region and then by the individual municipalities contained in the various provinces). Once they have obtained registration in the provincial register of the small municipality that still has these licenses available and have rented a garage where they can park the car, they can apply for publication of the tender.

This whole distorted situation is a consequence of the lack of effective competition in this sector in Italian reality. The truth is that none of these people, except for the few entrepreneurs who actually live in small towns, are really interested in carrying out their activities in small suburban towns. They only want the license, the authorization title enabling them to register their car for rental with a driver. A car that will then perform 90% of service in large city centres where licenses have been exhausted for years and where no government has so far been able, not only to completely liberalize, but not even to expand the numerical quota of such licenses. In fact, the Legislative Decree of 14 December 2018, n. 135, art. 10-bis, paragraph 6, had established that until the national public computer archive of rental companies with drivers was fully operational, the issuing of new authorizations was not permitted, thus further hindering the liberalization of the sector.

But it should be emphasized that only a short time ago, the very recent Judgment of the Italian Constitutional Court of 19 July 2024, n. 137 [25], established the unconstitutionality of the aforementioned art. 10-bis paragraph 6, thus reopening the possibility of issuing new rental licenses. The Court noted that limited distortion of competition occurred as a result of the contested legislation, not only was the well-being of the consumer unduly compromised, but something broader was as well, which concerns the effectiveness of the enjoyment of certain constitutional rights, as well as the interest in the economic development of the country. It affected the freedom of establishment in a very negative way.

There are many European countries where reforms on non-scheduled transport were introduced before. An example of positive reforms in taxi business liberalization could be the United Kingdom (UK). In 2015, the UK's taxi industry underwent significant changes with the enactment of the Deregulation Act 2015 [26]. This legislation aimed to reduce regulatory burdens across various sectors, including taxi and private hire services. Notably, it introduced measures affecting the duration and renewal of taxi and private hire vehicle (PHV) driver licenses. The Act standardized the duration of taxi and private hire services driver licenses to three years and PHV operator licenses to five years, unless a shorter period is specified. This change aimed to reduce administrative burdens on drivers and operators. This provision aimed to enhance service flexibility and availability for consumers. Traditional taxis (especially London's Black Cabs) faced significant competition from Uber and other private platforms. Taxi fares fell, and digital platforms transformed the way taxis are ordered. The development did not end there, and in 2020 the UK Government issued, for the first time, Statutory Taxi and Private Hire Vehicle Standards [27] to safeguard the most vulnerable in society. In Italy, services for individuals with disabilities are primarily managed at the local level – there are not common regulations.

In 2018, Finland implemented significant reforms to its taxi industry by establishing the Act on Transport Services [28], aiming to increase competition and improve service availability. The key changes included removing restrictions on the number of taxi licenses and deregulating fare pricing, allowing market forces to determine supply, demand, and prices.

In 2000, the Netherlands implemented reforms to liberalize its taxi industry, aiming to enhance competition, improve service quality, and reduce fares. The key changes included removing restrictions on the number of taxi licenses and allowing market forces to determine pricing structures. The latest decision of the Netherlands is to restrict all newly registered taxi and rental cars in the big cities to zero-emission vehicles after 2025. This comes about after the policy decision to allow municipalities to introduce zero-emission zones in cities; however, these zero-emission zones can now also include taxis [14].

Those examples of good practices only further highlight the stagnation of Italy's non-scheduled transport services and the requirements for demands.

IV. Conclusions

The non-scheduled transport industry in Italy remains heavily restricted by a system of limited licenses, strong lobbying organizations, loopholes in the laws, and outdated regulations that hinder market efficiency and consumer choice. The scarcity of licenses has created an artificial barrier to entry, leading to inflated secondary market prices for consumers and a lack of availability of taxis and NNC services.

Solutions could be related to the implementation of anti-monopoly regulations to ensure fair competition, which would allow access to everyone who meets the requirements and avoid abuse of one's rights. Allowing for temporary or seasonal licenses to address peak demand periods could help to avoid tourists' dissatisfaction. Special regulations for vulnerable consumers are necessary in the state level.

The aforementioned Constitutional Court ruling is the legal key to liberalizing the irregular transport sector. If not a total liberalization, this Ruling should lead to an inevitable increase in the number of licenses that can be issued. Now it is up to the Italian executive power to find creative solutions that allow the different interests involved to be balanced: those of the entrepreneurs already in possession of taxi and rental licenses with drivers, for which they have paid large sums of money, even contracting debts with the banks; those of the new entrepreneurs eager to undertake this profession; and last but not least, the legitimate interests of the citizens/tourists who use this service. This ruling aligns with broader European trends observed in countries like the UK, Finland, and the Netherlands, where liberalization policies have successfully improved service availability, pricing, and working conditions while maintaining regulatory oversight. Experiences of these countries demonstrate good practice that a carefully planned liberalization process can lead to a more efficient, equitable, and innovative taxi industry.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 439-446

The Synthesis of Diversity Management Concept and Upper Echelons Theory

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Abstract*—Diversity management and the Upper Echelons Theory (UET) are essential in analysing the need for specific leadership compositions to strategically impact enterprises' financial performance. Authors consider that diversity management emphasizes fostering inclusivity and social integration, whereas UET envisions that top management team (TMT) characteristics directly influence corporate decisions and financial outcomes. The article highlights synergies and identifies differences in approaches and future research directions, striving to interlink these concepts for the applicability in practice. This conceptual literature review examines academic articles, as well as PhD theses, selected by keywords. Studies on the Diversity Management (DM) concept and articles related to the Upper Echelons Theory (UET) were selected based on relevance. The findings suggest that diverse top management teams enhance strategic decision-making by integrating varied capabilities and knowledge in the team, which serves for better strategic decision-making, affecting the financial outcomes of the enterprise, and in particular, it is beneficial in times of crisis. Effective diversity management extends beyond demographic factors, setting the need to incorporate education, experience, and other cognitive attributes emphasized in UET. As an asset, there is also the need to look further at the social networks of top management team members, shaping management strategies and the financial performance of the Top management team members. Even though there is significant literature in the diversity management field, the links between surface-level and deeper-level diversity management are lacking. Studies often treat the concept of Diversity Management and UET as separate domains, except for gender issues, limiting the potential to integrate those insights fully. The article advocates a shift beyond the traditional concept of diversity, equity, and inclusion (DEI) perspectives and strives to develop an overarching understanding of diversity as a combination of surface-level diversity and competencies people acquire, by introducing a new concept - systemic diversity management.

Keywords*— *Upper Echelons Theory, Diversity Management, Top Management Team, Financial performance.

I. INTRODUCTION

This article contributes to finding the coherent interlinkage between the need for the two frameworks, Diversity Management and Upper Echelons Theory, and proposes a more comprehensive approach to diversity management. Combining surface-level diversity with the characteristics of the Upper Echelons Theory, the authors offer a unifying approach for leveraging people's diversity to enhance enterprises' financial performance.

European enterprises face increasing pressure to respond to complex social, political, economic, and technological challenges. The economic changes are due to the proximity of human-made crises, such as war in Ukraine, and changes in perceptions about economic development in the United States of America and other markets. As enterprises seek to improve strategic performance and innovation, the composition and characteristics of top management teams (TMTs) have come under growing scrutiny. Two influential frameworks—**Diversity Management (DM)** and **Upper Echelons Theory (UET)**—offer important yet often separately applied insights into how leadership traits influence organizational outcomes. Since the early 60s and the foundation of the European Union, diversity management has emphasized inclusivity, representation, and leveraging workforce variety as a competitive advantage. Upper Echelons Theory posits that an organization's strategic choices and performance are based not only on leaders' demographic characteristics but also on their cognitive characteristics, education, risk appetite, decision-making style, and others.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8638
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Despite the established benefits of both approaches, the existing literature often treats them in isolation, limiting their practical and theoretical integration. Recent studies suggest that diversity in leadership supports social inclusion goals and enhances decision-making quality, resilience, and financial outcomes, especially under conditions of uncertainty. However, challenges remain, such as finding ways to use the top management team's competencies, which might be more influential, using deep-level diversity traits, and providing a methodological approach in applying Upper Echelon Theory. Moreover, while UET has traditionally focused on surface-level traits such as age or tenure, it lacks tools to account for the complex, cognitive, and experiential differences that diversity management often highlights.

This article addresses these gaps by reviewing academic literature to explore how UET and DM can become an overarching framework and approach. It argues for a shift toward systemic diversity management, which incorporates both observable and deep-level characteristics of leaders and integrates them into strategic management processes of the enterprises. By interlinking or synthesizing characteristics set into the Upper Echelons theory of the top management teams with the diversity management concept, the article aims to provide a cohesive approach that reflects the realities of modern organizations and their need for diverse, strategically capable leadership teams.

II. Materials And Methods

This article used a conceptual literature review methodology appropriate for integrative synthesis. The article relies entirely on secondary sources; no primary data is collected. Its primary objective is to conceptually interlink the Diversity Management (DM) and Upper Echelons Theory (UET) frameworks by identifying their theoretical synergies, overlapping dimensions, and existing gaps. The review is designed to summarize existing knowledge and provide a critical and analytical synthesis of literature at the intersection of concepts of Diversity management and Upper Echelons Theory.

The authors employed a keyword-based selection strategy for identifying relevant academic sources to construct the conceptual foundation. The reviewed materials include peer-reviewed journal articles, PhD theses, and conceptual studies addressing Diversity Management and Upper Echelons Theory. The inclusion criteria prioritized literature that demonstrated relevance to the thematic scope, conceptual contributions to understanding top management diversity, and theoretical elaboration on surface-level diversity (e.g., gender, ethnicity, age) and deep-level diversity (e.g., education, experience, and cognitive frames). The review includes research from the mid-1980s through the early 2020s, beginning with the foundational contribution of Hambrick and Mason (1984), which introduced the Upper Echelons perspective.

Among the key sources likely referenced are Homberg and Bui's (2013) systematic review of top management team (TMT) diversity, Wrench's (2007) historical analysis of diversity management in Europe, and Yang and Konrad's (2011) integration of institutional and resource-based theories in the context of DM. These and other scholarly works provide the theoretical and contextual grounding necessary for the synthesis undertaken in this article.

The conceptual review strategy is organized around several focal points. First, the authors describe positive and negative implications of Diversity Management—emphasizing human resource inclusion, equity, and social integration—and Upper Echelons Theory, which highlights the impact of executive characteristics on strategic organizational outcomes. Second, they identify a conceptual common ground wherein TMT **diversity** emerges as a bridging construct, linking inclusion-focused initiatives with strategic decision-making effectiveness. Third, the article critiques the predominant focus in the current literature on surface-level diversity, particularly gender, while highlighting a need for broader integration of deep-level attributes such as values, cognitive styles, and professional backgrounds.

The authors propose developing a novel theoretical framework termed Systemic Diversity Management.

In conclusion, this article contributes to the field by applying a systematic conceptual literature review to the intersection of DM and UET, drawing upon four decades of theoretical development. Through critical synthesis of the findings in the literature, the study builds the basis of the understanding of how diversity at the top management level can simultaneously advance organizational inclusivity and performance. The authors suggest a shift toward interdisciplinary integration, enabling a more comprehensive and practical application of diversity-related concepts in contexts of contemporary entrepreneurship.

Diversity management has developed as a fascinating field of study, particularly in the business sector, understanding that the workforce is fundamental for economic growth. Diversity management aims to enhance inclusivity and leverage workforce diversity for economic and organizational gains. This article gives an insight into the history of the diversity management concept, its application, and the theoretical foundations supporting its impact on business performance.

Diversity management emerged in the United States during the 1950s and 1960s as a response to civil rights movements, legal frameworks on equal employment opportunities, and affirmative action policies [1]. Initially, enterprises strived to introduce as obligatory rules and regulations, but gradually recognized diversity as a strategic asset for competitive advantage [2]. In the 1980s and 1990s, diversity management expanded beyond legal regulations. It expanded to become part of the broader organizational goals, such as innovation, market expansion, and corporate social responsibility [3].

Diversity management has been a fundamental concept in Europe since the creation of the economic union, and it

has been influenced by policies promoting social integration rather than affirmative action [4]. The Treaty of Rome (1957) [5] laid the foundation for gender equality in the labour market, but a comprehensive approach to diversity management was only generally fostered by demographic changes and globalization in the last decades of the 20th century [6].

Several theoretical perspectives have strived to understand the impact of Diversity Management on business performance. The Upper Echelons Theory suggests that diversity in top management enhances decision-making and organizational performance by integrating different perspectives and experiences [7]. Cognitive psychology research supports this by highlighting the role of diverse cognitive styles in problem-solving and innovation [8]. Additionally, organizational diversity frameworks emphasize the need for structural interventions to foster inclusivity and introduce diverse perspectives to improve decision-making [9]. These frameworks suggest exploring beyond traditional diversity training to embed inclusivity into core business processes to have more extensive results, as well as indicating that vast responsibility lies in the hands and decisions of the top management teams.

A vast amount of research findings indicate a positive correlation between diversity management and the performance of enterprises, particularly regarding labour productivity, workforce innovation, and employee retention [10]. However, the effectiveness of diversity management depends on its implementation. Some authors argue that diversity initiatives should be integrated strategically into the organization's business approach, rather than treated as standalone initiatives or even programs without integration into the business processes, once again pointing towards decision-making processes in the enterprise [3]. Despite all the placements and approaches to implementing diversity management programmes, such elements as trust have also been identified as a significant element in ensuring the success of diversity initiatives [11]. Trust within diverse teams enhances collaboration, reduces conflict, and fosters a sense of inclusion, leading to improved organizational outcomes.

Diversity management faces challenges such as resistance to change, lack of inclusive leadership, and ineffective implementation strategies [12]. Some researchers emphasize and confirm the need for researchers to focus on developing models integrating diversity management with corporate strategy to maximize its impact on business performance [13].

Diversity management has faced evolution from respecting the need to find a workforce and utilizing all the resources available in society to a strategic business norm. While its application varies across regions, the overarching goal remains to create inclusive work environments that drive innovation and performance and provide social inclusion for all societal groups. The article's author concludes that diversity management is crucial for social inclusion, but should be fostered by a more targeted approach focusing on strategic aspects of the enterprise, meaning top management teams are responsible for the strategic decisions in the management strategies for developing business.

a) Definitions: surface-level vs. deep-level diversity.

According to the literature, diversity is commonly categorized into two primary types: surface and deep. Surface-level diversity refers to observable attributes that are immediately apparent without needing personal interaction, such as age, gender, race, ethnicity, and physical abilities. In contrast, deep-level diversity encompasses less visible characteristics, including individuals' values, attitudes, and beliefs, which add more value to inclusion than demographic traits [14], [15].

Looking at the top management team of enterprises, there is a need to look further than surface-level diversity and to see more in-depth diversity to gain possible outcomes considering more profound in depth diversity, which has been neglected in the contrasts with surface-level diversity, which has been historically defined by plainly visible demographic characteristics [16]. Literature research indicates that deep-level diversity can have a higher impact on team performance and organizational success. Acknowledgment and proper use of knowledge about the more profound level diversity of the members of the top management teams can provide possibilities for increased productivity in economic terms [17].

Deep-level diversity highlights characteristics of individuals that can be hidden or highlighted at a person's discretion, such as beliefs, attitudes, and norms [18]. Meanwhile, surface-level diversity is defined as noticeable characteristics that distinguish individuals from each other [19]. Enterprises can develop a competitive advantage by embracing surface-level and deep-level diversity in the workplace, adding aspects that support mitigating differences, providing orientation, and reducing the possibility of conflict [20].

Ensuring recognition and valuing both types of diversity, enterprises can recognize and use accordingly everybody's differences, not only visible but also invisible characteristics among employees, and, more importantly, provide a constellation of Top management teams, using more profound levels of diversity for the gain of the productivity of the enterprises. The authors envision the need to link the characteristics of top management teams, identified in Upper Echelons Theory [21]. Considering both of these approaches and their implications, this approach should be titled - systemic diversity management.

b) Goals and benefits of diversity in organizations

The article by Thomas [22] underscores the critical role of communication in shaping and sustaining diversity within organizations, emphasizing surface-level attributes such as race, gender, and age, and deeper-level diversity rooted in values, knowledge, and social identity. Different aspects of diversity influence workplace relationships and cooperation among teams, confirming that communication

is critical for navigating differences and fostering inclusion in enterprises on any level. The authors argue that managing diversity effectively requires acknowledging that visible demographic differences are essential. However, leveraging diverse knowledge and perspectives in the context of top management teams to improve organizational financial outcomes is also essential. It highlights the need for a clear understanding of what composition would be the best in the top management teams, related to competencies, and how communication practices can bridge differences and enhance the benefits of a diverse workforce. Such authors as Lakshminarayanan S. [23] offer a strategic perspective on how diversity management can improve organizational effectiveness by fostering voluntary engagement through well-structured diversity events. By applying social marketing principles, the author demonstrates how segmenting employees, based on their self-perception of diversity and willingness to participate, enables organizations to design tailored events that resonate with diverse audiences.

Approach improves participation rates and strengthens organizational inclusivity of staff, as it creates spaces for information-sharing, acknowledgement of cultural differences, and skill development. These events are visible and strategic tools that communicate the organization's values and commitment to inclusivity, enhancing employee satisfaction, organizational reputation, and internal trust. The study highlights that the careful planning and communication of diversity initiatives, sensitive to both surface-level differences and more profound diversity of knowledge and experience, can transform diversity management from a compliance-driven activity into a source of competitive advantage and community-building within enterprises.

There are authors [24] convinced that diversity and inclusion are ethical commitments and are essential to organizational success. A study shows that diverse teams consistently perform better, offering greater creativity, faster problem-solving, and smoother communication. However, researchers highlight that diversity should be interlinked with inclusion, ensuring that all employees feel acknowledged, valued, and respected, to have better performance. The potential of team diversity is limited without proper inclusion activities, making employees feel excluded or disengaged. Several studies demonstrate that well-managed diversity fosters collaboration, innovation, and employee satisfaction. Placing diversity as a strategic advantage for organizations seeking long-term growth and resilience is crucial and brings some financial gains. Still question whether that is the maximum stay unravelled.

c) Challenges in implementing effective diversity strategies.

Implementing diversity management, addressing surface-level diversity within organizations, and having a general attitude of "value-in-diversity" perspective are accompanied by various challenges that influence their effectiveness. Although most industry researchers and reports indicate vast gains regarding implementing diversity management concepts [22] – [24], proving that a heterogeneous workforce contributes to better problem-solving, innovation, and market responsiveness, some critics caution against overestimating these benefits without acknowledging the inherent difficulties.

One of the main challenges is the increased potential for emotional conflict and interpersonal tensions among employees, mainly when differences in race, ethnicity, gender, or cultural background are not adequately acknowledged. Such tensions can result in decreased group cohesiveness, higher work avoidance or absenteeism rates, increased turnover, and reduced job satisfaction [25]. Additionally, diversity may lead to what researchers describe as "process losses" [26] whereby communication barriers, misunderstandings, and coordination costs hinder team efficiency and decision-making processes.

A critical challenge in diversity management is rooted in a delicate balance between fostering a sense of belonging and recognizing employees' uniqueness. Drawing on Brewer's Optimal Distinctiveness Theory (ODT) and subsequent research, it is clear that many diversity initiatives fail to address this dual need, which may explain the inconsistent relationship between diversity and organizational performance. Focusing on the internal activities to ensure belonging forces individuals to adapt, creating the need to hide their identity to align with the workplace culture. Meanwhile, emphasizing uniqueness without fostering a sense of belonging can lead to social fragmentation, stereotyping, and weakened team cohesion. [27]. So, inclusion should not be reduced to assimilation or differentiation but should integrate both dimensions, fostering an organizational culture in which individuals feel valued and their talent might thrive while being able to express their different perspectives and experiences. Addressing this balance is crucial so diversity management can go beyond symbolic gestures and deliver tangible benefits for individuals and organizations.

d) Intersection of Upper echelons Theory and Diversity management

The study by [28] revisits Upper Echelon Theory to explore the relationship between senior management diversity, diversity practices, and organizational performance. Authors establish that the demographic diversity of senior management teams is positively associated with the broader workforce's demographic composition and the adoption of diversity-oriented practices. This finding supports the notion that diverse leadership signals inclusiveness and promotes policies fostering workforce diversity. Secondly, the research emphasizes the important role of empowered diversity management managers in organizations where these managers hold decision-making power and are more likely to apply top management diversity to powerful and effective diversity initiatives. The study also demonstrates that diversity practices in organizations positively impact improved organizational performance, indicating that diversity at the leadership level can become a tangible business benefit when supported by realistic diversity infrastructures and organizational culture. The research

findings confirm the strategic importance of diversity management in fostering organizational outcomes.

The study [29] provides significant insights into the relationship between top management team (TMT) diversity and firm performance, revisiting the Upper Echelons Theory. Authors found that functional heterogeneity within TMTs positively influences strategic choices such as corporate consolidation and internal innovation, highlighting the constructive role of job-related diversity in fostering strategic decision-making. It indicates that increased age diversity within TMTs negatively impacts strategic choices, suggesting that social-category diversity, particularly age differences, may negatively impact consensus in the team and decision-making efficiency. The study also demonstrates that strategic choices, related to business expansion, specifically buying other companies and developing new ideas within the company, fully mediate the relationship between functional diversity and firm performance. These findings confirm the theoretical foundation that the observable characteristics of top managers shape organizational outcomes through strategic decision-making.

Research studies provide a comprehensive investigation into the emerging phenomenon of the Chief Executive Officer (CEO) activism and its strategic implications. While consumers may respond favourably to socially conscious CEO perspectives, investors tend to react negatively, perceiving activism as a potential distraction from shareholder value maximization. The research looks at how CEO activism relates to activities outside the market. It shows that when CEOs address socially progressive issues, their companies are more likely to get involved in corporate social responsibility (CSR). However, when CEOs support traditional values, this connection is not found [30].

e) Evidence of diverse top teams affecting strategy, innovation, or performance

In the academic literature, some studies provide empirical evidence on the strategic significance of diversity within research and development teams and its impact on innovative performance. Studies confirm that surface-level diversity (such as gender) and deep-level diversity (such as skills and educational background) positively influence innovation outcomes, particularly enhancing radical and incremental innovation in manufacturing firms [31]. Also, indications are evident that, despite the positive effects, excessive heterogeneity can negatively affect team cohesion and communication, limiting innovation effectiveness. It is pointed out that interaction between different dimensions of diversity—specifically gender, skills, and education—can create subgroups that may hinder innovation if not properly managed. It is possible to conclude that research and development diversity is a valuable strategic asset. However, its benefits depend on carefully balancing diversity dimensions to avoid internal fragmentation and maximize innovative potential.

Diverse TMTs contribute to broader perspectives by shaping firms' innovation strategies and overall performance, thereby influencing better strategic choices, mainly focusing on innovation fields, enhancing new product development, and firm competitiveness. However, the relationship is complex—while diversity can foster creativity and adaptability, it may lead to conflicts or slower decision-making [32].

The article by Eesley, Hsu, and Roberts provides a nuanced analysis of how the composition of top management teams (TMTs), specifically founding teams, influences venture performance depending on strategic and environmental conditions. Meanwhile, it confirms that the positive impact of TMT diversity is not universal. However, it is very much about the level of alignment with a firm's innovation strategy and commercialization environment [33]. Diverse founding teams, where success requires the development of broad organizational capabilities in the literature, are characterized by various functional backgrounds and tend to achieve superior performance in competitive environments. On the other hand, literature confirms that technically focused founding teams, composed predominantly of individuals with technical expertise, are confirmed to be better suited to commercialization environments and innovation-driven strategies, as they can advance technological development and leverage partnerships with incumbent firms. The initial composition of the founding team has a lasting impact on organizational structure and strategic direction, suggesting that early alignment between team characteristics, strategy, and environment is crucial for an enterprise's long-term success.

The strategic consensus within top management teams (TMTs) shapes innovation performance. While diversity in functional backgrounds or tenure can bring varied perspectives, it does not automatically lead to positive outcomes. Also, functional diversity enhances innovation only when TMT members share a common strategic vision. In such cases, different viewpoints are effectively integrated into decision-making. Diversity may trigger conflicts and undermine innovation development by ignoring the need for strategic consensus. Therefore, consensus helps align diverse perspectives and supports the team's ability to implement innovative strategies [34].

The study by [35] draws two key conclusions about the relationship between top management team (TMT) diversity, strategic leadership, and organizational performance. First, it confirms that TMT diversity alone has a positive but limited influence on organizational performance. Second, the research demonstrates that strategic leadership significantly strengthens this relationship, acting as a moderating factor that enhances the positive effects of TMT diversity. Strategic leadership increases the explanatory power of TMT diversity on performance from 10.4% to 18.0%, highlighting that diverse leadership teams are more effective when guided by change-oriented and structure-focused leadership behaviours. The conclusion reinforces the theoretical construct that strategic leadership is essential in translating the potential advantages of top management teams' diversity into tangible organizational outcomes.

The article by Schubert and Tavassoli shows that educational diversity among members of top management teams has a significantly positive impact on a firm's ability to implement innovation activities. Educational diversity broadens the cognitive base of decision-makers, enabling them to identify strategic opportunities better and formulate innovative agendas. However, the study highlights that while TMT diversity influences the decision to engage in innovation (the strategic phase), it does not directly impact innovation outcomes' actual success or novelty. Instead, the execution and market success of innovation depend more on middle management teams (MMTs). TMTs shape strategic direction and innovation engagement, while MMTs influence operational outcomes [36].

f) Theoretical tensions and alignments between UET and diversity goals.

One of the main challenges in the Upper Echelons Theory (UET) is that researchers and academics still do not fully understand how top executives think, which is often called the "cognitive black box." Researchers often rely on characteristics such as age, competency, or background rather than examining the actual decision-making processes of leaders. Upper Echelons Theory is criticized for lacking specific characteristics or criteria to test and measure its impact in realistic contexts. Another significant issue is the lack of focus on how top executives interact, even though team dynamics and relationships strongly shape strategic choices. Establishing clear cause-and-effect links remains problematic; it is often hard to tell whether executive traits drive outcomes or merely coincide with them. Researchers must address these limitations to make UET more effective for analyzing leadership in today's complex organizational environments [37].

More recent research has explored more specific factors that may shape strategic outcomes. For instance, leadership diversity has emerged as a key area of interest. Authors examine how diversity in top management teams, across gender, nationality, education, social background, and functional roles, can enhance corporate sustainability. Studies are showing that diverse leadership teams generally promote more sustainable behaviour. However, contextual factors such as industry and geography should also be considered when analysing their impact and outcomes in the context of firm performance. Researchers, focusing on surface-level attributes, very often conclude that gender diversity in executive roles, cross-cultural experiences, and varied educational backgrounds can all contribute to better strategic thinking and performance. However, for these benefits to materialize, diversity must be thoughtfully integrated into the leadership structure [38].

Some researchers emphasise the importance of leadership development for mid-level managers in high-turnover environments. Research provides strategies for successful leadership transitions, ensuring organizational knowledge during change, fostering effective communication, encouraging adaptability, measuring performance, and implementing formal and informal development programs. These findings enrich UET by highlighting how midlevel leaders, long overlooked, actively influence strategy and organizational performance through their unique traits and values [39].

Leadership characteristics also intersect with gender issues, particularly in fields like healthcare. A study by Frankl and Roberts (2018) proves that female executives influence positively the implementation of an organization's strategy by bringing collaborative, ethically grounded leadership styles that positively affect organizational culture and outcomes. While this supports UET's emphasis on leader traits shaping strategy, the study also highlights ongoing gender-based barriers, including underrepresentation and restricted access to high-level roles. It advocates for more inclusive executive structures to reflect diverse perspectives better and improve decision-making across sectors [40].

Illustrating the influence of types of leadership on organizational behaviour, researchers examine how different types of charismatic leadership affect corporate social responsibility (CSR) strategies. Research identifies three pathways: a) socialized charismatic leaders (SCL) prioritize integrative CSR and achieve trust-based, sustainable performance; b) neutral charismatic leaders (NCL) pursue strategic CSR for competitive gain; and c) personalized charismatic leaders (PCL), driven by self-interest, selective and symbolic CSR that can damage trust and lead to unstable performance results of the enterprice. This revelation reinforces UET's core idea that leadership values are crucial determinants of enterprises [41].

III. RESULTS AND DISCUSSION

A conceptual review discusses the need to link Diversity Management (DM) with Upper Echelons Theory (UET). The synthesis of these frameworks highlights how diversity in top management teams (TMTs) influences strategic decision-making and organizational outcomes, especially during crises.

One key insight is that cognitively diverse TMTs—those composed of individuals with varied educational backgrounds, experiences, and social networks—enhance decision-making quality. Beyond demographic traits such as gender or ethnicity, this deeper-level diversity strengthens leadership capacity, particularly in uncertain or complex environments.

The authors' conceptual literature review introduces the concept of systemic diversity management, extending traditional approaches to diversity management and applying the Upper Echelons Theory. It calls for integrating surface-level traits with more profound cognitive attributes emphasized in UET. This conceptual shift reframes diversity from being solely a matter of representation to a strategic asset that influences firm performance.

These findings lead to several critical discussion points. First, the conceptual disconnect between DM and UET limits opportunities for an integrated understanding of gains enterprises can acquire. While both address leadership and diversity, those rarely intersect

meaningfully outside gender-related topics. A unified framework is needed to connect these perspectives and explain how diversity drives strategic outcomes. Second, the field lacks consistency in how diversity is defined and measured. There is a need for a more evident categorization of diversity attributes—including demographic, experiences, and cognitive factors—to enhance research comparability and practical application to increase productivity.

To conclude, this article highlights the strategic relevance of diversity within leadership and the importance of moving toward a more integrated and standardized conceptual framework. Bridging DM and UET offers a richer understanding of how diverse leadership can shape organizational success in dynamic environments.

IV. Conclusions

This article focuses on two important concepts - Diversity Management (DM) and Upper Echelons Theory (UET)- each of which contributes valuable perspectives on the composition of teams in enterprises interlinked with organizational performance. However, these concepts remain disconnected mainly from existing research. Most studies focus predominantly on surface-level diversity traits such as gender or age. At the same time, deeper cognitive, experiential, and value-based dimensions—those most aligned with the strategic underpinnings of UET—are underexamined or excluded entirely. This lack of integration limits our understanding of how diverse leadership teams drive strategic decision-making, innovation, and resilience in complex organizational environments.

To fill this fragmentation, the authors of this article suggest the foundation of a new concept: **systemic diversity management**. The suggested approach combines diversity management's focus on demographic aspects and social inclusion of different groups with an identity-based focus with the strategic and cognitive emphasis of the Upper Echelons theory. Systemic diversity management acknowledges surface-level representation and deep-level competencies as critical for effective top management team design and performance outcomes. However, the conceptual framework remains in its formative stage. Developing **a robust, testable model of systemic diversity management** is recognized as an essential next step and is explicitly identified as a task for the authors in future research.

This forthcoming model will articulate how leadership diversity shapes strategic processes and how these dynamics can be embedded into organizational structures. By developing this integrated approach and designing a mathematical model to be applied in the practical, day-to-day business, the authors aim to contribute to theoretical clarity and create practical tools for organizations seeking to leverage leadership diversity as a strategic asset.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 447-453

Assessment of Factors Influencing Beekeepers' Activities in Latgale

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***Abstract*—There are approximately 3,400 beekeeping farms in Latvia with more than 100,000 registered bee colonies. Most of them are family businesses and are not united in cooperatives, organizations or producer groups. This study analyzes the operation of beekeeping farms in Latgale, evaluating the factors that affect their productivity and development. The aim of the study is to determine the relationship between beekeeping practices, farm size, education level, marketing strategies, bee diseases, climate conditions and other factors, and how they affect honey yields and farm openness in Latgale (Latvia). The study used correlation analysis between different factors. The results showed that professional beekeepers, for whom beekeeping is the main source of income, are more open to tourism, have registered with the Food and Veterinary Service (PVD), change queen bees in a controlled manner, sow nectar plants, have developed product identification marks, have a higher number of honey extractions per season, and on average collect more than 50 kg of honey from one colony per season. It was also found that the beekeeper's level of education and the farm's visibility have a positive impact on honey yield and sales price. For example, more educated beekeepers produce 15% more honey per colony on average, and their honey sales price is 10% higher. In addition, it was found that beekeepers who have fewer problems with neighbors using pesticides tend to have higher honey yields. These findings could be useful for developing recommendations for the sustainable development of the beekeeping industry in Latgale.**

***Keywords*—beekeepers, beekeeping industry, Latgale.**

I. Introduction

Latvia is a country with a significant agricultural sector. In 2020, farms managed 1.21 million hectares of owned land, which is 61.7% of the total managed agricultural land. The remaining areas were leased from other farmers. In the same year, there were 69 thousand economically active farms registered in Latvia, which managed 1.97 million hectares of agricultural land, which is 30.5% of the country's territory [1]**.** Agriculture and food production are important components of the national economy, accounting for 1 to 60% of the GDP of different countries [2]. This depends on the geographical location of the country, traditions, etc. factors. Beekeeping is one of the most important agricultural sectors in Latvia, which provides not only a valuable food product - honey, but also promotes the pollination of agricultural crops and biodiversity. Beekeeping traditions in Latvia are centuries old, and beekeeping is an important source of income for many rural residents. However, the beekeeping industry faces various challenges, such as climate change, bee diseases, pesticide use, competition from other countries and adulteration of beeswax and honey. Therefore, it is important to study the factors that influence beekeepers' activities and honey productivity in order to provide recommendations for the sustainable development of the sector.

In parallel, beekeeping also has other agricultural functions, such as seed production, organic farming. The main competitiveness factors in beekeeping are formed at the regional level, therefore a marketing strategy is needed

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8673
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to develop the potential and competitiveness of beekeeping in the local region [3]. Competition is one of the components of the marketing system that affects the company in choosing the market, selecting marketing intermediaries and suppliers, forming the product range and the entire complex of marketing activities. Beekeeping could be a sector that stimulates economic and social development, as in the long term competitiveness will be improved and the number of beekeeping products with high added value will increase [4] - [5]. Latvia does not have traditionally developed beekeeping regions [6]. In 2021, there were almost 3.4 thousand beekeeping farms in Latvia with more than 100 thousand registered bee colonies [7]. Honey farms are mostly family businesses/hobby and small, and they are not united in cooperatives, organizations and producer groups [3], [8]. Honey from various flowers is most widely available in Latvia, however, nectar from a specific plant is becoming increasingly popular [9].

This study analyzes the operation of beekeeping farms in Latgale, evaluating the factors that influence their productivity and development. The aim of the study is to determine the relationship between beekeeping practices, farm size, education level, marketing strategies and other factors, and how they affect honey yields and farm openness in Latgale (Latvia).

II. Materials and Methods

Research location: Latvia: Latgale: Rēzekne municipality and Ludza municipality. Time of conducting the study: 2024.

In Latvia, the Agricultural Data Center has registered approximately 3,400 beekeeping farms and more than 3,000 beekeepers, which means that there can be several beekeepers on one farm, and beekeeping is often a family occupation (Table 1).

TABLE 1 NUMBER OF INHABITANTS AND BEEKEEPERS IN LATVIA IN 2024 [10]-[12]

Ariel	***Population***	***Number of registered beekeepers***	***Number of beekeepers surveyed***
Latvia	1 839 766	>3000	-
Latgale	381283	-	-
Rezekne municipality	30051	-	26
Ludza municipality	23522	-	

Table 2 describes the criteria used in the study, their designation, explanation, and the extreme limits of the studied criterion.

The study used correlation analysis, which is a bivariate analysis that measures the strength of the relationship between two variables and the direction of the relationship. The Pearson correlation coefficient is used to measure the strength of the correlation, which shows the linear relationship between two data sets. In terms of the strength of the linear relationship, the value of the correlation coefficient ranges from +1 to -1, where a value of ± 1 indicates a perfect relationship between the two variables [13].

TABLE 2 TYPE STYLES DESIGNATION AND EXPLANATION OF THE CRITERIA USED IN THE STUDY

Desig nation	**Explanation of the criterion and its extreme limits**
A	beekeeping as a way of generating income (main activity - other)
B	degree of public openness of the farm (tourist attraction - none)
C	apiary registration with the Food and Veterinary Service (PVD) (yes – no)
D	nectar extraction site (sowing on the farm - I don't know)
E	type of design for beekeeping product presentation (designed for each product - not available)
F	beekeeping product design author (himself – none)
G	number of honey extractions per season (1 – 4≤ times)
H	honey yield from one colony per season (not counting - 100≤ kg)
I	number of beehives in the apiary (1 - 31≤ hives)
Y	beekeeper's educational level in beekeeping (self-study – higher education in beekeeping)
J	choice of beekeeping type (mobile – all types)
K	self-consumption of cosmetics from beekeeping products (yes - no)
L	processing of bee products on the farm (yes – no)
M	self-consumption of beekeeping products on the farm (only for bees – no)
N	type of wax used on the farm (own wax – only purchased wax)
O	pesticide use by surrounding residents (yes – no)
P	apiary enclosure (yes – no)
Q	number of wild bee swarms received in the apiary (yes – no)
R	obtaining organic farming status (yes – no)
S	frequency of queen bee replacement in a bee colony (every year - I don't know)
T	honey without additives for personal consumption (yes – no)
U	honey sales price (≤3.99 EUR. kg-1 - 11≤EUR. kg-1)
V	type of bee treatment (organic acids - I did not treat)
W	beekeeper's age (20 years – 61 ≤ years)
X	production of cosmetics from honey (yes – no)

III. Results and Discussion

Beekeeping is a traditional industry in rural Latvia. It is engaged in by many homesteads, private and large farms.

The number of colonies in farms varies: small ones from a few colonies and large ones – from 50-300 colonies (LR ZM, 2006). In Latvia, as in other countries, there are three categories of beekeepers [14]:

- Where are the professional beekeepers for whom beekeeping is the main source of income,
- Where beekeeping provides additional income and the main occupation is agriculture, crafts, pond farming, sawmills, farms where bees are needed for pollination of field crops (primarily clover) and gardens.
- Where beekeeping is a hobby, it gives the house a special atmosphere, the song of the bees, stings to strengthen health, and, of course, honey for yourself and your loved ones.

Looking at the categories of beekeepers, we can conclude that in Latvia, practically anyone who has the interest and opportunities can become a beekeeper. It just depends on what the main goal is – making a profit, expanding their business or as a hobby. This is also confirmed by the fact that 39% of beekeepers have beekeeping at the hobby level, and they distort the local honey market by selling honey below the cost price [15]. The results of the study also show a negative correlation between factors I and A (r = - 0.7) (Fig. 1). This means that in Rēzekne and Ludza counties, beekeeping with 1-3 bee colonies is more of a hobby than a way of earning income (A). This also means that beekeeping is also an environmentally friendly lifestyle, not just a way of making a living and earning income.

Professional beekeepers (Fig. 1), who have a large number of bee colonies (I), have registered with the PVD (C), sow nectar plants or take bees to "pastures" (D), have developed a design for their products (E), sell honey, not just give it to friends (M), process the products on their farm (L). Packaging, label and its design are part of the marketing complex element – the product (Fig. 1). Nowadays, it is often observed that people choose to purchase a product based on the manufacturer whose product is advertised the most. Another important factor is the type of packaging, labels, overall appearance, and design. To promote awareness and brand development, companies often attract influencers [16], social media and the online market also play a major role, and it is important to use various tools, especially if sales take place via the Internet [16] - [17]. Both the product packaging and the label design, the color combination on it, and the presence of symbols or logos are important for promoting awareness.

Honey contains practically all chemical micro- and macroelements important for human health [18]. Monoculture fields are increasingly appearing in Latvia [19] – [21]. Consequently, taking bees out to pasture (D) is becoming popular, which increases the honey yield from the colony. Although honey contains sugars and water, the uniqueness of the product is determined by substances that are less than 1%, such as proteins, polyphenols [9].

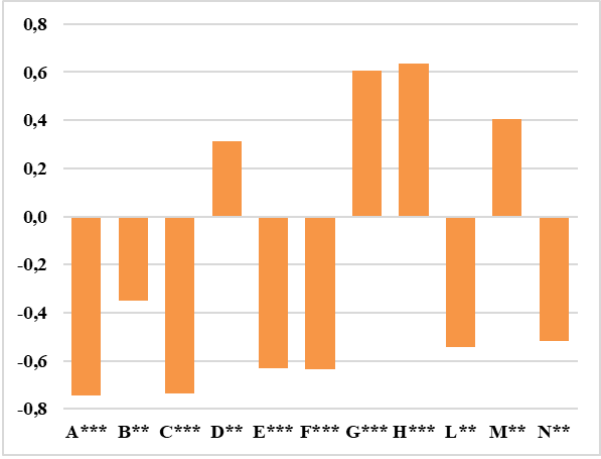

Fig. 1. Correlation coefficient values (n=26) for correlations between the number of beehives in an apiary (I) and various factors, where A – beekeeping as a way of generating income, B – degree of public openness of the farm, C – registration of the apiary with the Food and Veterinary Service, D – place of nectar extraction, E – type of design of beekeeping product presentation, F – author of beekeeping product presentation, G – number of times of honey extraction per season, H – honey yield from one colony per season, L – processing of bee products on the farm, M – self-consumption of beekeeping products on the farm, N – type of wax use on the farm.

***Note**: ** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); *** – the influence of the studied factors is reliable at the 99% significance level ($F_{fact}>F_{0.001}$)*

The most wild bee swarms are received (Q) by those beekeepers (Fig. 2) for whom beekeeping is more of a hobby (A), whose apiary is not registered with the PVD (C), whose queen bee change in the hive occurs uncontrolled (naturally) (S), whose apiary territory is not fenced (P), who are not engaged in the production of cosmetics from beekeeping products (K). Therefore, there is a tendency that the more bee swarms they receive (Q), the fewer times they extract honey per season (G), and the more natural meadows and forests they use for their bees (D).

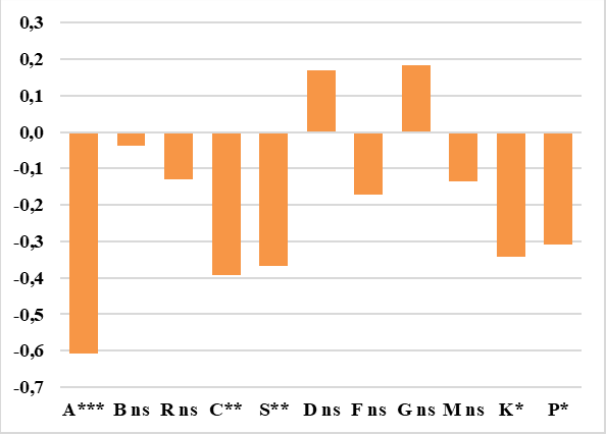

Figure 2. Correlation coefficient values (n=26) for correlations between the number of wild bee swarms received in the apiary (Q) and various factors, where A – beekeeping as a form of income generation, B –

degree of public openness of the farm, R – acquisition of organic farming status, C – apiary registration with the Food and Veterinary Service, S – frequency of queen bee replacement in the bee colony, D – place of nectar extraction, F – author of the design of the beekeeping product presentation, G – number of times honey is poured out per season, M – self-consumption of beekeeping products on the farm, K – self-consumption of cosmetics from beekeeping products, P – apiary enclosure.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$);** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); *** – the influence of the studied factors is reliable at the 99% significance level ($F_{fact}>F_{0.001}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$).*

Beekeepers who use stationary and traveling beekeeping (J) (Fig. 3), are open as tourist and sightseeing attractions (B), have created labels and logos for their products (E), carry out bee product processing on their farm (L), sell most of their production (M), use organic acids in bee treatment (V) and have received education in the field of beekeeping (at least 2-year courses in beekeeping) (Y).

Fig. 3. Correlation coefficient values (n=26) for correlations between the choice of beekeeping type (J) and various factors, where A – beekeeping as a type of income generation, B – degree of public openness of the farm, E – type of beekeeping product presentation design, L – processing of bee products on the farm, M – self-consumption of beekeeping products on the farm, V – type of bee treatment, Y – beekeeper's level of education in beekeeping.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$);** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$).*

Ensuring customer satisfaction is the key to a successful retail business [22]. Every type of business is associated with risk [23] - [24], including the production and sale of honey, therefore market research questions and objectives are important. Agriculture and food processing make up a significant part of the economy. In Latvia, agriculture and food processing make up 4.75% of the country's gross domestic product [2]. Beekeeping farms (Fig. 4) for which beekeeping is the main activity, not a secondary occupation or hobby (A), are open as a tourist attraction (B), have registered with the PVD (C) as home producers, change queen bees in a controlled manner (S), sow nectar plants (D), have developed product identification signs/logs/labels, social networks, etc. (E, F), and have a higher number of honey extractions per season (G). As a result, these farms have a higher honey yield from one colony per season (H), as well as processing of bee products (L) and wax (N), thought has been given to protecting the apiary from various animals and other uninvited visitors to the apiary, i.e. by fencing the apiary (P), and the age of the beekeepers themselves is mostly up to 40 years (W). The honey season in Latvia traditionally begins in April and lasts until the end of July, but for beekeepers who move their bees to heather, the season can also last until the first half of September. This is observed by beekeepers who use mobile apiaries. By sowing nectar plants and using a mobile apiary, beekeepers diversify the honey offer, i.e. offer more monofloral honey.

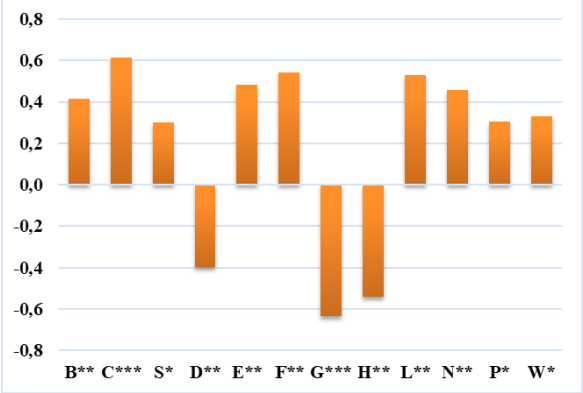

Fig. 4. Correlation coefficient values (n=26) for correlations between beekeeping as a type of income generation (A) and various factors, where B – degree of public openness of the farm, C – registration of the apiary with the Food and Veterinary Service, S – frequency of queen bee change in the bee colony, D – place of nectar extraction, E – type of beekeeping product presentation design, F – author of beekeeping product presentation design, G – number of honey extractions per season, H – honey yield from one colony per season, L – processing of bee products on the farm, N – type of wax use on the farm, P – apiary enclosure, W – age of the beekeeper.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$); ** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); *** – the influence of the studied factors is reliable at the 99% significance level ($F_{fact}>F_{0.001}$).*

In professional beekeeping, it is assumed that a single bee colony should produce more than 50 kilograms of honey, which most beekeepers, especially those who move their bee colonies to follow flowering plants, will have met and exceeded. This is also observed in their activities by beekeepers of open farms (B) (Fig. 5). The more recognizable the farm is (F), the higher the price at which honey is sold (U), the more often honey is extracted (G), and the greater the honey yield from the colony (H), the more educated the beekeeper is (Y), the fewer problems there have been with neighbors who use pesticides in their economic activities (O). After the privatization of land, which took place in Latvia in 1990-1995, there are many small farms in one parish or region, located next to each other, with different farming practices regarding the use of herbicides and pesticides that are harmful to bees [25].

The food chain system consists of two basic elements: the economy, which is formed by production and consumption, and the cultural elements in the use of a particular product [26]. It is important to create direct marketing activities so that organic products reach consumers as quickly as possible [8]. On the other hand, households can become more efficient both in domestic food use and in planning food purchases, as even those least inclined to change have to use alternative sales methods and marketing of their products [27]. Supermarkets are less involved in honey promotion, more standard operations are performed. In turn, beekeepers and farmers are more involved in various activities, for example, in 2022, 190 educational institutions and 73 beekeepers from all over Latvia participated in the campaign "European Honey Breakfast" [28], as well as every year on the second Saturday of September, the Latvian Beekeeping Association offers all interested parties to visit apiaries, where they can taste and buy honey, learn useful information about honey, from beekeepers who work in the association [29]. Such events are usually attended by beekeepers, for whom beekeeping is their main occupation. Many visitors to farms have indicated that this helps them choose products from a certain manufacturer [4]. Home-grown products attract buyers with their naturalness, as they are usually made without preservatives, artificial colors, etc. food additives, so buyers are willing to pay a higher price than for industrially produced products.

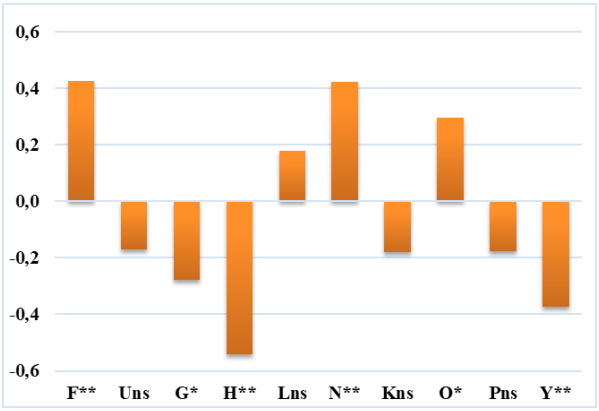

Fig. 5. Correlation coefficient values (n=26) for correlations between the degree of public openness of the farm (B) and various factors, where F – the designer of the presentation of beekeeping products, U – the selling price of honey, G – the number of times honey is extracted per season, H – honey yield from one colony per season, L – processing of bee products on the farm, N – the type of wax used on the farm, K – self-consumption of cosmetics from beekeeping products, O – pesticide use by the surrounding population, P – apiary enclosure, Y – the beekeeper's level of education in beekeeping.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$);** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$).*

If a beekeeper (Fig. 6) has registered with the PVD (C), has created a design for the products he produces himself or has used free templates (F), he extracts honey more often (G), has a higher yield from 1 colony per season (H), processes more products on his farm (L), produces more cosmetics from honey (X), and also uses his own products (K), and takes care of the safety of the apiary (P).

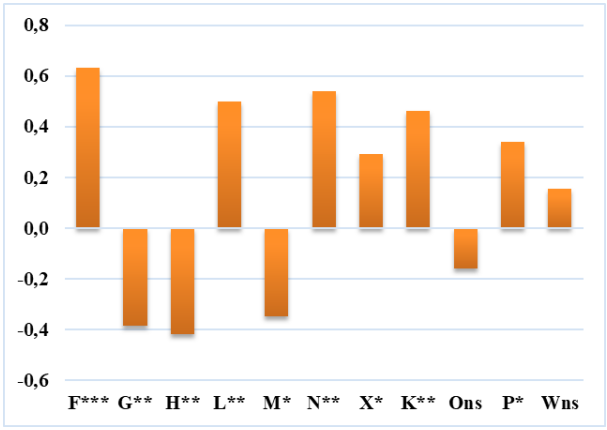

Fig. 6. Correlation coefficient values (n=26) for correlations between apiary registration with the Food and Veterinary Service (C) and various factors, where F – author of the design of the beekeeping product presentation, G – number of honey extractions per season, H – honey yield from one colony per season, L – processing of bee products on the farm, M – self-consumption of beekeeping products on the farm, N – type of wax use on the farm, X – production of cosmetics from honey, K – self-consumption of cosmetics from beekeeping products, O – use of pesticides by the surrounding population, P – apiary enclosure, W – age of the beekeeper.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$);** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); *** – the influence of the studied factors is reliable at the 99% significance level ($F_{fact}>F_{0.001}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$).*

The more a beekeeper (Fig. 7) is interested in the design of beekeeping products (E), the more he thinks up and creates the design of his own products (F). They calculate the cost of their own products more accurately and determine the appropriate selling price of honey (U), and‘ they use their own products more, both by testing different taste nuances, and by trying out new types of products, such as cosmetics, and prepare bees for hibernation themselves (organic farming).

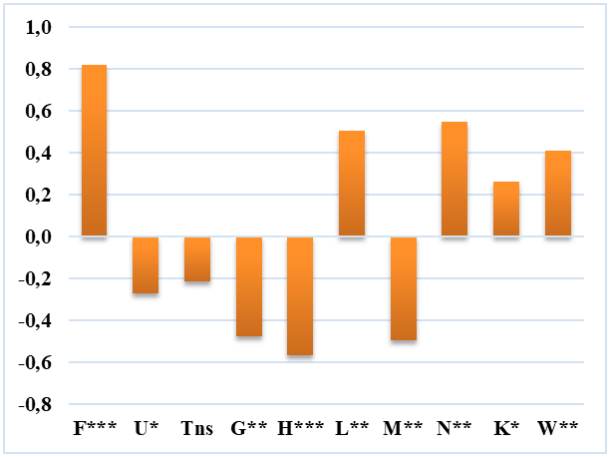

Fig. 7. Correlation coefficient values (n=26) for correlations between the type of beekeeping product presentation design (E) and various

factors, where F – author of the beekeeping product presentation design, U – selling price of honey, T – honey without additives for own consumption, G – number of honey extractions per season, H – honey yield from one colony per season, L – processing of bee products on the farm, M – self-consumption of beekeeping products on the farm, N – type of wax use on the farm, K – self-consumption of cosmetics from beekeeping products, W – beekeeper's age.

***Note**: * – the influence of the studied factors is reliable at the 90% significance level ($F_{fact}>F_{0.01}$); ** – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); *** – the influence of the studied factors is reliable at the 99% significance level ($F_{fact}>F_{0.001}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$).*

Beekeeping is mainly carried out by small family businesses in rural Latvia. Often, beekeeping is the only source of income for these people. In order to preserve beekeeping businesses in the country and rural residents, the state urgently needs to find a solution to protect the internal market for honey in Latvia and activate and support a solution to the problem at the EU level.

IV. Conclusions

Beekeeping in Latvia is diverse, encompassing both professional and hobby-level beekeepers. However, professional beekeepers who focus on beekeeping as their main source of income are more productive and open to development.

Farm size, beekeeper education level and marketing strategies are important factors that affect honey yields and farm openness. Professional beekeepers are more likely to use modern methods, are registered with the PVD, actively participate in market development and achieve better results.

A beekeeper's interest in product presentation design significantly influences his ability to create attractive and recognizable product packaging. This approach contributes to more accurate cost calculation and determination of an appropriate honey sales price, which in turn can improve farm income.

To preserve the beekeeping industry in Latvia, it is important to support beekeepers, promote their education and ensure a favorable environment for business. The state must find a solution to protect the internal market for honey and promote the sustainable development of the industry.

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Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 455-462

Responsible Governance in the Digital Age – Innovating for Sustainable Natural Resource Management

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***Abstract*— Digital transformation is fundamentally changing the approach to natural resource management in both the private and public sectors. In the context of increasing regulatory requirements and growing pressure on companies to integrate sustainable business models, digital technologies offer new opportunities for monitoring, optimization and transparency. At the same time, the public sector has an important role to play in stimulating sustainable practices through regulations, public policies and smart resource management. The mechanism of responsible governance in the context of digital and sustainable transformation is the object of the study and the aim is to analyze and evaluate how digitalization and sustainable management strategies can support effective natural resource management in the private and public sectors, focusing on the role of CSR. The objectives are: to investigate the main digital technologies and their application in natural resource management; to analyze the ESM strategies in enterprises and their impact on sustainable management; to assess the role of the public sector in supporting digital sustainable practices; to identify synergy between the public and private sectors for more effective natural resource management. The research thesis is that the successful combination of digital technologies and sustainable management practices leads to more effective and transparent natural resource management in both the corporate and public sectors, with CSR acting as a bridge between the two sectors. The results are expressed in: 1) digital technologies significantly improve natural resource monitoring, analysis and management. 2) ESG reporting and CSR are key enablers for integrating sustainable strategies into business, with management increasingly using automated platforms to assess environmental impacts. 3) the public sector plays an important role in promoting sustainable transformation through regulations, subsidies and smart infrastructure projects. 4) there are significant opportunities for synergy between business and the public sector through partnerships, data sharing and innovation in natural resource management.**

Keywords*— *responsible governance, sustainable natural resource management, digital and sustainable transformation.

I. INTRODUCTION

In the digital age, the transformation of classical management models is not just an opportunity, but an urgent necessity. The adoption of sustainable management practices requires a systematic approach that integrates technological innovations with environmental implementations. The authors focus precisely on the aforementioned connection between digitalization and sustainability in the management of natural resources, emphasizing the possibilities of technological solutions and, more precisely, their ability to serve as a catalyst for change in both the private and public sectors. [1]-[2]

In turn, the management of natural resources is a major factor in the sustainable development of society and environmental protection. With the expansion of digital technologies, they are becoming an increasingly large and unavoidable factor that presents new opportunities for

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8680
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monitoring, analysis, forecasts and optimization in the use and management of natural resources. Digital technologies are an effective tool when we talk about ESG (Environmental, Social, and Governance) criteria. ESG in themselves are the embodiment of people's aspiration for sustainability and social responsibility and serve as measures of these categories. To achieve environmental goals, improve social responsibility and engagement, and also to ensure transparency in management [3]. According to their functionality and application, digital technologies can be classified into the following five key categories, which have an important role in natural resource management (Table 1).

Regarding the management of natural resources and their management through digital tools, there are other criteria for their classification. Such criteria are the level of data processing, we distinguish between collection, processing, analysis and visualization; according to the degree of automation, we could distinguish those for automated management, decision-making and process control; according to the scope of application is another way of categorizing, for example.

TABLE 1 COMPARATIVE ANALYSIS OF DIGITAL TECHNOLOGIES

Technology	**Application**	***Advantages***	***Challenges***
Artificial intelligence and machine learning (AI & ML)	Pollution forecasting, resource optimization, data analysis	High accuracy of forecasts, ability to process large volumes of data	Need for large databases, complexity of algorithms
The Internet of Things (IoT)	Water, soil and air quality monitoring	Real-time data, early detection of problems	Limited energy efficiency, dependence on internet connectivity
Blockchain technology (BT)	Transparency in resource management, certification of sustainable practices	Transparency , security and immutability of data	High energy consumption for some protocols
Geographic Information Systems (GIS)	Resource mapping, ecological zone analysis and visualization	Spatial analysis, easy interpretation of data through maps	Dependence on up-to-date and accurate geographic data, need for specific skills and expensive software
Digital twins (DTs)	Ecological process simulations, human impact prediction	Possibility to test scenarios without real consequences	High complexity of creation and maintenance, requires significant computing resources

Source: Authors' own interpretation

The above classifications are also useful, but in the case of our study we use the classification that groups the technologies used according to their role in the management of natural resources, because in our opinion it reflects their relationship with ESG criteria. Grouped in this way, they reveal to us how each group of technologies contributes to achieving environmental, social and management goals. [4]

II. MATERIALS AND METHODS

Through a multifaceted methodological and empirical approach, we have analysed some innovations in sustainable natural resource management, focusing on the interaction of digital technologies with the public and private sectors. The respondents of the study were selected from all 27 regional cities in Bulgaria, the number was reduced, given the administrative overlap between Sofia region and Sofia city.

The methodological framework is a combination of quantitative and qualitative methods, our goal is to achieve a comprehensive and objective analysis. As the main data collection tool, we used structured interviews conducted in the period July - November 2024, with representatives of the main stakeholders. The sample covered the main groups of the public sector (33.3%), business (33.3%), educational institutions (13.3%), citizens (6.7%) and non-governmental organizations (13.3%). We used a combined approach for greater representativeness and credibility. We selected experts from the public and business sectors through purposive sampling, and citizens through random selection, in accordance with the principles of stratified sampling.

To assess the application and effectiveness of the considered digital technologies in natural resource management, we used multi-criteria analysis (MCA), including: Analysis of variance (ANOVA) - to identify statistically significant differences between groups; Correlation analysis - to find relationships between digital technologies and key indicators of sustainable management; Multi-criteria decision-making method (MCDM): TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) - for a comparative assessment regarding the implementation of digital technologies. The study also applied Content Analysis to enrich the quantitative methods and allows identifying key themes, patterns and attitudes. [5]

The collected data covers both quantitative assessments and qualitative responses of the respondents. The participants in the study assessed various indicators related to digital transformation and sustainable management on a ten-point scale, where 1 means "poor performance" and 10 – "excellent performance". Additionally, the participants had the opportunity to make free comments, which we use to enrich the analysis.

We combined the mentioned methods and thus realize our aspiration for a deeper and more detailed disclosure of the problems addressed in the study. Integration and consideration of the problem in its entirety allowed us to conduct this complex analysis of the impact of digital

technologies on the management of natural resources. Such a detailed consideration of the connections and dependencies is a stable basis for formulating recommendations for strategic decisions and implementing sustainable practices.

III. RESULTS AND DISCUSSION

A. Key digital technologies and their application in natural resource management.

The ESG criteria, as the abbreviation indicates and has already been mentioned, cover the following three areas: Environment, Social and Governance. Through structured interviews, we obtained the weights determined by the experts (environmental impact – 40%, corporate governance – 28%, social effects – 32%) and expert assessments. The initial data, as well as the corresponding calculations from the multi-criteria analysis (MCA) (1) are presented in Table 2. We use the MCA analysis to get an initial idea of the different alternatives. At this stage, favorites and technologies that do not correspond in the best way with ESG stand out from the calculations. [6]

$$P = E \times \omega_E + S \times \omega_S + G \times \omega_G \qquad (1)$$

Where:

P – Weighted Score

E: Environmental Impact Score

S: Social Impact Score

G: Corporate Governance Score

ω_E Weight for Environmental Impact (40%)

ω_S Weight for Social Effects (32%)

ω_G Weight for Corporate Governance (28%)

TABLE 2 MCA

Technology	**E (1-10)**	**S (1-10)**	**G (1-10)**	Average score	**P**
AI & ML	7,25	7,25	8,25	7,58	7,53
IoT	8,00	6,75	7,00	7,25	7,32
BT	5,50	5,75	8,50	6,58	6,42
GIS	8,25	7,50	7,00	7,58	7,66
DTs	7,25	6,50	7,50	7,08	7,08

Source: authors' own research

We continued with the analysis of variance (ANOVA) in detail. We defined two hypotheses, working with a null and an alternative.

H_0 Null hypothesis according to which we will not find large differences between the average ratings of technologies in terms of ESG.

H_1 Alternative hypothesis according to which the analysis will find significant differences between the average ratings of technologies in terms of ESG.

Then we moved on to calculating the overall average value (2)

$$\tilde{X} = \frac{Sum\ of\ all\ ratings}{Total\ number\ of\ ratings} \qquad (2)$$

$$\tilde{X} = \frac{93,7}{15} = 6,25$$

To determine the deviations of the average values of the (groups of) technologies from the overall average, we calculate the intergroup variance SSB (3) and the intragroup variance SSW (4) which reveals the differences in individual estimates. [7]

$$SSB = \sum_{i=1}^{k} n_i \left(\tilde{X}_i - \tilde{X}\right)^2 \qquad (3)$$

$$SSW = \sum_{i=1}^{k} \quad \sum_{j=1}^{n_i} \left(X_{ij} - \tilde{X}_i\right)^2 \qquad (4)$$

With the available data, we obtain for SSB = 16.02 and SSW = 7.81. We calculate the F-statistic (5) and compare it with the critical value at a given significance level of 0.05. The calculations show an F value of 5.13 and a critical value of 3.48

Because F = 5.13 > 3.48, we should reject the null hypothesis. We could argue from the results obtained in this way that the ESG criteria have large differences between the average ratings of the technologies. That is, the differences are not random and deserve to be examined in more detail. For this purpose, we apply TOPSIS analysis, going through the standard stages of matrix normalization, calculation of an ideal and antagonistic solution, followed by calculation of the distances between each row, finding the relative proximity to the ideal solution Ci and ranking. By going through the described steps, we obtain a relevant proximity to the ideal state, and through the values we perform the ranking (Table 3).

According to TOPSIS analysis, the most suitable technology in terms of ESG is GIS. This is the technology closest to the ideal solution. As can be seen from Table 3, BT technologies are not recommended at this stage.

B. Analyzing ESG strategies in enterprises and their impact on sustainable management

With increasing pressure from regulators, investors and society, businesses are increasingly integrating ESG (Environmental, Social, and Governance) strategies as a key tool for sustainable management.

TABLE 3 RANKING

Technology	C_i	Ranking
AI & ML	0,644	2
IoT	0,597	3
BT	0,522	5
GIS	1,000	1
DTs	0,584	4

Source: authors' own research

The key question facing businesses is how to transform their operations to combine economic efficiency, environmental responsibility and social sustainability. In this context, a needs analysis of ESG strategies in enterprises will be carried out. To successfully implement ESG strategies, enterprises need to address several key aspects:

a) Environmental dimension (E - Environmental), including: optimizing the use of natural resources through digital technologies (IoT, Big Data, AI); reducing carbon footprint and implementing circular economy; regulatory compliance (CSRD, ESRS).

b) Social dimension (S - Social), as follows: increasing employee engagement through ethical business practices; investing in training and enhancing digital skills of staff; adopting socially responsible policies - safe working conditions, diversity and equity.

c) Corporate governance (G - Governance), including: integration of ESG criteria in strategic management; transparency and accountability in decision-making; application of digital tools for monitoring and reporting (blockchain, AI-based reporting).

For the purpose of the study, we apply an analytical tool that represents how environmental (Environmental), social (Social) and governance (Governance) aspects intertwine and influence sustainable management in enterprises, namely the ESG matrix (Table 4). It will be visualized as a table with three main dimensions (E, S, G) along the horizontal and key impact areas along the vertical. The aim is that each cell will show how a particular ESG factor impacts the business.

This matrix is extremely useful for companies in the process of: 1/ strategic planning to identify important ESG priorities; 2/ assessing impact by analyzing the effects of sustainable business policies; 3/ ensuring reporting and transparency by demonstrating the ESG approach to stakeholders.

Next, the research focuses on the analysis of the relationship "ESG Strategies" – "Economics and Environmental and Nature Management" – "Profit and/or added value for enterprises".

TABLE 4 ESG MATRIX (INTERACTION BETWEEN ENVIRONMENTAL, SOCIAL AND GOVERNANCE FACTORS)

Area of impact	Environmental (ecology)	Social (social responsibility)	Governance
Resource management	Water optimization, energy efficiency, circular economy.	Workplace safety, working conditions, health.	Monitoring through ESG indicators, digital tracking systems.
Regulations and compliance	Compliance with environmental standards (CSRD, ESRS, Paris Agreement).	Compliance with ethical labor standards, equality and non-discrimination.	Transparency in governance, anti-corruption practices.
Innovation and digitalization	Implement IoT, AI, Big Data to reduce environmental footprint.	Social innovation – training, qualification.	Using blockchain and AI for reporting and control.
Financial management	Investment in green technologies and sustainable business models.	Engaging employees and customers through social projects.	ESG reporting for investors and stakeholders.
Reputation and brand	Positioning as a green business – competitive advantage.	Social responsibility as a factor for attracting customers.	Good governance increases investor confidence.

Source: Authors' own interpretation

Implementing ESG strategies in enterprises is a long-term business strategy that impacts both the financial performance and the added value of the enterprise. It can be argued that a complex relationship between ESG principles, natural resource management and the economic performance of enterprises is emerging, existing and evolving. This relationship will be examined in the context of the present work as follows:

a) The link between ESG factors and natural resource management strategies will be explored to determine how sustainability principles influence responsible environmental practices. *First*, environmental aspect (E). The focus is on optimization, energy sources, green financing. Resource optimization through energy efficiency, circular economy and low carbon technologies reduces operational costs. Reducing the carbon footprint and using green energy sources attracts sustainable investors. A focus on ESG can provide access to green financing and subsidies. *Second*, social aspect (S), which focuses on working conditions and social responsibility. Improving working conditions, employee health and safety increases productivity. ESG-focused businesses attract more engaged customers and investors who value social responsibility. *Third*, Governance aspect (G), which primarily relates to corporate governance. Good corporate

governance ensures transparency, reporting and effective management. At the same time, the integration of digital ESG monitoring solutions increases efficiency and reduces the risk of regulatory sanctions.

b) The interaction between ESG considerations and financial outcomes – whether in the form of costs or investments – will be analyzed to assess their impact on corporate performance. ESG strategies are often seen as an additional cost to the enterprise, but in realities they can be applied as a tool to create competitive advantage and long-term profitability. ESG increases the profitability of companies by: 1/ reducing operating costs through energy efficiency and circular economy. 2/ increasing market value as sustainable companies are preferred by investors. 3/ improving reputation and customer loyalty - today there is a growing trend for consumers to seek environmentally and socially responsible brands. [8] 4/ access to green financing and subsidies. According to reports by international financial institutions, companies with high ESG ratings have lower capital risk and higher long-term profitability.

c) The concept of added value, including activities that extend beyond profit-making, will be discussed in order to highlight the broader societal and environmental contributions of business entities. While the traditional business model measures success mainly through the financial result, the ESG approach creates multi-layered added value, which translates into economic added value (cost optimization, innovation in sustainable production); social added value (better conditions for employees, building trust in society); environmental added value (better management of resources and reduced environmental footprint). ESG-related strategies are an inevitable factor in modern management as they ensure not only regulatory compliance but also sustainable competitive advantage. The balance between economic performance and natural resource management is key to the long-term sustainability of both businesses and society as a whole. The balance between ESG policies, business profit and added value depends on the specific business model, industry and strategic priorities of the enterprise. Our study, based on the monitoring of a set of criteria in business activity, divided enterprises into three profiles. Profit-minded enterprises focus on profit (60%), with less emphasis on ESG. Eco-minded Enterprises are distinguished by ESG being the top priority (50%), with business profit being in the background. Open-minded Enterprises have a balanced approach between the three factors. If the enterprise is profit-driven, the focus will be on profit maximization, and ESG will play a role mainly in the extent to which it is necessary to regulate or improve reputation (fig. 1). When a company is eco-minded, it is more likely to place a greater emphasis on ESG policies, even at the expense of some short-term profit, but with the goal of long-term sustainability and reputational benefits (fig. 2). Open-minded enterprises (innovative and large companies) can seek an optimal balance by integrating sustainable practices that both bring profit and create long-term added value. Pursuing a balanced approach between the three factors as it shown in fig. 3. The three graphs visualize the allocation of ESG policies, business profit and value added for different types of businesses.

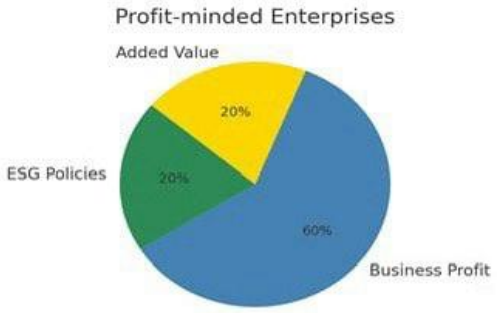

Fig. 1. ESG strategies via Profit-minded enterprises.

Source: Authors' own research.

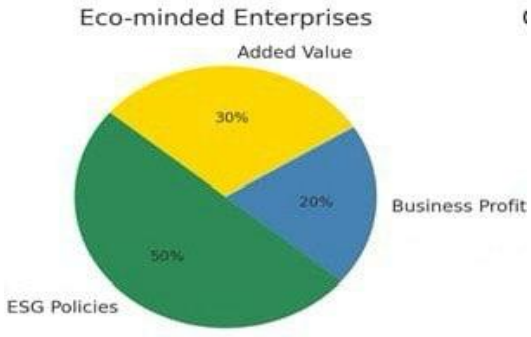

Fig. 2. ESG strategies via Eco-minded enterprises.

Source: Authors' own research.

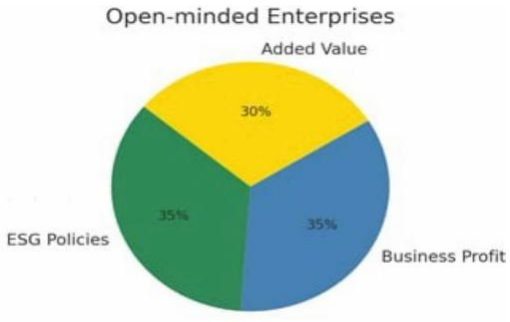

Fig. 3. ESG strategies via Open-minded enterprises.

Source: Authors' own research.

Next, an ESG Value Chain (fig. 4) will be created to illustrate how sustainable practices need to be transformed into competitive advantages. The graphic will include: 1/ ESG initiatives (sustainable raw materials, carbon footprint

reduction, social responsibility, management transparency). 2/ Internal processes (resource efficiency, automation, employee engagement). 3/ Business performance (reduced costs, access to green finance, increased reputation). 4/ Competitive advantages (increased customer loyalty, sustainable supply chains, regulatory relief).

C. Role of the public sector in supporting digitally sustainable practices

The public sector has a significant impact on sustainable practices through some basic instruments such as policies in various directions, regulations at different levels and a number of initiatives (Fig. 5). In addition to the main ones indicated in Fig. 5, which are mainly directed "outward", that is, impacts and efforts towards entities outside its functions. The public sector needs to initiate and implement activities directed "inward", concerning the internal functioning of the sector. Such could be incentives for the use of energy-efficient devices, reducing paper consumption, reducing, and other sustainable practices. In the context of ESG, we can also note the exceptional importance of the sector in the management of e-waste. For example, by building recycling systems and tracking them in real time and electronically. Another area of great importance for public decisions is the development of digital infrastructure, which will allow not only the administration itself, but also citizens and businesses to use digital services more intensively and regularly. [9]-[11]

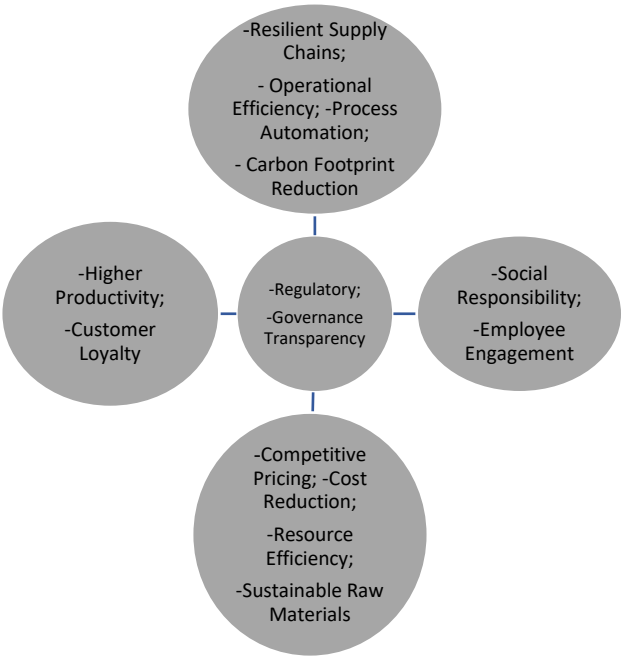

Fig. 4. ESG Value Chain.

Source: Authors' own interpretation

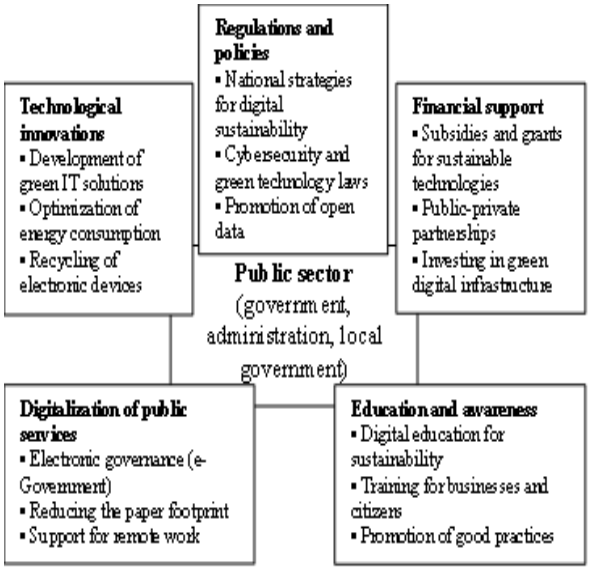

Fig. 5. Magnetization as a function of applied field.

Source: Authors' own interpretation

D. Synergy between the public and private sectors for more effective natural resource management

Public-private synergies in the context of more efficient natural resource management. [12] These synergies can be realized through various mechanisms, such as policy collaboration, innovation and digitalization, knowledge and resource sharing and joint initiatives, as follows:

a) Joint policy development. The private sector can provide expertise and innovation, while the public sector provides the regulatory framework and incentives for sustainable governance. A good example is partnerships to create national and international standards for sustainable use of natural resources.

National and international partnerships for setting standards in the sustainable use of natural resources play a key role in ensuring efficient and fair resource management, which is essential for sustainable development. These collaborations between the public sector (governments, regulators) and the private sector (companies, business associations) support the co-creation and implementation of standards that promote good practices, regulatory compliance and sustainability goals. By combining public leadership in establishing legal frameworks with private sector innovation and technical expertise, such partnerships enable the development of shared goals, certification schemes and mechanisms for integrating advanced technologies like digital monitoring tools and AI-based forecasting. They also foster the exchange of good practices across sectors and countries and facilitate joint efforts in monitoring and reporting. Initiatives like the Forest Stewardship Council (FSC), the Global Reporting Initiative (GRI) and platforms such as the Sustainable Agriculture Initiative exemplify the potential of coordinated action in driving sustainable resource use globally.

In the context of partnerships aimed at establishing national and international standards for the sustainable use of natural resources, it is essential to draw on global initiatives and proven best practices. International frameworks such as the United Nations Environment Program (UNEP), the Paris Agreement and the Convention on Biological Diversity (CBD) offer valuable guidance and platforms for cooperation between governments, the private sector and civil society. [13]-[15] These initiatives not only coordinate efforts for sustainable natural resource management but also encourage countries to adapt global standards to local conditions through innovation and collaboration. By facilitating the alignment of environmental goals with technological advancement and inclusive governance, such partnerships contribute significantly to achieving the global sustainability agenda, while also promoting economic efficiency and social well-being.

b) Investing in green technologies. Cooperation may involve funding green technology innovations aimed at reducing carbon emissions and improving resource efficiency, as demonstrated by public-private partnerships in renewable energy and sustainable agriculture. [16]

Investing in green technologies is one of the main drivers of sustainable development and a key factor in reducing carbon emissions and increasing resource efficiency. Through public-private cooperation, such innovation can be supported to deliver significant benefits for the conservation of natural resources and the reduction of negative environmental impacts. This type of partnership may encompass financing, technological advancement, collaborative research and the promotion of innovative business models.

Green energy solutions, including solar, wind and geothermal technologies, represent a central area of investment. Both the public and private sectors play an important role in financing and deploying renewable energy systems aimed at reducing dependency on coal and nuclear sources. Examples include investments in solar panels and wind farms, with good practices being public-private partnerships that develop such infrastructure in regions with high renewable energy potential. Energy efficiency is another significant domain, involving technologies that minimize energy consumption across industrial processes, transport, buildings and infrastructure. Notable examples include innovations in building insulation materials and the development of smart grids that optimize energy distribution and usage. Cleaner production technologies are also a focus of investment, particularly those that reduce carbon emissions in industrial operations. These include carbon capture and storage (CCS) processes as well as technologies for recycling and waste recovery. Financing programs aimed at supporting green industrial solutions that minimize waste and pollution are considered best practices in this context. Sustainable transport innovations such as electric vehicles (EVs), hybrid systems and alternative fuels like hydrogen-based engines are likewise essential. Public-private partnerships to develop charging infrastructure, as well as support for autonomous mobility and shared transportation platforms, contribute to the greening of the transport sector. Furthermore, the circular economy approach encourages investments in technologies for reuse, recycling and resource recovery. This reduces waste generation and maximizes material efficiency. Good practices in this area include investments in recycling technologies for plastics, glass and metals, which support the emergence of new business models focused on the reuse of products and materials. [17]

This raises the question of the role of the public and private sectors in investing in green technologies. The public sector contributes through funding mechanisms such as subsidies, tax incentives and regulatory frameworks that make green technologies economically viable. The European Union, for example, supports innovation through programs like Horizon Europe. The private sector, especially start-ups and tech companies, plays a leading role in developing renewable energy solutions, energy efficiency technologies and green innovations, often collaborating with universities and other industries. Collaborative research platforms between academia and business are fundamental for advancing technologies such as carbon sequestration or efficient renewables. Industry associations and initiatives like the Green Tech Festival and Circular Economy 100 further promote joint solutions and standards for sustainable development. [18]

c) Collaborative implementation and resource optimization. Public-private synergies in natural resource management create the conditions for long-term sustainability, innovation and economic efficiency. Through shared knowledge and data, public authorities can provide valuable environmental and climate information, while private actors use it to develop effective solutions for resource optimization, such as in water management. These synergies are further strengthened through joint initiatives for ecosystem restoration and sustainable land, forest and water use, as well as through co-financing of infrastructure projects that support energy efficiency, circular economy practices and responsible resource use. Such integrated efforts foster not only environmental stewardship but also economic resilience, making them a major driver for sustainable development.

An essential aspect of this cooperation is the establishment of common platforms for data sharing and analysis, where environmental trends can be monitored and addressed collectively. Co-investment in resilient infrastructure, such as smart irrigation systems or decentralized energy networks, demonstrates how both sectors can align efforts for greater impact. Pilot projects and demonstrators, jointly initiated by governments and businesses, can test new models for sustainable management before broader application. In addition, cross-sectoral partnerships enable the scaling of good practices and the replication of successful initiatives in different regions. Ultimately, these collaborative actions strengthen institutional capacity and promote a culture of joint responsibility in managing natural resources sustainably.

IV. CONCLUSIONS

The study showed how digitalization with its tools, strategies and policies can improve the management of natural resources in both the business and public sectors. The following statements were made:

First. Digital technologies contribute to better management of natural resources. Through their use and improvement, natural resource management will be transformed to new levels. Technologies such as remote sensing, AI-based analysis and IoT systems enable more precise monitoring, predictive planning and responsive interventions. Their integration leads to more efficient, transparent and adaptive systems that minimize resource waste and environmental harm.

Second. ESG initiatives and their monitoring are vital for the long-term implementation of sustainable practices, both by business and the public sector. Their integration into corporate and institutional strategies ensures accountability, drives innovation and aligns operational goals with environmental and social responsibility. Digital tools support the traceability and verification of ESG commitments, fostering trust and comparability across sectors.

Third. Maximum results would only be achieved through synergy and partnership between all stakeholders. A shared vision and coordinated action among governments, private companies, civil society and academia are key to scaling good practices and ensuring the sustainability of natural systems. The combined efforts of these actors enhance knowledge exchange, align investments and create the conditions for systemic change.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 463-468

Soil Tillage System and Precrops Influence on Spring Wheat Flag Leaf Area and Grain Quality Indicators

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***Abstract*—Spring wheat (*Triticum aestivum* L.) is the most widely grown spring cereal in Latvia. The aim of the research was to determine soil tillage system and precrops influence of spring wheat flag leaf area and grain yield quality indicators. Field trials were carried out at the Research and Study farm "Peterlauki" study site "Poki" (56°30.658' N and 23°41.580' E) of the Latvia University of Life Sciences and Technologies (LBTU) at year 2024. Spring wheat 'Berlock' was grown with two soil tillage systems (conventional and minimal soil tillage) and three different precrops (winter wheat, winter oilseed and spring oilseed rape). The flag leaf area (cm^2) has been analyzed by using scanner STD4800 and specialized computer software WinFOLIA. The determination of the yield components, grain yield ($t\ ha^{-1}$) and straw yield ($t\ ha^{-1}$) was made by sample sheaf analysis. Grain quality indicators: crude protein content; starch content; gluten content and Zeleny index, thousand grain weight were determined in Grain and seed study and research laboratory at LBTU. Significant differences ($p<0.05$) between soil tillage systems were found in flag leaf area and length. A strong positive correlation was observed between grain yield and flag leaf area r=0.854 for conventional and r=0.958 for minimal soil tillage system. Sample sheaf analysis showed significant differences in spike mass and grain weight. Among grain quality indicators, gluten content differed significantly and significant differences were associated with the precrops ($p<0.05$). It should be noted that in the 2024 growing season, July saw increased precipitations at the trial site.**

***Keywords*—Grain quality, soil tillage, spring wheat, WinFOLIA.**

I. Introduction

Wheat (*Triticum* spp.) belongs to the family of the Gramineae (*Poaceae*) and is the main agricultural commodity produced in Latvia in terms of number of farms, cultivated area [1], [2], [3] and one of the most important cereal crops worldwide [4], [5], [6], [7], [8], [9], [10]. Spring wheat crops in Latvia are harvested on average every year 22% of the total cereal area [11]. The climatic conditions in the Nordic-Baltic region facilitate the cultivation of both types of spring wheat and winter wheat. Notably, most of the harvested area in the Baltic countries is dedicated to winter wheat, with only about 20% of the area allocated to spring wheat cultivation. Given that a significant portion of spring wheat production in the Baltic countries and Norway is earmarked for breadmaking [12]. Wheat-based food products are staple in the diets of a large part of the world population. In 2020, 776 million tons of wheat were produced worldwide. Globally, around 20% of both the total daily energy and protein intake is accounted for by wheat-based products, making wheat rather irreplaceable in the human diet and a major contributor to food security [4], fodder and industrial purposes [8]. Whole-grain wheat is a nutritionally important source of

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8672
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dietary fibers, minerals, vitamins and bioactive phytochemicals [4]. It is rich in nutrients such as starch and protein, making it one of the primary sources of food for humans. Given its significance in fulfilling the basic dietary needs of people worldwide, ensuring the quality of wheat products is of paramount importance [5]. Scientific literature [13] mentions that wheat straw majorly remains unutilized and is often burned to clear the farming land, resulting in greenhouse gas emissions and adversely affecting soil fertility. Instead, this renewable and carbohydrate-rich wheat straw can be efficaciously utilized for second-generation bioethanol production. However, scientists have proven that wheat straw is mainly composed of 27–40% cellulose, 22–25% hemicellulose, and 15–25% lignin. A research group from Estonian Crop Research Institute [14] reported that high yields are one of the essential parameters in wheat farming. Farmers aim to increase yields by selecting the most suitable cultivars and soil tillage systems. By a group of researchers from Latvia [15] accepted that different minimum soil tillage practices are becoming more and more popular as the minimum soil tillage has several advantages compared to the traditional soil tillage system: lower costs, time savings, etc. Rotational cropping is an important and effective agricultural management practice that significantly contributes to crop yields, plant health, and soil structure [16]. Scientists [17] have proven in their research that the inclusion of pulses in crop sequences can ameliorate environmental impacts of cereal-based agricultural production systems by increasing soil carbon stocks, increasing N use efficiency and reducing incidence of pests. Additionally, scientists [16] have reported that crop rotation and systematic cultivation of diverse crops in a predetermined sequence within the same field over time, is one of the traditional agricultural practices that offers substantial benefits to the soil ecosystem, greatly contributing to plant growth. According to the research of many scientists [6], [7], [8], [18] weather conditions and temperature during the growing season is one of the main environmental factors affecting the growth, development and yield of plants. In turn grain yield in cereal crops is due to complex physiological and biochemical processes but is essentially associated with the carbohydrate accumulation process of grain filling, which in turn is attributed to leaf functionalities [10]. In turn an interesting conclusion has been discovered by researchers [19] that flag leaves, as the 'functional leaves' in wheat production, are the primary photosynthetic organ contributing 45–58% of photosynthetic performance during the grain-filling stage. Morphological traits related to flag leaves are determinant traits influencing plant architecture and yield potential in wheat [10]. Additionally, scientists [7], [9] have reported the flag leaf is the main component of the canopy in the middle and late growth stages of wheat and is an important organ that determines the grain-filling rate and the final yield. Thus, the leaf morphological traits variation can play an essential role for plants coping with environmental changes, and is strongly correlated with changes in temperature, precipitation, radiation, and soil nutrients [20]. The aim of the research was to determine soil tillage system and precrops influence of spring wheat flag leaf area and grain yield quality indicators.

II. Materials and Methods

Field investigation were carried out at the Study and Research farm 'Peterlauki' study site "Poki" (56º30.658' N and 23º41.580' E) of Latvia University of Life Sciences and Technologies during season 2024. The two-factorial trial with three precrops (winter wheat (W-W), winter oilseed (WB-N) and spring oilseed rape (SB-N)) and two tillage systems: conventional soil tillage system (CT) with ploughing at a depth to 25 cm and minimal soil tillage system (MT) with soil disc harrowing at a depth to 10 cm. The spring wheat 'Berlock' sowing at 16 May with Horsch Pronto 4DC a rate of 550 germinable seeds per m^2.

Plant material. Spring wheat (*Tritticum aestivum* L.) variety 'Berlock' (Sweden) was used in this experiment. The variety is medium-early, characterized by a very high yield potential, with high and good grain quality. Baltic trials, the yield can reach up to 9 t ha^{-1}[21].

The spring wheat flag leaves were taken in each field places at 10 replications according to the principle of randomization (BBCH 44). Spring wheat basic indicators of flag leaf length, width (cm) and area (cm^2) were analyzed by using scanner STD4800 and specialized computer software WinFOLIA (Fig. 1. A).

Sample sheaf's for spring wheat were taken at 3 locations randomly selected in each replication from a 0.125 m^2 area. The grain yield (t ha^{-1}) for spring wheat was calculated by an indirect method: calculation from sample sheaf analysis. Yield was recalculated in t ha^{-1} at 14% moisture and 100% purity. Straw yield and wheat structural elements were calculated from a sample sheaf too (Fig. 1. B).

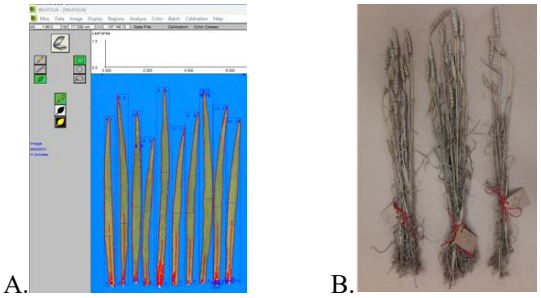

Fig. 1. Spring wheat flags leaves placed in the scanner (A) and sample sheaf (B).

Grain quality indicators: crude protein content (CP, %); starch content (SC, %); gluten content (GC, %) and Zeleny index (ZI, %) was measured using Near Infrared Spectroscopy (NIRS) method (analyzer InfratecTM NOVA (FOSS, Hillerød Denmark)) at the Latvia University of Life Sciences and Technologies in Grain and Seeds research laboratory. It is a whole grain analyser for testing multiple parameters by use of near-infrared transmittance technology. The thousand grain weight (TGW, g) was determined following the ISO 520:2010 standard.

Meteorological conditions were variable in the research year. Average day and night temperature from May till August was 17.1 °C in 2024 (Table 1 shows period from May 1 till August 31). The sum of precipitation in the research year was 68.2 mm, which is a total of 0.1 mm less (long-term observations).

TABLE 1. WEATHER CONDITIONS DURING THE FIELD INVESTIGATION

Month	Temperature, °C		Precipitation, mm	
	2024	*Long-term observations*	*2024*	*Long-term observations*
May	14.4	11.4	28.5	50.4
June	17.0	15.2	54.2	70.1
July	19.0	17.8	**131.4**	75.7
August	18.1	16.9	58.6	76.8
On average	17.1	15.3	68.2	68.3

Meteorological conditions according to Latvian Environment, Geology and Meteorology data.

Although the total precipitation seemed sufficient, spring wheat experienced drought stress in May (Table 1). The lack of rainfall and soil drought prevented the crop from fully benefiting from favourable temperature conditions, leading to a decrease in yield. Conversely, in July, excessive precipitation (131.4 mm) caused noticeable stress on the plants.

For data mathematical processing dispersion and correlation analysis were used. The significance of difference in results has been assessed at level of 95% using p-value which determined with Anova: Single factor.

III. RESULTS AND DISCUSION

Morphological traits related to flag leaves are determinant traits influencing plant architecture and yield potential in wheat [10]. WinFOLIA specialised computer software provides precise measurements of various leaf morphological parameters [22]. The results of our studies (Table 2) demonstrated that the area (p=0.48), length (p=0.45) and width (p=0.35) of the flag leaf of the studied spring wheat were not significantly (p>0.05) depending on precrops. In turn our research results showed that the soil tillage system (MT and CT) had a significant (p<0.05) impact on wheat flag leaf area and flag leaf length (p=0.04). Still, flag leaf width was not significantly different between the soil tillage systems (p=0.10) (see Table 2). The results confirm, that the flag leaf area in the conventional soil tillage system was, on average 5.1 cm² larger than in the minimal soil tillage system. Additionally, the flag leaf length in the conventional soil tillage system was on average 4.5 cm longer than in the minimal soil tillage system. Our data indicate that there was no significant difference (p>0.05) between yield and straw yield of spring wheat between the tillage systems and precrops (Table 2). Furthermore, researchers from the Institute of Plant Physiology and Genetics, National Academy of Sciences of Ukraine [7], reported that estimated yield losses in major wheat-producing countries due to drought stress range from 10 to 50%. In turn an interesting conclusion has been discovered by researchers from Latvia [11], their study concluded that the yield of spring wheat depends on the interaction of several factors: soil fertility, meteorological conditions, as well as the agricultural machinery used. If any of the factors change, crop yield changes. A study by Latvian scientists [11] observed significant differences in yields in different regions, which is similar to our study. Nowadays, not only yield amount but also yield quality is important. Latvian researcher's studies [23] suggest that the cultivar is the first criterion determining specific grain quality parameters, as well as environmental and management conditions. High yields are one of the essential parameters in wheat farming. Farmers aim to increase yields by selecting the most suitable cultivar or adjusting various agricultural techniques [14].

TABLE 2. SPRING WHEAT PARAMETERS OF FLAG LEAF, YIELD AND STRAW YIELD

Factors	Flag leaf area, cm^2 p=0.48	Flag leaf length, cm p=0.45	Flag leaf width, cm p=0.35	Yield, t ha^{-1} p=0.06	Straw yield, t ha^{-1} p=0.10
Precrops/Soil tillage system					
SB-N	13.5	20.0	0.7	2.95	4.28
W-W	9.2	16.3	0.6	1.60	1.83
SB-N	12.2	18.8	0.7	3.16	4.17
W-W	6.4	13.7	0.5	1.04	1.46
MT	**10.3***	**17.2***	**0.6**	**2.19**	**2.94**
Precrops/Soil tillage system					
WB-N	17.2	22.8	0.8	2.32	3.72
W-W	13.7	20.3	0.7	2.10	2.93
WB-N	17.1	24.1	0.7	2.74	3.61
W-W	13.4	19.5	0.7	1.76	2.82
CT	**15.4***	**21.7***	**0.7**	**2.23**	**3.27**
MT/CT	**p=0.04***	**p=0.04***	**p=0.10**	**p=0.94**	**p=0.69**

SB-N spring oilseed rape, W-W winter wheat, WB-N winter oilseed rape, MT – minimal soil tillage system; CT – conventional soil tillage system; *significant at p<0.05.

In the trial year was a strong positive correlation between spring wheat grain yield and flag leaf area (r=0.854) for conventional soil tillage and (r=0.958) for minimal soil tillage system. Similar results have been obtained in other studies conducted in Latvian conditions in winter wheat trials, where it was determined that the larger the flag leaf area, the higher the grain yield [24], [25].

Cereal grain yield is mainly determined by spike (ear) number, grains per m^2 or grain weight, while changes in grains m^2 are primarily associated with spike number [26]. Data statistical analysis confirmed that soil tillage system was no significant difference between grain quality indicators: spikes, pcs.; spikes mass, kg; grain weight, kg;

straw mass, kg; GC, %; SC, %; ZI, %; CP, % and TGW, g. In turn, in the trial year, a significant influence of the precrops were observed on spike mass (p=0.02), grain weight (p=0.03), and GC (p=0.04) (Table 3). On average, significantly higher spikes mass and grain weight was if precrops SB-N at MT system and WB-N at CT system, but GC, % content if precrops W-W in both soil tillage systems. Gluten plays an important role in dough formation and affects dough stability and bread loaf volume [27]. In the present study results show that the content of starch content was 56.3–57.0%, soil tillage did not significantly affect (p>0.05) the SC in grain. Our data indicate that there was no significant difference (p>0.05) in the ZI (57.0–57.6%) (Table 3) of spring wheat between the tillage system. Protein content shows grain suitability for processing. Researchers [11], reported spring wheat ZI ranging from 62.4 to 79.3%, respectively, which are higher than the results of our study. Protein content from 12–13% is suitable for bread making, but grain with higher protein content is used for lower quality grain improver [28]. CP content was 15.1% significant differences were observed based on soil tillage system (p=0.94) and precrops (p=0.33) (Table 3).

TABLE 3. SPRING WHEAT STRUCTURAL ELEMENTS OF THE SAMPLE SHEAF M^{-2} AND GRAIN QUALITY INDICATORS DEPENDING ON PRECROP AND SOIL TILLAGE SYSTEM

Factors	Spikes, pcs. p=0.07	Spikes mass, kg p=0.02*	Grain weight, kg p=0.03*	Straw mass, kg p=0.06	GC, % p=0.04*	SC, % p=0.40	ZI, % p=0.05	CP, % p=0.33	TGW, g p=0.29
Precrops/Soil tillage system									
SB-N	627	0.50	1.06	0.51	36.3*	57.4	54.9	14.6	23.6
W-W	333	0.26	0.57	0.22	39.1	56.6	59.0	15.7	24.0
SB-N	650	0.59	1.30	0.57	36.6	57.4	55.3	14.6	24.3
W-W	217	0.13*	0.29*	0.14	39.1	56.6	59.0	15.7	24.0
MT	**457**	**0.37**	**0.80**	**0.36**	**37.8**	**57.0**	**57.0**	**15.1**	**23.9**
Precrops/Soil tillage system									
WB-N	547	0.50	1.01	0.54	37.9	56.3	56.6	15.4	21.2
W-W	393	0.46	1.02	0.47	38.6	56.6	57.1	15.2	26.7
WB-N	517	0.62*	1.37*	0.60	37.3	57.1	56.1	14.9	26.5
W-W	403	0.24	0.53	0.28	39.6*	56.5	60.5	15.2	21.9
CT	**465**	**0.46**	**0.98**	**0.47**	**38.3**	**56.3**	**57.6**	**15.1**	**24.0**
MT/CT	**p=0.94**	**p=0.54**	**p=0.56**	**p=0.41**	**p=0.55**	**p=0.24**	**p=0.74**	**p=0.94**	**p=0.95**

Grain quality indicators: gluten content (GC, %), starch content (SC, %), Zeleny index (ZI, %), crude protein content (CP, %), thousand grain weight (TGW, g), *significant at p<0.05.

But in another study [11], it was similar data, where the CP content was from 15.5 to 17.3%. On the other hand, scientists from Poland [29] reported that more protein content of wheat grains sown in the plow system (average 13.5%), which are lower than the results of our study. Mathematical processing of the data showed that soil tillage system and precrops did not significantly (p>0.05) affect TGW. Data from our trial show that the average TGW depending on the tillage system was 23.9–24.0 g, which was lower than those of [11] in the study 46.7–48.9 and 34.1–34.3 g at researcher years.

IV. CONCLUSIONS

The results of our study demonstrated that the soil tillage system had a significant (p<0.05) impact on flag leaf area and length. The flag leaf area was on average 5.1 cm² larger and the length was 4.5 cm longer in the conventional soil tillage system compared to the minimal tillage system. In the evaluation of the correlation between spring wheat grain yield and flag leaf area, a statistically significant a strong positive correlation was obtained with (r=0.854) under conventional soil tillage and (r=0.958) under minimal soil tillage system. In contrast, the area, length, and width of the flag leaf in the studied spring wheat were

not significantly ($p>0.05$) affected by the precrops. Our data indicate that there were not significant differences ($p>0.05$) in the grain yield and straw yield of spring wheat between the different tillage systems and precrops. The significant influence of the precrops were observed on spike mass ($p=0.02$), grain weight ($p=0.03$), and GC ($p=0.04$). The analysis of grain quality indicators revealed that significant differences were observed in the gluten content ($p=0.04$). All significant differences were found between the precrops ($p<0.05$), not between soil tillage systems ($p>0.05$). Overall, spring wheat showed higher flag leaf and grain quality indicators in the traditional tillage system. It should be noted that the indicators obtained during the trial, were also influenced by the meteorological conditions, as the trial site was affected by flooding in the month of July. To adapt to climate change and minimize yield losses, farmers should select crop varieties that can withstand adverse weather, ensuring stable grain yields even under less favourable conditions.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 469-473

Prerequisites for Sustainable Blue Economy Development

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***Abstract* - This paper analyzes the opportunities and challenges in developing a sustainable blue economy in the Baltic Sea region, focusing primarily on clean technologies, renewable energy utilization, and circular material flows. The research methodology includes a comprehensive review of policy frameworks, technological innovations, and existing literature sourced from the Web of Science database, supplemented by bibliometric analysis to identify emerging trends and influential research. Results highlight significant environmental challenges such as pollution, overfishing, habitat degradation, and impacts from climate change. Despite these ecological threats, the findings reveal substantial economic growth opportunities through the adoption of sustainable practices. Critical factors identified for successful transition include effective resource management, technological innovation, and strengthened international collaboration. The study concludes that the Baltic Sea region has significant potential to become a global benchmark in sustainable marine and coastal resource management. Strategic recommendations emphasize the importance of enhancing policy support, fostering innovation, and promoting international cooperation to secure ecosystem preservation and economic resilience.**

Keywords - blue economy, circular economy, environmental sustainability, sustainable.

I. INTRODUCTION

The concept of the blue economy has become increasingly important in recent years as global society seeks sustainable, responsible and equitable ways to use and manage marine resources. To fully understand this approach and its impact, it is essential to analyze the meaning, fundamental principles, challenges and opportunities of the blue economy. [9], [11], [19]

The blue economy is a holistic and innovative approach to the sustainable development of water resources that emphasizes the responsible use and conservation of marine and coastal ecosystems. It seeks to strike a balance between economic growth, environmental protection and social equity, ensuring that marine resources are used wisely and for the long term. [18], [26]

This article will take an in-depth look at the principles of the blue economy and its relevance in today's world. It will analyze key challenges such as illegal fishing, pollution, habitat destruction and the impact of climate change, as well as explore the opportunities offered by innovation and sustainable management methods.

Bibliometrics offers useful results from authors' research output, trends, most cited articles and concentration of papers in high-impact journals. The first step was to select and extract data on current Web of Science (WoS) and Scopus scientific studies containing the terms specified in the search criteria in order to visualize scientific knowledge over time, providing high-quality data and complete descriptions that facilitate data processing and wide visibility in the scientific community. [1], [19] The WoS database was chosen for this study. This database is widely recognized as a reliable and multidisciplinary collection of research, and studies recommend its use because of the high proportion of exclusive journals. [6], [13]

II. MATERIALS AND METHODS

The blue economy is often represented by three interrelated pillars: economic, social and environmental. It seeks to balance economic growth, social equity (e.g. employment and poverty reduction in coastal areas) and environmental conservation. This three-pronged approach ensures long-term sustainability. [4], [10]

Economic Pillar: Navigating Prosperity

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8658
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The economic pillar of the blue economy is based on the sustainable exploitation of the economic potential of marine and coastal areas, while ensuring responsible resource management. Its main components are:

- Maritime industries – include fisheries, aquaculture, maritime transport, renewable marine energy and marine biotechnology. The effective development of these industries contributes to economic growth, creates new jobs and stimulates innovation. [4], [12]
- Resource efficiency – the foundation of a sustainable economy is the wise and responsible use of marine resources. This includes sustainable extraction, pollution reduction, waste management and maximising the value of marine resources. [2]
- Sustainable business – it is essential for companies to move towards environmentally friendly technologies and green supply chains. Sustainable businesses not only ensure economic growth, but also contribute to the preservation of marine and coastal ecosystems. [16], [21], [25]

Social Pillar: Empowering Communities

The social pillar of the blue economy highlights the importance of social equity and the well-being of communities by ensuring that marine resource management is fair and inclusive. Its key components include:

- Livelihoods – Sustainable maritime industries provide livelihoods for millions of people around the world, especially in coastal communities. The Social Pillar ensures that these livelihoods are secure, fair and sustainable, boosting local economies and employment. [5], [20]
- Local involvement – communities living near marine resources should have the opportunity to actively participate in decision-making about their management and use. Promoting local participation ensures public interest advocacy and sustainable solutions.[15], [23]
- Social inclusion – the social pillar promotes gender equality and equal opportunities for all, ensuring that both men and women, as well as socially disadvantaged groups, can fully participate in and benefit from the development of the blue economy. [20]

Environmental Pillar: Protecting Our Oceans

The environmental pillar of the blue economy highlights the importance of protecting the health and resilience of oceans and coastal ecosystems, ensuring the sustainable use of natural resources. Its main components include:

- Conservation of biodiversity – protecting marine ecosystems is essential to ensure the survival of endangered species and maintain the balance of nature. This pillar supports measures that contribute to the conservation of biodiversity and the sustainability of marine life. [22], [24]
- Ecosystem resilience – Oceans and coastal areas must be able to adapt to climate change, pollution and habitat destruction. Sustainable fishing, marine protected areas and other environmental protection measures strengthen the resilience and health of ecosystems. [7], [8]
- Environmental management – smart and responsible resource management helps to reduce the negative impact of human activities on the marine environment. This pillar emphasizes that long-term economic prosperity is closely linked to a healthy and preserved ocean ecosystem. [14]

III. Results and Discussion

The blue economy encompasses a wide range of sectors, including fisheries, aquaculture, maritime transport, renewable energy (e.g. offshore wind farms), coastal tourism and marine biotechnology. These sectors not only contribute to economic growth and job creation, but also contribute to the protection of marine ecosystems and the sustainable use of resources.

The author of the article believes that today the blue economy includes new innovative sectors in the directions summarized in the figure.

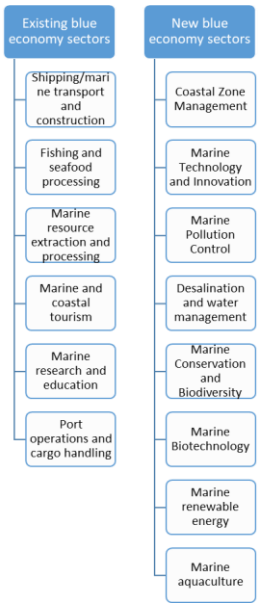

Fig.1. Existing and emerging blue economy sectors.

Characteristics of existing blue economy sectors:

Maritime transport and shipbuilding are essential blue economy sectors that contribute to global trade and economic growth, while introducing sustainable technologies to reduce emissions and protect marine ecosystems

Fisheries and seafood processing are important blue economy sectors that contribute to food security and economic development, while implementing sustainable fishing and processing methods to preserve marine resources for future generations.

The extraction and processing of marine resources is an important part of the blue economy, which contributes to economic development while adhering to the principles of

sustainable and responsible management to maintain the health of marine ecosystems.

Marine and coastal tourism is an important blue economy sector that contributes to local economies and employment, while relying on sustainable practices to preserve the viability of marine and coastal ecosystems for future generations.

Marine research and education are essential drivers of the blue economy, promoting innovation, sustainable resource management and public awareness of the protection of ocean ecosystems.

Port operations and cargo handling are important elements of the blue economy, contributing to global trade and economic growth, while introducing sustainable technologies and environmentally friendly logistics solutions to reduce the impact on marine ecosystems.

Today, the concept of the blue economy has expanded and new sectors need to be included in it according to the economic situation. In order to identify new blue economy sectors, members of the "Coastal Planning and Development Working Group" were involved in the discussion, which brings together Latvia's leading specialists in Marine Spatial Planning, who, using the Miro program, supplemented the existing blue economy sectors with new directions.

Coastal zone management is an essential tool of the blue economy, ensuring a balance between economic development, environmental protection and social well-being, promoting the sustainable use and conservation of coastal resources for future generations.

Marine technology and innovation are a driving force of the blue economy, promoting sustainable resource use, improving the efficiency of the maritime sector and helping to protect ocean ecosystems through environmentally friendly and improved solutions.

Marine pollution control is an essential component of the blue economy, which contributes to the protection of ecosystems, sustainable resource use and climate resilience by reducing pollution and promoting responsible human activity in the oceans and coasts.

Rising temperatures and water desalination can disrupt the balance of marine ecosystems, as it can change habitat conditions, threatening the survival and biodiversity of marine organisms, so these impacts need to be monitored and controlled, while maintaining the balance of marine ecosystems.

Marine protection and biodiversity are essential components of the blue economy, which promotes the health of marine ecosystems, ensures sustainable resource use and preserves marine life for future generations by reducing the development of invasive species in territorial waters.

Marine biotechnology is an important area of the blue economy that uses marine resources to develop new medicines, bioproducts and sustainable technologies, promoting innovation and environmental conservation.

Marine renewable energy, including wind farms, wave and solar energy, is an important element of the blue economy, contributing to sustainable energy production, reducing carbon emissions and helping to ensure sustainable energy supply in coastal and marine regions, as well as being a new economic niche on the coast.

Marine aquaculture is an important blue economy sector that contributes to sustainable food production, reducing pressure on wild fish resources and ensuring economic growth in coastal regions.

These new blue economy sectors are new elements in the blue economy that can provide new economic forms and opportunities for the development of coastal economies.

In conclusion, it should be emphasized that the three pillars of the blue economy – economic, social and environmental – closely interact to promote sustainable development. By balancing economic growth, social inclusion and responsible environmental management, the blue economy offers an integrated approach that ensures the sustainable well-being of oceans and coastal regions for future generations. One of the key examples of the principles of the blue economy is sustainable fishing, which not only prevents overexploitation of fish resources, but also promotes the implementation of responsible fishing practices, reduces bycatch and maintains the balance of marine ecosystems. This approach strengthens coastal communities by providing sustainable and stable incomes, while preserving marine resources for future generations.

The blue economy offers a wide range of benefits, including economic growth, job creation, food security, renewable energy sources and biodiversity conservation. By promoting responsible and sustainable practices, it contributes to the long-term viability and well-being of our oceans and coastal regions.

IV. Conclusions

The blue economy is becoming increasingly important as it offers sustainable and responsible ways to use and manage marine resources, while maintaining the health of ecosystems and promoting economic growth. It is based on three interrelated pillars: economic, social and environmental, which together ensure a balance between resource use, social well-being and environmental protection. The economic pillar promotes the development of new sectors, such as renewable marine energy and sustainable aquaculture, which create jobs and stimulate innovation. The social pillar ensures fair access to livelihoods, especially for coastal communities, promoting local economies and social inclusion. The environmental pillar emphasises the conservation of biodiversity and the protection of ecosystems, reducing pollution and the impact of climate change. The blue economy brings many benefits, including new economic growth, food security, renewable energy sources and ecosystem protection,

contributing to the sustainable development of our oceans and coastal regions.

ACKNOWLEDGEMENT

The Recovery and Resilience Facility project "Internal and External Consolidation of the University of Latvia" (No.5.2.1.1.i.0/2/24/I/CFLA/007) grant “Blue Economy: Combining Technology and Sustainability to Protect the Baltic Sea from Pollution”(No. LU-BA-ZG-2024/1-0022)

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 475-479

Promising Regional Models in the Context of Marketing Strategies for Tourism Development

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***Abstract*- Developing a marketing strategy in the tourism business is a special kind of challenge, especially in the context of digitalization, the implementation of artificial intelligence and the accelerated use of social networks. A key and strategic approach to tourism development and a successful marketing strategy is the use of promising regional models. Tourism managers can very successfully use these models to build effective competitive advantages in the tourism business.**

The emergence of the need to implement successful marketing strategies in tourism is caused by the constantly increasing level of service in the tourism sector, which is caused by changes in both the environment and changes in the behavior of tourists in their role as consumers. On the other hand, forms of communication are changing, newer means of transport are appearing, natural landscapes and ecosystems are changing, which also remodel tourist behavior. This is precisely where the prerequisites and challenges lie to formulate and describe promising regional models in the context of marketing strategies for tourism development.

Keywords- tourism, regional models, marketing strategy, consumer behavior, development, natural resources

I. Introduction

In the last few decades, tourism has focused on limiting its uncontrolled growth, which has been taking place since the middle of the last century, and has begun to pay significantly more attention to the main resource of any type of tourism activity, namely - to the natural resources that are used for its implementation. Starting from the first protected areas and ending with the formulation and practical application of the concept of sustainable tourism, in recent years a lot has been done to preserve the natural environment. [10]

The aim of this article is to present promising regional models in the context of marketing strategies for tourism development.

Mass tourism in recent decades has created conditions in which, even with the highest environmental requirements, tourism activity continues to have a negative impact on the natural environment, with the most vulnerable natural systems suffering most from mass forms of tourism activity, a significant part of which either cannot be restored in the foreseeable future, or their restoration will be too difficult and too resource-intensive [9].

II. Materials And Methods

The main reason for this is the need to constantly increase the level of service in the tourism sector, the emergence of increasingly modern means of transport and communication, as well as the need to adapt natural landscapes and ecosystems to the needs of tourism activity. Despite following the most precise norms of ecological compatibility, these factors continue to have a negative impact.

Changes in land use lead to fragmentation of the environment and, accordingly, to the death of a number of ecosystems. Pollution and the carbon footprint that tourism cannot help but leave (no matter how high the standards, transport, energy production and a number of other elements still leave their mark on nature), as well as the risk of introducing atypical biological forms that threaten existing ecosystems and under certain conditions can lead to their extinction. It should be noted that such processes do not only affect exotic destinations in the equatorial belt, but also apply to all regions, including the Balkan region.

It is precisely for this reason that there is a need to move to a new stage in the protection of naturalcomplexes and systems, with the path of unlimited prohibitions being one of the most unproductive, both because of the need for

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8628
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appropriate control over its observance and because this approach will disrupt the production processes of a number of tourist companies, a significant part of which strictly comply with environmental requirements. Such a new stage is positive tourism towards nature - a model in which the natural environment is not only the object of protection, but also of active restoration of already caused damage, and not on an incidental, but on a permanent basis. The concepts of sustainable tourism and positive tourism do not contradict each other. They complement each other, with the concept of positive tourism complementing and expanding the general concept of sustainable tourism. It is to a greater extent adapted to new and promising technologies in tourism management, transport, energy, construction and environmental protection.

Sustainable marketing in tourism can explore two fundamental approaches, that of market development using market segmentation and that of sustainable product development. It is realistic to investigate the implementation of sustainable marketing, presenting evidence of the motivations, mechanisms and barriers that businesses encounter, and of the successes in changing consumer behaviour and pursuing sustainability goals.

Important attention should be paid to the methodologies of sustainable tourism marketing, the breadth and complexity of the topic, as well as the numerous innovations. For the research to be realistic and truly broader, it is necessary to fully understand what contextual aspects influence these pro-sustainable interventions to achieve what results in other settings, to validate some of the exploratory studies and to establish the feasibility of scaling up pilot studies for more general use. [5]

On the other hand, as one of the private concepts of sustainable tourism, the concept of nature-positive tourism has its regional forms, each of which is the basis for finding organizational-economic, social and technical solutions, thanks to which this concept finds its expression in a particular region. Therefore, speaking of positive tourism, its regional forms should be sought that are adapted both to the natural conditions of the respective region and to the socio-economic and technological opportunities. [4]

A "roadmap" has been developed by specialists in the tourism industry, which includes general principles of nature-positive tourism, and at the same time, in each of the regions, decisions must be made based on the specifics of the respective countries and the level of development of tourism activity. [9]

According to this "map", the implementation of the positive tourism model consists of four main phases, each of which distinguishes separate steps that must be taken. The phases are as follows:

a) the first phase is defined by the document as the assessment and determination phase. It is about determining those activities that, by their nature, cause the greatest damage to biodiversity, as well as individual natural species. At the same time, within the first phase, the roadmap does not rely solely on a normative approach, implying the prohibitions of certain activities.

In one of the stages, it is envisaged to prepare the necessary analysis relating to the essence of the actions of tourism companies and, accordingly, an analysis of the business processes and technological opportunities that exist for changing business processes, which would integrate them to a greater extent into the system for the protection of individual species. Moreover, the roadmap does not provide for a unified model for action. It assumes that in each of the regions, depending on the specific natural and climatic conditions and economic situation, adequate and sufficiently individualized actions should be taken.

As one of the first steps, the "roadmap" implies the preparation of a list of protected and endangered species, as well as species that are threatened by the impact of other biological species incompatible with them. [1]

To a significant extent, the first phase can be implemented in most countries in the Balkans. In particular, it can be fully implemented in Bulgaria. It is enough to create the relevant administrative bodies (and they can be fully built on the basis of the existing structures of the Ministry of Environment and Water and the Ministry of Tourism). In this regard, achieving compliance between the costs and benefits that certain actions will have on the natural complexes of the respective region is of great importance.

For now, however, serious problems arise from the need to accurately estimate the losses that the tourism business would suffer as a result of the implementation of positive tourism measures. In many cases, such calculations can only be made with the help of local authorities, since a significant part of the tourism business both in Bulgaria and in the Balkans as a whole is built on the basis of already developed tourist centers, where the damage to natural complexes occurred too long ago and cannot be described and properly valued. [3] In order to achieve an accurate analysis of the damage and especially with a view to valuing the already destroyed natural environment, biological-mathematical algorithms for the restoration of destroyed natural complexes must be compiled and then the financial expression of this process must be presented.

Solving this extremely complex task requires the presence of two conditions: on the one hand, the development of accessible new technologies that will enable the effective restoration of destroyed and maximally endangered ecosystems, and on the other - the creation of such organizational conditions that will allow the implementation of such technologies.

It is extremely clear that the tourism business (which in most cases is medium or small) will not be able to cope with such tasks on its own. That is why it is extremely important to attract the bodies of both state and local government. Thus, the state government could fully provide the necessary financial conditions, both in the form of a targeted fiscal policy and in the form of active investment in the development of fundamental and applied sciences. Local government bodies should actively

cooperate with tourism business structures by building public-private partnerships, thus increasing the likelihood of attracting additional investments in activities positive for nature.;

b) the second phase of the "road map" is defined as a reduction phase. It provides for the gradual release of those activities that most threaten biological species and can be eliminated from the practice of tourism companies.

An important element is the determination of priorities, and those of them that are related to the specifics of the region. Unfortunately, such an analysis in the conditions of Bulgaria is carried out extremely difficult and affects only those regions in which the problems have reached a high degree of severity. In order to implement such an approach, active activity is necessary both from local authorities involved in environmental protection and from business. Several stages can be outlined that must be implemented in this direction:

-first of all, the systemic environmental problems in a specific region must be determined, and they must be classified and systematized, along with indicating the main reasons for the emergence of the relevant problems. Based on this systematization, the most risky factors must be determined, indicating those tourism activities that most provoke the manifestation of the relevant factors. Of course, this process should be implemented with the help of state institutions that can support the conduct of relevant research. It is important that the assessment of these factors is as objective as possible, as the tourism business has a high degree of trust in the relevant activities;

-next, tourism companies should analyze their business systems, the main goal of which is to exclude from them those elements that most threaten natural complexes, both in a specific period of time and those that may threaten natural complexes in the future. Of course, this does not mean that the tourism business should simply reduce its activities. Companies should develop such approaches that, on the one hand, reduce the harmful effects on natural complexes, and on the other hand, maintain and even improve their competitiveness. At first glance, this process is very difficult, if not impossible. In fact, however, this is not the case.

III. RESULTS AND DISCUSSION

The solution can be found in the implementation of three main processes: the introduction of new technologies, the use of optimized tourism products and processes, and the creation of a new type of information space for tourism activities.

In turn, the implementation of digital technologies affects the tourism system in numerous and complex ways, with mixed results for sustainability: while most changes would currently seem ambiguous – and some downright negative – there is significant potential for IT to support more sustainable tourism. However, this would require significant changes in the tourism system at global, national and individual business levels and requires tourism scholars to explore many new issues.

The main goal is still to enable tourists and tourism businesses to play an active role in overcoming environmental problems, since they are global environmental problems (climate change, pollution, ozone depletion, etc.) and the adverse impact of these problems on nature is increased. In addition, tourists and tourism businesses need to be informed about environmental specificities. At the same time, tourism businesses need to offer environmentally friendly products and services to green tourists in order to be sustainable. The importance of environmentally friendly performance of accommodation businesses in terms of the sustainability of the destination source should be realistically considered and assessed.

A number of studies in theory and practice show that tourists are extremely informed about green hotels. In this way, these hotels have sustainable competitive advantages. These hotels also have a positive impact on the sustainability of the destination.

New technologies that should find a place in tourism should not only be within the framework of environmental standards, but also be able to be included in the process of restoring natural complexes, by being integrated into the relevant business processes of tourism companies. With the advent of the Fourth Industrial Revolution, tourism enterprises must orient themselves in acquiring such equipment that best meets their individualized needs, as the leading guideline in this regard should be precisely the protection and restoration of natural complexes. [6]

Optimization of tourism products, in the context of the restoration of natural complexes in the region, does not at all mean their banal reduction. Moreover: today's tourism products already need a certain improvement, thus they must correspond to the new requirements that tourists have.

Accordingly, optimization of tourism products will make it possible, on the one hand, to eliminate those elements that both tourists and management are trying to modernize, and on the other - the protection of natural complexes can be considered as an independent factor around which relevant tourism products can be formed, or to modify those that exist today. [11] In this way, the optimization process leads not to the reduction, but to the development of tourist products, which can have a very high degree of individualization. [2]

In practice, such optimization can be implemented in any type of tourism. As an example, culinary tourism can be cited, in which, within the framework of the offer of certain products, a number of elements related to the protection of natural complexes are included, as this process is closely related to culinary art.

In this sense, the soil for such tourist products is particularly favorable on the Balkan Peninsula, since most of the national dishes and drinks have a direct connection with the products of a certain natural system. Tourists can be offered the opportunity to gain experience not only in

preparing dishes, but also to actively participate in the restoration of the natural system that produces the products for them.

The third element, namely the information environment of tourism, is perhaps, in today's conditions, the most significant for the active development of nature-positive tourism. A well-modeled and purposeful information environment can be the basis for the needs of this type of tourism. Of course, in this regard, a number of activities are already being carried out that promote the ecological behavior of tourism.

However, it must be said that these elements of the information environment are rather informative in nature, detached from specific tourist products and destinations. This, to a significant extent, also determines their relatively weak impact on both tourists and tourist operators.

Creating an information environment for the positive towards nature implies a different approach. The creation of messages in this environment must relate to a specific object, territory, specific natural species or system. The possibilities for the restoration of natural systems must be clearly demonstrated, demonstrating the specific steps that must be implemented for this.

It is also important to demonstrate how positive tourism will achieve a certain result for the environment. The more detailed presentation of the process is as possible, significantly increases the level of trust, generates an element of empathy on the part of tourists. In the process of creating an information environment, it is important to create feedback between the source of information and its recipients. It is precisely for this reason that social networks and other electronic media have an important contribution to the process. In them, feedback is significantly easier, and its mass nature allows for reducing tension in its implementation.

When modeling the information environment, one of the main accents should be placed on the active position for the restoration of natural complexes and, above all, on the activity of tourism enterprises in this direction. [7]

Today, the creation of such a full-fledged information environment in the Balkan countries is lacking. Obviously, much needs to be done in this direction, and here competition between countries is a counterproductive approach. Joint efforts are needed to implement the relevant information strategy;

-Creating a unified strategy for nature-positive tourism. Isolated positive actions related to the implementation of nature-positive tourism cannot produce the expected effect if this activity is not planned in advance and systematically implemented over a significant period of time.

This requires the creation of a unified strategy in this direction, and the strategy should have not so much a recommendatory as an imperative character. Otherwise, environmental protection authorities will continue to observe a decrease in biodiversity and, accordingly, a decrease in the opportunities for competitive advantages over the tourism industry in the Balkans.

It is essential for the implementation of the strategy that it covers a sufficiently long time horizon, the most suitable in this regard may be the period of 20-30 years. This is the time needed to begin the process of restoring biological species and safely preserving existing ones. [8] During this period, conditions are also created for the operation of economic mechanisms that allow the implementation of the approach.

The strategy should be based on the systematic nature of the process, and all aspects of the introduction of this model of tourism activity should be reflected in it - from technical solutions to the activation of local communities in the implementation of the strategy. In addition, it would be appropriate for the strategy to consider more than one option for addressing problems related to biodiversity and especially models of action related to the restoration of biological species.

c) The third phase is related to the implementation of monitoring and reporting on the activities carried out.

The set goals of positive tourism are achievable only and exclusively when the changes affect both the practice of tourism itself, and all economic and non-economic structures, as well as the management bodies of the public sector. It follows that monitoring and reporting are of essential importance for the implementation of the concept, since they are the basis for the coordination of actions in the individual elements of the implementation of the concept.

The implementation of monitoring and documentation of the activity require the development of specific methodologies for this purpose, which, on the one hand, correspond to the specifics of the sites, and on the other hand, enable management to receive information that is suitable for the implementation of management functions.

It should be noted that the developed methodologies must reflect the processes in the positive concept of tourism not only in its static state, but also in dynamics. This in turn implies that within the framework of documentation, constantly operating indicators should be used, which should be unified over a long period of time.

d) The fourth phase of introducing nature-positive tourism is defined as cooperation and communication.

As in any new area, in the field of nature-positive tourism, achieving results cannot be based solely on administrative measures. Obviously, for real effectiveness, there should be an internal understanding of the essence of the process and the presence of both individual and group interest in achieving results.

Accordingly, the effectiveness of the model can be realized in the process of cooperation, and this process has two main forms: cooperation between public administration and private tourism business and cooperation between states in the field of positive tourism.

Quite naturally, one of the most appropriate forms of cooperation between tourism business and public administration is the creation of public-private

partnerships, which could, if legislators so wish, receive a more special status, consistent with the specifics of the goals they set themselves. This form of cooperation has a different degree of development in the individual countries of the Balkans. Therefore, it would be appropriate to adopt the experience of such countries as Greece, as well as Serbia, where such forms have proven their effectiveness.

Of course, public-private partnerships are not the only form of cooperation important for the development of positive tourism. No less important is the active cooperation between the scientific community and the tourism business. The essence of positive tourism requires such a form, thus ensuring a high degree of scientific validity of the decisions made. In this form, different forms could also be considered, and each of the countries of the region could choose the appropriate model, depending on the historical characteristics of such a type of cooperation. In Bulgaria, this type of interaction is currently relatively poorly represented, and in this regard, the practical experience of neighboring countries could be used.

These two forms of cooperation in the introduction of positive tourism towards nature do not exhaust all possibilities. Of great importance is the participation in the implementation of this concept of local communities, which can be defined as the main "recipient" of the benefits of positive tourism. Accordingly, they have sufficiently broad opportunities to support this business model. For the Balkans and in particular for Bulgaria, one of the serious and still unused opportunities is the creation of tourist cooperatives, which can, on the one hand, implement part of the individualized tourist services, and on the other - carry out a number of activities related to monitoring the natural environment in the respective destination.

IV.CONCLUSIONS

It is an indisputable fact that promising regional models in the context of marketing strategies for tourism development play a key role. The emphasis in marketing strategies is precisely sustainability, in parallel with the implementation of digital technologies. The future development of tourist destinations will show how well these regional models are implemented and how much applied marketing will lead to an increase in tourists in a regional aspect.

The implementation of promising regional models in the context of marketing strategies for tourism development has a number of theoretical and practical applications, that provide the implementation of digital technologies affects the tourism system in numerous and complex ways, with mixed results for sustainability: while most changes would currently seem ambiguous – and some completely negative – there is significant potential for IT to support more sustainable tourism. And for this would require significant changes in the tourism system at the global, national and individual business levels and requires tourism scholars to explore many new issues.

In addiction, the opportunity for tourists and tourism enterprises to play an active role in overcoming environmental problems is important, since they are global environmental problems (climate change, pollution, ozone depletion, etc.) and the adverse impact of these problems on nature is increased. And tourists and tourism enterprises need to be informed about the natural specificities. Very important is that tourism enterprises must offer environmentally friendly products and services to green tourists in order to be sustainable. The importance of environmentally friendly performance of accommodation companies in terms of the sustainability of the source of the destination must be realistically considered and assessed.

These effects can be achieved precisely through the implementation of promising regional models in the context of marketing strategies for tourism development

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 481-486

Adaptive Reuse Potential (ARP) Model for Age-Friendly Social Housing: a Systematic Literature Review

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***Abstract*— This systematic literature review examines the Adaptive Reuse Potential (ARP) Model and its application in developing age-friendly social housing. The study synthesizes research on the ARP Model's components, benefits, and variations, focusing on its relevance to repurposing existing buildings for social housing. Our findings reveal that the ARP Model offers a robust framework for assessing buildings' suitability for adaptive reuse, with significant potential for promoting sustainable urban development and creating age-friendly living environments. The model's consideration of multiple obsolescence factors allows for a comprehensive evaluation of a building's adaptive reuse potential. Variations of the model, including the Green Adaptive Reuse Model and the Adaptive Sustainable Reuse Model, further enhance its applicability to age-friendly social housing development by incorporating additional sustainability and decision-making criteria. By critically analyzing existing literature, we highlight the model's strengths in addressing complex urban regeneration challenges and meeting the evolving needs of aging populations. The ARP Model demonstrates particular efficacy in bridging architectural preservation with contemporary social housing requirements, offering a nuanced approach to repurposing underutilized urban spaces. This comprehensive evaluation underscores the importance of interdisciplinary considerations in adaptive reuse strategies, integrating architectural, social, and environmental perspectives. This review concludes that the ARP Model and its variations provide valuable tools for decision-making in adaptive reuse projects, particularly in addressing the growing demand for age-friendly social housing. However, there is scope for further development of the model to more explicitly incorporate age-friendly design principles.**

Keywords*— *adaptive reuse potential (ARP) model, age-friendly housing, social housing, building obsolescence.

I. Introduction

The adaptive reuse of existing buildings has emerged as a sustainable solution to address the increasing demand for social housing, particularly for aging populations. This approach not only provides much-needed housing but also contributes to urban conservation efforts by minimizing urban sprawl and preserving cultural heritage [1]–[3]. As cities worldwide grapple with the dual challenges of housing shortages and aging populations, the concept of adaptive reuse has gained significant traction among urban planners, architects, and policymakers.

The Adaptive Reuse Potential (ARP) Model, developed by [4]–[7], offers a structured approach to evaluating the potential of existing buildings for adaptive reuse. This model provides a quantitative framework for assessing a building's suitability for repurposing, considering various factors that influence its potential for successful adaptation. As such, the ARP Model has become an invaluable tool in the field of urban regeneration and sustainable development.

The growing interest in age-friendly social housing adds another dimension to the application of the ARP Model. With the global population aging rapidly, there is

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8624
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an urgent need for housing solutions that cater to the specific needs of older adults while promoting social integration and community well-being. The adaptive reuse of existing buildings for age-friendly social housing presents an opportunity to address this need while simultaneously preserving urban heritage and promoting sustainable development.

This systematic literature review aims to explore the ARP Model's components, benefits, and variations, with a specific focus on its application in developing age-friendly social housing. By synthesizing existing research on the ARP Model and its applications, this review seeks to provide a comprehensive understanding of the model's potential for guiding adaptive reuse projects in the context of age-friendly social housing development.

The review addresses the following research questions:

1. What are the key components and principles of the ARP Model?
2. How effective is the ARP Model in assessing buildings for adaptive reuse?
3. What variations of the ARP Model have been developed, and how do they contribute to its application?
4. How can the ARP Model be applied to the development of age-friendly social housing?

By addressing these questions, this review aims to contribute to the growing body of knowledge on adaptive reuse and age-friendly housing. It seeks to provide valuable insights for researchers, urban planners, architects, and policymakers involved in the development of sustainable and inclusive urban environments. Furthermore, by identifying potential areas for further development of the ARP Model in the context of age-friendly housing, this review aims to stimulate future research in this important field.

II. Materials and Methods

This study employs a systematic literature review methodology to synthesize existing research on the Adaptive Reuse Potential (ARP) Model and its application in age-friendly social housing development. The systematic approach ensures a comprehensive and unbiased review of the available literature, facilitating the identification of key themes, trends, and gaps in the current body of knowledge.

A comprehensive search of academic databases, including Google Scholar, Scopus, and Web of Science, was conducted. The search utilized a combination of keywords and phrases, such as "Adaptive Reuse Potential Model," "ARP Model," "adaptive reuse," "social housing," "age-friendly housing," "sustainable urban development," and "building obsolescence." Boolean operators (AND, OR) were employed to combine these terms and enhance search precision. The search was not restricted by publication date to ensure a thorough review of the model's development and applications over time

Studies were included in the review if they met specific criteria: they must focus on the ARP Model or its variations, discuss adaptive reuse in the context of housing or urban development, be published in English to ensure accurate interpretation, and be peer-reviewed journal articles, conference papers, or book chapters to ensure quality and reliability.

Relevant information was extracted from the selected studies, including descriptions and explanations of the ARP Model's components, discussions of the model's benefits and limitations, details of variations or adaptations of the original ARP Model, applications of the model in housing or urban development contexts, discussions of the model's relevance to age-friendly or social housing, and any critiques or suggestions for improvement of the model.

The extracted data was synthesized to identify key themes, trends, and gaps in the literature related to the ARP Model and its application in age-friendly social housing. This process involved categorizing the information according to the research questions, identifying common themes and patterns across different studies, noting any conflicting findings or interpretations, and recognizing gaps in the current research or areas for further investigation.

III. Results and Discussion

The Adaptive Reuse Potential (ARP) Model, developed by [4], [8], provides a comprehensive framework for evaluating the potential of existing buildings for adaptive reuse. This model has gained significant attention in the field of urban regeneration and sustainable development due to its systematic approach to quantifying reuse potential.

The concept of useful life is central to the ARP Model. It represents the optimal point in a building's lifespan for repurposing. This is calculated using two key parameters: Building's Physical Life (Lp), which is an estimated value representing how long the building is expected to last physically, typically assigned a value of 100 years or less for modern buildings, though values of 150 and 200 years can also be used for more durable structures; and Building's Age (Lb), which is the number of years from when the building was constructed to the current year or year of assessment. The useful life (Lu) is calculated somewhere within the range between Lb and Lp. According to the model, the adaptive reuse potential (ARP) of a building reaches its peak at Lu and then declines to zero as the building ages towards its physical life (Lp).

The ARP Model considers seven obsolescence variables, each evaluated independently. Physical Obsolescence assesses the wear and tear of the building based on its maintenance policy, rated from 0% (high maintenance) to 20% (low maintenance). Economic Obsolescence considers the building's location and its impact on value, ranging from 0% (high-density location) to 20% (low-density location). Functional Obsolescence evaluates the adaptability of the building's spatial layout, rated from 0% (low conversion cost) to 20% (high

conversion cost). Technological Obsolescence assesses the building's energy efficiency, ranging from 0% (low energy demand) to 20% (high energy demand). Social Obsolescence considers the suitability of the building's function in the market, rated from 0% (fully owned spaces) to 20% (fully rented spaces). Legal Obsolescence evaluates compliance with building design and standards, ranging from 0% (high-quality design/compliance) to 20% (low-quality design/compliance). Political Obsolescence assesses community or public interest in the building, ranging from -20% (supportive environment) to 20% (inhibiting environment). These percentages are not cumulative; instead, each variable is equally considered in assessing the building's overall obsolescence.

The model generates an index of reuse potential, known as the ARP score, which is expressed as a percentage. This score helps in benchmarking, timing, and ranking mutually exclusive projects. Scores above 50% indicate high adaptive reuse potential, scores between 20% and 50% indicate moderate adaptive reuse potential, and scores below 20% indicate low adaptive reuse potential.

Fig. 1. illustrates the Adaptive Reuse Potential (ARP) Model, which provides a framework for evaluating the potential of existing buildings for adaptive reuse. This model quantifies their reuse potential, assisting in prioritizing buildings for conversion based on their adaptability to new uses. This division represents roughly one-third of the area under the decay curve in each category.

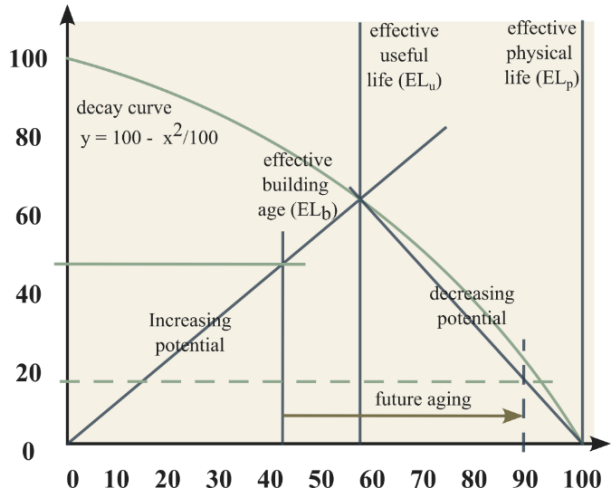

Fig. 1. Adaptive reuse potential model [8], [9].

The ARP Model offers several significant benefits in the context of urban regeneration and sustainable development. It facilitates a shift in traditional property stakeholder decision-making processes toward more sustainable practices and outcomes. By identifying and ranking existing buildings with significant potential for adaptive reuse, the model enables the industry to embrace sustainable development strategies. The model aids in identifying buildings where resource efficiency benefits can be maximized, thereby promoting reduced environmental impact through decreased material consumption and waste generation on a larger scale [10]–[12]. Additionally, by providing a framework for assessing the reuse potential of existing structures [13]–[15], the ARP Model supports the preservation of cultural heritage and historical significance, particularly important in urban areas where older buildings contribute significantly to the character and identity of neighbourhoods. The model also helps identify buildings where adaptive reuse can be most economically beneficial, enhancing overall economic efficiency in urban development projects.

Several variations and extensions of the original ARP Model have been developed to address specific contexts or incorporate additional considerations [16], [17]. The Adaptive Reuse Decision-Making Model expands on the ARP concept to aid practitioners in deciding whether to reuse or demolish existing buildings. It integrates critical factors including financial considerations of capital investment, asset condition, regulatory requirements, and sustainability principles across environmental, economic, and social dimensions.

This decision-making model, as illustrated in Fig. 2. provides a comprehensive framework for evaluating whether existing buildings should be repurposed or demolished.

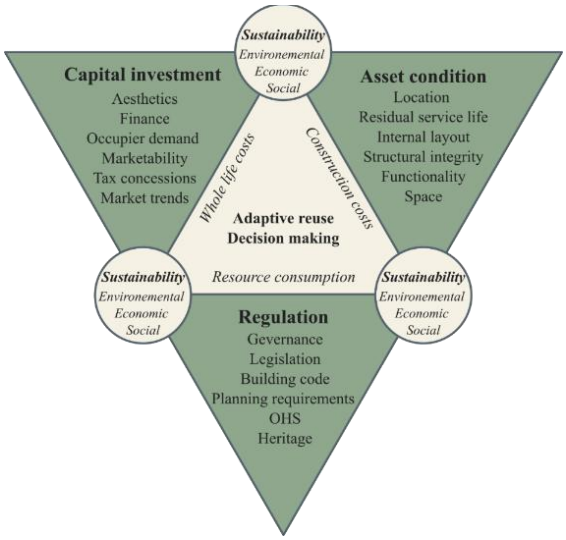

Fig. 2. The adaptive reuse decision-making model [8], [18]

The Green Adaptive Reuse (GAR) Model incorporates green building principles into the adaptive reuse of existing structures, aiming to enhance environmental, social, and economic performance through seven major design criteria and emphasis on eco-friendly materials and energy efficiency [19], [20]. The Adaptive Sustainable Reuse Model focuses [21] on revitalizing historical and cultural heritage buildings, integrating advanced decision-making techniques and taking a participatory approach engaging local stakeholders. The Sustainable-Driven Adaptive Reuse Model emphasizes [22] the integration of sustainability into the redevelopment of existing buildings, highlighting multifaceted benefits and using multi-criteria analysis to assess project viability.

In applying these models to age-friendly social housing, several key considerations emerge. The model can be adapted to prioritize buildings with potential for incorporating accessibility features crucial for age-friendly housing, such as ramps, wider doorways, and elevators. By evaluating the social obsolescence factor, the model can help identify buildings well-situated for community integration, with good access to community facilities, public transport, and healthcare services. The technological obsolescence factor can be used to assess a building's potential for energy-efficient retrofitting, particularly important for maintaining affordable operating costs in age-friendly social housing. The functional obsolescence factor can help identify buildings with layouts adaptable to the changing needs of older residents, particularly those that can be easily modified to incorporate universal design principles. While not explicitly part of the original ARP Model, considerations of health and safety are crucial for age-friendly housing and could be incorporated into the assessment of physical obsolescence, with buildings that can be easily upgraded to meet health and safety standards for older adults receiving favourable scores.

This systematic review examines the Adaptive Reuse Potential (ARP) Model's application in age-friendly social housing development, revealing both its capabilities and limitations. The model's seven obsolescence factors (physical, economic, functional, technological, social, legal, and political) provide a comprehensive framework for evaluating buildings, effectively addressing our first research question about key components and principles. The model's quantitative scoring system, which clearly categorizes buildings based on their adaptive reuse potential (high: >50%, moderate: 20-50%, low: <20%), demonstrates its effectiveness in assessment, answering our second research question.

Various adaptations of the model, including the Green Adaptive Reuse Model and Adaptive Sustainable Reuse Model, have enhanced its applicability by incorporating sustainability metrics and advanced decision-making techniques. These variations, addressing our third research question, show the model's evolution to meet contemporary challenges in urban development. Regarding our fourth research question, the model shows strong potential for age-friendly social housing development through its adaptable framework, though some modifications may be needed for optimal application.

The model's primary strengths lie in its comprehensive framework, quantitative assessment approach, and flexibility in adaptation to various contexts. Its integration of multiple stakeholder perspectives and sustainability principles makes it particularly valuable for current urban development challenges. However, several limitations exist, including insufficient explicit criteria for age-specific requirements, an overemphasis on economic factors at the expense of social considerations, and gaps in addressing smart technology integration. The model's complexity can also make implementation challenging, particularly in different cultural and regulatory contexts.

Future development opportunities include creating specialized assessment criteria for age-friendly housing requirements, better integration of smart technologies, and enhanced consideration of social factors specific to older adults. The model could benefit from incorporating innovative funding approaches for social housing and structured methods for stakeholder participation, particularly involving older adults in the evaluation process.

These findings suggest that while the ARP Model provides a strong foundation for evaluating adaptive reuse potential, targeted modifications would enhance its effectiveness for age-friendly social housing development. As global populations age and housing demands evolve, such refinements will become increasingly important in supporting sustainable urban development strategies.

IV. Conclusion

- This systematic literature review demonstrates that the Adaptive Reuse Potential (ARP) Model and its variations offer valuable tools for assessing and prioritizing buildings for adaptive reuse in the context of age-friendly social housing development. The model's comprehensive approach, considering multiple obsolescence factors, aligns well with the complex requirements of creating suitable living environments for older adults.
- The ARP Model provides a structured framework for decision-making in adaptive reuse projects, offering several key benefits:
- It promotes sustainable urban development by encouraging the reuse of existing building stock, reducing the need for new construction and preserving cultural heritage.
- The model's consideration of multiple obsolescence factors allows for a holistic evaluation of a building's potential, ensuring that various aspects crucial for age-friendly housing are considered.
- The flexibility of the model and its variations allows for adaptation to specific contexts and requirements, making it a versatile tool for diverse urban environments.
- By providing a quantitative measure of adaptive reuse potential, the model facilitates objective comparison and prioritization of potential projects, aiding in resource allocation and strategic planning.
- However, the review also suggests areas for further development and research:

- There is potential to more explicitly incorporate age-friendly design principles into the model, enhancing its specificity for age-friendly housing projects.
- Further exploration of the economic aspects specific to age-friendly social housing could strengthen the model's applicability in this context.
- Integration of smart city concepts and digital technologies into the ARP Model could enhance its relevance in increasingly digitalized urban environments.
- More emphasis on participatory approaches in the model could ensure that adaptive reuse projects better meet the needs and preferences of older adults.
- Empirical studies and case analyses of the ARP Model's application in age-friendly housing projects would provide valuable insights for refining and validating the model.
- In conclusion, the ARP Model and its variations provide a robust foundation for decision-making in adaptive reuse projects aimed at developing age-friendly social housing. By leveraging these tools, stakeholders in urban planning and development can make informed decisions about adaptive reuse projects, contributing to sustainable urban development while meeting the housing needs of aging populations.
- Future research should focus on developing a specialized version of the ARP Model that explicitly incorporates age-friendly considerations, potentially enhancing its effectiveness in this specific application. Additionally, practical case studies and longitudinal research on the application of the ARP Model in age-friendly housing projects would provide valuable insights for practitioners and policymakers.
- As cities worldwide grapple with the dual challenges of aging populations and the need for sustainable urban development, the ARP Model offers a valuable framework for creating innovative, inclusive, and sustainable housing solutions. By guiding the transformation of existing buildings into age-friendly social housing, this approach has the potential to significantly contribute to the creation of more livable and inclusive urban environments for all ages.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 487-496

Exploring Organizational Citizenship Behaviour Dimensions and Organizational Performance Measurement Systems in Manufacturing Companies of Latvia: a Perspective on Industry 4.0 and 5.0

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***Abstract*— The European Union (EU) is actively driving industrial transformation through initiatives such as the transition from Industry 4.0 to Industry 5.0, which emphasizes sustainability, human-centricity, and resilience. As an EU member state, Latvia aligns with these developments, leveraging Industry 5.0 to enhance efficiency, quality control, worker safety, and customer experience. While existing research highlights Industry 5.0's positive impact on Organizational Performance (OP), concerns remain regarding its influence on the nature of Organizational Citizenship Behaviour (OCB). OCB, defined as voluntary, value-adding behaviour beyond prescribed tasks, is considered a source of competitive advantage due to its intangible nature. Despite extensive research on OCB's relationship with OP, inconsistencies persist in OP measurement, particularly within Latvian manufacturing companies operating in the Industry 4.0 and 5.0 context. This study aims to identify relevant OP measurement indicators and OCB dimensions specific to Latvian manufacturing companies. The research is particularly relevant given the sector's historical significance in Latvia, its decline following independence in 1991, and its recent resurgence. By focusing on Latvia, the study eliminates cross-cultural variations and provides deeper insights into industry-specific OCB-OP dynamics. A qualitative research approach is employed, using semi-structured interviews with company owners and top managers in Latvia's manufacturing sector. Due to the sensitive nature of the study, face-to-face interviews facilitate richer insights through direct observations and explanations. Thematic content analysis is applied to analyse qualitative data. This research contributes to the existing body of knowledge by bridging the gap in OP measurement and OCB dimensionality within the evolving Industry 5.0 landscape. The findings offer practical implications for manufacturing companies, policymakers, and researchers, enhancing understanding of how OCB supports OP during the transition to Industry 5.0 principles.**

Keywords*— *Organizational Citizenship Behaviour Dimensions, Organizational Performance Measurement Systems, Manufacturing Companies in Latvia, Industry 4.0 and 5.0

I. INTRODUCTION

European Commission considers European industry as a key driver of social and economic transitions [1]. Latvia, as a member state of the European Union, aligns with the EU's initiatives, including the introduction of Industry 5.0 concept by the European Commission in 2021. Thus, Latvian manufacturing companies are operating within the framework of Industry 4.0 while transitioning toward the principles of Industry 5.0: (i) sustainability, (ii) human-centricity and (iii) resilience [2]. According to Wolniak [3]manufacturing companies that adopt Industry 5.0, benefit from improved (i) efficiency, (ii) quality control, (iii) worker safety, (iv) customer experience, etc. A review and analysis of Industry 4.0 and 5.0 show a positive effect of Industry 5.0 on Organizational Performance (OP) in manufacturing companies by addressing the limitations of Industry 4.0 to ensure that technologies serve to enhance human capabilities rather than replace them [4]. However, Industry 5.0 also raises concerns from the employee

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8671
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perspective [5] including its impact on the nature of Organizational Citizenship Behaviour (OCB) [6]. Campbell & Wiernik [7] state that OCB encompasses performance behaviour that adds value because it helps support the broader functioning and mission of the organization. Moreover, OCB is outside the prescribed task performance structure in that it is voluntary [7]. From the Resourced-Based View (RBV), OCB is a source of competitive advantage for a company, because OCB is more difficult for competitors to see, it makes OCB less visible than task performance to competitors, and the value created by OCB is more likely to be captured by the employing firm [8]. Meta-analysis also has shown that OCB is positively related to unit and organizational performance [9, 10].

Although existing literature supports the positive relationship between OCB and OP, as well as the positive impact of Industry 4.0 and 5.0 on OP and their influence on OCB, there is inconsistency in measuring OP and no research identifying the relevant dimensions of OCB for Latvian manufacturing companies operating within the context of Industry 4.0 and 5.0. For example, Baumane-Vītoliņa et al. [11] measure OP by Organizational Innovativeness and Organizational Competitiveness while Eremina et al. [12] propose the following financial indicators to measure OP: sales growth, EPS growth, ROE, Gross profit/assets, Gross profit/margin, operating profit margin, net profit margin, total shareholders return. Furthermore, no research to date has examined which dimensions of OCB are most relevant for Latvian manufacturing companies during ongoing transition to Industry 5.0. Given the evolving nature of industrial transformation, it is essential to explore how organizations conceptualize and assess OP and how OCB manifests in this specific context. Therefore, this paper aims to explore the practices used by Latvian manufacturing companies to assess OP and identify the key dimensions of OCB that are relevant in the context of industrial transformation.

The article is based on semi-structured interviews with owners and top managers of companies that operate within the manufacturing industry in Latvia. Given that OP measurement and OCB dimensions frameworks vary across industries and regions, and that existing literature does not provide a standardized models for this specific context, a qualitative approach is applied for answering the RQs, because it allows for an in-depth exploration of what quantitative methods may overlook.

This research contributes to the body of existing knowledge in this field because the Manufacturing industry is the most important sector of the EU economy – it drives its growth and propels its technological and innovation development [13]. Moreover, to analyse the manufacturing industry within one country would be useful to avoid possible cross-cultural differences. Latvia as a context for the research was chosen because in this post-soviet country, manufacturing was strong during the Soviet period and it faced a sharp drop after the proclamation of independence in 1991 [14]. During the last decade Latvian manufacturing increased again with a new force in terms of value-added % of GDP (Appendix A). Moreover, the choice of the manufacturing industry in Latvia is justified by the fact that one of the authors of this research has more than 5 years of work experience in this industry and Holstein & Gubrium [15] consider that "the interviewer's background knowledge can sometimes be an invaluable resource for assisting respondents to explore and describe their circumstances, actions, and feelings".

The research consists of three parts. The first part gives a brief overview of the literature and methodologies used for this work. The second is a research part which provides content analysis and discussion of its results. The third part gives implications and conclusions.

II. Materials and Methods

A. Literature review

a) Organizational Performance.

When stakeholders of an organization analyse, argue, or make decisions, they rely on qualitative and/or quantitative data, either at a point in time or dynamically, this may involve comparisons with other organizations or may be conducted independently. Utilizing these data to align operations with strategy enables organizations to achieve long-term success ensuring that all dimensions contribute to organizational strategy [16]. The concept of measuring effectiveness which is grounded in organizational strategy is Organizational Performance (OP) [17], this concept has many definitions (see Table 1) and is considered to be a subjective phenomenon [18].

Al-Matari, Al-Swidi & Hanim [19] argue that OP represents the fundamental aspect of strategic management. Furthermore, Lebas [20] states that performance measurement and performance management are closely intertwined and cannot be seen as separate constructs because what is to be measured explains the context of performance. Waggoner, Neely, and Kennerley [21] support this statement and argue

TABLE 1 DEFINITIONS OF ORGANIZATIONAL PERFORMANCE

Definition	Source
"Performance is a notion polarized on the announced result, but it also conveys a value judgment on the result finally obtained (positive or negative) and the process which made it possible to achieve it''	[22]
''Performance is a relative concept defined in terms of some referent employing a complex set of time-based and causality-based indicators bearing on future realizations. Performance is about the capability of generating future results''	[23]
''Performance, therefore, can be defined as the evaluation of the constituents that try to assess the capability and ability of a company in achieving the constituents' aspiration levels using efficiency, effectiveness, or social referent criteria''	[24]
performance consists in ″achieving the goals that were given to you in convergence of enterprise orientations″	[25]
organizational performance is the organizations' ability to attain its goals by using resources in an efficient and effective manner.	[26]

that performance measurement systems should not only be carefully designed and implemented, but also evolve over time in response to four main influencing forces: internal and external influences, process and transformational issues. In their work Richard et al. [27] described the following types of OP measurement: (i) objective (accounting, financial market, mixed accounting/financial market and survival measures) and (ii) subjective (fully subjective self-report, quasi-objective report which assess objective measures through self-report), and concluded that existing empirical research shows a high correlation among all measures.

Thus, OP as a concept struggle with both clarity of definition and standardization of measurement [28] and thanks to its multidimensional nature it cannot be characterized with one operational measure [27]. According to Carton and Hofer [29, p. 25] ‘’It is clear from the prior empirical studies that there has been no consistency in the measures used to represent the construct of overall organizational performance in strategic management and entrepreneurship research’’. Due to fast-changing technologies and a competitive environment, manufacturing companies need to understand performance measures [30]. In this paper, the authors address the challenges associated with measuring OP in Latvian manufacturing companies within the context of Industry 4.0 and 5.0. and the first Research Question (RQ) is: What metrics for OP are currently used in Latvian manufacturing companies?

b) Organizational Citizenship Behaviour.

Organizational Citizenship Behaviour (OCB) is a concept that describes such types of employee behaviours which are not included in a job description and are not rewarded directly but positively influence the effectiveness of the organization [31]. OCB is a multi-dimensional concept and, for example, Podsakoff et al. [32] used in their study the following dimensions: (i) Altruism – helping other employees in their tasks or solving their problems; (ii) Conscientiousness – doing beyond minimum job requirements regarding to attendance and breaks; (iii) Sportsmanship – tolerating difficult circumstances without complaining; (iv) Courtesy - being considerate or polite with co-workers to prevent problems; (v) Civic Virtue – concerning about a company and participating/involving themselves in a life of a company. However, existing literature provides evidence that the dimensions of OCB are not consistent due to their contextual dependence: for example, they can vary by country [33]or by industry [34]. Thus, this paper aims to contribute to the existing body of knowledge by identifying the dimensions of OCB applicable to Latvian manufacturing companies from the perspective of Industry 4.0 and 5.0 and second Research Question (RQ) is: What types of Organizational Citizenship Behaviours are currently recognized in Latvian manufacturing companies?

B. Metodology

Following Kaplan & Norton [35] this research uses a qualitative approach to identify context-specific metrics for OP and dimensions of OCB.

Townsend, Loudoun and Lewin [36] state that qualitative research methods are now common in social sciences and particularly research on relations at work, including HRM. Qualitative research for this article is made in accordance to the model, proposed by Myers [37]: philosophical assumption, research method, data collection techniques, data analysis approach, written record

The first three steps of this model are presented in the current subchapter as related to methodology. The fourth step is both in this subchapter (how the authors organize data) and the next chapter Results and Discussion (how the authors interpret and report data). The fifth step is the article itself because Myers [37] states that the last step of a qualitative research project is to write it up.

a) *Philosophical assumption*.

Saunders et al. [38]states that the research philosophy plays a critical role in shaping the entire research design. For this article, the philosophical assumption is rooted in interpretivism, which aligns with qualitative research methods. Interpretivism assumes that reality is socially constructed and subjective, and it emphasizes understanding the meanings and experiences of individuals within a particular context.

Based on the technology-driven Industry 4.0, value-driven principles of Industry 5.0 and literature review it can be assumed that in manufacturing companies of Latvia, (1) OP measurement should demonstrate value-driven indicators and (2) OCB should include dimensions that align with technological advancements.

b) *Research method*

The research aims to identify currently used measurements for OP and the perception of the dimensions for OCB within Latvian manufacturing companies. To reach this aim authors use qualitative research because ‘’this type of research evaluates opinions, views, and characteristics’’ [39, p. 33].

c) *Data collection techniques*

Because of the fact that this paper investigates data based on emotions, experiences and feelings it is preferable to use interviews rather than questionnaires [40]. To answer the RQs, semi-structured interviews are used because (i) the sequence of questions may vary, (ii) the questions are in general form and (iii) this type of interview allows asking more questions about what can be seen as significant replies [41]. Moreover, Denscombe [40]states that through the fact that answers of semi-structured interviews are open-ended, an interviewee is more emphasized on elaborating points of interest.

For semi-structured interviews, the most common are one-to-one interviews [40]. Firstly, they are relatively easy

to arrange. Secondly, the interviewee is the only source through which opinions and views are expressed. The third advantage is that such interviews are easy to control. Providing face-to-face interviews would also add relevance to the research through observations and asking for explanations behind the answers. At the beginning, the authors wanted to use purposive sampling to sample respondents to ensure that they are relevant to the RQs. However, this approach was met with unpredictable problems because no one agreed to be interviewed. When it became clear that it was impossible to maintain this approach the authors began to search the experts through acquaintances using "snowball sampling" [41]. The main advantages of this selection are the willingness and openness of participants during the interview process. As a result, the authors arranged 9 interviews with owners and top managers of Latvian manufacturing companies (Appendix B). The selection of these experts was based on specific inclusion criteria: (i) Industry Experience, (ii) Position and (iii) Knowledge of Industry 4.0 and 5.0. The participants in interview were required to have substantial experience within the manufacturing industry, as this would ensure their deep understanding of OP and OCB. Specifically, they must have had at least 5 years of experience in the sector. Experts were selected based on their roles within the companies - only owners (or co-owners) and top managers were included, as their strategic decision-making authority and oversight of company operations made them suitable to provide insights into OP and OCB. To ensure the accordance to third criteria they were selected based on their familiarity with the ongoing technological advancements and transformations related to Industry 4.0 and 5.0.

The experts were proposed to conduct interviews in Latvian, English or Russian. Three experts chose English and six Russian. The experts present in the Latvian manufacturing industry 8 manufacturing companies. They are: by gender – 8 males, 1 female; by work experience in manufacturing – 8 more than 10 years, 1 more than 5 years; by position - 4 owners (co-owners) and 5 top managers.

Before interviews, the experts were introduced to the meaning of (1) OP and subjectivism of its measuring and (2) OCB and its contextual dimensionality. This introduction ensured that all respondents had the same understanding of the concepts. Interviews were based on the question guide (Appendix C). According to Corbin and Strauss [42]guiding questions usually are open-ended at the beginning and then they tend to become more focused. Thus, the questions that give further information would be concentrated on specific concepts regarding different measures of OP and dimensions of OCB. Interviews and data collection were provided until no new conceptual insights were generated and repeated evidence was contributed for the categories.

d) *Data analysis approach*

For this qualitative research, the authors use the content analysis method. Znang and Wildemuth [43, p. 1] state that" qualitative content analysis emphasizes an integrated view of speech/texts and their specific contexts". Moreover, it "goes beyond counting words" while allowing "to understand social reality in a subjective but scientific manner" [43]. Zhang and Wildermuth [43, p. 2] argue that "qualitative content analysis involves a process during which raw data is condensed into categories based on valid inference and interpretation". The content analysis is inductive and that's why before the process of coding it is useful to determine theoretical frameworks that would be used during analysis. The main purpose of this research is to identify measurements for OP and dimensions for OCB within Latvian manufacturing companies. That's why it is logical after organizing data to distinguish from all factors named by experts only those indicators which are measuring performance in their organizations and only those types of out-of-role employee behaviours which positively influence organizational performance.

Before discussing of results, the authors checked the validity of the received data. Thomas [44] insists that one of the ways to assess the trustworthiness of findings is to compare with findings from previous research. For this purpose, the author would add categories that can be obtained from the interviews but are not directly related to the RQs:

- Linking technology transformation to Organizational Performance,
- Linking Organizational Citizenship Behaviours to Organizational Performance.

The authors chose these factors because there is consistency in previous findings which are related to them.

Schilling [45] argues that first of all the researcher has to decide whether to transcribe all interviews or only its main questions. To add value to the research the authors decided to make whole transcriptions using the WORD transcribe function which allows to receive text information based on audio recordings. All transcripts are written in Russian and English in MS Word format because all interviews were provided in Russian or English. As for one of the authors Russian is the native language, this would ensure that the author won't lose any important points due to translation from Russian into English [42].

"The codes are assigned to a text part of any size, as long as they represent a single theme or issue of relevance to the research question" [43]. MS Word tool – "Review" was used to help during the process of coding. It allows writing the codes as comments in the Margins of the document. The codes based on transcripts in Russian were translated and written in English. After all 9 transcripts were coded; the next step was copying all codes with corresponding parts of interviews into 9 separate MS Excel files. Then, to combine all codes they were pasted into a new file. As a result, the authors got one spreadsheet which contains 9 columns with codes (one per each interview).

To make the next step authors needed to group received codes into subcategories. For this purpose, all cells which contain codes were coloured in accordance to relative subcategories. In the final document, the authors linked the

categories with subcategories and subcategories with codes. The next part of this step of qualitative content analysis – the interpretation and reporting of the findings, - is described in the fourth chapter of this paper.

III. Results and Discussion

In this chapter, the organized data was analysed through theoretical frameworks. These frameworks helped the authors to structure data in accordance to defined Categories:

(1) Linking technology transformation to Organizational Performance, (2) Linking Organizational Citizenship Behaviours to Organizational Performance, (3) Organizational Performance Measurement (4) Organizational Citizenship Behaviour Dimensions.

The first two categories were used to assess the trustworthiness of this qualitative content analysis, third and fourth categories are directly related to the RQs. The third and fourth categories were developed based on the RQs, ensuring that the analysis remained focused on identifying relevant OP measurement approaches and OCB dimensions within Latvian manufacturing companies during Industry 4.0 and 5.0. Due to the fact that the authors knew that the majority of interviews would be held in Russian, additional research was done to find the correct Russian interpretation of the terms ‘’Organizational Performance’’ and ‘’Organizational Citizenship Behaviour’’ and as a result, the authors while interviewing Russian speakers, used terms ‘’Эффективность организации” и “Гражданское поведение в организации”.

A. Linking technology transformation to Organizational Performance

During interviews, all experts showed examples that link technology transformation to OP which strongly supports the existing literature [46]. For example, E7 said that digital transformation, though resisted initially, is expected to improve efficiency and organizational adaptability and E5 mentioned that thanks to new technologies company performs better and can control processes to cut costs and ensure quality of production.

B. Linking Organizational Citizenship Behaviour to Organizational Performance

All experts said that out-of-role behaviours of employees help to improve OP which aligns with existing knowledge [47]. E7 explained during the interview that self-driven and cooperative behaviours help employees meet individual KPIs, ensuring the organization fulfils its broader performance goals while E1 argued that voluntary behaviours are a critical success factor because they significantly contribute into productivity and problem-solving.

Thanks to the presence of both first categories in the results of the content analysis across all interviews, the authors demonstrated the trustworthiness of their research.

C. Organizational Performance Measurement

The analysis reveals a mix of quantitative (financial and productivity metrics) and qualitative (quality management, efficiency, customer satisfaction, employee-centric, strategic metrics) measurements. These categories form a holistic view of how Latvian manufacturing companies evaluate their performance, addressing both short-term outputs (e.g., profits, project timelines) and long-term outcomes (e.g., customer satisfaction, company reputation). The detailed results are presented in Appendix D.

The transition to Industry 4.0 and 5.0 has brought significant changes to how manufacturing companies measure OP. This study explores the key performance metrics currently used by Latvian manufacturing companies, highlighting how digital transformation and human-centric approaches influence these measurements. Based on interviews with experts, OP metrics can be categorized into financial, quality management, productivity and efficiency, customer-centric, employee-centric and strategic metrics: Financial Metrics (Net sales, gross margin, return on investment (ROI), and EBITDA, revenue generation across different regions and entering new markets, capacity utilization, cost-to-output ratio, and long-term investment planning); Quality management (Product quality and delivery performance); Productivity and Efficiency (Resource utilization and technological integration); Customer-centric (market reach and reputation); Employee-centric (Employee satisfaction, engagement and performance); Strategic (Long-term planning and market adaptation). The results also show the link between Performance Metrics and Industries 4.0 and 5.0 context. Industry 4.0 focuses on digital transformation, automation, and real-time tracking. The adoption of digital tools enhances productivity and efficiency, with key indicators including Technology adoption rate (AI, robotics, IoT, GPS tracking), Real-time monitoring of production processes (QR codes, automated accounting, machine diagnostics), Operational efficiency improvements through digitalization (Cost-to-output ratio, uptime tracking). Industry 5.0 shifts the focus towards a human-centered, resilient and sustainable approach. Metrics reflecting these principles include: Employee satisfaction and engagement (Workplace satisfaction surveys, training effectiveness); Customer trust and satisfaction (Client feedback, compliance with high-quality standards) and Integrating automation (digital tools enhancing employee productivity and efficiency).

D. Organizational Citizenship Behaviour dimensions

While most behaviours align with traditional OCB dimensions, the interviews reveal emerging behaviours unique to Industry 4.0 and 5.0: (i) a stronger emphasis on technological curiosity, digital adaptability, and structured creativity. (ii) shift towards employee well-being, purposeful communication, and sustainability. The detailed results are provided in Appendix E.

Our research aligns with Organ’s OCB dimensions, demonstrating how employees in Latvian manufacturing

companies exhibit various discretionary behaviours that contribute to OP. The findings highlight five key dimensions of OCB and how they manifest in the context of Industry 4.0 and 5.0 transformations: Altruism (Helping others), Conscientiousness (Responsibility & Work Ethic), Civic Virtue (Commitment to Organization), Courtesy (Respect & Collaboration), Sportsmanship (Adaptability & Resilience).

However, our findings suggest that industry transition introduce four new behavioural expectations: Innovation and creativity (employees take the initiative to upskill, explore new technologies, and participate in digital transformation efforts), Adaptability and Proactivity (engagement in new technologies), Reflection and Communication (dedicated time for reflection and clear purposeful interactions), Customer focus (customer orientation).

IV. Conclusions

Latvian manufacturing companies employ a combination of financial and non-financial metrics for OP measurement. While financial KPIs remain critical, technological advancements under Industry 4.0 have led to the technological integration metrics. Simultaneously, the Industry 5.0 human-centric principle emphasizes employee satisfaction. The ability to balance automation with human-centric approaches will define long-term success in the evolving industrial development. Findings regarding types of out-role behaviours indicate that OCB dimensions are expanding in response to Industry 4.0 and 5.0 Employees demonstrate a stronger inclination toward proactiveness and adaptability, innovativeness and creativity, reflection and communication and customer orientation—dimensions not traditionally emphasized in OCB research. Thus, this study proposes an extended OCB model that integrates behaviours influencing organizational performance in manufacturing environments within Industry 4.0 and 5.0.

For future research empirical testing of the results would strengthen the validity of the findings and contribute to the academic and practical understanding of OP measurements and OCB in Industry 4.0 and 5.0 within Latvian manufacturing companies. Such validation would contribute to a more standardized understanding of OP and OCB in Industry 4.0 and 5.0, supporting both academic research and practical implementation in manufacturing firms.

From a theoretical perspective, this research contributes to the ongoing discourse on OP measurement by demonstrating how Industry 5.0 extends traditional OP frameworks beyond financial and efficiency indicators. It also expands OCB theory by identifying new dimensions—such as proactivity and adaptability, creativity and innovativeness, reflection and communication and customer orientation—and adding them to traditional OCB dimensions. Thus, this extended model not only provides a pathway for empirical testing but also enhances theoretical discourse by illustrating the context-specific application of OCB.

From a practical perspective, the findings offer insights for companies operating in the manufacturing sector. Understanding the evolving nature of OP measurement could help companies align their measurement systems with reaching strategic goals. Additionally, recognizing the emerging dimensions of OCB allows HR managers to refine employee engagement, training, and leadership development initiatives to foster behaviours that enhance organizational performance and reinforce the need for a strategic alignment between employee citizenship behaviour and organizational goals.

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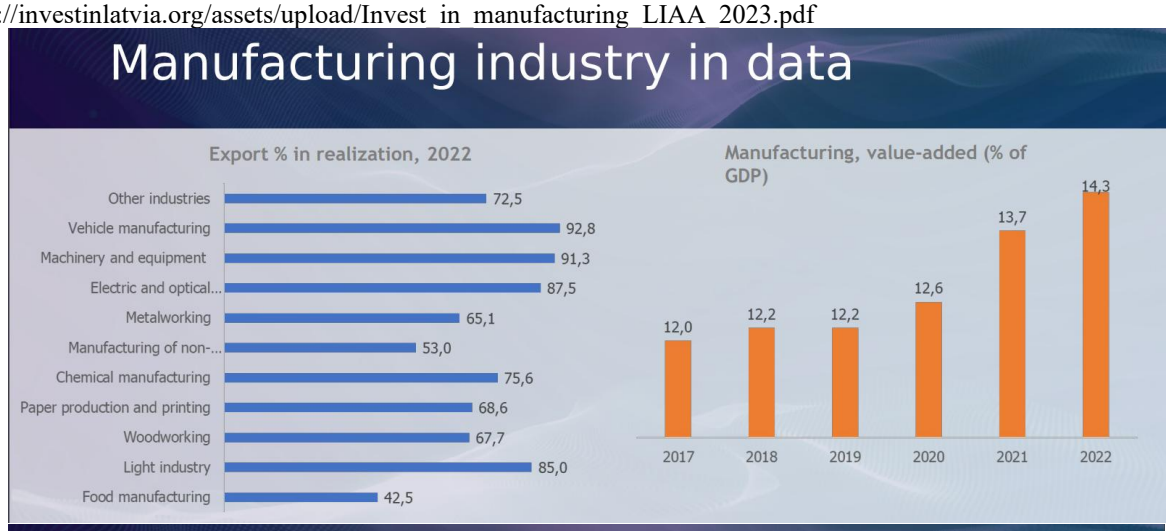
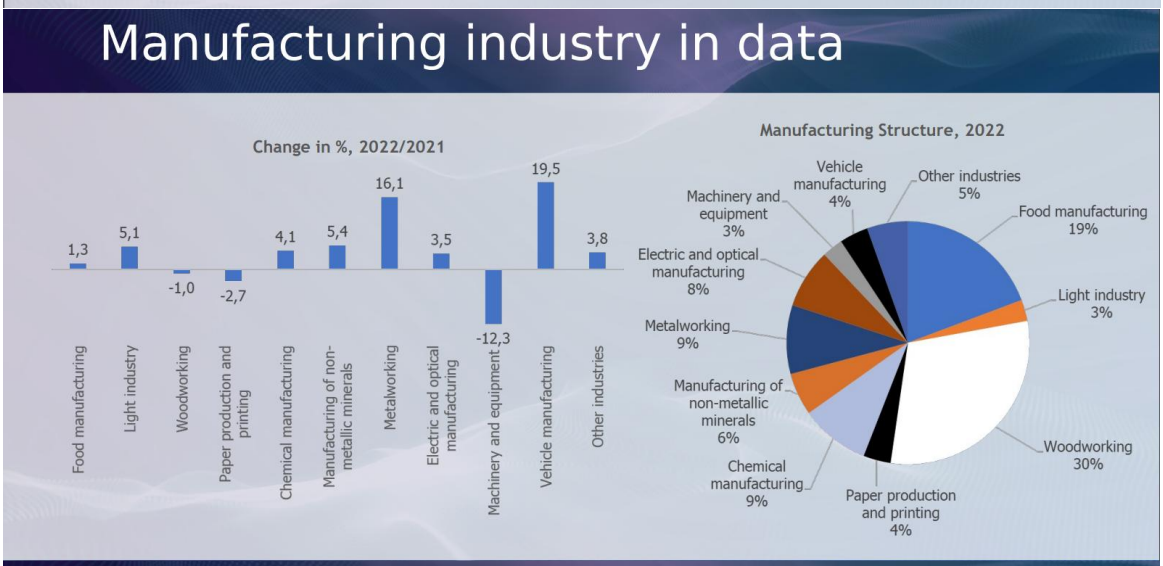
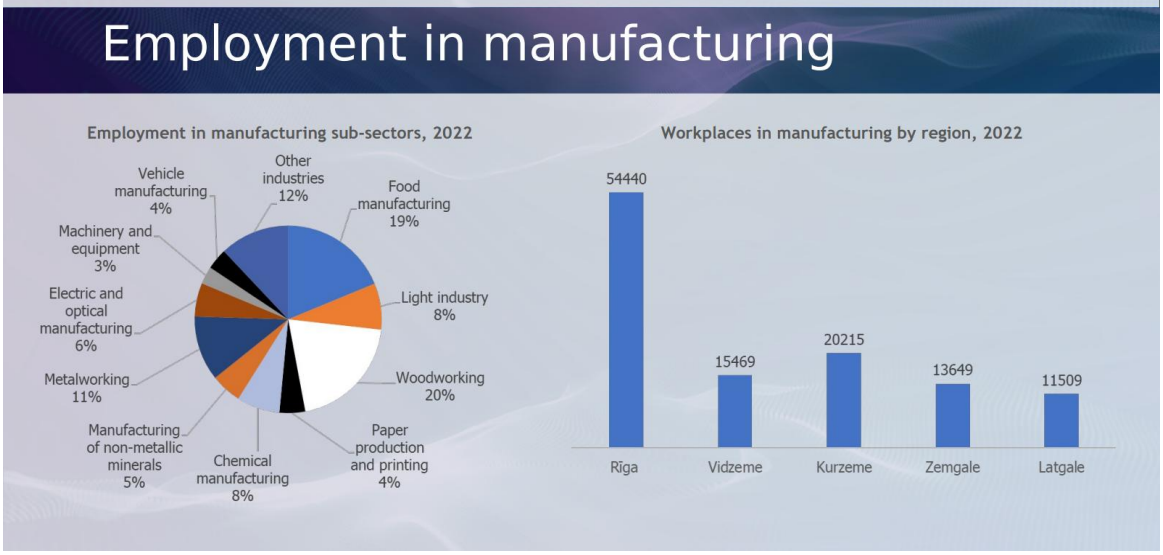
Appendix A. Based on LIAA investment report

https://investinlatvia.org/assets/upload/Invest_in_manufacturing_LIAA_2023.pdf







Appendix B List of interviewees

Expert	Name of the company	Position
E1	TONUS ELAST SIA	Marketing Director
E2	A/S Marupes Metalmeistars	Head of Production
E3	OE Trans line, SIA	Owner
E4	SIA MEDPRO NUTRACEUTICALS	Owner
E5	SIA Groglass	Director
E6	Chemical Technologies, SIA	Director
E7	Frame House group, SIA	Owner
E8	SIA Groglass	Head of Innovations
E9	SIA Roug	Owner

Appendix C Question guide for interviews

1.In the history there were five Industrial Revolutions (showing picture with their infographic). Now manufacturing companies in Latvia are working in the context of two industrial revolutions: Industry 4.0 and Industry 5.0 What do you think about the influence of these Industries 4.0 and 5.0 on your company?

2. There are surveys which show that Organizational Citizenship Behavior lead to Organizational Performance because it consists of proactive types of employee behaviors which are not included in their job description but influence companies' overall performance (showing picture with their infographic). The example of such behaviors is assisting other employees in their work or helping new employees to understand some nuances about work place. What do you think about such behaviors? What types of such behaviors in your company can you recognize as helpful to the company performance?

3. There are different types of measurement systems which are utilized to assess Organizational Performance (showing picture with their infographic). What measurement do you use in your company?

Appendix D Organizational Performance (OP) Measurements

Category	Subcategory	Measures Identified	Interviews Mentioned
Financial Metrics	Profitability	Net sales, gross margin, EBITDA, ROI, profitability, revenue, production volumes.	E1, E2, E3, E5, E8, E9
	Cost Efficiency	Input costs to output results, cost-saving through automation, time and resource optimization.	E5, E6, E7
Quality Management	Product Quality	Compliance with ISO standards, EU Medical Device Regulations, stringent quality checks.	E1, E4, E6
	Customer Satisfaction	Customer feedback, claims, NPS scores, surveys, repeat business.	E1, E3, E8, E9
	Delivery Performance	Timeliness, quality, and accuracy of deliveries.	E8
Productivity and Efficiency	Resource Utilization	Capacity utilization, machine uptime, productivity per hour, time spent on projects, deviations from set resource standards.	E4, E5, E8, E9
	Technological Integration	Use of automation, GPS tracking, automated accounting, QR coding, advanced machinery diagnostics, digital design tools.	E3, E6, E7
	Workflow Optimization	Shift to collaborative workflows, daily and weekly tracking of metrics (plan adherence, time losses, production output).	E5, E6
	Speed and Time Reduction	Time spent on tasks and processes, quick response times, reduction in handling customer requests.	E6, E7
Customer-Centric Metrics	Market Reach and Reputation	Turnover rates, market share, reputation, and customer satisfaction as reflected in external perceptions.	E1, E2, E3
	Customer Trust	Instilling confidence through quality, reliability, and meeting diverse customer demands.	E7, E8, E9
	Marketing Analytics	Tracking customer behavior, engagement, and conversion rates.	E7
Employee-Centric Metrics	Employee Satisfaction and Engagement	Annual surveys, employee turnover rates, workplace satisfaction, employee training and development, feedback loops.	E2, E5, E8
	Employee Performance	Individual KPIs, human-driven productivity metrics (e.g., pieces per man-hour).	E1, E8
Strategic Metrics	Long-Term Planning and Viability	Long-term capacity planning, adaptation to economic fluctuations, balancing flexibility with efficiency, focusing on larger projects with	E4, E7, E9
	Market Adaptation	Readiness to embrace digital realities, managing external market pressures, tracking geopolitical compliance (e.g., sanctions).	E2, E6, E7

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Appendix E. Organizational Citizenship Behaviour (OCB) dimensions.

Category	Subcategory	Measures Identified	Interviews Mentioned
Innovation and Creativity	Self-Driven and Creative Thinking	Finding innovative solutions, targeting unconventional markets.	E1, E6, E7
	Structured Creativity	Proposing business-relevant creative ideas.	E5, E6
Altruism	Collaboration and Support	Helping colleagues, mentoring newcomers, fostering teamwork.	E1, E2, E3, E6, E7
	Teamwork and Support	Supporting others through acts of kindness beyond formal roles.	E7, E9
	Fostering Positive Work Climate	Resolving conflicts, promoting harmony.	E2, E9
Conscientiousness	Commitment to Procedures	Adhering to ISO standards and organizational processes.	E1, E8
	Reliability and Accountability	Consistently completing tasks accurately and taking ownership of duties.	E8,E 9
	Respect for Workplace	Maintaining a clean, professional workspace.	E2, E6
	Persistence and Systematic Work	Maintaining focus and organized efforts, even under challenging conditions.	E8, E9
Adaptability and Proactivity	Adaptability and Change Acceptance	Embracing technological and procedural changes.	E1, E4, E7, E9
	Proactivity and Problem Solving	Solving problems, offering suggestions, and seeking guidance when needed.	E3, E6, E9
	Employee Engagement with Technology	Taking initiative to adopt and implement new tools and processes.	E3, E4, E9
Sportsmanship	Hard Work and Dedication	Voluntary overtime, flexibility, and structured effort.	E2, E4
	Generational Behavioral Differences	Older employees' flexibility vs. younger employees' work-life balance priorities.	E2
Reflection and Communication	Reflective Practices	Dedicated time for reflection (e.g., no-meeting days), flexible work-from-home policies.	E5
	Cultivating Mindful Communication	Ensuring clear and purposeful interactions in meetings and emails.	E5
Civic Virtue	Civic Virtue	Loyalty, pride, and promoting the company externally.	E7, E9
Customer Focus	Customer Orientation	Building strong client relationships through kindness and communication.	E3, E9
Courtesy	Respect and collaboration	Creating a sense of belonging, fostering collaboration and friendship.	E7, E9

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 497-502

Soda Lignin from Pre-treated Birch Residue and Its Possible Application in Biocomposite

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***Abstract*—In pulping, the pretreatment of wood has advantages over untreated wood due to enhanced pulp yield and reduced chemical and energy consumption. This study examined the effect of alkaline treatment of birch sawdust on the chemical composition of the sawdust and soda lignin separated from black liquor obtained by soda pulping of the treated birch sawdust. It was found that the alkaline pre-treatment of birch sawdust led to a remarkable removal of hemicelluloses and reduced its mechanical strength. A lower content of acidic and methoxyl groups in the chemical composition of the alkaline lignin obtained by soda pulping of the pretreated sawdust showed the advantage of polycondensation reactions that proceeded during the formation of its primary structure over destruction. The possibility of using the modified soda lignin in a biocomposite was demonstrated. The composite material was fabricated from a blend of recycled polypropylene and polylactic acid, reinforced with ammoxidized wheat straw. The conducted mechanical tests demonstrated the potential of the modified soda lignin to replace more than 30% of the synthetic compatibilizer in the composite formulation without deteriorating the properties of the biocomposite.**

Keywords*—sawdust pretreatment, modified soda lignin, composite, wheat straw, mechanical properties.

I. INTRODUCTION

The integration of advanced biomass conversion processes and state-of-the-art equipment in biorefineries allows for the simultaneous production of multiple outputs, maximizing resource efficiency and economic viability. The biorefinery approach is particularly significant for modern wood chemistry and technology, as it promotes the utilization of lignocellulosic materials, unlocking their potential through innovative chemical pathways.

There are many ways to pretreat wood biomass, such as steam explosion, autohydrolysis, acid hydrolysis, ammonia treatment, chemical pulping, solvent extraction, etc. These methods are directed to an increase of the reactivity of the biomass components, making the extraction process easier and more efficient [1]-[3]. For an increase in the intensity and selectivity of the delignification process during wood pulping, and for a decrease in the consumption of cooking reagents, water, and heat consumption, the pretreatment of wood biomass with alkaline solutions (NaOH, $Ca(OH)_2$, NH_4OH) along or together with other additives is cost effective and promising [4]-[6]. The main aim of the initial stage of the alkaline pre-treatment of wood biomass is the partial destruction of the lignocellulosic matrix to facilitate the removal of hemicelluloses and lignin during pulping.

Technical lignin extraction from wood occurs during different pulping processes used for cellulose production. It is known that approximately 50–70 million tons of technical lignins as a by-product are produced at pulp and paper mills per year. However, the main amount of technical lignins is used for power generation at the mills, but the formed wastewater as a sequence of pulping can negatively affect the environment. Only 1–2% of the produced lignin is utilized for obtaining value-added products [7]. Given lignin's significant economic and industrial potential, extracting high-purity lignin from lignocellulosic biomass is essential for its effective subsequent usage. Technical lignins are used as binders,

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8660
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plasticizing and dispersing agents, phenol substitutes in phenol-formaldehyde resins, bio-additives to plastics and composites, carbon fiber precursors, etc. [8]-[12].

Technical lignins obtained by alkaline pulping can be classified depending on the presence of sulfur, namely, the sulfur-containing lignin – Kraft and sulfur-free lignin – soda [13]. Soda lignin is a by-product of the cooking of hardwood and herbaceous plants [5]-[14]. Compared with Kraft pulping, the major advantage of soda pulping is the absence of sulfur, which is a reason for the unpleasant odor during the production of cellulose as well as the closeness of the chemical composition and the structure of soda lignin to that of native lignin. The molecular weight of the soda lignin is lower than that of kraft lignin and lignosulfonates [1]-[6].

This work studied how alkaline pretreatment affects the chemical composition of birch sawdust and the lignin extracted from it via soda pulping. It also investigated the potential usage of the modified soda lignin in a wood-plastic composite filled with wheat straw.

II. Materials and Methods

Birch sawdust was supplied by a company Latvijas Finieris Ltd. The fractionated sawdust with particles $\leqslant$ 250 μm was characterized by elemental analysis (Elementar Analysensysteme, Langenselbold, Germany) and wood composition (lignin, cellulose and hemicelluloses) according to standard methods (TAPPI T222 om-11 standard, [15], TAPPI T203 cm-99 standard [16], and TAPPI T264 om-97 [17] standard, respectively). The elemental analysis of the birch wood sawdust revealed the following composition: 48.1% carbon (C), 5.9% hydrogen (H), 45.7% oxygen (O), 2% nitrogen (N), and 0.1% sulfur (S).

Wheat straw from a Latvian peasant farm was processed by drying, crushing, and sieving to obtain lignocellulosic fibers $\leqslant$ 250 μm. Then, the fibers were ammoxidized by the mechanochemical treatment in planetary ball mill (Retsch, Germany) with zirconia balls at the rotational speed of 300 rpm for 30 min. The ammoxidation was performed with the reaction mixture of $NH_4OH/(NH_4)_2S_2O_8$ at an O/NH_3 mass ratio of 0.2. After the treatment, the ammoxidized wheat straw fibers were washed to a neutral medium, dried and milled for obtaining the particles less than 100 μm.

The pretreatment of birch sawdust was carried out by alkali hydrolysis as it was shown early [18], using 0.5-5.0 g/L NaOH solution at 60 °C for 5 h with a sawdust-to-water mass ratio of 1:20. After the procedure, the isolated pretreated sawdust was washed, dried and was ready for pulping.

Soda lignin samples were obtained from initial and the pretreated birch sawdust by pulping in a laboratory reactor under the following conditions: NaOH concentration – 4.5%, hydromodulus – 1/7, duration – 90 min, temperature – 165 °C and pressure 0.6 MPa. The purification of the precipitated lignin samples was done by three repeated dissolutions with 0.1M NaOH, and subsequent precipitation with concentrated sulfuric acid. Each time, the lignin precipitate was carefully washed on the filter with diluted sulphuric acid (1%) and then with hot water. After triple dissolution/precipitation, the content of Klason lignin in both the lignin samples was more than 90%. The content of Klason lignin was determined according to TAPPI T222 om-02 standard [15].

The chemical composition of the lignin samples was determined by elemental (Elementar Analysensysteme GmbH, Langenselbold, Germany) and functional analysis, according to Zakis [19].

The content of acid groups in the lignin samples was found from the curves of conductometric titration obtained with a Radiometer Analytical Titrolab 90 with autoburette ABV 901 (Radiometer Analytical SAS, Villeurbanne Cedex Lyon, France) at 25 ºC.

Fourier Transform Infrared (FT-IR) spectroscopy was performed using a Perkin Elmer Spectrum One apparatus (Perkin Elmer, Waltham, MA, USA) at the range of wavenumbers from 4000 to 450 cm^{-1} (30 scans), at a resolution of 4 cm^{-1}. The tablets were prepared by mixing 20 mg of a sample with 200 mg of KBr, and then the tablet compression method was used.

Ultraviolet (UV) spectroscopy of lignin samples was carried out using a Genesys 10UVUV/VIS spectrophotometer (Termo Fisher Scientific, San Jose, CA, USA).

The composite samples reinforced with the ammoxidized wheat straw were obtained by the extrusion and molding methods using HAAKE MiniLab II and MiniJet II (Thermo Fisher Scientific, Germany) at a temperature of 175 °C, a circulation time in the two-screw extruder of 5 min, the screws rotational speed of 130 rpm, and a molding pressure of 60 MPa at a temperature of 120 °C. Maleated polypropylene (Licocene PP MA7452, Clariant) was used as a compatibilizer (CB).

A binary polymer blend of recycled polypropylene (rPP) and polylactic acid (PA) at a mass ratio of 95/5 was served by a polymer matrix in a new wood-plastic composite. rPP had a density - 0.9 t/m^3, a melt flow index - 5.2 g/10 min at 230 °C and 2.16 kg (Nordic Plast Ltd., Olaine, Latvia). Polylactic acid 2002D was purchased from NatureWorks LLC (USA) and had a density of 1.25 t/m^3 and a melt flow index of 5–7 g/10 min at 210 °C and 2.16 kg.

The milling of birch sawdust was carried out with a planetary ball mill (Retsch, Haan, Germany), but wheat straw with a knife mill and sieved using a mill “Pulverisette 0” (Frisch GmbH, Idar-Oberstein, Germany).

III. Results and Discussion

A. Pretreatment

The hydrolytic destruction of wood residue due to the alkali treatment was evaluated by analysing the changes in the composition of the sawdust, specifically in cellulose, lignin, and hemicellulose content. Their content before and after the alkaline treatment of the sawdust is presented in

Fig. 1. It has been seen that, with increasing the NaOH concentration, the relative content of cellulose in the pretreated sawdust increases by 25.5 %, but the content of hemicellulose decreases almost twice relative to their content in the initial sawdust. The change in the relative content of lignin in the pretreated sawdust is expressed to a lesser extent than cellulose and hemicellulose that may be associated with the resorption of lignin on the cellulosic surface.

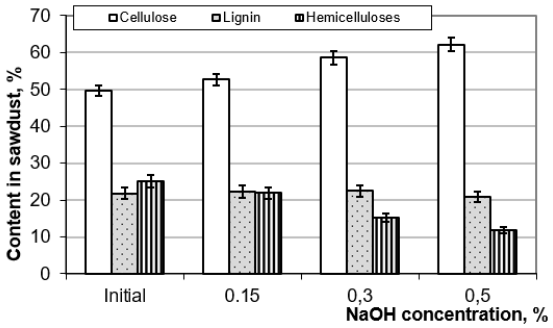

Fig. 1. Content of cellulose, hemicellulose and lignin in birch sawdust before and after the alkaline treatment

The effect of hydrolytic degradation of the lignocellulosic matrix on its mechanical strength was assessed by analyzing the fractional composition of both the initial sawdust and the sawdust treated with a 0.5% NaOH solution after milling in a planetary mill. The changes in the lignocellulosic matrix composition of the treated sawdust led to the reduction of its mechanical strength (Fig.2).

According to Fig. 2, as the alkali concentration increases from 0.15% to 0.50%, the amount of fine particles less than 100 μm in the hydrolyzed sawdust rises from 8 to 12 times when compared to the corresponding particle content in the initial milled sawdust. It is assumed that the pronounced growth of the finest particle content in the pretreated sawdust fractional composition, particularly at the highest alkali concentration, is associated with the essential removal of hemicelluloses from the lignocellulosic matrix of the treated sawdust.

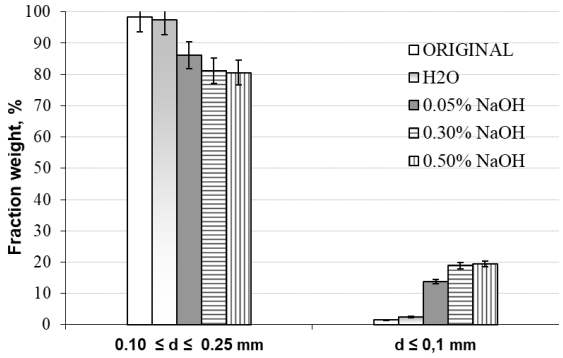

Fig. 2. Content of fractions in initial and pretreated sawdust depending on NaOH concentration after milling

Therefore, based on the generalization of the results obtained, it can be concluded that the highest extent of the hydrolytic destruction of the lignocellulose matrix occurs when birch sawdust was treated with a 0.5% NaOH aqueous solution. The initial and alkali-treated birch sawdust samples are shown in Fig. 3.

B. Characteristics of soda lignin samples

Table 1 shows the chemical composition of the lignin samples obtained by the soda pulping of the initial sawdust and sawdust treated with 0.5% NaOH solution as well as the yield of biorefined products – soda lignin and pulp. The obtained results indicate that the yield of both lignin and pulp is higher for the pretreated sawdust than for the initial one. According to Table 1, the soda delignification of the alkali-treated sawdust, compared to the pulping of the initial sawdust, leads to a decrease in the content of both phenolic hydroxyl and carboxyl groups. A decrease in the content of the acidic groups in soda lignin from the pretreated sawdust is accompanied by its notable demethoxylation.

Fig. 3. Initial and pretreated birch sawdust

TABLE 1 CHEMICAL CHARACTERISTICS OF SODA LIGNIN AND PULP

Sawdust	Pulp		Soda lignin						Yield, % from wood	
	Yield, %	*Lignin content in pulp, %*	*Yield, %*	*OCH_3, %*	*Acid (OH) groups, %*			*Klason lignin, %*	*Pulp + lignin*	*Water-soluble destruction products*
					OH_{all}	*OH_{fen}*	*OH_{COOH}*			
SLI	51.7	3.2	19.6	15.9	6.2	2.7	3.5	91.9	71.3	28.7
SLT	54.5	2.5	22.5	13.4	4.1	1.7	2.4	92.8	77.0	23.0

The content of methoxyl groups in the soda lignin from the treated sawdust (SLT) is 15.1% less than in the lignin from the initial sawdust (SLI). The total yield of the obtained biorefined products derived from the treated

sawdust - pulp and lignin - is 5.7% higher than in the case of cooking SLI, while the pollution of the environment with the water-soluble destructive products obtained during the pulping of the treated sawdust is lower. A decrease in the content of phenolic hydroxyl and carboxyl groups along with the enhanced demethoxylation, may indicate prevalence of polycondensation reactions over depolymerization processes, proceeded between the released lignin fragments during the delignification of the pretreated sawdust.

The changes in the chemical compositions of the lignin samples were consistent with the results of the obtained FTIR spectra analysis presented in Fig. 4. In both FTIR spectra, the bands at 1323 cm^{-1} and 835 cm^{-1} are assigned to syringyl rings and are characteristic bands for hardwood lignin. The significantly lower absorbance band observed at 3410 cm^{-1}, which is associated with hydrogen-bonded hydroxyl groups found in phenolic and phenyl propane aliphatic structures, along with the bands at 2933 cm^{-1} and 2837 cm^{-1} due to C-H stretching vibrations in methoxyl groups in the FTIR spectrum of SLT, indicates a reduced presence of these functional groups in this sample compared to SLI.

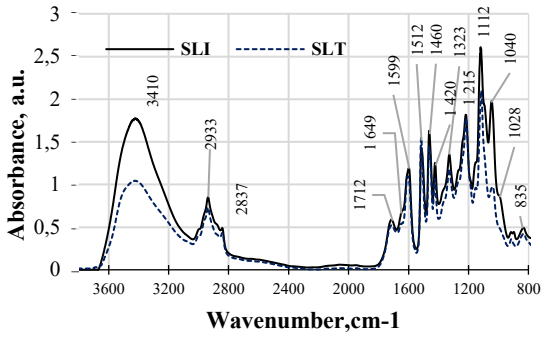

Fig. 4. FTIR spectrum of soda lignin samples obtained from initial and pretreated sawdust

This observation further confirms that the structure of SLT is more condensed than that of SLI. The FTIR peaks in the range of 1712-1595 cm^{-1} are assigned to the presence of unconjugated and conjugated carbonyl and carboxyl groups in lignin. Within this range, SLI has a higher absorbance than SLT which may indicate a lower content of these functional groups in the lignin sample obtained from the hydrolysed sawdust, which is consistent with the results presented in Table 1. The bands at 1596 cm^{-1}, 1512 cm^{-1}, and 1420 cm^{-1} are assigned to skeletal vibrations and C=O group stretching in the syringyl and guaiacyl aromatic rings. The relatively higher intensity of the band at 1512 cm^{-1} compared with that of the band at 1595 in both spectra is gained by the features of hardwood lignin structure. The bands at 1323 and 1215 cm^{-1} correspond to the syringyl structures of lignin. The most significant difference in the FTIR spectra of the lignin samples is observed in the range of absorbance bands of 1112-800 cm^{-1}. These bands are attributed to C-C ring vibrations, overlapped with the absorbance of C-O vibrations in aliphatic hydroxyl and ether C-O-C groups. The intensity of the absorbance bands in this band range is remarkably higher for SLI than for SLT. A decrease in the intensity of the absorbance bands which corresponds to the presence of aliphatic and phenolic hydroxyl groups, and ether bonds in SLT in comparison with SLI may also indicate its more cross-linked chemical structure.

Fig. 5 shows the UV spectra of both soda lignin samples dissolved in an alkaline solution. The absorbance in the UV region results from the ionization of phenolic hydroxyl groups of phenylpropane units, as well as structures containing carboxyl groups, hydroxystilbenes, quinones, and charge transfer complexes. The absorbance of SLI is higher than the absorbance of SLT, which may be due to a more cross-linked polymer structure of SLT decreasing the phenolic hydroxyl group content.

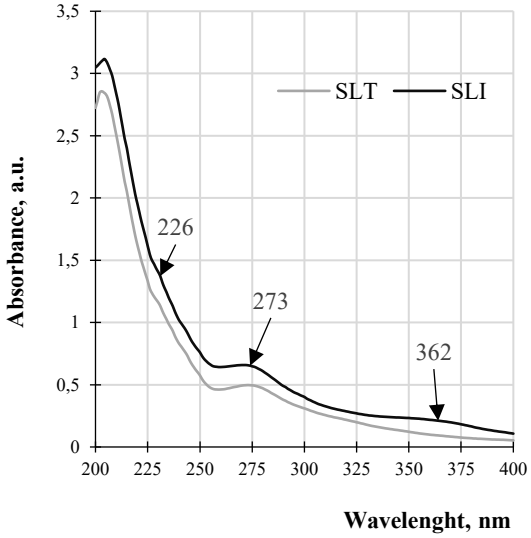

Fig. 5. UV spectrum of soda lignin obtained from original and pretreated sawdust

The pronounced peaks at 205 nm, 273 nm, and a less pronounced shoulder at 227 nm are presented in both UV spectra of the lignin samples. At the same time, a maximum at 362 nm assigned to carboxyl groups is absent in the UV spectra of SLT.

Thus, the analysis of the results presented in Table 1, FTIR and UV spectra, allows to conclude that SLT had a more condensed structure than SLI.

C. Composite samples

The composite samples reinforced with the wheat straw microparticles (< 100 μm), containing the compatibilizer (CB) and modified soda lignin (MSL) were fabricated by extrusion and moulding methods. For increasing the compatibility of the initial wheat straw with the polymer matrix, it was ammoxidized by introducing amide and imide groups in its functional composition by using a mechanochemical method. The ammoxidized wheat straw had the following elemental composition: 47.52% C, 43,6% O, 6.16% H and 2.72% N. It contained 54.1% cellulose, 22.3% lignin and 18.3 % hemicellulose.

The modified soda lignin (MSL) was used as a functional additive. It was modified by the

mechanochemical method in the planetary ball mill at a rotational speed of 600 rpm for 5 h in the presence of $(NH_4)_2S_2O_8$. MSL had the following elemental composition: 57.62% C, 35.97 % O, 5.85% H, and 0.56% included N, S, and trace of metals. Its chemical composition contained 10.75% hydroxyl, 11.18% methoxyl and 3.7% carbonyl groups.

The formulations of the obtained biocomposites are given in Table 2.

TABLE 2 FORMULATIONS OF COMPOSITE SAMPLES

Nr.	Formulations			
	Polymer matrix, rPP/PA, %	***Ammoxidized wheat straw, %***	***CB, %***	***MSL, %***
1	50	50	-	-
2	50	47	3	-
3	50	47	2	1
4	50	47	1	2

Table 3 and Table 4 show the results of testing the mechanical properties of the composite sample filled with 50% ammoxidized wheat straw. It can be seen that the obtained sample is characterized by low values of mechanical strength in both tension and bending and insufficient impact viscosity.

TABLE 3 TENSILE PROPERTIES OF COMPOSITE SAMPLES

Nr.	Tensile properties		
	Tensile straight, MPa	***Tensile modulus, MPa***	***Elongation, %***
1	15.5±1.8	1044±22	3.2±0.4
2	28.9±2.1	920±17	3.8±0.3
3	29.3±1.9	952±18	3.8±0.3
4	25.1±2.2	992±21	3.5±0.5

TABLE 4 BENDING PROPERTIES AND IMPACT VISCOSITY OF COMPOSITE SAMPLES

Nr.	Bending properties and impact viscosity			
	Bending strength, MPa	***Bending modulus, MPa***	***Deformation, %***	***Impact viscosity, kJ/m²***
1	21.7±2.0	2337±25	1.4±0.2	13.8±1.5
2	38.9±2.3	2557±22	2.4±0.3	23.7±1.7
3	39.7±2.3	2591±23	2.4±0.3	24.0±1.6
4	34.5±2.5	2479±27	2.6±0.4	22.1±1.8

The comparatively high values of the mechanical moduli and the low values of bending deformation indicated the stiffness of the resulting composite structure. To improve compatibility between the polymer matrix and the amooxidized wheat straw, a compatibilizer - maleated polypropylene in the amount of 3% was introduced into the composite formulation. According to the results of mechanical testing, this leads to an increase of 86% in tensile strength, 79.1% in bending strength and 72.3% in impact toughness. At the same time, the increase in the values of tensile and bending moduli is less significant and amounts to only 9.6% and 10.8%. At the same time, the composite sample becomes less stiff.

Taking into account the fact that the modified soda lignin contained an increased content of hydroxyl and carbonyl groups capable of interacting with maleic anhydride, it was of interest to study the possibility of its use as a compatibilizer in combination with maleated polypropylene at different mass ratios. According to tables 3 and 4, the mixture containing 2% CB and 1% MSL has the same positive effect as 3% CB on the compatibility of the matrix with the filler in the composite. The mechanical properties of the composite sample in the presence of the new compatibilizer are practically the same as in the case of the composite containing maleated polypropylene. This indicates that the modified soda lignin can replace more than 30% of the synthetic compatibilizer in the composite consisting of a rPP/PA polymer matrix and the ammoxidized wheat straw. The substitution of CB with the modified soda lignin in the composite by more than 60% leads to a slight decrease in mechanical properties and impact strength. This may indicate a physicochemical interaction between CB and MSL during the processing of the composite material, for which a CB: MSL ratio of 2:1 may be optimal.

IV. CONCLUSION

The pretreatment of wood residue before pulping resulted in the extraction of soda lignin, which had a lower content of acidic and methoxyl groups, indicating a more cross-linked structure. Mechanical tests of the biocomposite, which was filled with the ammoxidized wheat straw particles, demonstrated that the mechanochemically modified soda lignin could effectively replace over 30% of the synthetic compatibilizer in the biocomposite without deteriorating its mechanical properties.

V. ACKNOWLEDGMENTS

The authors have received funding for this study from FLPP project Nr. lzp-2023/1-0605.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 503-507

The Impact of Food Labeling on Consumer Choices in Latvia

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***Abstract*— Food labelling plays a crucial role in promoting sustainable consumer behaviour by providing essential information on product origins, environmental impact, and ethical standards. This study aims to evaluate the influence of food labelling on consumer purchasing decisions and sustainability awareness in Latvia. A comparative analysis and synthesis of secondary data sources, including academic literature, policy documents, and market surveys, were conducted. Findings show that while food labels enhance product credibility and consumer trust, there remains a significant gap between awareness and actual purchasing behaviour. Barriers such as label complexity, higher prices, and inconsistent regulatory enforcement reduce the effectiveness of sustainability labels. These insights highlight key factors shaping consumer trust in food labelling and offer recommendations for improving sustainable consumption practices in Latvia.**

Keywords*— *Consumer behaviour, food labelling, regulatory framework, sustainability.

I. Introduction

In recent years, food labelling has become widely recognised as an important tool for helping consumers choose more sustainable products by clearly showing a product's environmental and ethical features. The European Union (EU) has continuously updated its regulatory framework for food labelling to improve transparency and help consumers make informed decisions about sustainable and healthier food options [1]. Nonetheless, the practical effectiveness of these labels, particularly in smaller markets such as Latvia, remains uncertain. This paper synthesises recent academic research from 2020 to 2025, focusing specifically on how food labelling influences consumer behaviour in Latvia. The analysis includes a comparative perspective, evaluating Latvian consumer responses against trends observed in other Baltic states and the broader EU context, addressing both the potential and limitations of sustainability labels [2].

Sustainability labels on food are intended to inform consumers and encourage eco-friendly choices. In the European Union (EU), food labelling regulations have evolved to guide consumers towards healthier and more sustainable diets. In recent years, academic interest in the effectiveness of food labels as tools for promoting sustainability among consumers has grown significantly. According to Cook et al. [3], although consumers generally respond positively to sustainability labels, the actual impact of these labels on purchasing behaviour remains limited. This limited effect mainly occurs because consumers often do not fully understand what the labels mean, making it harder for them to turn their environmental concerns into actual buying choices. Consumers demonstrate some willingness to pay a premium for sustainably labeled products, particularly for items certified as organic. Trust also plays a crucial role in this context—labels backed by government bodies or independent certification agencies are perceived as significantly more reliable than those issued directly by manufacturers. In addition, labels that use simple visuals like colours or easy-to-understand symbols are usually better at helping consumers make sustainable choices.

Several academic case studies focus on country-specific dynamics. In Latvia, Naglis-Liepa et al. [4] conducted a representative survey (n=1000) to examine consumer support for "prosocial" foods (local and eco-friendly options). The study revealed strong pro-environment attitudes: most Latvian consumers agreed that it is important for food to be produced in an environmental friendly way. On a scale from 1 ("agree") to 4 ("disagree"), the average response was around 1.8, showing strong overall support for sustainable food choices. Interestingly, even people with lower education and those living in rural areas expressed strong support. However, when posed a

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8701
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tougher choice – would you give up a favourite product if it is not sustainable? – respondents were less certain, with the average response closer to 2.2 ("somewhat agree"). This indicates that although consumers generally support sustainability in principle, they hesitate when it means changing their personal buying habits.

At the EU level, researchers have also analysed market trends in labelling. Nes et al. [5] examined sustainability claims on new food products across 19 European countries. They found a steady increase of labelled product launches – an annual growth of 2.8% in the share of new products with sustainability labels from 2005 to 2021. Environmental claims, like "eco-friendly" or "organic," make up about 68% of all labeled new food products, while purely social claims, such as "Fairtrade," account for just 4%. The remaining labels include both environmental and social aspects. This shows that companies mostly focus on environmental labels because that is what consumers demand most. However, the wide variety of labels used today (over 200 different kinds in Europe) can confuse consumers, even though they are meant to help people make sustainable choices.

The European Commission, recognising the proliferation of green claims, has been working on tightening and harmonising labelling rules. The Farm to Fork Strategy (2020) explicitly commits the EU to introduce a Sustainability Labelling Framework by the end of 2024 to empower consumers towards sustainable choices [6]. This new framework is envisioned to integrate nutritional, climate or environmental, and social information into a coherent labelling approach. In theory, such a holistic EU sustainability label could simplify the landscape – one label to cover carbon footprint, fair trade, animal welfare, etc., rather than dozens of different logos. The Ecodesign for Sustainable Products Regulation (ESPR), which came into force on July 18, 2024, aims to enhance product sustainability in the EU by improving circularity, energy efficiency, recyclability, and durability [7].

Despite the comprehensive approach, this study has certain methodological limitations. Since the analysis relies exclusively on secondary data, it does not include direct consumer observations or experimental data. Consequently, while the synthesis of existing research, policy reports, and surveys provides valuable insights into consumer behaviour and attitudes, the findings should be interpreted with caution when assessing actual purchasing behaviours in Latvia.

II. Materials and Methods

This applied research relied on diverse secondary data sources to examine food labelling and sustainable consumer behaviour in Latvia. The information was gathered from recent peer-reviewed studies on food labelling, sustainability, and consumer behaviour provided empirical findings and theoretical context; policy documents and official reports from the EU and Latvia were reviewed to understand regulatory frameworks and national context; findings from industry surveys and market research to capture consumer trends and behaviour in real-world markets; comparative regional data comparing consumer behaviour across the Baltic and the EU to put Latvia's situation in context.

Using the above sources, comparative analysis was conducted a to highlight similarities and differences between Latvia and other regions in terms of sustainable consumer behaviour and food labelling impacts. Key indicators were identified for comparison – such as consumer awareness levels of sustainability labels, trust in those labels, willingness to pay a premium for eco-labeled products, effectiveness of labels in changing behaviour, and the strength of related policies.

To ensure a comprehensive analysis, an integrative interpretation process was applied, combining data from multiple sources. Insights from reports, surveys, and academic literature were cross-validated, comparing findings to identify consistent trends and explain discrepancies. Quantitative data (e.g., statistics and survey results) were analysed for consistency, while qualitative insights (case studies, interviews, and narratives) were examined for recurring themes. For example, research on Latvian consumers indicated an increasing willingness to pay more for local and environmentally friendly products [4], aligning with international studies reporting a 10% price premium for sustainability [8]. When multiple sources confirmed similar patterns, these were interpreted as strong evidence of food labelling influencing purchasing behaviour. By synthesising quantitative trends with qualitative context, the study constructed a cohesive narrative on how food labelling impacts consumer choices in Latvia.

There are three key consumer-response dimensions that determine the effectiveness of food labelling in promoting sustainable consumption: awareness, trust, and willingness to pay. Awareness reflects how well consumers recognise and understand sustainability labels, with EU-wide data showing that 56% of Europeans identify the organic logo, providing a benchmark for Latvia [9]. Trust in labels depends on their perceived credibility, as excessive labelling schemes have been found to create confusion and skepticism, reducing their effectiveness [10]. Finally, willingness to pay assesses whether consumers are ready to spend more on sustainably labeled products, with international surveys indicating around 10% premium for such goods, a trend also observed in Latvian market studies [8].

III. Results and Discussion

An EU-wide survey indicates that taste, food safety, and price are the top factors for shoppers, whereas environmental impact ranks much lower [11].

Awareness of sustainability labels among Latvian consumers is growing, but it still lags behind Western Europe in some areas. EU survey data show that 56% of Europeans recognise the EU organic farming logo, making it the most recognised quality label in Europe [9]. In contrast, less than one in five Europeans recognise the EU's geographical indication logos (PGI/PDO), which suggests that organic is the flagship sustainability label capturing the

public's attention. While country-specific awareness levels vary, newer member states like Latvia tend to have lower recognition of EU labels due to shorter exposure. For example, a few years after joining the EU, only about 40% of Baltic consumers recognised the organic logo, according to earlier studies [12]. This number is higher now in Latvia, but still under the EU average. Local initiatives exist – Latvia has its national quality label (the "Green Spoon" or "Zaļā karotīte") to denote food made in Latvia according to high-quality standards.

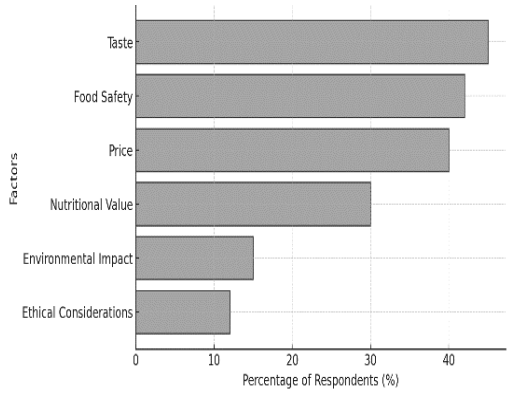

Fig. 1. Consumers' priorities when buying food in the EU. Source: European Commission, "Special Eurobarometer 505: Europeans, Agriculture and the CAP," 2020. Available: https://data.europa.eu/data/datasets/s2241_505_eng?locale=en [20].

Yet, a 2023 survey conducted by the Centre for Sociological and Political Studies (SKDS) uncovered that many Latvians overestimate their ability to identify local products from packaging alone. Over 40% believed they could tell if a product is Latvian just by the package, but when tested, only 9.8% actually correctly identified certain imported items' origins [12]. This discrepancy points to label confusion: people think they recognise local or eco labels, but in practice they are often misled by branding. As a result, 60% of Latvian respondents said the country should introduce a special label for Latvian-made products to make them easier to spot and support. This reflects a strong consumer desire for clearer origin labelling as a component of sustainability (supporting local farmers, reducing "food miles").

Latvian and Baltic consumers report high trust in labels that have official or third-party backing. A comparative study by Liobikienė & Brizga (2022) found that in Latvia and Lithuania, "confidence in green products" (i.e. trust that eco-labelled goods truly meet environmental standards) significantly influenced green purchasing behaviour [13]. In Estonia, by contrast, personal values played a slightly bigger role than trust in determining purchases. This implies that building trust in labels is especially critical in Latvia – consumers need to believe the label claims are credible.

Retail market analyses by McKinsey show that in Europe, products making environmental or social claims have seen faster sales growth than those without such claims [14]. Over a recent five-year period, goods with ESG (environmental, social, governance) labels grew about 28% in sales versus 20% for conventional products, accounting for 56% of total market growth in food and beverages. These labeled products now make up almost half of retail sales in their categories, indicating that consumer demand is gradually shifting toward sustainability. In Latvia, one can observe the increasing shelf space for organic dairy, free-range eggs, and fair-trade coffee in supermarkets, suggesting that a segment of consumers is actively seeking out and buying labelled sustainable goods. Especially among younger, urban Latvians and higher-income groups, there is a growing cohort for whom certifications like organic certifications (often referred to as "BIO" in retail markets), Fair Trade label, or Rainforest Alliance label add value to a product.

Another crucial factor is the role of retailers in integrating sustainability labels into everyday shopping practices. While consumer awareness of sustainability labels has grown significantly, the visibility and accessibility of eco-labelled products largely depend on decisions made by retail chains. In recent years, major Latvian retailers such as Rimi and Maxima have started to allocate dedicated shelf space for organic and environmentally certified products, simplifying consumer choices.

While interest in sustainable food is rising, several barriers hinder Latvian consumers from consistently choosing eco-labeled products. A significant barrier is the economic constraint arising from the combination of relatively high prices for sustainably labeled goods and comparatively low household income levels. Latvia's GDP per capita is still below the EU average, and food budgets are tight for many households [15]. Another barrier is the lack of clear information or confusion caused by the excessive number of sustainability labels available on the market. The European Court of Auditors (ECA) in 2024 reported that consumers are "exposed to a growing number of labels, logos and schemes" that are not systematically tracked [16]. A single food item might carry multiple labels (organic, fair trade, carbon footprint, etc.), which can overwhelm or confuse shoppers. Closely related is the issue of limited understanding of what labels signify. Neither the EU Commission nor Latvian authorities currently provide regular public education on sustainability labels. The ECA audit found that there is no systematic monitoring or education about consumer understanding of food labels in EU member states. As a result, many consumers do not fully grasp the significance of labels. In Latvia, older generations who did not grow up with these concepts may be unsure how e.g. a "Rainforest Alliance" label relates to their purchase.

Social and cultural factors also play a role as barriers. Interestingly, surveys have shown that Latvians (and Estonians) report slightly lower concern about climate change than the EU average, yet they exhibit some higher climate-friendly behaviour [13]. This paradox may be due to ingrained habits (e.g. home gardening, picking wild berries, which are sustainable by default but not driven by "green" ideology). As sustainable consumption gains popularity, peer influence and societal norms act as

incentives. In Estonia and Latvia, researchers found that subjective norms (perceived social pressure or encouragement) significantly influence green purchasing. If friends, family, or media in Latvia emphasise buying seasonal local produce or avoiding plastic packaging, individuals are incentivised to conform to these emerging norms.

A study on eco-label use found that consumers choose a label mostly because of the attributes it signifies (e.g. better quality, no harmful chemicals) and secondarily because of the label's reputation or credibility [17]. This means that a well-known label can serve as a shorthand for "better product" in the consumer's mind. As more Latvians become familiar with labels like Fairtrade or MSC (sustainable fisheries), these can increasingly tip the decision in favour of the labelled product, even at a slight price premium. Making labels simple and informative is a key incentive. When an eco-label is easy to understand at a glance, it can nudge even those who are not actively looking for it. For example, a "traffic light" style eco-score (rating a product's environmental impact A–E with colours) is being tested in some European markets and has shown promise in guiding choices subconsciously. In Latvia, products with such labelling can already be found on the shelves of major retail chains, including Lidl, Sky, and Rimi, where eco-certified and organic goods are increasingly promoted as part of their sustainability commitments.

Enforcement of labelling rules in Latvia falls to national authorities (primarily the Food and Veterinary Service, along with consumer rights protection centres). According to the ECA's audit, all EU member states have control systems in place for food labelling compliance. In 2024 Latvia was highlighted as one of a few countries that had not updated its multi-annual food labelling control plan as of the audit (along with Denmark, Malta, Slovenia) [18]. The European Commission followed up with Latvia on this issue, while Latvia implements EU labelling laws, there may be gaps in monitoring and enforcement capacity (possibly due to limited resources or administrative delays).

This review reveals several gaps in current research on food labelling and sustainable behaviour, especially relevant to Latvia and similar markets. First, there is a lack of country-specific consumer research in the Baltic context. Much of the literature aggregates EU consumers or focuses on larger countries. Latvia's unique cultural and economic context – such as the patriotic preference for local food and the lower purchasing power – means consumer responses to labels may differ from the EU average. There is a need for more real-world observational research on how labels actually impact behaviour (as opposed to stated preferences). Many existing studies rely on surveys or lab experiments. The 2023 review emphasised that further research should occur in real purchasing environments with representative populations [3] to capture genuine behaviour. This is especially pertinent in Latvia, where little field data exists on, for example, how the introduction of a new label or a change in label design affects sales of a product.

There is also a research gap in the interaction of multiple labels and messages. We know from broader studies that too many labels can confuse consumers, but it remains unclear how best to present multi-faceted sustainability information. It is vital to understand should environmental, social, and health information be combined into one label, or do consumers prefer separate messages. The EU is moving toward integrated labelling, yet little research has been done on how consumers in Latvia or the Baltic would react, for instance, to a single sustainability score versus separate organic and fair-trade logos.

With digital advancements, digital labelling and information access are becoming increasingly relevant, yet research in this area remains limited. In Latvia, younger consumers are likely to use smartphone apps to scan QR codes for detailed product information, as some companies already provide links to sustainability reports. Investigating whether Latvian consumers actively engage with digital sustainability information and how it influences their trust and purchasing decisions would contribute to understanding this emerging trend [19].

Finally, a critical gap highlighted by policy auditors is the lack of systematic monitoring of consumer needs and understanding [18]. This is not just a policy gap but a research opportunity.The lack of continuous data on how well consumers comprehend labels, both at the EU and Latvian levels, highlights a critical research opportunity.

IV. Conclusions

Food labelling plays a critical role in shaping not only consumer choices but also broader industry practices and public policy. In Latvia and the Baltic region, the growing prevalence of sustainability labels reflects a wider movement towards greener consumer behaviour. Although taste and price remain the primary drivers of food purchases, clear and credible labels have the potential to gradually shift consumer priorities toward sustainability.

The findings of this study show that food labels are effective only when they are easily understandable, trustworthy, and supported by proper certification. In Latvia, the strong cultural support for local products and increasing environmental awareness offer a unique opportunity to promote responsible consumption through sustainability labelling. However, barriers such as high prices, label confusion, and limited consumer education still inhibit the full impact of these initiatives.

Importantly, food labelling should be seen as more than just an informational tool — it acts as a catalyst for responsible and sustainable consumer behaviour. Well-designed labelling can bridge the gap between consumer values and actual purchasing decisions, motivating individuals to make choices that align with environmental, ethical, and social goals. Therefore, making food labels a truly effective tool for sustainable consumer behaviour, it is essential to build trust through strict regulation, simplify labelling schemes to reduce consumer confusion, and invest in public education efforts.

Future research should prioritise studying real-world purchasing behaviour and testing integrated labelling strategies in the Latvian context. By strengthening the link between labelling practices and sustainable consumption, policymakers and businesses can foster a more responsible, environmentally conscious consumer culture.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 509-514

Evaluating the Performance of EFAS Hydrological Predictions in Latvian River basins: A Comparison with Observational Data

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***Abstract* — This study evaluates the performance of the European Flood Awareness System (EFAS) [1] in predicting hydrological variables by comparing EFAS reforecast data with observational data from the Latvian Environment, Geology and Meteorology Centre (LVGMC). Using the open-source LISFLOOD hydrological model [2], the study examines the accuracy of ECMWF-driven predictions of river discharge and water levels across Latvia's diverse river basins. The study employs a variety of interpolation techniques, including linear interpolation and nearest neighbour interpolation, to extract grid data from the Copernicus Early Warning Data Store (EWDS) [3] dataset at hydrological station points. To assess prediction accuracy, a range of statistical and error metrics, including Mean Error (ME) [4], [5], Root Mean Squared Error (RMSE) [5] - [7], Nash-Sutcliffe Efficiency (NSE) [5], [8]-[12] and Kling-Gupta Efficiency (KGE) [5], [12], [13], are utilized. The analysis highlights the effectiveness of EFAS in different seasonal and hydrometeorological conditions, identifying both strengths and limitations in the model's performance. Furthermore, the study explores potential calibration approaches to including regional forecasting capabilities, particularly in light of climate change impacts on low-flow and drought period predictions. This research provides valuable insights into the application of continental-scale hydrological models at the regional level, offering recommendations for improving the accuracy of flood forecasting systems.**

Keywords* — *EFAS, hydrology, REFORECAST, ECMWF, verification

I. Introduction

Predictive analysis – in other words, combining observations with exemplary information to reconstruct weather and climate – plays a major role in numerical weather forecasting. This study will include this dataset, which provides the grid simulated hydrological time. The data consistently reflect the most important hydrological variables in the field of the European Flood Awareness System (EFAS) [1].

The data reflect the most important hydrological variables in the European flood awareness system (EFAS). This dataset has been created using the open source LISFLOOD hydrological model [2] at 1X1 arcade resolution (~ 1.5 km EFAS latitude) with meteorological overforecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble. Reforecasts are forecasts that run on past dates and are typically used to

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8705
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evaluate the proficiency of the forecast system or to develop tools to correct forecast statistical errors.

Hydrological data is critical for building flood prediction models. Hydrological modelling can help predict the extent and duration of flooding, which is essential for alerting the population of affected areas in a timely manner. Hydrological data are also essential for flood risk management and long-term mitigation strategies. In the context of climate change, the low-flow period and drought forecast are also significantly increasing. Each region has a unique hydrological profile made up of topography, climate, land use and other factors. Reforecasts of river discharges are proposed twice a week with lead time of up to 46 days, with 6-hour periods of 20 years [3].

Recent research has highlighted challenges in converting continental-scale hydrological predictions into regional and local applications. Arnal et al. [14] demonstrated that the skill of seasonal hydrological forecasts varies significantly across regions of Europe, significantly limiting areas with complex terrain. So Wanders et al. [15] found that reduction methods can significantly improve the accuracy of local projections when applied to continental models. Pappenberger et al. [16] further underlined the importance of a comprehensive verification system for the assessment of hydrological forecasting systems at several spatial scales. Verification of EFAS forecasts against observation data from national hydrological monitoring networks, such as the one maintained by State Limited Liability Company "Latvian Environment, Geology and Meteorology Centre" (LVGMC), provides important insights into the performance of models at different spatial scales and hydrometeorological conditions.

In the field of hydrology accurate methods of data retrieval and interpolation are essential for reliable analysis and forecasting.

Fig. 1. Area of the EFAS reforecasts of river discharges.

If your figure has two parts, incorporate the labels "(a)" and "(b)" in the figure. At the same time, do not incorporate captions in the figures. Do not put captions in "text boxes" linked to the figures. Do not put borders around the outside of your figures. Use the abbreviation "Fig. 1" even at the beginning of a sentence.

The purpose of this article is to address an important issue in hydrological data analysis by comparing EFAS predictions with observational data from LVGMC.

This research aims to quantify the accuracy, reliability, and systematic biases of ECMWF-driven LISFLOOD predictions when compared to ground-truth measurements from Latvia's comprehensive monitoring network. By examining performance across different seasons and river basins, this study will identify specific conditions under which model performance excels or deteriorates. Furthermore, the analysis will explore potential calibration approaches to improve regional forecasting capabilities based on identified discrepancies between predicted and observed data.

II. MATERIALS AND METHODS

A. Data Extraction

The study involves 7 years (2013-2019) of EWDS grid data (ECMWF reanalysis dataset) mining at geographical data points of hydrological stations. Since the choice of interpolation method significantly impacts data accuracy, this study comprehensively evaluates the effectiveness of different interpolation techniques.

For data retrieval, we utilized the griddata function from the Python package xarray [17], [18] to extract point data by applying three distinct grid data interpolation methods:

- Linear interpolation: This method, widely used in scientific computing, estimates values at unknown points by fitting a straight line between known data points. Implementation was carried out using SciPy [19], a fundamental Python library for numerical computing.
- Nearest neighbour interpolation: A computationally efficient method that assigns the value of the closest grid point to the target location. This approach prioritizes processing speed over smoothness of results, making it particularly useful for large datasets where computational resources are limited.

B. Quality Assessment

A comprehensive set of errors and statistical indicators is used to assess the quality of the data obtained, each providing insights into different aspects of interpolation performance.

C. Basic Error Metrics

- Mean Error (ME) [4],[5]:

$$ME = \frac{1}{n}\sum_{i=1}^{n}(F_i - O_i) \quad (1)$$

The ME measures the average difference between forecast data (F) and observed data (O). A value closer to zero indicates better performance, with positive values indicating overestimation and negative values indicating underestimation.

- Root Mean Squared Error (RMSE) [5]- [7]:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(F_i - O_i)^2} \quad (2)$$

- Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{F_i - O_i}{O_i}\right| \quad (3)$$

D. Correlation Metrics

- Spearman's Rank Correlation (R_Spearman) [5], [20]:

$$R_{Spearman} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(R(O_i) - \overline{R(O_i)}\right)\left(R(F_i) - \overline{R(F_i)}\right)}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R(O_i) - \overline{R(O_i)}\right)^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R(F_i) - \overline{R(F_i)}\right)^2}} \quad (4)$$

This non-parametric measure assesses the strength and direction of monotonic relationships between forecast and observed data, making it robust against outliers and non-linear relationships.

- Anomaly Correlation Coefficient (ACC) [5], [21]-[23] :

$$ACC = \frac{1}{n}\frac{\sum_{i=1}^{n}(F_i - \bar{F})(O_i - \bar{O})}{\sigma_O \sigma_F} \quad (5)$$

ACC measures the correlation between the variation patterns of forecasted and observed data. A value closer to 1 indicates that the forecast accurately captures the observed data's anomaly patterns.

E. Advanced Efficiency Metrics

- Watterson's M (Watt_M) [5], [8]

$$Watt_M = \left(\frac{2}{\pi}\right) sin^{-1}\left(1 - \frac{\frac{1}{n}\sum_{i=1}^{n}(F_i - O_i)^2}{\sigma_F^2 + \sigma_O^2 + (F - \bar{O})^2}\right) \quad (6)$$

This metric provides a normalized measure of agreement between forecasts and observations.

- Nash-Sutcliffe Efficiency (NSE) [5], [9]-[12]:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(F_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \quad (7)$$

This metric provides a normalized measure of agreement between forecasts and observations.

- Modified Nash-Sutcliffe Efficiency (NSE_{mod}) [5], [8]:

$$NSE_{mod} = 1 - \frac{\sum_{i=1}^{n}|F_i - O_i|^j}{\sum_{i=1}^{n}|O_i - \bar{O}|^j} \quad (8)$$

This modification to the NSE formula allows for adjusting sensitivity to outliers through the parameter j, with j=1 reducing sensitivity and higher j values increasing it.

- Relative Nash-Sutcliffe Efficiency (NSE_{rel}) [5], [8]:

$$NSE_{rel} = 1 - \frac{\sum_{i=1}^{n}\left|\frac{F_i - O_i}{O_i}\right|^2}{\sum_{i=1}^{n}\left|\frac{O_i - \bar{O}}{O}\right|^2} \quad (9)$$

This version of NSE is particularly useful for evaluating relative differences, reducing the influence of magnitudes.

F. Kling-Gupta Efficiency Metrics

- Kling-Gupta Efficiency Metrics (KGE_{2009}) [5], [12]:

$$KGE_{2009} = 1 - ED_9 \quad (10)$$

where

$$ED_9 = \sqrt{\left(s[1]\cdot(r-1)\right)^2 + \left(s[2]\cdot(\alpha-1)\right)^2 + \left(s[3]\cdot(\beta-1)\right)^2}, \quad (11)$$

$$r = \frac{\sum_{i=1}^{n}(O_i - \bar{O})(F_i - \bar{F})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}\sqrt{\sum_{i=1}^{n}(F_i - \bar{F})^2}}, \quad (12)$$

$$\beta = \frac{\bar{O}}{\bar{F}}, \quad (13)$$

$$\alpha = \frac{\sigma_F}{\sigma_O}, \quad (14)$$

where s represents the scaling factors to be used for re-scaling the Pearson product-moment correlation coefficient (r), α, and β, respectively, σ_O and σ_F are the standard deviations of *O* and *F* respectively.

Gupta et al. [11] created this metric to demonstrate the relative importance of the three components of the NSE, which are correlation, bias and variability.

- Kling-Gupta Efficiency 2012 (KGE_{2012}) [5], [13]:

$$KGE_{2012} = 1 - ED_{12} \quad (15)$$

where

$$ED_{12} = \sqrt{\left(s[1]\cdot(r-1)\right)^2 + \left(s[2]\cdot(\gamma-1)\right)^2 + \left(s[3]\cdot(\beta-1)\right)^2} \quad (16)$$

$$\gamma = \frac{\sum_{i=1}^{n}F_i\sqrt{\sum_{i=1}^{n}\left(F_i - \bar{F}\right)^2}}{\sum_{i=1}^{n}O_i\sqrt{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)^2}} \quad (17)$$

This 2012 modification of KGE reduces the cross-correlation between bias and variability ratios, providing to more independent assessment of these components.

G. Additional Metrics

- Lengendre-Marsden Index (LM Index) [5], [24]:

$$LM_{index} = 1 - \frac{\sum_{i=1}^{n}|F_i - O_i|}{\sum_{i=1}^{n}|O_i - \bar{O}|} \quad (18)$$

This index is less sensitive to extreme values than NSE, providing a more robust assessment for data with outliers.

III. Results and discussion

For data retrieval, the nearest neighbour interpolation method gave better results than linear interpolation. Turned out that difference between upstream basin areas between in first step selected retrieved data and existing database information differs by 0.00027 to 13.48%. It was accepted that basin area difference can be no larger than 0.2%. This area difference can be linked to specific subbasin division methods.

TABLE 1 STATISTICAL INDICATORS FOR ANALYSED NEAREST NEIGHBOUR INTERPOLATION METHOD DATA

Season	Statistical Indicators											
	ME	***RMSE***	***MAPE***	***R_Spearman***	***ACC***	***Watt_M***	***NSE***	***NSE mod***	***NSE rel***	***KGE (2009)***	***KGE (2012)***	***LM Index***
DJF min	-80.80	0.35	0.32	0.12	-0.07	-0.03	-0.63	-0.39	-19.54	-0.27	-0.35	-0.39
DJF max	15.16	134.46	0.94	0.80	0.79	0.53	0.57	0.42	0.83	0.67	0.72	0.42
MAM min	-137.70	1.10	0.22	0.35	0.40	0.12	-1.43	-0.46	-1.28	-0.02	-0.54	-0.46
MAM max	17.75	195.98	0.57	0.92	0.93	0.66	0.76	0.44	0.83	0.78	0.79	0.44
JJA min	-36.63	0.35	0.41	0.06	0.14	0.05	-36.41	-4.52	-90.65	-4.11	-2.46	-4.52
JJA max	32.81	118.59	1.20	0.78	0.89	0.58	0.70	0.47	0.62	0.67	0.68	0.47
SON min	-0.45	0.38	0.42	0.25	-0.05	-0.02	-17.56	-2.66	-86.10	-3.94	-2.82	-2.66
SON max	39.21	78.38	1.38	0.89	0.90	0.65	0.73	0.41	0.80	0.82	0.82	0.41

The analysis focuses on the data comparison using statistical indicators. The data were analyzed for different seasons, as they are commonly used in hydro-climatological studies: winter (DJF), spring (MAM), summer (JJA), and autumn (SON). Runoff variation across seasons can be significant and driven by different factors. Seasonal data analysis can provide insights into periods when the model performs most effectively.

TABLE 2 STATISTICAL INDICATORS FOR ANALYSED LINEAR INTERPOLATION METHOD DATA

Season	Statistical Indicators											
	ME	***RMSE***	***MAPE***	***R_Spearman***	***ACC***	***Watt_M***	***NSE***	***NSE mod***	***NSE rel***	***KGE (2009)***	***KGE (2012)***	***LM Index***
DJF min	-91.36	0.34	0.31	0.12	-0.07	-0.03	-0.57	-0.36	-9.44	-0.26	-0.33	-0.36
DJF max	2.79	139.54	0.93	0.80	0.79	0.56	0.60	0.42	0.83	0.71	0.75	0.42
MAM min	-170.57	1.11	0.23	0.35	0.40	0.11	-1.42	-0.51	-1.28	-0.04	-0.55	-0.51
MAM max	0.14	234.31	0.60	0.92	0.93	0.66	0.76	0.44	0.89	0.77	0.77	0.44
JJA min	-58.83	0.31	0.41	0.06	0.14	0.08	-11.03	-1.92	-30.82	-1.68	-1.32	-1.92
JJA max	24.52	136.82	1.16	0.78	0.89	0.58	0.65	0.42	0.71	0.71	0.67	0.42
SON min	-1.23	0.36	0.41	0.25	-0.05	-0.02	-5.19	-1.19	-31.25	-1.55	-1.02	-1.19
SON max	28.29	46.73	1.37	0.89	0.90	0.66	0.76	0.48	0.86	0.83	0.83	0.48

The statistical analysis results for both the linear and nearest neighbor interpolation methods, based on the retrieved data compared to the observed data, were similar. Table 1 summarizes the seasonal minimum and maximum values for the nearest neighbor interpolation dataset, while Table 2 summarizes the statistical indicator values for the linear interpolation dataset. The highest differences in RMSE were observed in spring, which can be explained by the fact that the highest values and the largest value amplitudes are typically observed or modeled during this period. Also, spring season can be characterized as period with the highest correlation values for different correlation

metrics - Spearman's Rank Correlation (R_Spearman) up to 0.93, Kling-Gupta Efficiency Metrics 0.77-0.78, NSE 0.44-0.89, lowest values show NSEmod, which reacts to outliers in data.

When considering the best correlation performance, the lowest correlation for both retrieved datasets compared to the observed data occurred in the two seasons most exposed to low-flow periods—winter and summer. This can be explained by the fact that the model is more suitable for high-flow periods than for low-flow periods. The results in this study were obtained from the entire set of stations. Autumn season data correlations showed good performance; many indicators were higher than 0.8 for both data sets. Autumn showed the best performance for RMSE values.

When exploring the results for different hydrological stations separately, it becomes evident that the dataset includes stations with very good performance as well as stations with poor performance. This variation occurs both from year to year and between different seasons.

Data quality is highly related to river basin properties – catchment size, soils, land-use changes, deforestation, urbanization and many others. All these factors give impact, so data analysis could be done more detailed – by sorting hydrological stations into respectively hydrological regions or grouped by different classes to to achieve more comprehensive results.

This study showed that most of stations gave satisfying correlation results for all seasons and in lack of available observation values modelled values can be the valuable substitute. However, given that the correlation results for some stations were not acceptable, one must remain cautious when using this data, as data inconsistencies may exist.

IV. CONCLUSION

This study offers examination of modelled data comparison to observed data by different statistical indices. Key findings indicate that best performance is for high flow periods, but less correlation is seen in low-flow periods – winter and summer. In addition, the study highlights differences between different station performance.

According to the interpretation by authors of this paper for many stations correlation between analysed data sets is strong enough to be practically applicable.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 515-521

Ways to Restore Ukraine's Environment in the Post-War Period

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***Abstract* – The environmental crisis in Ukraine caused by the war will have significant consequences for hundreds of years to come and will affect neighboring countries and the world at large. Obviously, it is impossible to return the environment to its pre-war state, but it is possible to activate all scientific potential and human resources to improve the situation and allow ecosystems to gradually rebalance. The purpose of the article is to identify the main directions for overcoming the environmental crisis in Ukraine in the post-war period. The article analyzes the environmental consequences of the war, presents research by Ukrainian and European scholars, and focuses on international cooperation in solving environmental problems. The main environmental challenges, including soil, water, and air pollution, destruction of forests, etc. are discussed. The publication outlines areas of environmental rehabilitation related to innovative technical activities, implementation of foreign experience, public initiative, and an expanded range of environmental education and awareness. Innovative approaches of Ukrainians to combat the environmental crisis related to water, soil and air purification are emphasized. The environmental problems in Ukraine during the war period and plans for environmental restoration in the postwar period are covered in the works of Ukrainian ecologists (T. Denysenko, O. Mudrak, O. Naidenova, S. Rudyshyn and others) and European ecologists (W. Filho, J. Eustachio, D. Pietrzyk-Reeves, J. Carbonell). The article provides a list of Ukrainian NGOs engaged in environmental protection activities and organizing various environmental public initiatives. Particular attention is paid to the results of a survey of the population of Vinnytsia, Lviv, and Khmelnytsky regions, which showed the readiness of the population to engage in environmental activities. The article focuses on raising the environmental awareness of citizens as a basis for sustainable development of the country. The article emphasizes the need for an integrated approach that combines public policy, research, civic initiatives and international cooperation to effectively restore Ukraine's environment in the postwar period.**

Keywords* – *ecological restoration, ecological consequences of war, sustainable development, nature-based solutions, ecological education, public participation.

I. Introduction

Around 30% of Ukraine's protected areas (over 1.2 million hectares) have been damaged by the hostilities. According to the Ministry of Environmental Protection and Natural Resources of Ukraine, as of November 2024, 180 million tonnes of carbon dioxide were released into the atmosphere as a result of shelling and forest fires. In addition, about 425,000 hectares of forests are contaminated with mines and unexploded ordnance, making it difficult to restore and use them. Ukraine's

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8679
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water resources have also suffered significant damage. Russian shelling destroyed sewage treatment plants and port infrastructure, especially in the Mykolaiv area, causing untreated sewage to enter the sea. Russian tankers sank as a result of the fighting, spilling thousands of tonnes of fuel oil into the Black Sea, polluting more than 60 km of coastline and killing dolphins and other marine animals. The destruction of the Kakhovka dam released more than 90,000 tonnes of heavy metals, which flowed into the Dnipro River and the Black Sea, causing toxic pollution of water and soil. Mines and missile debris in coastal waters pose a danger to marine life and impede navigation, which also hinders scientific research and environmental monitoring. In addition to natural ecosystems, agricultural land has also been severely damaged. Due to explosions, shelling and heavy machinery, the soil lost its fertility. Some fields were rendered unusable for cultivation due to contamination with heavy metals and explosive residues. Experts estimate that restoring the fertility of these lands will take decades and significant investment. Many species of fauna, especially rare and endangered species, were forced to leave their natural habitats. Shelling and explosions have destroyed bird nesting sites and disrupted animal migration routes. Some species of animals living in the steppes and forests have significantly reduced in number. Despite the large-scale destruction, Ukraine has already begun work to restore the natural environment. The government, together with international organisations, is developing programmes to clear mined areas, clean up water resources and restore forests [13].

During the international online conference "The Environmental Consequences of russian War in Ukraine: Together for the future recovery of the Ukrainian environment" highlighted and analysed the environmental damage caused during the first months of the war, and focused on the territories of the most affected regions – Zaporizhzhia, Dnipro and Kharkiv [4]. The World Wide Fund for Nature (WWF) provides recommendations on how to restore Ukraine's natural resources after the war, focusing on nature-based solutions: developing a national plan for water restoration, investing in artificial forests, implementing nature-based solutions, adapting Ukrainian legislation to European standards, and documenting environmental crimes [5].

Studies by W. Filho, J. Eustachio, M. Fedoruk, T. Lisovska on environmental problems in Ukraine have shown that the detonation of explosives and the movement of heavy military equipment damage the soil structure, contaminate it with heavy metals (Zn, Cu, Pb, Cr, Ni, Cd), which reduces yields by 5-10%, and emissions from military vehicles and explosions increase the level of PM2.5, NO_2 and CO, which exceeds all-Ukrainian healthcare organisation safe standards. This causes respiratory diseases and threatens the environment. Studies have also highlighted a number of health problems caused by environmental issues, including contaminated water causes intestinal infections, dehydration and exhaustion, toxic substances in the air cause respiratory problems, skin irritation and increase the risk of cancer, heavy metal contamination of soil reduces crop yields, leading to malnutrition and weakened immunity, loss of natural resources and toxic poisoning negatively affect the liver, kidneys and nervous system, explosions cause hearing damage and psychological stress [7].

According to J. Carbonell, Ukraine's environmental problems are the problems of the whole world, and to solve them, it is important to develop environmental nationalism, which combines environmental rhetoric with national interests, which allows for wider public support. Ecological nationalism is based on resource conservation, the use of modern cleaning technologies, thorough environmental education, and broad international cooperation [1]. In his scientific works, D. Pietrzyk-Reeves supports the opinion of J. Carbonell and emphasises environmental activism as the primary way to overcome the environmental crisis. First and foremost, environmental activism is based on environmental education, raising environmental awareness of society, involves performing tasks that are feasible for everyone (sorting garbage, caring for stray animals, planting greenery), then – intensifying technological utilisation and recycling of garbage, developing chemical / biological agents for soil restoration, water and air purification, etc [10].

Organisations such as the United Nations Economic Commission for Europe (UNECE), the United Nations Environment Programme (UNEP) and the Organisation for Economic Co-operation and Development (OECD) have established the Platform for Action for a Green Recovery of Ukraine. This initiative aims to coordinate international efforts to support the country's environmental recovery. The main areas of "green" reconstruction include the application of sustainable procurement principles in the design, selection of materials and construction processes to ensure environmentally friendly and energy-efficient infrastructure; reducing dependence on fossil fuels through the development of renewable energy sources and improving energy efficiency are key elements of the strategy [4].

Ukrainian ecologists (O. Angurets, Y. Bengus, O. Vasylyuk, S. Zhuk, O. Mudrak, V. Parkhomenko, K. Polyanska and others) are actively researching the impact of the war on the environment and documenting the environmental consequences of hostilities. Ukraine identifies environmental issues as one of the priorities in the recovery process. Among the 10 points of the Peace Formula, the eighth is dedicated to environmental safety. In the document, Ukraine emphasises the importance of the international community's support in ensuring

environmental safety and counteracting the environmental consequences of war: environmental damage assessment; accountability for damage; recovery and reconstruction, including the transition to a green economy. Cooperation with international organisations and states is key to effectively responding to the environmental challenges of war, as well as to support Ukraine in its efforts to restore ecosystems and counteract the environmental consequences of war [9]. In her research, K. Belousova argues that it is possible to overcome the environmental crisis by changing the paradigm of thinking (the need to overcome self-centred attitudes towards nature, raising citizens' environmental awareness as a basis for sustainable change); developing "a green economy" and implementing environmental standards; developing science and introducing technological innovations, focusing on the European "green course" and joining European environmental initiatives [8]. T. Denysenko argues that Ukraine's priority is to create a sustainable and ecological environment, to ensure that environmental policy has a cross-cutting impact on all sectors of the economy, to create a modern transparent system of state and environmental control, and to restore the natural environment in the war-torn regions (Luhansk, Donetsk, Kyiv, Chernihiv, and Sumy oblasts) [2].

In February 2024, a High-Level Working Group on the Environmental Consequences of the War was established, comprising Ukrainian and European officials. This group signed the Environmental Pact for Ukraine, which defines strategies for post-war environmental restoration, including demining, environmental restoration, and building a green economy. The main tasks of the pact include demining (detection and disposal of mines and shells in contaminated areas, cleaning soils and water bodies from heavy metals and chemicals, and restoring agricultural land fertility); restoration of the natural environment and biodiversity (cleaning rivers and lakes from pollution and debris, protecting rare species of animals and plants, including many endemic species that live only in Ukraine); building a green economy and sustainable development (establishing renewable energy sources: solar, wind, solar thermal, and support for environmental start-ups and innovative solutions in the field of energy and waste management) [6].

To date, international cooperation in environmental policy has already been tangible, as projects to demine agricultural land in Kherson and Mykolaiv regions have been developed in cooperation with the European External Action Service (EEAS), a project to restore wetlands in the Askania Nova reserve is being implemented with the support of the European Environment Agency (EEA), and the construction of solar power plants in the de-occupied territories of Mykolaiv and Zaporizhzhia regions is being financed in cooperation with the European Investment Bank (EIB). In addition, the EU candidate status encourages Ukraine to implement environmental reforms and adapt to European environmental standards, which will contribute to sustainable development and economic growth.

The purpose of the article is to identify the main directions of overcoming the environmental crisis in Ukraine in the post-war period.

The purpose of the study is to develop models for overcoming the environmental crisis in Ukraine in the postwar period based on the analysis and systematization of theoretical developments on this issue.

II. MATERIALS AND METHODS

According to the website of the Ministry of Environmental Protection and Natural Resources of Ukraine, 3,750 cases of damage to the natural environment were recorded as a result of the war. In particular: 1622 cases of air pollution, 2912 cases of soil pollution, and 216 cases of water pollution, each of which has numerous negative consequences. The hostilities resulted in the burning of 66,877 hectares of forests and other green spaces, which resulted in the emission of approximately 54,685,316 tonnes of harmful substances into the atmosphere. The combustion of 722,741 tonnes of oil, oil products and gas resulted in additional emissions of 979,526 tonnes, while other sources of pollution caused another 98 tonnes of harmful substances. The area of contaminated land is 18,303,827 m², and the area of contaminated soil is 747,928 m². About 1,693 tonnes of pollutants were released into water bodies, and the weight of foreign objects, materials, waste and other substances in water bodies reached 36,205,704 kg. The Ministry's official data showed a deep environmental crisis in Ukraine, which had significant environmental problems even before the war, including the disposal of radiation emissions from the Chornobyl nuclear power plant, waste sorting and disposal, water treatment, etc [13].

Restoring Ukraine's environment is a complex task that requires a comprehensive approach and the introduction of modern technologies. Several innovative solutions for environmental rehabilitation are currently being developed and implemented:

- *Nature-based solutions*. The United Nations Development Programme (UNDP) in Ukraine implements projects aimed at restoring ecosystems. These solutions include moss modules, rain gardens, living walls, and composters for organic waste, which help clean the air and improve the urban environment.
- *Legislative initiatives*. The Ministry of Environmental Protection and Natural Resources of Ukraine is working on a

framework law "On the Basics of Green Recovery", which will define key principles and approaches to sustainable recovery of the country in line with European standards.

- *Technological progress*. The use of geoinformation technologies, energy-saving equipment, development of purification filters, etc.
- *Environmental education.* Raising environmental awareness among the population, developing the environmental consciousness of the younger generation, shaping the environmental culture and foresight of Ukrainians [4].

In the course of the study, we used the following methods: theoretical: a method of analysing scientific data to determine the theoretical foundations of the problem, a method of systematising and generalising the theoretical provisions of the problem; empirical: questionnaires and surveys among respondents of higher education institutions on their readiness to participate in environmental activities and implement environmental activism in everyday life.

III. Results and discussion

Every day, Ukraine's nature is suffering major harmful effects from the war and requires radical steps to restore and preserve the environment. Ukraine is implementing a number of innovative approaches to clean up and restore the areas affected by the war. For example, it is investing in reforestation and wetland restoration, which helps to sequester carbon, conserve biodiversity and improve water balance. Enterprises are increasing the use of modern bioseptic tanks, which reduce energy consumption and minimise emissions, helping to reduce the negative impact on the environment. Industrial sectors are using the latest methods of wastewater treatment, which contributes to the conservation of water resources and an environmentally friendly economy. Ukraine is developing software for analysing and modelling alternative scenarios for cleaning the environment and developing effective action plans, which helps to optimise wastewater treatment processes. In addition, Ukrainian scientists are working on the development and implementation of biodegradable bottles made from plant components that fully decompose in 18 months, which helps reduce plastic pollution. Ukraine has joined the European LIFE programme, which is an EU financial instrument for environmental protection and financing of environmental and climate measures. Cooperation between different sectors of the economy and integration of environmental principles into all areas of restoration contribute to sustainable development and effective environmental restoration [3].

With the support of the Ministry of Environmental Protection and Natural Resources of Ukraine, the EcoThreat app was developed to provide users with reliable information about the state of the environment in different regions of Ukraine, including air quality, radiation pollution and water resources. The interactive map shows up-to-date data from monitoring systems and facts of environmental threats caused by russian aggression [13].

After the outbreak of full-scale war in Ukraine, a number of legislative acts aimed at restoring and protecting the environment were adopted. The Environmental Treaty for Ukraine, developed by the International Working Group, contains 50 recommendations for assessing the environmental impact of the war, compensation for damage and green recovery. In response to the environmental consequences of the war, a roadmap for reforming environmental damage assessment legislation was developed to improve the system of state environmental control and ensure compensation for environmental damage. In addition, the Criminal Code of Ukraine provides for liability for crimes against the environment, in particular under Articles 438 and 441, which relate to violations of the laws and customs of war and ecocide. These legislative initiatives are aimed at ensuring effective restoration and protection of the environment in Ukraine in the post-war period.

The war in Ukraine has also had a significant impact on environmental education, bringing new challenges and tasks. In the context of limited resources and environmental problems, it is important to teach students how to use natural resources and energy rationally, as well as to implement environmentally humane practices in their everyday lives. Ukraine participates in the organisation of environmental competitions, festivals, and outdoor eco-lessons for students. The public is encouraged to participate in various public initiatives.

There are more than 500 environmental non-governmental organisations (NGOs) in Ukraine, active at both the national and local levels. Of these, about 28 have national status and are registered with the Ministry of Justice of Ukraine. These NGOs cover a wide range of environmental issues, including nature conservation, climate change, energy, transport, environmental education and monitoring the environmental impact of war. They actively engage with government agencies, international partners and local communities. NGOs protect the environment, restore natural resources and raise environmental awareness, the most prominent of which are:

- *Ecology. Law. People (EPL)* is a non-governmental organisation that provides legal protection of the environment and monitors violations of environmental legislation.
- *SaveEcoBot* is an online platform and application that provides up-to-date information on the state of the environment in different regions of Ukraine and publishes analytical data.

- *The World Wide Fund for Nature (WWF)* in Ukraine is an international organisation that supports projects to restore natural ecosystems and conserve biodiversity.
- *The Ukrainian Nature Conservation Group (UNCG)* is an association of scientists and activists involved in research and conservation in Ukraine.
- *Global Environment Facility (GEF)* in Ukraine – finances projects to restore the environment and develop sustainable energy.
- *Zero Waste Lviv* is an organisation that promotes the concept of zero waste and waste sorting.
- *National Ecological Centre of Ukraine (NECU)* – promotes environmental policy and advocates for sustainable development.
- *Ukrainian Youth Climate Association (UYCA)* – unites young people to fight climate change and raise environmental awareness.
- *Let's do it Ukraine* is part of an international movement that organises environmental clean-ups and environmental education.
- *EcoClub (Rivne)* – promotes the development of renewable energy sources and energy efficiency in Ukraine.

These organisations deal with the problems of overcoming the environmental crisis, offer many public initiatives for people of different ages, and conduct workshops, trainings, and courses on environmental literacy. It is worth noting that the environmental sector in Ukraine is not limited to NGOs, but also includes government agencies, research institutes, educational institutions, civil society initiatives and international organisations. This demonstrates the diversity and breadth of the environmental movement in the country. However, due to the military operations in Ukraine, their activities are limited, they cannot pursue a broad environmental policy in the frontline areas, i.e. in the epicentre of the environmental threat, and they only try to overcome the consequences of pollution in Ukrainian territories. Although there is a lot of work being done, it is not as effective as it could be, as it does not address the source of the problems, only the consequences.

The above measures show that Ukraine is actively moving towards preserving the natural environment, restoring resources, and stabilising the environmental crisis in the post-war period.

In order to check the readiness of the population for active restoration and environmental protection work in the post-war period. These regions are safe compared to other regions during the war. Lviv region has strong eco-initiatives in waste recycling and energy efficiency. Vinnytsia region has a developed system of waste management and green space. In Khmelnytskyi region, there is a growing interest in renewable energy and agroecology. All three regions are dominated by the agricultural sector. Large-scale farming, the use of chemicals and changing landscapes create a high demand for environmental solutions: sustainable agronomy, soil protection and ecosystem approaches. That is why these areas were a logical choice for the study. We conducted a survey among 473 respondents in Vinnytsia, Khmelnytskyi and Lviv regions. The questionnaire included 10 key questions. The first of them was “What do you know about the environmental situation in Ukraine during the war period?” Answering this question, 328 (69.3%) respondents gave a short answer: “the ecological situation is terrible”, “Ukraine is in a deep ecological crisis”, “the war has added to the radiation tragedy at the Chernobyl nuclear power plant”, etc.; 145 (30.7%) respondents gave a more detailed answer, including: “large-scale destruction, explosions, fires, water, soil and air pollution – all this has catastrophic consequences for the ecology of Ukraine. The emissions of heavy metals and chemicals from burnt equipment and ammunition are particularly dangerous”. In general, the questionnaires of all respondents showed a deterioration in the environmental situation in Ukraine.

The second question of the questionnaire, “Where do you get information about environmental threats and dangers related to the war?” received the following popular answers: “from the media”, “from social networks – You Tube, Tic-Tok, Facebook”, “from magazines and newspapers”, and the Ukrainian population also learns information from various Telegram channels. In addition, 52 (10.9%) respondents indicated that they follow environmental information through the organisations “Ecology. Law. Human (EPL)” and “SaveEcoBot”, which publish analytics and maps of environmental pollution, as well as monitor reports from the Ministry of Environmental Protection and Natural Resources of Ukraine.

To the third question, “What environmental problems do you consider to be the most pressing after the war?” we offered the following answers: “air and soil pollution”, “destruction of forests and natural ecosystems”, “water pollution”, “garbage and wreckage of military equipment”, “radiation and chemical hazards”, and “their own option”. The respondents' task was to choose the most pressing problem. The answer to the question was almost unambiguous: 419 (88.9%) respondents chose “their own option” and listed the above problems.

To the fourth question, “What consequences of the war have had the greatest impact on nature in your region?” we offered the following answers: “environmental pollution in general”, “loss of biodiversity”, “destruction of natural landscapes”, “deterioration of water resources” and “my own option”. And 328 (69.3%) respondents chose the option “environmental pollution in general”.

The respondents answered the fifth question of the questionnaire "What eco-habits are typical for you?" as follows: 159 (33.6%) – "I have no eco-habits", 97 (20.5%) – "I sort garbage, try to dispose of waste properly", 94 (19.9%) – "I save resources: water, electricity, heat", 43 (9.1%) – "I take care of green spaces", 38 (8.0%) – "I take care of stray animals", 27 (5.7%) – "I participate in environmental initiatives of my community", 15 (3.2%) – "I donate to environmental funds for forest restoration". The findings showed that a large number of respondents have insufficiently developed environmental awareness and motivation to implement environmental practices in their everyday lives. Respondents mostly interpreted their position as follows: "there are more general issues now", "nothing will change from me and my actions, let the state deal with it". However, 314 (66.4%) respondents are engaged in various types of environmental activities, which can be an effective basis for overcoming the ecological crisis.

To the sixth question of the questionnaire "Are you ready to support the policy of environmental activism in Ukraine?" 41 (8.7%) respondents answered that they would most likely not support it due to different life circumstances, 126 (26.6%) respondents said they would definitely support it, despite different life circumstances, and 306 (64.7%) respondents said they would support it if they got to know the conditions in more detail and knew a clear algorithm of actions. Here is a detailed answer from one of the respondents: "I would support the policy of environmental activism, because the state of the environment directly affects our health, the future of our children and the overall quality of life. I have been sorting waste for three years now, but I would gladly support the initiative to green the territory, and I am ready to help restore the environment in the de-occupied territories on a volunteer basis even after the war".

The seventh question was: "Who should primarily deal with the environmental crisis?" And to this question, 104 (21.9%) respondents answered "the state", 68 (14.4%) – international organisations, and 301 (63.7%) – "me". The results demonstrate the active life stance of the population and their desire to change the conditions and quality of life for the better.

The eighth question "What environmental steps should the state take in the process of environmental policy?" received the following answers: "to record military environmental crimes of the russian federation", "to involve international organisations in solving environmental problems", "to develop a system of environmental education in Ukraine", "to establish the process of waste disposal and recycling", "to develop alternative energy", "to organise more frequent eco-initiatives among the population", etc.

The ninth question, "How will Ukraine's active environmental policy affect global environmental policy?" received the following answers: "stimulating international cooperation, which will increase confidence in the country on the world stage and create opportunities for joint projects", "reducing greenhouse gas emissions and switching to renewable energy sources will help reduce global pollution", "successful Ukrainian practices in the field of eco-innovation and sustainable development can be used by other countries as an example to follow, which will allow us to popularize our experience", "protection of natural resources and ecosystems of Ukraine, which is part of the global ecosystem, will have a positive effect on the entire planet", "reorientation of the economy to environmentally friendly production will increase the competitiveness of Ukrainian goods on the global market", "raising the level of environmental awareness of the population in Ukraine can become an example for neighboring countries, contributing to global changes in humanity's attitude to nature".

To the tenth question, "What can you personally do to overcome the environmental crisis in Ukraine?" the respondents answered as follows: "I will separate waste and recycle it"; "I will try to buy less plastic, choose reusable bags, bottles and containers, and avoid disposable items"; "I will save water and electricity, use energy-saving light bulbs and household appliances with a high energy efficiency class"; "I will not litter nature and will participate in cleaning parks, forests and water bodies during environmental campaigns", "If possible, I will prefer a bicycle or public transport to a car", "I will support organizations and projects that protect nature", "I will spread environmental knowledge among friends and acquaintances, because change begins with each of us", "I will behave responsibly while outdoors, not leave garbage and not harm the environment".

It is noteworthy that in answering the tenth question, each respondent chose their own way to stabilize the environmental crisis, which they proposed. And while 159 (33.6%) of respondents answered the fifth question that they had no eco-habits, answering the tenth question, respondents were able to analyze their life activities and determine what they could do for the environment on their own. The results show that Ukrainians are aware of the acute environmental crisis, are ready to engage in environmental activities, but need clear paths and civic initiatives to overcome it. In our opinion, an active environmental position will be a step towards overcoming the environmental crisis.

IV. ACKNOWLEDGMENTS

We would like to thank Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Khmelnytskyi Humanitarian and Pedagogical Academy, Ivan Franko National University of Lviv, and Vinnytsia Agrarian University for their help and assistance in conducting the survey among different age groups.

V. CONCLUSIONS

The war in Ukraine has caused large-scale environmental damage, affecting the quality of air, water and soil, as well as the country's biodiversity. Despite the difficult situation, Ukraine is already implementing innovative approaches to environmental restoration: from nature-based solutions and technological innovations to the development of environmental education and international cooperation.

The results of the survey show that people are aware of the severity of the environmental crisis and are ready to participate in environmental protection activities. Most respondents recognize the need to separate waste, save resources, and support environmental initiatives. However, a significant number of respondents need clear instructions and public projects to intensify their environmental activities.

Synergy between the state, civil society, and international organizations is an important condition for successful recovery. Priorities should include demining, restoring forests and water resources, developing a green economy, and improving the legal framework. Environmental education and awareness-raising will play a key role in shaping a culture of sustainable development.

Thus, the restoration of Ukraine's environment in the postwar period is possible only if a comprehensive approach is taken, with active participation of the population and integration of environmental principles into all spheres of life.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 523-527

Natural Soil Amendment Application in Agriculture

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***Abstract*—The aim of research was to evaluate the impact of low rates of application of environmentally friendly organo-mineral soil amendments on yields components (number of productive tillers m^2, 1000 grain weight, grain number per ear), grain yield and yield quality of spring and winter wheat under organic farming conditions. Soil amendments were obtained based of forest logging residues - lignocellulosic biomass, after isolation of polyphenols by water extraction and enrichment with silicon (Si), included the content of polyphenolic compounds. The soil amendments were used for seed material treatment. Field experiments were carried out in the certified organic farming field. The control variant and organo-mineral soil amendments, containing inorganic oligomer in various mass ratios (three variants) were tested. The varieties (spring wheat 'Robijs', winter wheat 'Edvins'), certified for growing under organic farming conditions, were used in trial. It was shown that the treatment of seed material with organo-mineral soil amendments increased the number of productive tillers as well as have a beneficial effect on the yield (the increase till 21.6% compared to the control) but decreased the number of grains per ear of spring wheat, depending on concentration of inorganic oligomers). In variant with the highest tested concentration of inorganic oligomer, a trend towards yield growth for winter wheat can be observed. The obtained results show that the treatment of seed material with promotes plant growth and development, researches should be continued.**

Keywords*— *organo-mineral soil amendments, organic farming, wheat, quality, polyphenols

I. Introduction

Wheat is the most widely cultivated cereal grain worldwide and plays a vital role in agriculture. Internationally, wheat provides approximately 55% of carbohydrates and 21% of the dietary calories consumed worldwide. Wheat also contains other beneficial components such as minerals (Cu, Mg, Zn, Fe, and P), protein, vitamins (riboflavin, thiamine, niacin, and alpha-tocopherol), also provides significant amounts of biologically active components that are essential or beneficial to human health. These include not only protein, vitamins, and dietary fiber, but also phytochemicals, such as polyphenols, which are primarily composed of flavonoids, phenolic acid, proanthocyanidins, and other compounds with powerful antioxidant, bacteriostatic, anti-infective, and preventive properties against numerous health problems [1-4]. In the previous study, the authors indicated that soil amendments increase yield and improve cereals' target composition [5]. Therefore, it is necessary to evaluate the effects of the resulting soil amendments on wheat yield and grain chemical composition, focusing on polyphenols, which could be done using the analytical pyrolysis method.

II. Materials And Methods

A. Field experiments

Field experiments were carried out in 2023/2024 growing season (winter wheat) and in 2024 (spring wheat)

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8670
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at the certified organic farming field (N 56º 69.275′, E 25º 14.173′). The soil at the site was sod-podsolic sandy loam. The soil is characterized by the following: pH_{KCl} 5.6, organic matter content 27 g kg^{-1}, P_2O_5 content 105 mg kg^{-1} and K_2O content 201 mg kg^{-1} of the soil. The cultivars 'Edvins' and 'Robijs', characterised by good productivity and winterhardiness (for winter wheat) under organic farming conditions, were used in the field trials. For winter wheat plot size was 0.9 m^2 (2 m x 0.45 m (3 rows)), four replicates, seed rate – 500 seed per m^2. For spring wheat plot size 13.5 m^2 (1.5 m x 9 m), sown with seeding machine Hege 80, four replications, seed rate – 550 seed per m^2.

The control variant and three variants of organo-mineral soil amendments, containing inorganic oligomer in various mass ratio, were tested: S1 – without soil additive; S2 – soil additive with 5% of Si; S3 – soil additive with 10% of Si and S4 – soil additive with 15% of Si.

Soil amendments were obtained based of forest logging residues-lignocellulosic biomass, after isolation of polyphenols by water extraction and enrichment with silicon (Si), included the content of polyphenolic compounds. The soil amendments were used for seed material treatment.

Organic or some other type of fertilizer have not been used in the previous 5 years, except for plant residues after harvest.

The grain yield of winter wheat obtained by indirect method – using a plant samples, in turn the grain yield of spring wheat obtained by harvester "Wintersteiger". After harvesting, grain was weighed, grain purity and moisture content detected and yield data were recalculated to standard moisture (14%) and 100% purity.

B. Yield-forming components

Yield-forming components were determined at growth stage (GS) 87-89 of wheat according to BBCH scale (the phenological growth stages of cereals according to the 'Biologisce Bundesanstalt, Bundessortenamt und Chemische Industrie' (BBCH) scale). The plant samples collected in each plot at two locations from 0.5 m^2: number of productive tillers per 1 m^2, grain number per ear calculated as the total number of grains in the plant samples divided by the number of productive tillers. Weight of 1000 grains determined according to standard EN ISO 520:2011 "Cereals and Pulses", using a "Pfeuffer CONTADOR" seed counter and an electronic balance.

C. Grain quality analyses

The quality indicators: protein content (%), gluten (%), Zeleny index, volume weight for the crops studied using near-infrared spectroscopy (NIRS) with analyzers Infratec TM NOVA. Falling number (s) for winter wheat was determined by the Hagberg-Perten method (ISO 3093: 2009).

D. Meteorological conditions

Meteorological conditions were characterised by measurements of air temperature (Fig.1) and precipitation (Fig. 2.), compared with long-term values. Data were obtained from the Skriveri Observation Station of the Latvian Environment, Geology, and Meteorology Centre (www.meteo.lv).

During the sowing of winter wheat (27.09.2024.), soil conditions for seed germination were favourable. October were very rainy, with warm air temperature. Vegetation ended on November 17, 2024, but renewed on March 15, 2025. The winter was warmer than long-term observations. The vegetation period of 2024 was characterized as dry and hot, and were not favourable for the growth and development of both winter and spring wheat. For several years now, the average daily air temperature had exceeded the long-term average air temperature, and this year it was also significantly higher.

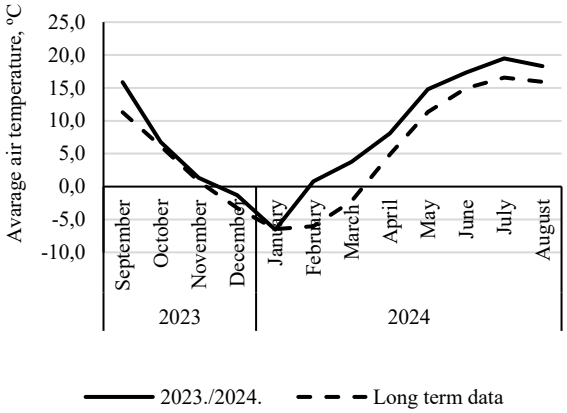

Fig. 1. Average air temperature in 2023/2024 growing season (Skriveri Observation station), ºC.

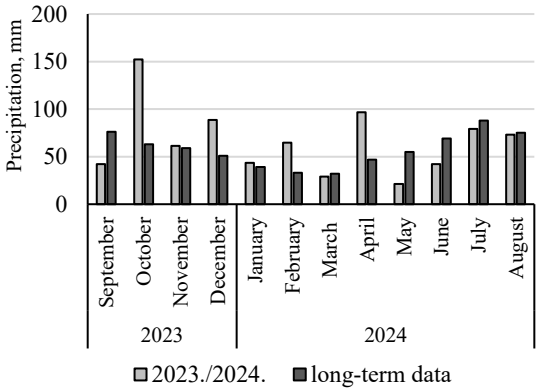

Fig. 2. Amount of precipitations in 2023/2024 growing season (Skriveri Observation station), mm.

During the sowing of spring wheat (02.05.2025.), soil conditions for seed germination were good, but a drought period began in May, which lasted until mid-august. Only in the first decade of June the amount of precipitation reached a norm (96% of the norm). Dry and hot weather promoted the ripening of wheat, winter wheat was harvested already on July 25, but spring wheat – on August 5, 2025. Drought stress is also evidenced by the short height of wheat (spring wheat only 50-55 cm).

D. Chemical characterization of grain

Analytical pyrolysis of wheat samples was performed using Frontier Lab Micro Double-shot Pyrolyser Py-

2020iD directly coupled with gas chromatography-mass spectrometer Shimadzu GC/MS/FID-QP ULTRA 2010 (Shimadzu, Kyoto, Japan). The individual compounds were identified based on GC/MS using Library MS NIST 11 and NIST 11s. The relative area of the peak of individual compounds was calculated using Shimadzu software based on GC/FID data. The variation coefficient of the measurement was ≤ 3%.

E. Statistical analyses of data

The analysis of variance by R-studio was used for statistical analysis of the experimental data (yield forming compounds, yields). Bonferroni test was used for the comparison of means at $p<0.05$. Significantly different values were labelled with different letters in superscript (^{a,b}). If effect of studied factor was not significant ($p>0.05$), used symbol "n".

III. RESULTS AND DISCUSSION

A. Yield components

Yield of any crop is mathematical function of separate yield components such as the number of plants per unit area and productivity of an individual plant. For cereals the number of productive tillers per 1 m^2, number of grain per ear, and 1.000 kernel weight is measured.

Yield components formed sequentially throughout the plant' development. The yield-forming elements of the crops affect the yield by interacting each other [6].

Analysing the yield-forming components for winter wheat, no significant ($p>0.05$) differences among the variants were found (Table 1).

TABLE 1 YIELD-FORMING COMPONENTS OF WINTER WHEAT

Variants	Number of productive tillers per 1 m^2, pieces	Number of grains per ear, pieces	Weight of 1000 grains, g
S1	308.8^{n}	28.8^{n}	33.5^{n}
S2	309.9^{n}	28.8^{n}	33.7^{n}
S3	317.0^{n}	29.3^{n}	33.4^{n}
S4	322.1^{n}	29.8^{n}	33.6^{n}

S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si; ^{n} - effect of studied factors was not significant ($p>0.05$).

The treatment of seed material with organo-mineral soil amendments increased the number of productive tillers of spring wheat. A significant increase ($p<0.001$) of productive tillers compared to the S1 (without soil additive) was obtained only in variant S4 with the largest concentration of Si (15%) (Table 2.).

However, in that variant (S4) were obtained significantly lower ($p<0.001$) grain number in ears. The weight of 1000 grains was similar in all tested variants, which can be explained by the dry period during the maturation of the grain.

TABLE 2. YIELD-FORMING COMPONENTS OF SPRING WHEAT

Variants	Number of productive tillers per 1 m^2, pieces	Number of grains per ear, pieces	Weight of 1000 grains, g
S1	338.9^{b}	26.8^{ab}	31.1^{n}
S2	367.8^{ab}	27.5^{a}	31.7^{n}
S3	396.1^{ab}	26.3^{ab}	31.2^{n}
S4	433.8^{a}	25.3^{b}	31.4^{n}

S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si; ^{n} - effect of studied factors was not significant ($p>0.05$),^{a,b} – effect of studied factors was significant ($p<0.05$)

B. Grain yield

The obtained yields correspond to the average yields in trials conducted under organic farming conditions in the Baltic region [7-9]. Treatment of seed material with organo-mineral soil amendments, containing inorganic oligomer, increased the grain yield both spring and winter wheat. However, a significant yield increase ($p<0.001$) compared to the S1 (without soil additive) was obtained only in variant S4 (soil additive with 15% of Si) for spring wheat (Fig. 3.).

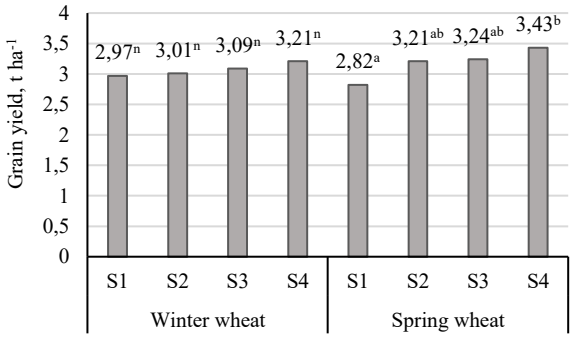

Fig. 3. The grain yield of wheat, t ha^{-1}.
S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si; ^{n} - effect of studied factors was not significant ($p>0.05$) for winter wheat, ^{a,b} - effect of studied factors was significant ($p<0.05$) for spring wheat.

C. Grain quality

The grain quality indicators were analysed using near-infrared spectroscopy only for spring wheat. The dry and hot weather also significantly affected the grain quality of spring wheat. Unfortunately, the grain quality indicators do not meet the requirements of food wheat. The grain has a good protein content (12.4-13.5%) and gluten content (23.1-26.4%) as well as gluten quality (Table 3).

However, the grain obtained in the trial has a low volume weight (<730 g L^{-1}) (Table 3).

D. Chemical characterization of grain

The Py-GC/MS/FID data represent volatiles formed from cellulose, hemicellulose, lignin, and extractives. Carbohydrates-derived volatiles represented 98-99% of

the total wheat biomass volatile organic products. When comparing wheat samples with and without soil additive, the relative content of phenyl- and benzyl derivatives in wheat samples grown on treated soil (S2-S4) was higher, thereby demonstrating the beneficial effect of soil additives on target compounds content (Fig. 4.).

TABLE 3. PROTEIN CONTENTS AND QUALITY FOR SPRING WHEAT

Variants	Protein content, %	Gluten, %	Zeleny index, ml
S1	13.5	25.7	51.86
S2	13.5	25.8	52.11
S3	13.0	24.7	47.38
S4	12.4	23.1	43.11

S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si

TABLE 4. VOLUME WEIGHT AND FALLING NUMBER FOR SPRING WHEAT

Variants	Volume weight, g L^{-1}	Falling number, sec
S1	726.6	300
S2	717.8	307
S3	724.7	289
S4	729.0	292

S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si

The target compound tended to grow with the content of Si in the soil additive. However, this increase was within the variation coefficient.

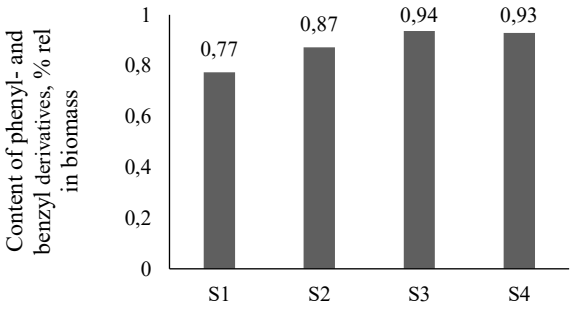

Fig. 4. Soil additive effect on the content of phenyl- and benzyl-derivatives in wheat based on analytical pyrolysis data of wheat samples: S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si.

The content of total phenyl and benzyl derivatives formed from extractives ranged from 0.77 to 0.93 rel% in biomass. Among the phenyl and benzyl-derived volatiles, the predominant one is phenyl, 3 and 4 methyl-derived volatiles as methoxy-substituted benzoquinone, which has been proven to have potential antitumor and immunostimulating activity (Fig.5).

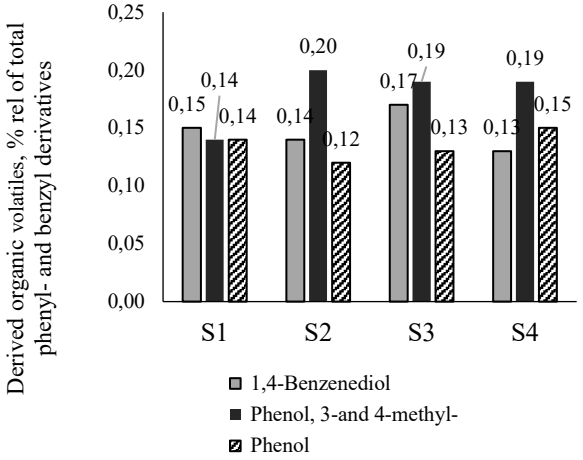

Fig. 5. Analytical pyrolysis data of phenyl and benzyl-derived volatiles of wheat samples: S1 – without soil additive; S2 – soil additive with 5% of Si, S3 – soil additive with 10% of Si; S4 - soil additive with 15% of Si

IV. CONCLUSIONS

In variant with the highest tested concentration of inorganic oligomer, a trend towards yield growth for wheat can be observed (increase of productive tillers).

The study's results showed a positive effect of the soil additive (S2-S4) on the content of biologically active compounds in wheat samples. The higher content of phenyl and benzyl derivatives in wheat grains may indicate an increased content of phenolic acid, flavonoids, benzoquinone compounds, etc., – compounds with documented antitumor and immunostimulating properties.

The obtained results show that the treatment of seed material with promotes plant growth and development, researches should be continued.

V. ACKNOWLEDGMENTS

Rural Support Service of the Republic of Latvia, European Agricultural Fund for Rural Development (EAFRD), Measure "Cooperation", project No. 23-00-A01612-000008 "Wasteless application of residual logging biomass for obtaining of environmentally friendly plant protection products and soil additives".

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 529-535

Significance of Groundwater Resources for Provision of Water Consumption in Varna District

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***Abstract*— This study highlights the significance of the groundwater resources in present state of water use in Varna District in the context of provision of essential needs and demands of the society and economic development. The household water supply in the Varna region sourced from groundwater over an eight-year period (2016–2023) is analysed. A primary trend identified in water consumption is the decrease in the volume of used groundwater. Household consumption represents a significant portion of the total water usage, predominantly concentrated in the city of Varna. Public water supply dominates, accounting for over 99% of the total water volume during the period under review. The overall reduction in water consumption is approximately 22.4%. Industrial water usage remains stable throughout the study period, with an upward trend observed in specific sectors such as the chemical and food processing industries. Agricultural consumption of freshwater from groundwater sources is also notable, particularly in cases of private water supply for irrigation of agricultural crops. The water use from private water supply in this sector fluctuate considerably, ranging from 1,367,245 m³ in 2016 to 2,040,130 m³ in 2023. Water consumption in Varna region shows significant seasonal variation. A general trend of water consumption indicates pronounced seasonal irregularities, with a sharp increase during the summer months, especially in resort areas and settlements with tourism development potential. The expansion of settlements, including the incorporation of new territories into urban planning and the reclassification of agricultural lands, has not been accompanied by adequate water supply infrastructure in recent years. This has hindered the provision of reliable water services to consumers. Sustainable management of groundwater resources and the optimization of their utilization will be the key to ensuring long-term water security in the region.**

Keywords – Groundwater abstraction, Water supply, Private water supply, Water consumption

I. INTRODUCTION

On a global, national, and regional scale, the quality and quantity of groundwater resources are of critical importance [5], [11], [21], [22]. Groundwater is one of the most valuable natural resources, playing a crucial role in urban, rural and industrial development. It serves as a primary water source for industrial processes and plays significant role in sustaining ecosystems and biodiversity. The significance of groundwater is most evident in regions with limited surface water resources or during drought seasons. Groundwater serves as a primary source for drinking water supply, agriculture, industry, and energy production [2], [3], [4], [18], [19], [22]. Moreover, it plays a vital role in maintaining the water balance of ecosystems, providing moisture to rivers and wetlands even during periods of low precipitation. According to the latest report by the European Environment Agency (EEA), groundwater provides approximately 65% of the drinking water in the European Union and over 25% of the water used in agriculture. [1], [9].

Nevertheless, globally, and particularly in Europe groundwater is under considerable pressure from human activities, excessive water abstraction, leading to depletion, decrease in groundwater levels and a decline in water quality [1], [6], [9], [19], [25]. Past and present patterns of resource utilization have led to high levels of pollution, environmental degradation, and depletion of natural resources. Simultaneously, seasonal variations in surface water availability are becoming increasingly unpredictable, which inevitably affects the state of groundwater resources as well [2], [3].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8691
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In the context of globalization, increasing human population, respectively constantly increasing water consumption, and climate change, sustainable management of groundwater is becoming a primary challenge for modern societies [6], [10], [11], [20].

Bulgaria and Varna region in particular is no exception to the broader global and European trends, e.g. 24% of all EU groundwater bodies are in poor chemical status, while 9% are in poor quantitative status, referring to years from 2016 to 2021. The combined assessment of chemical and quantitative status reveals that 29% of groundwater body areas lack sufficient capacity to meet the needs of ecosystems and society due to deterioration in quality or quantity [14]. In recent years, groundwater abstraction in Bulgaria has accounted for 47-55% of the total water abstracted for public water supply in the country [1], [9]. In Varna district the water consumption varies seasonally and increases significantly during the summer period mainly due to the large number of tourists and recreational users visiting the resort areas.

The present study aims to analyse groundwater consumption trends by different users for the period 2016–2023, with focus on groundwater abstraction and consumption analysis, and thus to highlight the groundwater resources importance in the context of water provisioning for Varna region.

II. MATERIALS AND METHODS

The Varna district is located in the North-Eastern part of Bulgaria. It covers area of 3 818 km², representing approximately 3.44% of the territory of Bulgaria. The region comprises of 158 settlements, gathered in 12 municipalities: Varna, Aksakovo, Avren, Beloslav, Byala, Vetrino, Valchi Dol, Devnya, Dolni Chiflik, Dalgopol, Provadia, and Suvorovo municipality [26].

The permanent residents of Varna district reach 434191 inhabitants in 2023, accounting for 6.7% of Bulgaria's population. Thus, the district of Varna ranks third in terms of population after the capital Sofia and the Plovdiv region [26]. During the summer tourist season, the population of Varna town increases significantly, reaching over a million.

Publicly available data on water abstraction and consumption from the National Statistical Institute of Bulgaria, Eurostat, as well as data from the Black Sea Basin Directorate were used to determine the significance of groundwater resources for meeting water needs in Varna region. Balance calculations are attached to the data. The data were obtained through comprehensive control and operational monitoring from points of groundwater bodies in independent karst basins, alluvial deposits, and high-flow springs with a discharge rate of no less than 1.0 l/s. Additionally, data were collected from facilities operated by "Water Supply and Sewerage" companies, "Irrigation Systems," boreholes from self-monitoring networks, and facilities constructed for groundwater observation (monitoring points).

The use of the withdrawn water quantities by the purpose of water abstraction has been analyzed. The distribution by production activities is grounded on reported data and balance calculations.

III. RESULTS AND DISCUSSION

Within the Varna district, 18 groundwater bodies have been identified, distributed across 5 aquifer horizons as follows: Quaternary Aquifer Horizon – 4 groundwater bodies, Neogene Aquifer Horizon – 7 groundwater bodies, Upper Cretaceous Aquifer Horizon – 2 groundwater bodies, Lower Cretaceous Aquifer Horizon – 3 groundwater bodies and Malm-Valanginian Aquifer Horizon – 2 groundwater bodies [24].

All groundwater bodies in Varna district are appointed in good quantitative state during the whole period from 2021 to 2023. Three underground water bodies are identified as being exposed to pressure from marine intrusion due to proximity to or less than 1 km from the Black Sea coastline: BG2G000000Q014 Pore waters in the Quaternary of the Dvojnitsa River: BG2G000000Q002 Pore waters in the Quaternary of the Batova River; BG2G00000PG026 Pore waters in the Paleogene-Eocene Varna-Shabla

Due to differenr factors - agricultural pressure, industrial pressure, pressure from urban wastewater and salt water penetration 27,77% of groundwater bodies in Varna district are assessed to be in poor chemical condition.

Water abstraction from all water bodies is carried out for different purposes – for drinking and domestic water supply, for agricultural purposes (irrigation), for industrial purposes, for cooling, for aquaculture and others. The available water quantities vary significantly by groundwater bodies: from 18 l/s (BG2G000000Q002 Pore waters in the Quaternary of the Batova River) to 2126 l/s at BG2G000000N018 Pore waters in the Neogene-Sarmatian Northeastern and Middle Dobrudzha.

The inner structure of abstracted freshwater is dominated by the surface water sources. The relative share of groundwater varies from 9.9% in 2016 to 11.06% in 2020 of total gross water abstraction. Surface waters are the main and highest source of total water abstraction and water supply. Their share remains relatively stable, with a single drop observed in 2020, attributed to industrial stagnation and the global health crisis.

In 2023, the share of groundwater is higher compared to 2016, which may indicate an increased need for alternative water sources or a reduction in the availability of surface water. The peak groundwater abstraction was observed in 2017 (581.75 million m³), while the lowest level was in 2021 (538.81 million m³). Groundwater abstraction in 2023 reached 546.48 million m³, demonstrating a slight recovery compared to 2021.

During the analyzed period, there is a general trend of declining water abstraction from both surface and groundwater sources for public water supply in the

country. In 2016, water abstraction from surface water sources was 421.29 million m³, reaching its lowest level in 2020 (360.05 million m³). After 2020, a slight recovery was observed, reaching 381.53 million m³ in 2022, but in 2023, there was another decline to 372.31 million m³.

Groundwater abstraction started at 454.07 million m³ in 2016 and reached its peak in 2017 with 467.90 million m³. Subsequently, a decrease followed, reaching 429.15 million m³ in 2022, followed by a slight increase to 433.55 million m³ in 2023. This indicates a greater reliance on groundwater sources for drinking water needs and highlights their significance in ensuring potable and domestic water supply security (Fig. 1).

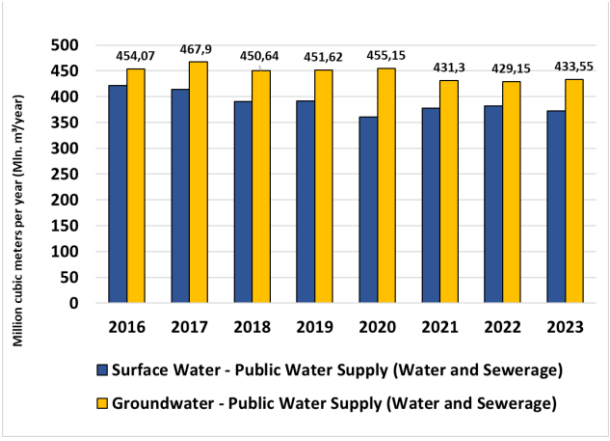

Fig. 1. Drinking water abstraction by sources, Bulgaria (2016-2023), Based on National Statistical Institute data.

The presented data show the annual volume of abstracted water (million m³) from Groundwater Bodies in the Varna district over an eight-year period (2016 –2023). Changes in water abstraction levels, as well as the overall trend, are influenced by natural (seasonal), socio-economic, and climatic factors specific to the region.

Within 2016 - 2021, a steady decline in the volume of abstracted water was observed. A slight recovery occurred in 2022, yet abstraction volumes remained below those recorded at the beginning of the period. Maximum water abstraction of 777.27 million m³ was recorded in 2016 and minimum – 601.60 million m³ in 2022. Total reduction of 175.67 million m³, corresponding to a 22.6% decrease was registered comparing 2016 in 2022 (Fig. 2) [16], [17].

Changes in water abstraction levels are due to decreasing precipitation and increasing droughts, exerting pressure on the region's water supply, particularly during the summer months [18]. Another reason might be the reduced water consumption in industry and agriculture, reflecting shifts in economic activities and resource efficiency. This trend underscores the need for adaptive water resource management to address challenges associated with climate variability and evolving water demands across different sectors.

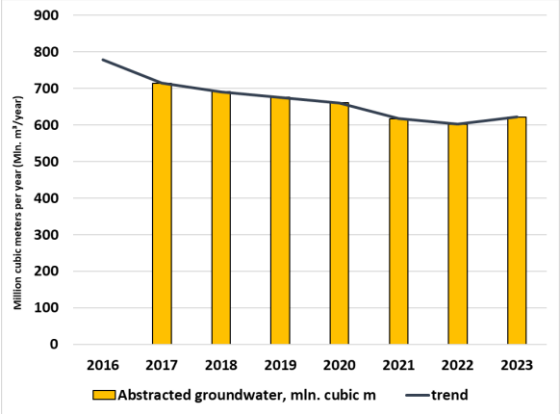

Fig. 2. Abstracted Water Volumes (Mln m³) from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD - Varna Data.

Regarding public drinking and household water supply from groundwater sources in the Varna Region, the volume of abstracted water has significantly declined over the years, from 70.41 million m³/year in 2016 to 54.65 million m³/year in 2023. Public water supply dominates, accounting for over 99% of the total water volume during this period. The overall reduction amounts to approximately 22.4% (Fig. 3).

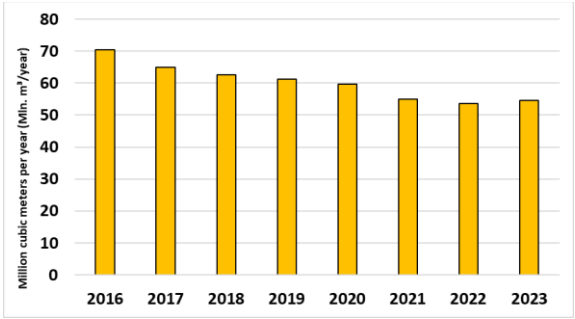

Fig. 3 Utilized Water by Type of Water Supply from Groundwater Bodies in the Varna Region (2016–2023).

In contrast, private drinking and household water supply, where abstracted water is used for domestic consumption, represents significantly lower volumes, fluctuating between 0.588 million m³/year (2021) and 0.758 million m³/year (2020). The minimum recorded volume was in 2016 (0.588 million m³/year), followed by an increase of approximately 28.8% until 2020, after which a decline was observed in 2021 (Fig. 4). While this type of water supply accounts for around 1% of total water use, it plays a crucial role in local and remote areas of the city and suburban zones. Although the volumes remain relatively low, they are highly sensitive to local variations in water sources within the region.

A detailed analysis of public drinking and household water supply reveals that water consumption is highest during the summer months, particularly in 2016, when a peak of 6.402 million m³ was recorded. The lowest consumption is observed during winter. In 2022, the most significant decline of water usage was recorded, dropping to 3.780 million m³, as illustrated in Fig. 5.

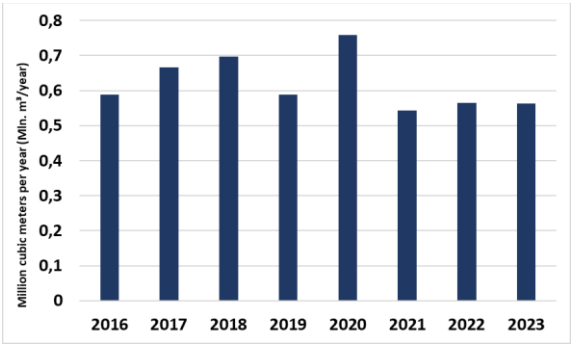

Fig. 4. Utilized Water by Type of Water Supply from Groundwater Bodies in the Varna Region (2016–2023).

A seasonal analysis of private drinking and household water supply reveals pronounced seasonal fluctuations, with increased water consumption during the summer months. (Fig. 6).

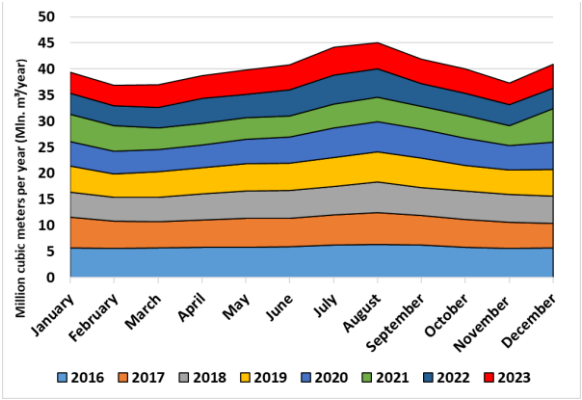

Fig. 5. Monthly Utilized Water for Public Drinking Water Supply from Groundwater Bodies in the Varna Region (2016–2023)

July and August consistently show the highest water consumption across all years, with a peak recorded in 2018 (0.0795 million m³). In August 2023, water consumption slightly decreased to 0.4905 million m³. Winter months also exhibit a trend of increased water usage, while spring and autumn remain relatively stable, with moderate growth in certain years. Despite being lower than summer consumption, winter water usage peaked at 0.0672 million m³ in 2020.

The main trend in water use for public irrigation of agricultural crops shows a significant decline of 85%, decreasing from 0.650 million m³ in 2016 to 0.096 million m³ in 2023. The data indicate a steady and continuous decrease in water use, with minor variations. This decline is primarily attributed to utilization of alternative water sources, reduction of agricultural land and irrigation needs (Fig. 7).

In contrast, private water supply for agricultural irrigation exhibits significant fluctuations, ranging from 1.367 million m³ in 2016 to 2.040 million m³ in 2023, marking an increase of 49.3% over the period. This growth reflects structural changes in groundwater use in the Varna Region, indicating a greater reliance on private water sources for irrigation. The volume of abstracted water for livestock farming varies between 0.856 million m³ (2022) and 1.092 million m³ (2019), showing moderate fluctuations over the years. Water use for aquaculture remains insignificant compared to other sectors in agriculture, forestry, and fisheries. The recorded volumes range from 0.0008 million m³ (2016) to 0.004 million m³ (2023). Although small in scale, the most recent data indicate a decline in water use for aquaculture activities.

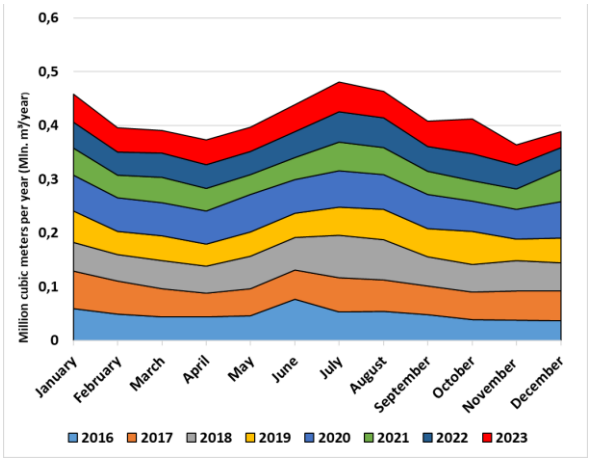

Fig. 6. Seasonal Variation in Private Drinking and Household Water Supply from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

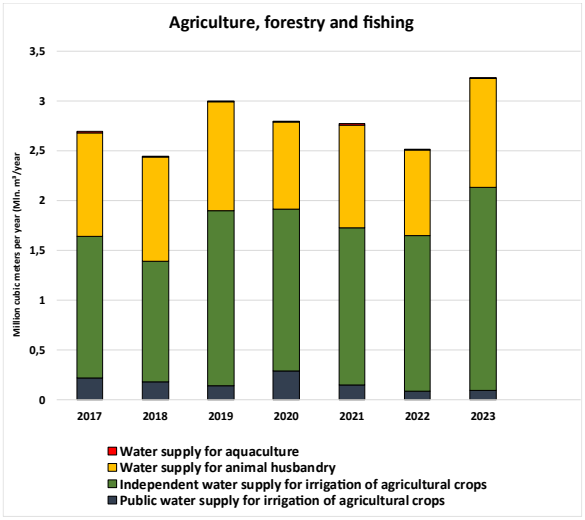

Fig. 7. Water Consumption from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

A significant seasonal pattern in irrigation water use is observed, with high volumes recorded during the summer months of June, July, and August (Fig. 8 and 9). This trend is directly related to the need for crop growth maintenance during the hottest months of the year, highlighting the importance of proper resource allocation and integrated water management.

The observed trends necessitate a seasonal strategy for water resource management. Climate change, rising temperatures, and irregular precipitation patterns may further increase irrigation demands. Spring and summer are the most vulnerable seasons in terms of climatic anomalies, requiring adaptive measures to ensure water availability. High water consumption during these months

exerts significant pressure on available water resources, particularly in regions of the Varna area with limited access to water. Implementing integrated water management strategies is essential to mitigate the impacts of seasonal fluctuations and ensure sustainable agricultural production.

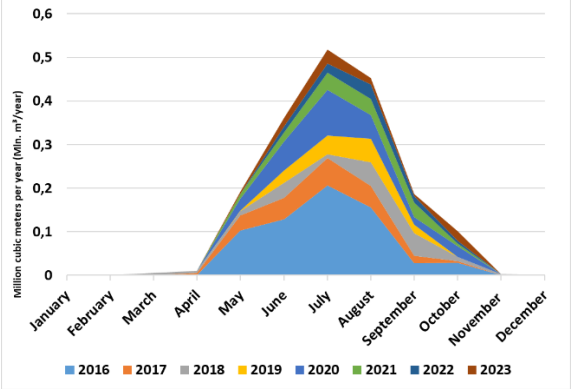

Fig. 8. Monthly Utilized Water for Irrigation from Public Water Supply from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

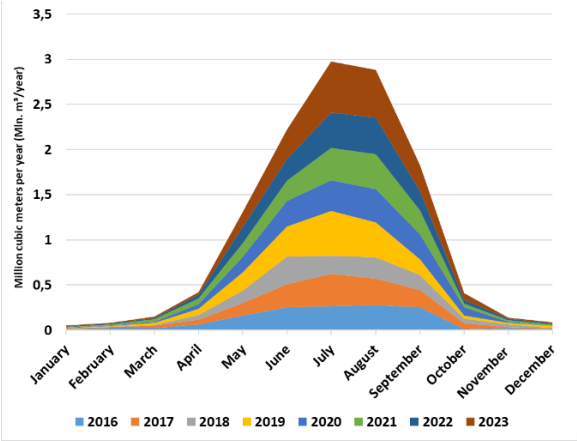

Fig. 9. Monthly Utilized Water for Irrigation from Private Water Supply from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

A steady increase in water consumption for livestock farming is observed during March, April, and May, coinciding with increased agricultural and breeding activities in this period. July and August show the highest water consumption, with peaks recorded in 2023 (0.0185 million m³) and 2018 (0.100 million m³). Winter months (December, January, February) have the lowest water usage, with values ranging between 0.0016 million m³ and 0.022 million m³. This pattern highlights the seasonal variations in water demand, with higher requirements during spring and summer and reduced consumption in winter.

An analysis of water usage for aquaculture reveals that the highest values were recorded in December 2017 (0.065 million m³), where consumption significantly exceeded that of other months. A similar peak was observed in December 2021 (0.0029 million m³), indicating periodic increases in water demand for aquaculture activities.

The lowest consumption levels were recorded in 2016 and 2020, with minimal monthly water use for aquaculture. This variability suggests that aquaculture water consumption is highly dependent on specific operational cycles and external factors such as seasonal production and environmental conditions.

An analysis of water abstraction for cooling reveals two distinct phases during the study period (2016–2020). A 54.8% decrease in water use for cooling was observed, reaching an absolute minimum of 0.942 million m³ in 2020. This decline is attributed to technological advancements, reduced industrial production, and shifts in the economic structure of the Varna region- Recovery Phase (2021–2023). Following 2020, water abstraction volumes began to recover, reaching 1.735 million m³ in 2023, approaching the 2016 level of 2.084 million m³ (Fig. 10). This revitalization of industrial activity in the region places significant pressure on groundwater bodies, which remain the primary source of drinking and household water supply. The growing demand highlights the need for integrated water resource management strategies to ensure sustainable groundwater use amid increasing industrial recovery.

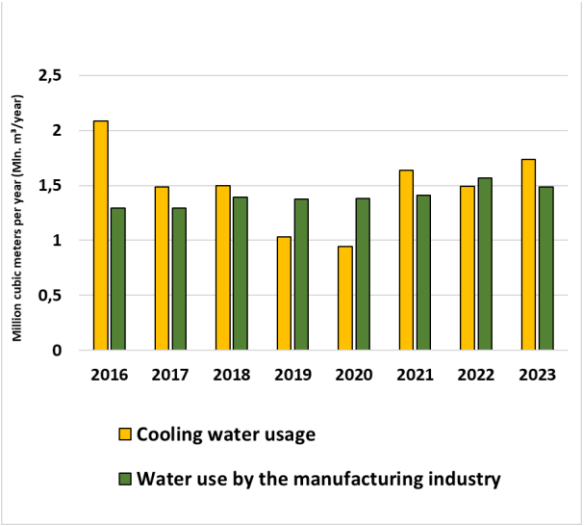

Fig. 10. Water Abstraction for Cooling and Manufacturing Industry from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

A peak in water consumption for cooling is observed during the summer months (July and August), particularly in 2021, when volumes exceeded – 0.290 million m³ in August, 0.221 million m³ in July. The lowest consumption is recorded in February and December, with the minimum value of 0.457 million m³ in November 2021 (Fig. 11). During the winter months (December–February), a general decline in water consumption is observed, except for December 2023, when volumes reached 0.165 million m³. This seasonal variation highlights increased cooling demands during the hottest months, emphasizing the

importance of resource planning and efficiency measures to optimize water use in industrial processes.

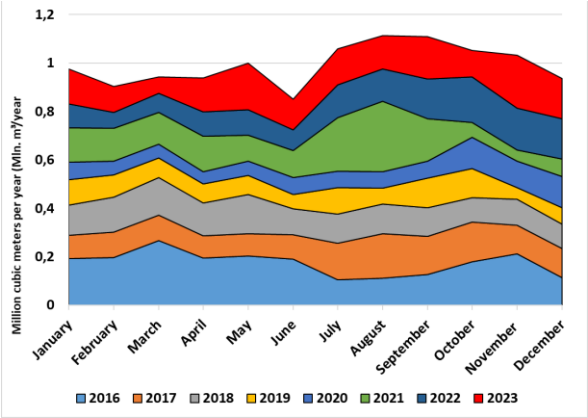

Fig. 11. Seasonal Water Consumption for Cooling from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

A significant shift is observed in the trend of water use for industrial water supply, including self-sufficient drinking and household water supply, particularly in cases where abstracted water is utilized for the production of food, pharmaceuticals, or cosmetic products. In 2022 was recorded the highest water consumption at 0.1567 million m³, marking a 20.9% increase compared to 2016. The lowest consumption was in 2016 (0.131 million m³), with the most significant growth occurring between 2021 and 2022. Stabilization was observed in 2023, but water abstraction volumes remained high. This trend reflects growth in the industrial sector, as well as substantial changes in production processes that require increased water consumption. These findings emphasize the need for efficient water management strategies to support industrial expansion while ensuring sustainable water resource use.

The highest water consumption levels are observed during the summer months (June, July, and August), with July 2022 recording the peak consumption at 0.157 million m³. Spring months (April and May) also exhibit high consumption, particularly in 2022. The lowest consumption levels occur during winter months, especially December and January, with the minimum recorded at 0.076 million m³ in December 2016. December 2021, however, shows a significant increase, reaching 0.211 million m³, indicating variations in industrial demand (Fig. 12). These seasonal fluctuations highlight the dynamic nature of water demand in the manufacturing sector, influenced by seasonal production cycles, economic activity, and industrial processes requiring water-intensive operations.

Water consumption for other purposes experienced the largest decline from 460 644 m³ in 2016 to 281 945 m³ in 2017, representing a 38.8% decrease. After 2018, the data indicate a steady increase, with volumes reaching 502 651 m³ in 2023, marking a 78.3% rise compared to 2017 (Fig. 13). Despite the upward trend, significant fluctuations and dynamic variations in water use for other purposes remain evident, highlighting the variable demand influenced by multiple factors.

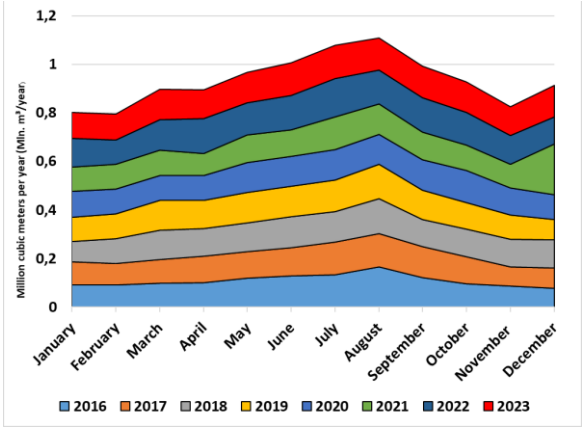

Fig. 12 . Monthly Utilized Water for the Manufacturing Industry from Groundwater Bodies in the Varna Region (2016–2023), Based on BSRBD – Varna Data.

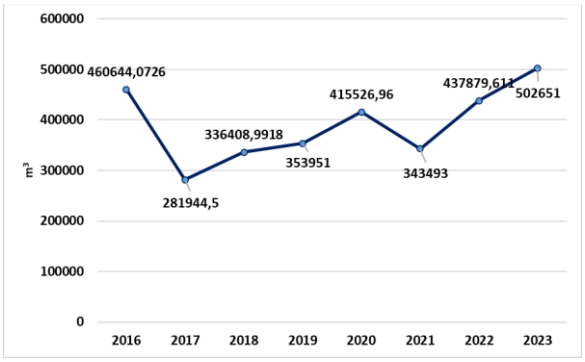

Fig. 13. Abstracted Water Used for Other Purposes from Groundwater Bodies in the Varna Region (2016–2023).

The highest recorded consumption was in August 2023 (84 195 m³), significantly exceeding previous years. Summer months (June, July, and August) consistently show high values, reflecting seasonal demands. The lowest consumption was recorded during winter months, with January 2017 registering only 7354 m³. A notable increase was observed in October 2023 (51 882 m³), marking a significant deviation from previous years.

IV. CONCLUSIONS

The share of groundwater in total water consumption in Bulgaria increased from 9.9% in 2016 to 11.06% in 2020, indicating a growing dependence on groundwater as an alternative source for the country.

Groundwater abstraction in the Varna region for the period 2016–2023, showing a decline of 22.6%, highlights a positive trend in resource management. Groundwater used for drinking purposes through public water supply accounts for between 90% and 87% (2016-2023) of the total water consumption in the area. The data emphasize the current state of water consumption in the Varna region and the significant role of groundwater in compensating for the shortage of surface water.

Groundwater is critically important for the water supply of the Varna region, especially during seasonal peaks in consumption and in the context of climate change. During the summer season, when water consumption increases significantly due to the influx of tourists and seasonal workers, groundwater provides a critical reserve for domestic, agricultural, and industrial needs. A clearly defined peak in groundwater use is observed during the summer months, demonstrating its significance in the context of unpredictable rainfall and droughts in the region.

Changes in the structure of groundwater use in the area and the recovery of water consumption in industry and agriculture after 2021 highlight the need for sustainable groundwater exploitation to ensure water security and supply stability in the region.

Industrial water consumption remains stable, with growth in specific sectors such as the chemical and food processing industries. Water use for cooling in the industry showed a significant decrease until 2020, with a decline of up to 54.8%, followed by a recovery until 2023, reflecting the economic revitalization of the region.

Agricultural water consumption through public water supply decreased by 85%, which may be due to a shift to alternative water sources or a reduction in agricultural land. However, private water supply for irrigation showed a growth of 49.3%, highlighting the increased dependence on independent water sources for agricultural needs.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 537-545

Production and Consumption of Organic Food in the Republic of Bulgaria - Problems and Prospects

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Abstract. **Abstract: The article examines the trends and prospects for the production of organic food in the agricultural sector in the Republic of Bulgaria in the short and long term, as well as the problems faced by producers of organic food and organic products in a national and pan-European perspective. The production of organic food in the agricultural sector of the Republic of Bulgaria lags significantly behind compared to other countries. It represents only 2.3% of the total agricultural production of the country. At the same time, the Republic of Bulgaria, both in terms of climate, soils, and the degree of preservation of natural ecosystems, is extremely favorable for the development of organic agriculture and production of organic food in the agricultural sector. By offering relatively healthier food products and by protecting the environment, the production of organic food in the agricultural sector works in the interests of consumers. The production of organic food and organic products aims to support the health of consumers and is beneficial to the entire society.**

Keywords—improving environmental sustainability, organic food production, shortening organic food supply chains, supply chain control

INTRODUCTION

The production of organic food in the agricultural sector, both on a global and pan-European scale, has grown extremely rapidly in recent decades at the end of the 20th and the beginning of the 21st century. This increase is caused by a complex of factors, among which the leading ones are:

- the aspiration of more and more people towards healthier eating;
- the desire of people in developed countries to consume better quality and more complete foods;
- the desire of more and more people to reduce the consumption of foods that have been treated with plant protection preparations and other chemical agents due to the appearance of allergies and other health problems;
- the attempt to limit the production and sale of genetically modified agricultural products;
- the desire of more and more people for an environmentally friendly lifestyle and diet.

The production of organic food in the agricultural sector in the Republic of Bulgaria at the current stage of development of the Bulgarian agriculture significantly lags behind both in European and global terms. At the same time, the demand for organic food in the commercial network and in the network of local farmers' markets in the Republic of Bulgaria is constantly growing. Currently, demand for organic foods is outpacing supply. This is the reason why the areas sown with agricultural organic products or used for organic animal husbandry are constantly increasing and at a rapid pace. The last two years are an exception, when these areas decreased by 20%. This decrease is in 2023 compared to 2021. The reasons for this decrease are complex. First of all, the political instability during this time period can be pointed out as a reason. Secondly, a serious reason is the strengthening of bureaucratic requirements and changes in regulatory measures. Thirdly, we can point out the effects of the Covid-pandemic, which affect both the production and consumption of organic food in Bulgaria.

In terms of growth rate, organic production in Bulgaria in the last two decades has seen a relatively rapid development. These high rates of growth of the areas for

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8674
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the production of organic food put our country in seventh place in the world in terms of the increase of the areas on which plant crops and breeding animals are grown according to the requirements for organic production, according to data from research by [4]. Despite the rapid pace of development, organic agriculture and the production of organic food, in particular, in the Republic of Bulgaria are still lagging behind both in comparison with other European countries and in relation to the dynamics of consumption growth.

In practice, a large part of the organic foods sold in Bulgaria are imported from other countries. Taking into account the fact that, according to the assessment of the former Minister of Agriculture and Food in the Republic of Bulgaria, only 5% of the food offered in the commercial network in Bulgaria was produced in the country. In this modest 5%, the relative share of organic foods of agricultural origin is even smaller [18]. The production of organic food in the agricultural sector of the Republic of Bulgaria represents only 2.3% of the country's total agricultural production. In parallel, a significant part of this production is aimed at export, because biofoods are in high demand on international markets. Organic foods are sold at higher prices and provide better profitability compared to foods that do not have the characteristics and status of organic foods.

In contrast to the recent past, when food production in the agricultural sector mainly pursued quantitative results, today more and more attention is paid to the quality of food and to the formation of sustainable food systems in the context of the European and national orientation towards the development of "green economy'.

It can be summarized that the Republic of Bulgaria in many respects has a good potential for the production of organic food. This potential is manifested in the following conditions and facts, which turn Bulgaria into a unique producer for some of the organic foods, which occupy an increasingly large share in the consumer basket of Bulgarian and European citizens [11].

First of all, the favorable climate for the production of agricultural products can be highlighted;

In the second place, a factor strengthening the potential for organic food production in Bulgaria, we can place the good traditions in the field of agrarian food production, mainly in the sectors of fruit growing, vegetable production, game and fish farming, beekeeping and mushroom growing;

The third most important factor forming the potential for biofood production is the relatively preserved and clean nature as a result of deindustrialization;

A fourth factor, in this regard, is the transition from a conventional to a "green economy", where organic food production is an essential component of the European Union's green strategy.

The fifth factor is the development of specialized small farms, which try to offer their ecologically clean agrarian products on the local markets and even supply some of the large commercial chains in Bulgaria.

Sixth in order, but no less significant factor, are the "fashionable" trends in nutrition, in which organic foods are becoming more and more desirable and more and more sought after not only by paying buyers, but even by mass average consumers of quality food.

MATERIALS AND METHODS

Publications in the specialized literature, as well as data from specialized Internet sites, will be the priority source of data for this presentation. I will try to summarize, systematize and organize data on the production and consumption of organic foods in the Republic of Bulgaria. The National Statistics Office in the Republic of Bulgaria does not publish separate data on the production and consumption of organic foods. They are included in the data on general agricultural production and consumption. This makes it difficult to provide detailed and systematized data on this market segment in the Bulgarian economy.

The priority method that I have used as an author is the Specialized Literature Review Method. In principle, this method involves a precise search, evaluation and summary of scientific evidence from existing studies, scientific reports and academic articles related to the topic of this study. This is a good method for detecting and specifying deficits in existing knowledge in this subject area.

The method of content analysis of some of the existing publications on the topic of the production and consumption of organic food in the Republic of Bulgaria was also used by the author.

The study also uses a comparative analysis of data from similar studies, to the extent that the existing information base on the problem under consideration allows. The comparative characteristics of the production and consumption of organic food in the Republic of Bulgaria allow us to more clearly identify the trends and prospects for the country in these processes. “The comparative analysis as method is used to compare the situation in different types of agricultural holdings within Bulgaria. It helps to contextualize the findings and understand the relative performance or characteristics of the subject of study” [10]

RESULTS AND DISCUSSION

Advantages and specifics of organic food production in the agricultural sector

Let's start with the definition of organic foods or "bioproducts". "Organic products in the EU are produced and tested in accordance with environmental protection and animal welfare standards... The idea of organic certification is to give guarantees for clean and natural food, especially in big cities, where tracing the origin of food is difficult and personal contact with producers is often impossible. There are strict regulations regarding the labeling of organic

products. Among them are listing the exact composition and origin of all input raw materials, country of production and certification authority" [17].

Another distinction that consumers often do not make is the difference between organic foods and organic products and organic foods and organic products. Also in specialized literature, the term "organic foods" is used as a synonym for organic foods. Similarly, eco-agriculture is used as a synonym for organic agriculture.

Eco foods (environmental foods), on the other hand, are a product of agricultural production and natural extraction from ecologically clean areas. It is about production in areas with unpolluted soils, air and water. When extracting the raw materials used for the production of ecological foods, ecologically clean areas are also taken into account - flat, hilly or mountainous. Most often, eco products are raw materials and foods of plant or animal origin collected from nature.

Unlike organic products (organic food and organic raw materials), which are grown in specialized conditions of organic farming and go through a series of tests to guarantee and certify their organic origin, (in case they meet all regulatory requirements and conditions), for eco food products do not have such a strict requirement for production control and monitoring. For them, it is sufficient to prove that the terrain or the area from which they were produced or mined is ecologically clean - it is far from industrial and natural pollutants, from mining and ore mining activities or busy infrastructural transport arteries.

But in order for a food product or raw material to be declared and distributed as eco food, its origin from an ecologically clean area must be guaranteed.

As noted in publications that compare organic food and organic food, there are no significant differences between eco and organic food. Both organic foods and eco foods are grown under conditions that guarantee their maximum natural, natural origin without the use of chemicals and synthetic materials. As chemicals that are used as a result of harmful human intervention in the literature, the following are indicated: "synthetic pesticides, herbicides, antibiotics, hormones, chemical fertilizers, GMOs, preservatives, addition of artificial flavors, colors and flavorings" [16].

Another common synonym for organic food is the term "organic" food. Organic food in specialized publications is defined as "food grown without the help of genetic engineering, pesticides, soil conditioners and other synthetic substances. These foods have a proven higher content of vitamins and trace elements, and their extraction and processing are more environmentally friendly. Bulgarian organic foods are mainly fruits, nuts, herbs and spices, as well as organic vegetable oils, tobacco, vegetables, meat, jam and honey" [21].

In Irena Stefanova's opinion, "the terms organic, ecological or biofood mean the same thing - food grown without the help of genetic engineering, pesticides, soil enhancers and other synthetic substances to protect it from insects or low yield" [13].

The question arises, why do we have three different names and specifications for the same thing in the Bulgarian language? It is probably a matter of translations of terminology from different languages, because all three names are neologisms in the Bulgarian language. The other assumption is that perhaps there is a ratio of parts to whole. Perhaps the broadest concept is ecological foods. Any food centuries ago, when chemical means of plant protection - pesticides, herbicides and insecticides - were not yet known, was practically ecological. The second degree of narrowing is organic foods, they are undoubtedly ecologically clean, but they can be grown by different producers, even if they are not certified. The smallest is the subset of organic foods in this complex. The special thing about them is that they must be produced in specialized, certified (by authorized organizations and institutions) farms.

All three types of production and consumption of eco-foods, bio-foods and organic foods are important moments in the movement of mankind towards the future eco-civilization of mankind. As Ernst Ulrich von Weizsäcker and Anders Weikman note, creating an ecocivilization involves combining a “holistic and symbiotic approach rather than narrowly defined standards” [1]. One of the examples of a symbiotic approach that the authors give in their Club of Rome 50th anniversary publication is with the Xiang Yin Wei Ye Chinese Farming Corporation located in Caoxiang, Shandong Province. "to minimize the use of hormones or other animal medications, the feed used (for farmed animal food - my clarification YT) comes from well-controlled, healthy soil, with local herbs added to boost the animals' immune systems. Deliveries of fresh milk (by the farmer corporation) are limited to a certain distance to ensure quality” [1]. At the same time, the same authors summarize that organic food farms in China are not profitable enough. They advise farms producing organic food to also offer "accommodation, recreation and food on the farm" as an alternative rural tourism option. Another idea of theirs to increase motivation is to attract workers and employees in these farms as partners in agribusiness with a share in the distributed profit. [1].

If we summarize the advantages of the production and consumption of organic food in the agricultural sector, they are expressed in the following several directions:

- Create greater added value in the agricultural sector;
- Make it possible to apply sustainable practices in agricultural production;

- Contribute to the preservation of sustainable and healthy ecosystems in regions with developed organic agriculture [12];
- Contribute to the reduction of soil, air and water pollution from pesticides, herbicides and insecticides;
- Reduce the danger of unstudied and possible negative effects of genetically modified foods and products and such foods produced with the addition of hormones, on the health of people and animals;
- Enable consumers, and to some extent also producers, to lead a healthy and environmentally friendly lifestyle;
- Reduce food losses and the volume of waste thrown away by people, through price rationalization of consumer spending;
- They shorten supply chains, as shown by the example above with the Chinese farming corporation Xiang Ying Wei Ye, which limits the supply of fresh milk to a certain distance to ensure quality;
- Last but not least, organic foods and organic products contribute to the preservation of biodiversity. "At least 766 scientific reports have concluded that organic farming produces more biodiversity than other farming systems. Very often, on the principle "plants help plants", a wide range of crops is used - mixed crops, honey and medicinal plants, useful species, field protection belts. Mixed bean areas are an environment for various insects and birds" [12]. The same author also highlights the contribution of organic agriculture to the preservation of "agrobiodiversity": "The inclusion of little-used species (often as rotational crops to maintain soil fertility) reduces the erosion of agrobiodiversity, creating a healthier gene pool - a basis for future adaptation" [12].
- A big advantage of the production of organic foods and bioproducts is the environmental services that this production provides to the agro-ecosystem. These specific "ecological services" of bioproduction include: "soil formation and soil stabilization, waste recycling, carbon sequestration, nutrient cycling, predation, pollination, and habitat" [12]. Via these specific environmental services reduce the hidden costs of agriculture to the environment in terms of the degradation of natural resources.

All these advantages, although systematized in a telegraphic form, make it possible to conclude that the production and consumption of organic food has great prospects, both nationally and globally. At the same time, taking into account the actual consumption of organic foods at the current stage, it is logical to note that this process of imposing and scaling this type of consumption will be relatively slow and difficult. The basis for such a forecast is given by the fact that the food problem continues to be one of the main problems facing humanity and still in food production both in the agricultural sector and in industry, the quantity is given precedence over the quality of the food produced.

The reduction of food loss and the volume of food waste as a result of the production and sale of organic foods

Organic foods are an important part of the healthy lifestyle and nutrition of modern people. They minimize various allergic reactions, contribute to a more natural way of life for people. Their environmental friendliness often helps to reduce the carbon footprint and achieve zero carbon emissions.

If we look at global food loss and waste in general (not just organic food), a 2011 FAO estimate found that every year a third of all food produced in the world for human consumption never reaches the consumer's table. This means not only a missed opportunity for the economy and food security, but also a waste of all the natural resources used to grow, process, pack, transport and market food.

Food waste occurs at all stages of food supply chains for a variety of reasons that depend greatly on local conditions within each country. On a global level, a pattern is clearly visible; in high-income regions, the volume of food waste is higher in the processing, distribution and consumption stages, while in low-income countries, food losses occur in the production and post-harvest phases. In low-income countries, lack of infrastructure and lack of knowledge about proper food storage and handling, combined with unfavorable climatic conditions, favor food spoilage. In higher income countries, aesthetic preferences and arbitrary sell-by dates are the leading factors contributing to much of the food waste. [5].

Within the EU, about 10% of the food that is offered to consumers is thrown away. At the same time, more than 37 million people in the EU cannot regularly afford quality and wholesome nutrition [19].

One of the most recent statistical estimates of absolute food losses indicates 58 million tons of food waste in the EU in 2021 [19].

The production of Bulgarian organic food and organic products from the agricultural sector could be our trademark both in the country and abroad. This type of production can contribute to increasing the income of Bulgarian citizens, as well as be a prerequisite for even larger-scale development of culinary and agricultural tourism.

The Farm to Fork strategy for the EU food sector provides for clearer definition of the expiry dates of products and an end to their misinterpretation. With this

strategy, the Commission is also committed to researching the amount of food that is wasted throughout the food chain [19].

The "Farm to Fork" strategy plans to reduce waste by 10% in the production and processing of food products and by 30% in retail, restaurants, food services and households.

In March 2024, the European Parliament adjusted its position on the revision of the rules. MEPs want to reduce waste in the production and processing of food products by at least 20%, and in retail trade, restaurants, food services and households - by at least 40% by 2030. Parliament also proposes that the European Commission assess whether for 2035 higher targets should be introduced (30% and 50% respectively) [19].

The European Union wants to reduce the impact that waste leaves on the environment. Ambitious targets for recycling and reducing the use of landfills have been adopted, and new requirements on packaging waste are being prepared.

The aim is to encourage the transition to a more sustainable model of consumption and utilization of resources, known as the circular economy [6]. In October 2022, the European Parliament approved changes to the persistent organic pollutants rules to reduce the amount of hazardous chemicals in waste and production processes. The new rules introduce stricter limits, ban certain substances and aim to prevent harmful substances from entering through recycling [6]. The amendments to the rules adopted by the European Parliament are also related to the regulatory requirements for the production of organic food in the agricultural sector in the EU member states.

At the global level, different scenarios have also been developed to reduce food waste. Measures in this direction are subordinated to the idea of reducing humanity's carbon footprint and mitigating climate change

One of the UN's goals regarding sustainable development - UN Sustainable Development Goal 12 (SDG 12) is formulated as "Ensure sustainable consumption and production patterns" and includes a specific goal to reduce food waste: "by 2030 to halve per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" [5], [7].

Within the framework of SDG 12, a 50% reduction in food waste is planned by 2030. The proposed scenario assumes a reduction in the carbon footprint of food waste by 38%, or 1.4 GtCO2 per year. This would be equivalent to the greenhouse gas emissions of the Japanese economy. Despite data and models uncertainties, the magnitude of the figures above suggests that reducing food loss and waste at global, regional and national levels would have a significant positive effect on public resources and climate change in particular [5].

Prospects for the production of organic food in the Republic of Bulgaria

To begin with, I will refer to a study by Nadka Kostadinova, Georgi Alexiev, Konstantin Stankov from the University of Thrace in Stara Zagora, who in their collective publication in 2016, which state that "in recent years, organic agriculture in Bulgaria is one of the sectors, which in the conditions of crisis is developing at a rapid pace, with the areas and the number of producers included in a control system constantly increasing" [11]. I immediately hasten to make the stipulation that there is a difference between organic farming and the production of organic food in the agrarian sector. On the face of it, this distinction seems like a play on words, but in fact organic farming is a broader concept. It includes not only the production of organic foods, but also the production of bio-raw materials and bio-feeds in the agricultural sector. The latter are still poorly represented both in Europe and in the Republic of Bulgaria. The predominant production from organic farming is organic food.

In the Republic of Bulgaria, organic production, including the production of organic food in the agricultural sector, is still poorly represented - as a percentage of the total agricultural area. The areas for organic production in our country have the lowest share among all other EU countries. Most of the ecological production in the form of organic foods and bioproducts (honey, wax, herbs, mushrooms, etc.) is exported abroad, with about 6-7% finding a market in our country as well [20].

In the Republic of Bulgaria, organic production is still taking its first steps. At the same time, according to general expert assessments, this is an extremely suitable sector for Bulgaria - both because of its real natural features and not so unpolluted land, and because of its image as a traditional producer of quality agricultural products. At the moment, especially organic beekeeping and the production of bee products, which is a traditional agricultural activity in Bulgaria, show high and competitive results.

In an interview with the farmer Ivaylo Todorov, it is noted that the areas sown with organic food in Bulgaria have decreased by 20% in the last two years. It is about the period 2021-2022. "According to the statistics I saw, notes Mr. Todorov, it is clear that the farmers who offer organic production and the areas with such production are decreasing every year. Despite all the efforts and subsidies, our main challenge is heavy bureaucracy. The control is extremely large, the agricultural producers give up and it is seen that in 2 years the areas with organic production have decreased by nearly 20%." This is noted by Ivaylo Todorov, an entrepreneur in agriculture in the program "Made in Green" with presenter Roselina Petkova. The interview was published on August 14, 2023 [14].

A) Prospects for the production of organic food in the Republic of Bulgaria in the short term

The prospects for the development of organic food production in the Republic of Bulgaria in the short term are determined by two strategic documents - the European Plan for Recovery and Development and the National Development Program Bulgaria 2030. They outline 4 pillars of the implementation of the plan and program in the coming years:

1. Itovative Bulgaria;
2. Green Bulgaria;
3. United Bulgaria;
4. Just Bulgaria [2].

The production and consumption of organic food corresponds to the second pillar in the National Development Plan until 2030. Within the implementation of the "Green Bulgaria" program, various measures are foreseen, some of which are aimed at improving the environment. Measures 6.4 and 6.5 of the plan are related to the production and trade of organic foods: "Measure 6.4 Improving the capacity of SMEs in connection with the transition to a circular and low-carbon economy; and Measure 6.5 Promotion of green products with the EU Ecolabel, the System for Verification of Ecological Technologies and Circular Design." [8].

One of the promising areas of organic food production in the Republic of Bulgaria is the production of organic vegetables in the agricultural sector. This type of organic production has a large set of positives, due to its following features:

- Quality, healthy food with high biological value is produced;
- Production is based entirely on the use of organic substances and excludes the introduction of chemical substances in the form of fertilizers and plant protection preparations;
- Protects the environment from pollution and maintains the ecological balance;
- Preserves, maintains and enriches natural soil fertility;
- Protects water basins and groundwater from contamination with chemical substances;
- Reduces the cost of chemical pesticides and fertilizers by using only on-farm biological agents.

The experts from the Audit Chamber in the Republic of Bulgaria state that "the process of issuing permits for control activities is also not sufficiently effective. Issuance of permits for control activities during most of the audited period was carried out without established internal rules and procedures" [22].

The Court of Audit also registered "cases of issuing permits for control activities without the applicants' procedures meeting important regulatory requirements", and the finding in other cases is that "there is no confidence that they fulfill the requirements of Regulation (EC) No. 834/2007 due to lack of documents" [22]. The database of the persons performing control for compliance with the rules for organic production of agricultural products and food does not provide the necessary traceability for the activities of the controlling persons. This can be used in bad faith by the operators (producers, traders and processors) on the one hand, and on the other hand, it creates a risk of errors in the implementation of control in the commercial network by the Bulgarian Food Safety Agency (BFSA) [22].

b) Prospects for the production of organic food in the Republic of Bulgaria in the long term

Biological production has been proven to be applied successfully in the Republic of Bulgaria. In recent years, it has been one of the sub-sectors in the agro-sector that has seen growth in terms of areas, animals and the number of operators included in a monitoring control system according to EU regulations.

Control and certification in organic production is carried out by a control body for certification of biological products at the Agency for Biological Certification EOOD, accredited by the Executive Agency "Bulgarian Accreditation Service" according to BDS EN ISO/IEC 17065:2012. The body certifies Live or unprocessed agricultural products; Processed agricultural products intended for food; Fodder; Planting and sowing material; Yeast used for food or feed. The agency does not certify aquaculture, aquaculture products and wine, which also refers to agricultural production in a broad context.

Farmers certified by the Agency for Biological Certification EOOD receive Certificates recognized in over 35 countries.

The Agency for Biological Certification EOOD (ABS EOOD) itself holds Permit No. BG-BIO-17 of July 18, 2019, issued by the Ministry of Agriculture and Food for the control and certification of products in accordance with the requirements of Regulation (EC) No. 834/2007, Regulation (EC) No. 889/2008. From January 1, 2022, ABS EOOD carries out certification and control according to the provisions of Regulation (EU) 2018/848 and the legislation applicable to it [9].

One of the great advantages of organic food production is that this type of production and consumption contributes to the implantation of sustainability in modern agricultural production and thus supports the sustainable development of the national and world economy.

Sustainability in agro-production implies, first of all, the recovery of production experience, production knowledge and skills, and also the seed and breeding base of local productive varieties and breeds. This can only be achieved in the long term. As noted in a publication by BG Farmer, "At the genetic level, traditional and adapted seeds and breeds are preferred due to their greater resistance to diseases and climatic stress" [12].

First of all, this implies the education of personnel for the agricultural sector and, in particular, personnel to work in farms, agrarian enterprises, which are oriented towards the application of sustainable agricultural practices and aim at productions that are ecologically clean and meet the standards and requirements for organic and organic food.

Secondly, in perspective, the scientific service of the agricultural sector should be strengthened, aimed at searching for seed base, varieties, plants and breeding animals from breeds that have declined or are on the verge of extinction, in order to select those of them that can be the basis for future ecologically clean agricultural productions.

Thirdly, the state should simplify the procedure for regulating the production of ecologically clean organic food and organic food. This implies digitizing the entire control and monitoring procedure of this type of production, as well as creating a package of incentives for future ecological production. In parallel with this, the non-governmental organizations that protect the interests of consumers of agrarian products and food produced in the agricultural sector should also carry out monitoring and civil control over the producers of eco-food in the broadest sense of the word as an additional guarantor of the quality and purity of the offered eco-products. In terms of competition, the producers themselves could also mutually control each other and monitor their competitors in the industry to comply with the regulatory requirements and prevent unfair competitive practices that would compromise biologically clean productions in the agricultural sector. Of course, mutual control must be based on compliance with the legal order and transparency in the actions of competitors in this type of proceeding.

The production and consumption of organic food and organic products directly corresponds to the achievement of Goal 12 of the Sustainable Development Goals (SDGs) - "Responsible Consumption and Production". [7]

Already in 2021, an electronic register of organic producers in the Republic of Bulgaria was created and updated. "The idea and purpose of the register is to reflect the requirements of the EU regulations by creating the most complete database possible for the activities of all operators who carry out organic production. Through it, the mandatory notifications that the controlling persons must make to the competent authority (the minister), the competent unit (Directorate "Biological Production") and the Food Safety Agency (FFSA)" [15] are carried out.

According to information from BABH, all registered farmers in the Republic of Bulgaria are about 103,000. Of all of them, about 6,000 certified operators deal with organic production. To them we can add the beneficiaries under measure 11 of the Program for the Development of Rural Areas, who are about 3,000 people.

In this case, in order to stimulate the development of organic agriculture and the production of organic food, Bulgaria is developing a separate measure: 11 "Organic Agriculture" within the framework of the Program for the Development of Rural Areas 2014 - 2020. Within this measure, two sub-measures are implemented:

Sub-measure 11.1 Payments for conversion to organic farming per hectare of FFA;

Sub-measure 11.2 Payments for maintenance of organic farming per hectare of EPA.

The measure definitely has a positive effect and contribution to the sustainable development of rural areas, contributing to the environment and mitigating the effects of climate change and supporting small and medium-sized farms, most of which are family farms, because as shown by national statistics, the areas covered from organic farming have been growing in recent years.

There are three types of incentives on which organic agriculture can rely, and which can be applied in the conditions of the Republic of Bulgaria in the future [12]:

"1. Consumer or market organic farming – products are clearly identified through certification and labelling. Consumers make an informed decision about how their food is produced, processed and marketed.

2. Organic agriculture organized by services – in countries such as those of the European Union, subsidies are offered for organic agriculture to generate environmental goods and services, such as reducing groundwater pollution or creating a more biologically diverse landscape.

3. Organic agriculture driven by farmers - some farmers believe that conventional agriculture is unsustainable and have developed alternative ways of production to improve the health of their family, the agricultural economy and/or their independence" [12].

In March 2021, the European Commission launched an action plan in the field of organic production within the European Union. "The plan envisages achieving the European Green Deal target of 25% of agricultural land being used for organic farming by 2030" [23].

The plan covers 23 measures and spheres of action, grouped in three directions:

- strand 1: stimulating demand and ensuring consumer confidence
- strand 2: stimulating the transition and strengthening the entire value chain
- strand 3: organic production as a role model — improving the contribution of organic agriculture to environmental sustainability" [23].

The last third direction has the greatest importance in the context of the prospects for the development of organic production and, in particular, the production of organic food and beverages in the Republic of Bulgaria.

CONCLUSIONS

Currently, in the Republic of Bulgaria, it is expected to maintain the trends of increasing the number of organic operators and the size of the areas in the control system of ABS EOOD, as well as an increase in the species diversity of organically grown crops and farm animals. The Ministry of Agriculture and Food continues to work towards ensuring the implementation of state policy in the field of supervision and control of organic production and compliance with the requirements of European and national legislation in the field.

By offering relatively healthier food products and by protecting the environment as much as possible, organic food production in the agriculture-sector works for the interests of consumers and to support their health, and from there works for the benefit of the whole society.

The production of organic food and its future depend on the ability of consumers to inform themselves and appreciate the value of healthy organic food, as well as to obtain better logistical access to this type of food, by shortening supply chains and by innovative practices to improve the moment solvency of end users.

The production and consumption of organic food in a longer perspective can only be guaranteed by its (production's) harmony with nature. Therefore, organic farming should not be seen only as an ecological alternative, it has the difficult task of ensuring to a large extent the solution of the food problem of humanity.

Specifically, with regard to the prospects and potential of the Republic of Bulgaria in the production and consumption of organic food, it is good to make the following distinction:

With regard to the production of organic food in the Republic of Bulgaria, it can be summarized that it has great potential, but nevertheless, the good prospects for this specific production should not be taken as a "given". Undoubtedly, this type of agrarian production has a future, and specifically in Bulgaria it has traditions, it has potential, there are quite a few naturally clean and protected areas from excessive industrialization, which can be a base for the development of organic agriculture and ecological animal husbandry. But at the same time, there are also problems related to a lack of coordination between institutions (for example, between the Ministry of Environment and Water and the Ministry of Agriculture and Food on the occasion of the restriction of pasture livestock in the Central Balkan region), problems with control and monitoring of operators and organic food producers, problems of a financial and logistical nature. All these problems for now put Bulgaria in the position of a potential, but not promising producer of organic food. For this reason, regardless of the problems, the adopted course of growth of organic production and specifically the production of organic food can be defined as correct and promising.

This is dictated by the growing importance of organic agriculture not only in the European Union, but also on a global scale. It is a fact that the demand for organic products is increasing every year. Europe is still the second largest producer of organic food and organic products in the world. Most of the Bulgarian organic foods and products are intended for foreign markets (over 80% according to [11]). The sub-sector of the production of organic food and organic products in the country is developing upward and undoubtedly has a future.

The potential for organic food production and consumption in the Republic of Bulgaria can only be realized through the joint efforts of society, the state, farmers involved in organic production and their associations, as well as non-governmental organizations supporting the development of this type of production and consumption. Joint integrated efforts are needed to achieve the SDGs. Organic food producers prioritize various good practices in their actions to maintain environmental sustainability, based on the understanding of the indivisible nature of the SDGs [3] and seeking opportunities to achieve synergies between sectoral policies supporting and promoting organic production and consumption.

With regard to the consumption of organic food in the Republic of Bulgaria, the situation in perspective is different. In contrast to the production potential, the consumption potential of the Bulgarian consumer is relatively limited. This limitation is determined by many factors and circumstances, the most important of which are:

- The relatively low level of income (the lowest in the EU according to Eurostat data);
- The relatively high prices of organic foods on the Bulgarian market;
- The relatively small market – about 6.5 million population according to the latest population censuses, which is constantly decreasing with each passing year by about 50-60,000 people;
- The lack of a culture of healthy food consumption among a large part of Bulgarian citizens;
- The lack of sufficient advertising of the benefits and importance of organic foods in the Bulgarian media;
- Insufficiently good health education in the Bulgarian education system.

In conclusion, we can distinguish the potential and prospects for the production and consumption of organic food in the Republic of Bulgaria. With regard to the production of organic food in the country, there is potential, but weak possibilities for the realization of this potential. Regarding the consumption of organic food in Bulgaria, the potential is limited, but the outlook is optimistic and will be largely determined by the increase in the income of Bulgarian citizens in the process of the country's integration into the Eurozone and the Schengen area.

ACKNOWLEDGMENTS

I would like to express special thanks to the management of the Varna Free University "Chernorizets Hrabar" and especially to the head of the Department of "Public Order and Security" - Assoc. Prof. Dr. Stefko

Burdzhiev for their support and assistance in the preparation of the research material presented to your attention.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 547-554

Marine Litter Accumulation and Distribution on Durankulak Beach (Black Sea coast, Bulgaria)

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***Abstract*—Marine litter is a worldwide concern because of its negative impact on coastal and marine ecosystems due to anthropogenic pressure. Despite implementation of the Marine Strategy Framework Directive (MSFD 2008/56/EC) there is an inability for national monitoring to cover all significant areas in particular Descriptor 10, indicator D10C1 ''Beach macrolitter''. This study represents marine litter accumulation and distribution on Durankulak shoreline, Bulgarian North East Black Sea coast. Through regular monitoring along a fixed sampling unit by an unmanned aerial vehicle (UAV) to acquire georeferenced images of the coastline, the report provides detailed data on seasonal variability of accumulation, abundance and typology of beach macrolitter. Marine litter accumulation surveys were carried out in four seasons from May 2024 to January 2025. Marine debris was collected, quantified and categorized in order to determine its abundance, composition and seasonal variations in accumulation rates. The results showed that accumulation alters from 183 to 600 items per 100 m section in different seasons. Total number of items recorded is 2821, with a total amount of 67.887 kg. Marine litter was classified in to eight main categories ''Artificial polymer materials'' (90.18% of total number of items), ''Rubber'' (2.52%), ''Cloth/ Textile'' (0.78%), ''Paper/ Cardboard'' (0.96%), ''Processed/ Worked wood'' (1.31%), ''Metal'' (2.16%), ''Glass/ Ceramics'' (1.95%), and ''Unidentified'' (0.14%). Significant amount of marine litter collected was of transborder origin. The results shows that there was variation on aggregation and composition of beach litter. Predominant category is „Artificial polymer materials" and that trend remains unchanged in a seasonal plan.**

Keywords*— *Bulgarian Black Sea coast, Marine litter, MSFD, monitoring, seasonal accumulation.

I. INTRODUCTION

As a significant environmental issue feturing with complexity and overseas problem, marine litter (ML) is the main subject of a number of international and regional conventions, strategies and national plans (UNEP, MSFD, BSC). Republic of Bulgaria, as an EU member state, fulfils national and regional commitments on the implementation of the MSFD 2008/56/EC [1], [2]. As a Black Sea country, it participates in the activities of the Black Sea Commission and the relevant advisory groups [3]. Despite implementation of the Marine Strategy Framework Directive (MSFD 2008/56/EC) there is an inability for national monitoring to cover all significant areas in particular Descriptor 10, indicator D10C1 "Beach macrolitter".

Marine litter (ML) includes any persistent, manmade, processed or assembled material abandoned or discharged to the marine environment as a result of anthropogenic activities [1], [2]. ML has become environmental, economic, social and health, aesthetic and cultural problem at global, regional and local scale [3], [4], [5].

ML enters the environment via two main types of human activities - on land and at sea. [6]. Land-based sources include inefficient municipal waste management, illegal dumping, inefficient wastewater treatment plants, riverine and urban runoff, accidental discards [7]. ML with a sea-based origin enters the marine environment due to maritime activities, fishing, platforms and waste dumping at sea [4],[8].

The composition of ML includes a huge variety of materials and the plastics are the biggest part of it [9],[10]. Increasing amount of ML worldwide, and specifically plastics are found in all marine environmental matrix – water, sediment an biota. accounting for at least 85 % of total marine litter [5]. ML has become a marker of Anthropocene with its widespread negative effect on coastal and marine ecosystems, wellbeing of societies, especially the coastal population [5]. ML affect a wide range of marine and coastal fauna by entanglement and

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8689
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ingestion of parts, especially different shapes and sizes of synthetic polymer materials (plastics) [1]. Moreover plastics become a part of the food chain and end up consumed by humans.

Current study presents results of one year ML monitoring survey on beach litter, analytic results regarding ML accumulation and distribution on Durankulak shoreline, Black Sea coast, Bulgaria.

II. MATERIALS AND METHODS

The object of monitoring are beach macro litter (> 2.5 cm), as it was classified in MSFD, Descriptor D10, criteria D10C1 [1], [2].

The ML monitoring survey polygon was chosen on Bulgarian North East Black Sea coast in the range of Durankulak beach competely composed of sand (Fig.1). Monitoring site was selected according to Guidance on Monitoring of Marine Litter in European Seas, EC, MSFD, TG "Litter"[11], [12]. It fulfils the requirement and criteria – more than 1 km length, sufficient to have 2 sampling units with length of 100 m each, along the water edge.

Sampling units of 100 m in length (Section 1 - North and Section 2- South) were monitored, covering the whole area between the water edge and dunes (the back of the beach). The width of beach sampling unit was mesured perpendicular to the shoreline in four seasons. Location is accessible during the all seasons for continuous monitoring.

Fig. 1. ML survey polygon: Durankulak beach, Black Sea coast, Bulgaria.

Monitored area falls into 2 protected areas of NATURA 2000 - "Durankulak Lake", code BG0002050, Directive 79/409/EEC on the conservation of wild birds and "Durankulak Lake", code BG0000154, Directive 92/43/EEC on the conservation of natural habitats and wild flora and fauna [13]. The chosen sampling units in accordance to [14],[15], reflect different pressures and levels to exposure to litter. Durankulak beach strip is orientated E-NE (Fig.2), adjacent to the water edge, extremely exposed to waves and prevailing winds from N-NE [16].

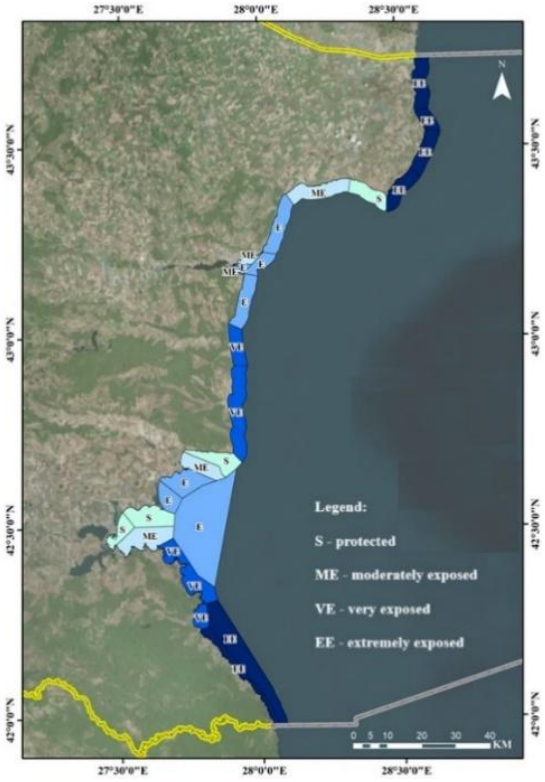

Fig. 2. Exposure to sea waves, Black Sea coast, Bulgaria (modified from BSBD, [16]).

Beach macrolitter surveys were organised regularly in four seasons in 2024-2025. Monitoring campaings were carried out once in each season in 2024-2025, spring (May), summer (July), autumn (September) and winter (January) [12], [17].

Fig. 3. ML items, Durankulak beach.

Sampling and all collected ML items from each section were recorded, quantified and categorized in 8 main categories according to the type of material: ''Artificial polymer materials''(APM), ''Rubber'', ''Cloth/ Textile'', ''Paper/ Cardboard'', ''Processed/ Worked wood'', ''Metal'', ''Glass/ Ceramics'', and ''Unidentified''. Classification, calculation and weight measurement were done on site in accordance to Guidance on Monitoring of Marine Litter in European Seas, EC, MSFD, TG "Litter" [12],[13],[17].

III. RESULTS AND DISCUSSION

Total number of items recorded in 4 seasons is 2821noc., broken down by seasons as follows: 867 noc. in spring season, 783 noc. in the winter monitoring season,

followed by summer – 656 noc., and autumn with 515 noc.

The total amount of ML for the hole monitoring period is 67.887 kg. The biggest weight recorded in spring 25.168 kg, followed by autumn with total weight of 22.081 kg. On third place is 11.123 kg for summer season. And last is winter season with the lowest ML of 9.515 kg. The findings show during the spring season the quantity of beach litter is higest both in number of items and wight but in the rest of monitored period there is not full correlation between thne number of ML and their recorded weight due to the diversity of collected materials.

TABLE 1 ML SEASONAL ACCUMULATION BY MAIN CATEGORIES, [NOC.]

Main category	Beach litter noc. per season, 2024-2025			
	Spring	***Summer***	***Autumn***	***Winter***
Artificial polymer materials	787	565	467	725
Rubber	19	19	21	12
Cloth/ Textile	8	6	0	8
Paper/ Cardboard	3	19	2	3
Processed/ Worked wood	14	8	10	5
Metal	21	14	8	18
Glass/ Ceramics	14	24	6	11
Unidentified	1	1	1	1
Total iems, noc.	867	656	515	783

Data obtained on beach litter accumulation and distribution per category, with regard to the main group of materials, are presented in Table 1 and Table 2.

The results showed that accumulation alters from 515 to 867 items in different seasons. The biggest number of items belongs to main category „Artificial polymer materials“ for the hole period of monitoring. The seasanol variation in APM category is in the interval: 467 noc.(Autumn) – 787 (Spring).

Seasonal varriation of ML shows domination of different items varying in composition and number with the highest level of abundance recorded on Durankulak beach in the spring (867 items). Prevailing in summer (total 656 item) were plastic/polystyrene pieces, followed by crisps and sweets rappers. In the autumn season (510 items) collected ML was dominated by plastic caps/lids drinks. Winter ML accumulated (783 items) was prevalent by plastic and polystyrene pieces.

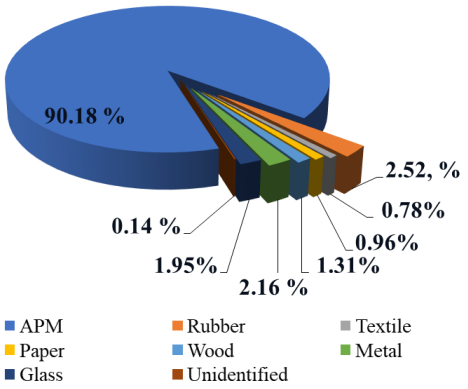

Fig. 4. Percent composition of total marinel litter items.

TABLE II ML SEASONAL ACCUMULATION BY MAIN CATEGORIES, WEIGHT [KG]

Main category	Beach macrolitter weight, [kg] per season, 2024-2025			
	Spring	***Summer***	***Autumn***	***Winter***
Artificial polymer materials	15.823	1.115	1.115	1.115
Rubber	3.217	0.024	0.024	0.024
Cloth/ Textile	1.115	2.500	2.500	2.500
Paper/ Cardboard	0.024	1.075	1.075	1.075
Processed/ Worked wood	2.500	1.414	1.414	1.414
Metal	1.075	0.000	0.000	0.000
Glass/ Ceramics	1.414	1.115	1.115	1.115
Unidentified	0.000	0.024	0.024	0.024
Total wight, [kg] per season	25.168	11.123	22.081	9.515

Predominant category from 8 main types [12],[17] is APM with realative share of 90.18 % of the total number of items collected. Second main group of materials abondoned on Durankulak beach is ''Rubber'' with 2.52 % (Fig. 4).

All items included in Top 10 belong to the main category APM which determines their predominance (Table III). During the monitoring and sampling was identified presence of significant amounts of ML with transborder origin mainly from food products, packaging

and beverages („Plastic caps/lids drinks“, „Plastic caps/lids chemicals, detergents“, „Crisps packets/sweets wrappers“). The general circulation in the Black Sea basin is influenced by the inflow of fresh water from the Danube, Dnieper and Dniester bringing waste of terrestrial origin [18]. The presence of ML of crosborder origin confirms the influence of the main Black Sea current on their transport and distribution along the Bulgarian Black Sea coast.

TABLE III ML ACCUMULATION, TOP 10

№	Top 10 ML items			
	General Name	*TSG-ML*	*NOC*	*Share, [%]*
1	Plastic/polystyrene pieces 0 - 2.5 cm	G75	378	13.40
2	Plastic caps/lids drinks	G21	336	11.91
3	Other plastic/polystyrene items (identifiable)	G124	187	6.63
4	Plastic/polystyrene pieces 2.5 cm > < 50cm	G76	155	5.49
5	Plastic caps/lids chemicals, detergents (non-food)	G22	146	5.18
6	Crisps packets/sweets wrappers	G30	127	4.50
7	Plastic construction waste	G89	89	3.15
8	Small plastic bags, e.g. freezer bags incl. pieces	G4	85	3.01
9	Foam sponge	G73	73	2.59
10	Cigarette butts and filters	G27	62	2.20

Lolly sticks“, TSG-ML General code, G31 and „Straws and stirrers“ TSG-ML General code, G35, are not part of the Top 10. Recorded amounts in this study are close to those of cigarette butts and significantly lower than accumulation indicated in previous studies [19],[20]. Although they are not dominant factor in the studied area should be considered as an important factor on ML accumulation and distribution.

Seasonal variation in accumulation rates for two sections demonstrates similarity in spring, summer and autumn but differences in winter with a maximum number of items per 100 m collected (Fig. 5).

Weight of ML is determined in D10 national monitoring, criteria D10C1 but in other international studies it is not considered as a factor in relation to Clean Coat Index (CCI), Plastic Abundance Index (PAI), accumulation index (AI), etc.[19], [20]. Analysis of the weight of ML component is not included in the present study and the focus is on the number of identified ML items and their inclusion in the main classification groups and subgroups.

Seasonal distribution of ML at both monitored sections is dominated by APM followeed by category „Rubber“. Results gained show similarity in the distribution of the main groups of materials. The main difference in seasonal variations is the minor presence of „Paper/cardboard“ in the southern section (Fig. 6 and Fig.7).

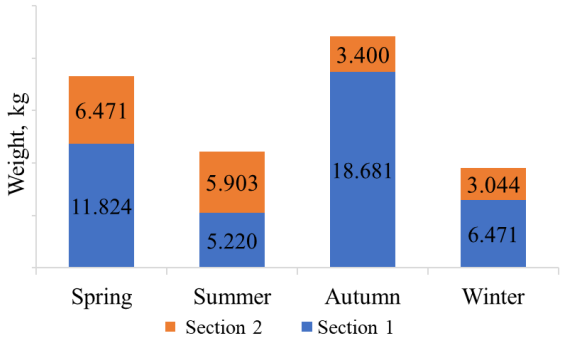

Fig. 5. ML seasonal accumulation, weight [kg] per section.

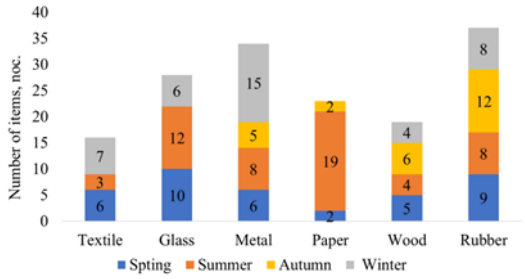

Fig. 6. Seasonal accumulation of main group materials, Section 1 (North)

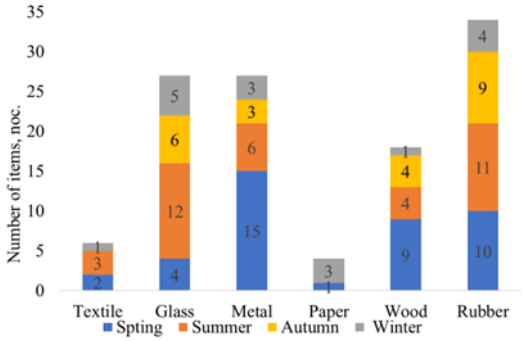

Fig. 7. Seasonal accumulation of main group materials, Section 2 (South).

All the samples of marine beach litter were processed, classified, categorized and quantified. The data gained from the 4 monitoring campaigns were analyzed and the Top 10 marine litter items were identified.

Regarding the achieved results „Plastic/ polystyrene pieces 0 - 2.5 cm“, TSG-ML General code G75 are the largest and most abundant amount of ML. At section 1 in the winter season were recorded 172 items. Results present lower amount at section 2 an in the spring they are even absent at both sections (Fig. 8).

„Plastic caps/lids drinks“, TSG-ML General code G21 is presented in all seasons, at both sections. This ML item dominates at section 1 in the winter, and section 2 in the

spring but decrerases in autumn along the monitored units (Fig. 9).

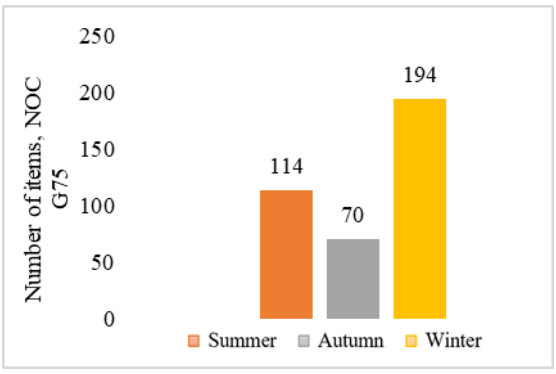

Fig. 8. Seasonal distribution of „Plastic/polystyrene pieces 0 - 2.5 cm“ (TSG-ML General code G75).

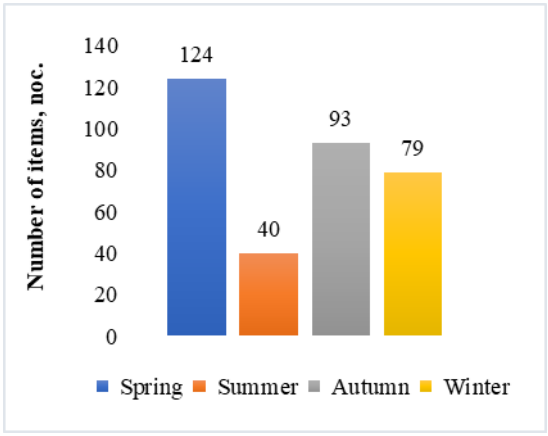

Fig. 9. Seasonal distribution of Plastic caps/lids drinks (TSG-ML General code G21).

Subcategory „Other plastic/polystyrene items (identifiable)“, TSG-ML General code G124, is the third in order regarding monitoring data but shows a stable presence in both sections, throughout the year. A maximum number of plastic cups is noted in winter at the northern part of the studied area (Fig.10).

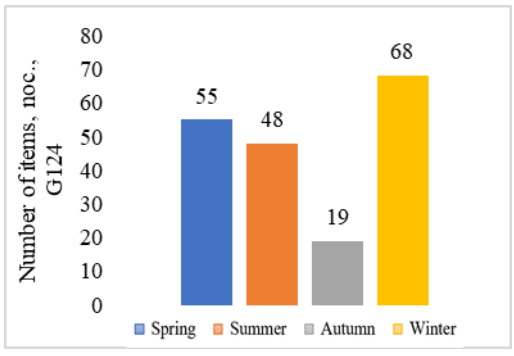

Fig. 10. Seasonal distribution of Other plastic/polystyrene items (identifiable)“, TSG-ML General code G124).

„Plastic/polystyrene pieces 2.5 cm > < 50cm“, TSG-ML General code G76 is the fourth most popular item of ML on Durankulak beach. in regards to results.

Seasonal dynamics shows strong presense at North section with high values in the winter. At South section it is less represented, in the spring season it is not even available (Fig. 11).

„Plastic caps/lids chemicals, detergents (non-food)“, TSG-ML General code G22 in the studied area has a constant presence, sampled during the all monitoring period and slightly increased values in the spring season at section 2 (Fig. 12).

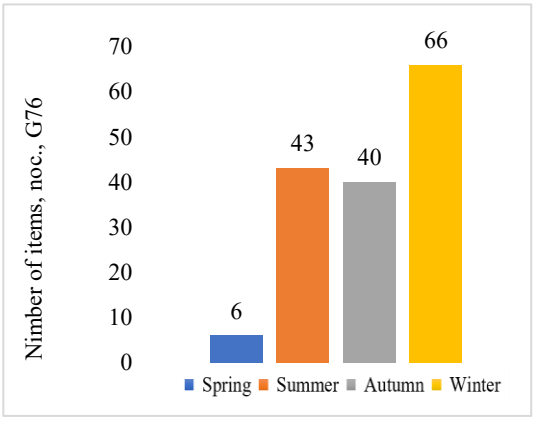

Fig. 11. Seasonal distribution of Plastic/polystyrene „pieces 2.5 cm > < 50cm (TSG-ML General code G76).

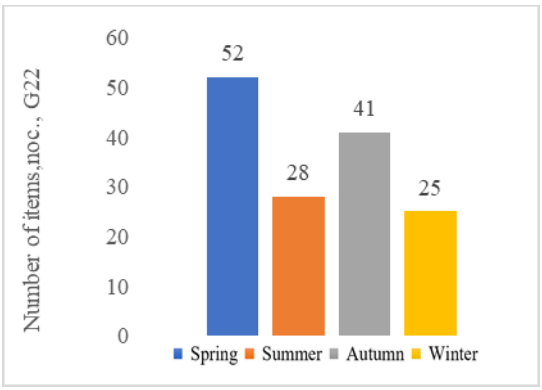

Fig. 12. Seasonal distribution of Plastic caps/lids chemicals, detergents (non-food) TSG-ML General code G22.

„Crisps packets/sweets wrappers“, TSG-ML General code G30, are identified is a dominant ML item in section 2 for the summer season, lower level in spring and winter and abcent in the autumn.

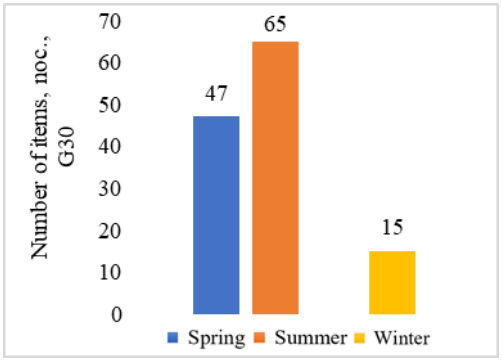

Fig. 13. Crisps packets/sweets wrappers, (TSG-ML General code G30).

„Plastic construction waste“, TSG-ML General code G89 and „Small plastic bags, e.g. freezer bags incl. pieces“, code G4, presented similar seasonal distribution and accumulation. Although they different in origin both items are accumulated the most in the spring, reduced to missing quantities in the summer and again available in the autumn-winter season (Fig.14, Fig. 15).

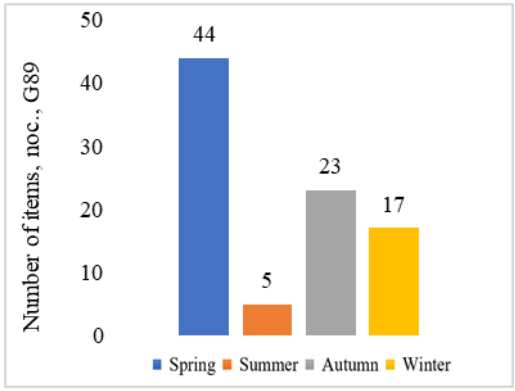

Fig. 14. Plastic construction waste“, (TSG-ML General code G89).

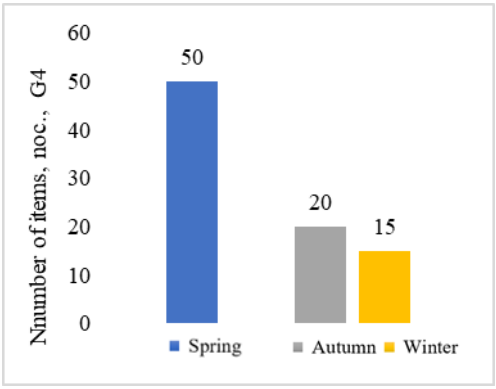

Fig. 15. „Small plastic bags, e.g. freezer bags incl. pieces“, (TSG-ML General code G4).

The last two items evaluated are „Foam sponge“, TSG-ML General code G73 and „Cigarette butts and filters“, TSG-ML General code G27. Their seasonal dynamics of accumulation shows insignificant to absent quantities. „Foam sponge“ is collected in the spring and summer , and a very small amount in the winter. „Cigarette butts and filters“ are last in the ranking, which is the opposite of previous studies [19],[20] (Fig.16, Fig.17).

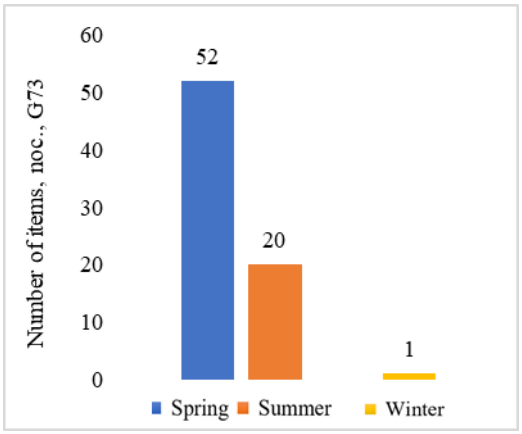

Fig. 16. „Foam sponge“, (TSG-ML General code G73).

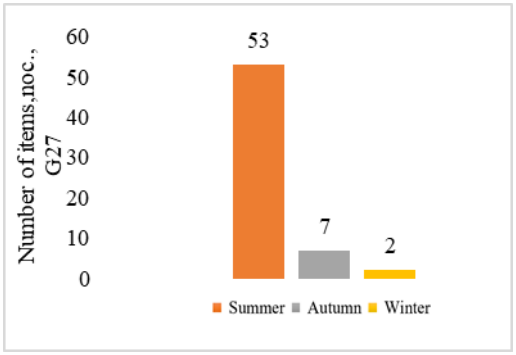

Fig. 17. „Cigarette butts and filters“, (TSG-ML General code G27).

IV. CONCLUSIONS

Data and information from the seasonal monitoring conducted in 2024 – 2025 presented in the report provides detailed informatin on seasonal variability of accumulation, abundance and typology of beach macrolitter on Durankulak shoreline, Black Sea coast, Bulgaria.

As a result of conducted surveys a total number of items recorded in four seasons is 2821, with a total amount of 67.887 kg. The data gained from monitoring campaigns were analyzed and were identified Top 10 of marine litter items. Syntethic polymers had the highest distribution in all seasons on Durankulak beach classified in main category „Artificial polymer materials“ with 90.18 %. The second main group of abondoned materials is ’’Rubber’’ with 2.52 %.

The most widespread ML was determined „Plastic/ polystyrene pieces 0 - 2.5 cm“ and the biggest abundant amount of this item at 100 m section was in the winter season recorded 172. The total amount of ML accumulated on section 1 is 1525 items, and 1291 on section 2. Cigarette butts, straws, stirrers and lolly sticks are not a leading factor in composition of ML, although their numbers are close to become a part of Top 10.

Predominant part of collected ML is from the group of artificial polymer waste, mainly related to food and beverages (bottles, cups, caps, packaging, bags, straws), cigarette butts and filters, polystyrene, polyurethane foam. Despite the remoteness from highly urbanized areas, it was ascertained presence of transboundary ML transfer – plastic caps from drinks, labels and packaging of beverage products.

During all seasons of monitoring Durankulak beach no dangerous or suspicious objects were found, such as military debris or ammunition but parts of shotgun cartridges, pharmaceutical packaging, medical equipment and syringes were found. There were no seen dead animal, birds or specimens nor floating pollutants were visually identified on the sea surface. Despite not a big number of cigarette butts and filters, the maximum amount in that category of materials is recorded during the summer months, when the beach is actively visited.

The data analysis showed that there is seasonal distribution and variation on aggregation of ML on Durankulak beach. Plastic materials were predominant category and that trend remains unchanged in a seasonal plan for studied coastline. As a result of the analysis, as main pressure was assumed recreational activities and transborder tranfer of ML with the significant impact of air and sea transport of small-sized and lighter materials, in particular group„Plastic/ polystyrene pieces 0 - 2.5 cm“.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 555-561

Balancing Transport Regulation and Sustainability: the Mobility Package's Environmental Impact

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***Abstract* – The European Union's Mobility Package was introduced to improve road transport regulation but has generated significant debate due to its economic, legal, and environmental implications. One of its most controversial provisions is the requirement for trucks to return to their home base every eight weeks. While intended to ensure fair competition, this rule has led to an increase in empty runs, resulting in higher CO_2 emissions and operational inefficiencies. The study evaluates this regulation by integrating a legal analysis of the European Court of Justice ruling, a review of EU environmental laws, and a statistical analysis of road freight data. The findings indicate that, rather than enhancing sustainability, the return obligation contradicts the EU's Green Deal and Fit for 55 objectives by increasing emissions and congestion. Statistical data reveals that empty mileage rose from 20% in 2020 to 21.8% in 2023, with national transport (25.9%) experiencing greater inefficiencies than international transport (13.1%). The ECJ annulled the provision due to its disproportionate economic and environmental impact and lack of impact studies carried out before new regulations are adopted (further ex-ante assessments. The study concludes that future transport policies should prioritize reducing empty runs, ensuring compliance with EU primary law, and conducting ex-ante regulatory assessments to align economic and environmental priorities effectively.**

Key words – Mobility package, empty rungs, EU transport policy, sustainability

I. Introduction

The European Union (EU) introduced the Mobility Package to enhance road transport efficiency, improve drivers' working conditions, and promote environmental sustainability. One of its most debated provisions is the requirement for trucks to return to their home base every eight weeks. While intended to combat unfair competition and prevent "letterbox companies" firms registered in low-cost jurisdictions while operating elsewhere - the rule has had unintended consequences, particularly in terms of environmental impact. Several studies [1], [2], [3], [4], [5] argue that this measure increases empty vehicle kilometers, raising CO_2 emissions, operational costs, and inefficiencies in freight logistics. Others maintain that the provision ensures fairness in the EU transport market by preventing companies from exploiting regulatory loopholes [6], [7], [8].

The Mobility Package has also been criticized for contradicting the EU's Green Deal objectives, which aim for climate neutrality by 2050 [9]. Research suggests that the regulation inadvertently increases road transport emissions as trucks are forced to return without cargo [10], [11]. The European Commission acknowledges that transport accounts for 25% of total EU greenhouse gas emissions and emphasizes the need for sustainable transport solutions [10]. However, the return obligation appears to conflict with these sustainability goals.

This study examines the impact of the Mobility Package's vehicle return requirement on empty runs in EU road transport and analyzes the primary motives behind its annulment by the European Court of Justice (ECJ) [12]. By integrating legal analysis, statistical data analysis, and environmental evaluations, this research provides a critical perspective on EU transport regulations. It is important to carry out thorough impact assessments before introducing new rules to make sure that future policies balance economic, legal, and environmental priorities effectively.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8682
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II. Materials and Methods

The EU Mobility Package, adopted in 2020, introduced regulations to improve road safety, enhance drivers' working conditions and ensure fair competition. Key provisions include updated tachograph requirements for monitoring driving hours [13], market access regulations to prevent unfair competition [14], and electronic transport information systems to reduce administrative burdens in cross-border logistics [15]. The Posting of Drivers Directive clarifies wage and working conditions for international truck drivers [16].

However, one of the most controversial measures is requiring trucks to return to their home base every eight weeks. While aimed at fair competition and driver welfare, critics argue it contradicts EU climate goals by increasing emissions. The European Commission says, "Transport accounts for a quarter of the EU's greenhouse gas emissions and is still growing. To achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050" [9].

"Recipients of European legislation are usually the Member States. According to Article 258 of the Treaty on the Functioning of the European Union (TFEU), the Member States and their central governments are responsible for ensuring compliance with EU law" [17]. This provision highlights that compliance with EU law is a fundamental obligation of Member States, requiring them to ensure adherence at all levels of government. However, in this case, the Mobility Package rules are compulsory for Member States despite possible objections to the Green Deal.

The EU's environmental policy framework is built on fundamental principles such as sustainability, integration and the precautionary approach, guiding legislative actions across various sectors, including transport [18].

The EU's commitment to environmental sustainability is enshrined in its founding treaties, which mandate "competitive economy and sustainable development" [19].

The European Climate Law sets a legally binding framework for climate neutrality by 2050, including a 55% reduction in greenhouse gas emissions by 2030 (compared to 1990). The Fit for 55 package supports these goals by reinforcing CO_2 limits for vehicles, advancing alternative fuel infrastructure, and updating energy taxation [20].

The efficient and green mobility promotes rail transport investment, zero-emission urban mobility, and decarbonized public transport. The EU's Political Guidelines for 2024-2029 reaffirm these goals: "We will scale up investment in clean energy infrastructure, including renewables, low-carbon technologies, and CO_2 transport infrastructure" [21]. The EU also emphasizes digitalization in transport to enhance efficiency and reduce emissions [22].

The EU Green Deal and Fit for 55 provide a decarbonization roadmap. However, achieving success depends heavily on active stakeholder engagement. The Political Guidelines for 2024-2029 acknowledge: "We must and will stay the course on the European Green Deal but also listen and respond to partners impacted by EU legislation" [21].

The 2011 European Commission White Paper on Transport aims to shift freight from road to energy-efficient rail and waterways, stating: "30% of road freight over 300 km should shift to rail or waterborne transport by 2030, and more than 50% by 2050" [23]. This target underscores the EU's commitment to reducing carbon emissions and improving logistics sustainability.

"Scientists and institutions that have analyzed and conducted research on the Mobility Package often emphasize the possible negative consequences not only for the sustainable development of the transport sector but also for the performance of companies. Business representatives also point out that the Mobility Package leads to increased distances travelled by road vehicles, additional costs and time costs" [3]. These findings indicate that while the Mobility Package aims to regulate the transport sector, its implementation may create challenges.

Although the Mobility Package aims to enhance drivers' working conditions and promote fair competition, its environmental repercussions contradict the EU's sustainability objectives. "More poorly utilized homecoming trips will reduce the overall efficiency and capacity of the truck transport system, with ensuing needs for more trucks, more drivers, and more congestion and negative environmental impact" [2].

Botyrius [1] examined the broader effects of the Mobility Package and highlighted the contradiction in policy objectives: "This is at odds with the EU's Green Deal plans, which aim to make the EU climate neutral by 2050." The provision intended to improve drivers' safety and working conditions inadvertently reduces the effectiveness of the Green Deal by perpetuating reliance on high-emission transport. The environmental impact of the Mobility Package is profound, as it may result in millions of tons of additional CO_2 emissions [2].

The political response to the Mobility Package has been divided mainly between Western and Eastern European countries. Countries like Germany and France support the package, arguing that it ensures fair competition and protects drivers' rights. However, Eastern European countries, such as Lithuania and Poland, say that the rules disproportionately burden their transport sectors. Study have shown that "the biggest negative impacts are projected for Eastern European transport companies, which are responsible for the bulk of international, cabotage, and cross-border transport" [3].

Lithuanian haulers, in particular, have criticized the package for creating a "discriminatory" burden that favors Western EU companies, which are better positioned to absorb compliance costs. "It creates different conditions for haulers from different EU Member States" [4].

Advocate General Giovanni Pitruzzella's Opinion, delivered on Nov. 14, 2023, reinforced this ruling. He

argued that the measure disproportionately burdened transport operators, particularly in peripheral Member States such as Lithuania, Bulgaria, and Romania, restricting their competitiveness in the EU market [24]. Additionally, he highlighted the absence impact assessment, raising concerns about the rule's legal validity and the transparency of the legislative process. Pitruzzella's Opinion further reinforced the ECJ's ruling. He argued that:

- The absence of an adequate study evaluating the return obligation's impact on competition, operational costs and the environment raises concerns about its legal validity [24].
- The EU legislature has not demonstrated why a less restrictive alternative, such as increased monitoring of letterbox companies, would not have been sufficient to achieve the same objectives [24].

His Opinion reflects broader concerns regarding regulatory overreach. The lack of alternative measures, such as targeted enforcement against fraudulent transport companies, suggests a failure of regulatory imagination. Instead of imposing a broad obligation on all transport operators, a more tailored, risk-based regulatory approach could have been pursued.

III. Results and Discussion

A. Conflicts Between the Mobility Package and EU Sustainability Goals

The Table 1 summarizes discernible contradictions between EU environmental legislation, primary treaty provisions, and sustainability policies, highlighting how the Mobility Package may conflict with the EU's climate and mobility goals.

Table 1 Environmental Laws Analysis

Key Insights	Potential contradictions
Conflict with EU Climate Goals	The European Climate Law and Fit for 55 package aim to reduce greenhouse gas emissions by 55% by 2030 and achieve climate neutrality by 2050. [20]. However, the Mobility Package's vehicle return obligation could increase CO_2 emissions by forcing empty truck trips, contradicting these targets.
Contradiction with the "Green Deal"	The EU's "Green deal Vision" promotes alternative transport and zero-emission mobility. [9]. Mobility Package continues to favor road transport, increasing reliance on high-emission freight instead of encouraging a shift to sustainable alternatives.
Inconsistency with Stakeholder Centric Policy	The EU's Political Guidelines stress the importance of adapting regulations based on stakeholder feedback, particularly concerning the Green Deal. [21]. However, the rigid structure of the Mobility Package does not sufficiently account for the concerns of affected transport operators.

B. Empty Runnings of Road Freight Vehicles: No Signs of Reduction

The regulation mandating the return of vehicles to their home base every eight weeks has sparked debates about its environmental impact. Several studies emphasize the unintended consequences of this measure, particularly its contribution to increased carbon emissions and empty running of road freight vehicles. "This rule is expected to reduce market capacity as vehicles will be required to return to their home countries and might be forced to run on empty during their returning journeys" [5].

"Looking at the impact of the Mobility Package on additional journeys, in 2023, the number of journeys made by trucks could increase from 1,1 % to 2 %, or from 1016,000 to 1915,000 additional trips. When analyzing the Mobility Package's impact according to the Member States' geographical location, it should be noted that the most negative impact is projected for Eastern European transport companies" [3].

In addition, the forced return of vehicles, especially from peripheral countries, results in numerous empty journeys, significantly increasing fuel consumption and emissions.

Empty runs, or the movement of freight vehicles without cargo, remain a significant issue in the EU road transport sector. According to Eurostat, around one-fifth of total road freight vehicle-kilometers in the EU were carried out by empty vehicles in both 2020 and 2023 [25].

The data on road transport carried out by empty vehicles, categorized by type of operation in 2020 and 2023, is presented in Fig. 1.

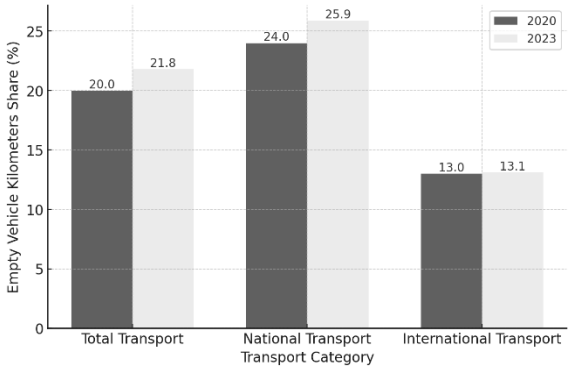

Fig. 1. Road transport performed by empty vehicle by type of operation in 2020 and 2023

According to Fig. 1, the share of empty vehicle kilometers in total road freight transport increased from 20 % in 2020 to 21,8 % in 2023. This rise was primarily driven by national transport, where the percentage of empty trips grew from 24 % to 25,9 % over the same period. In contrast, international transport remained relatively stable, with only a minor increase from 13 % in 2020 to 13,1 % in 2023.

The EU aims to reduce empty runs (or empty mileage, where trucks travel without cargo) as part of its

sustainability and efficiency goals in logistics and transport. The analysis of statistics from 2020 onward shows that no reduction has been achieved. Instead, the share of empty vehicle kilometers has remained stable or even increased.

Country-level data (Fig. 2) highlights disparities in empty mileage across the EU. Countries like Ireland, Austria, and Luxembourg exhibit the highest shares, indicating inefficiencies in freight logistics. In contrast, Denmark and Portugal have relatively lower empty mileage, likely due to better route planning or stronger logistics networks.

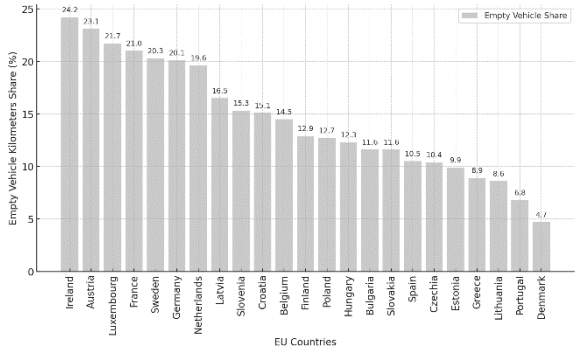

Fig. 2. Share of Empty Runs in International Road Transport by EU Countries in 2023

Reducing empty runs - particularly in national transport – through digital freight matching, multimodal transport investment, and optimized logistics hubs is crucial for enhancing efficiency and meeting the EU's Green Deal and Fit for 55 climate objectives.

C. Environmental Impact Analysis of the Vehicle Return Provision

The assessment of the vehicle return obligation within the EU Mobility Package highlights significant negative environmental impacts, particularly due to the increase in road freight traffic. The study conducted by the European Commission's Directorate-General for Mobility and Transport found that the increased vehicle movements stemming from this rule would undermine EU climate targets, leading to increased CO_2 emissions, air pollution, and congestion [21].

According to the study, "the environmental impacts from the provision will be directly linked to the potential increase in traffic flows (in vehicle-kilometers)" [26]. The provision could result in up to 2,9 million tons of additional CO_2 emissions in 2023 under the simple market compliance scenario, representing "an increase of 4,6 % on the international road freight emissions in 2023 in the baseline" [26].

The International Road Transport Union (IRU) also highlighted concerns over the regulatory impact of the Vehicle Return Provision, emphasizing its potential to disrupt the road transport sector and exacerbate environmental challenges. [27].

Beyond CO_2 emissions, the report states that "costs of air pollution due to negative health effects and other damages were estimated at EUR 25,9 million associated to an increase in NO_x and PM2.5 emissions in 2023 under the simple market compliance scenario" [26]. Under all market restructuring scenarios, these costs were estimated to range between EUR 4.5 million and EUR 25,9 million.

The provision would increase the distance heavy goods vehicles travel and cause major congestion at key transport hubs. The study estimates that the new provision could result in up to 2,5 million additional vehicle-kilometers in 2023, representing an increase of 4.8% in international road freight vehicle kilometers under simple market compliance [17]. This would significantly impact border crossings, especially between Eastern and Western Europe. For example, at Vidin – Calafat (Bulgaria-Romania), waiting times were projected to increase from 130 minutes to 282 minutes, and at Nadlac – Nagylak (Romania-Hungary), from 55 minutes to 162 minutes [26].

A major finding of the study was that the environmental costs of the provision were not compensated by any economic benefits. As noted in the report, "the negative impacts on the environment are not compensated by any additional benefits from trade as the volume of cargo transported by freight is expected to remain unchanged compared to the baseline (i.e., business-as-usual case in 2023)" [26].

TABLE 2 ENVIRONMENTAL IMPACT ANALYSIS

Impact Category	Key Findings
CO_2 Emissions Increase	Up to 2,9 million tones of additional CO_2 emissions in 2023 (4.6% increase in international road freight emissions, in case of simple market compliance). All market restructuring scenarios result in 0,5 to 2,9 million tones additional CO_2 emissions (0,8 % - 4,6 % increase). [26].
NO_x and PM2.5 Emissions Increase	EUR 25.9 million in air pollution costs due to increase NO_x and PM2.5 emissions in 2023 under the simple compliance scenario. All market restructuring scenarios estimated costs range from EUR 4,5 million to EUR 25,9 million. [26].
Increased of Additional Vehicle-kilometers	2,5 million additional vehicle-kilometers (4,8 % increase in international road freight) under the simple compliance scenario. All market restructuring scenarios result in 0,4 million to 2,5 million additional vehicle-kilometers. [26].

The table 2 highlights the negative environmental impacts of the vehicle return obligation, including increased CO_2 emissions (up to 2,9 million tones), higher air pollution costs (EUR 25,9 million), and worsening congestion at key transport hubs. Additionally, it emphasizes that these negative effects are not offset by any trade benefits, making the provision environmentally and economically inefficient.

D. Legal Assessment of the ECJ Decision on the Return of the Vehicle Rule

The ECJ annulled point 3 of Article 1 of Regulation 2020/1055, which introduced paragraph 1(b) in Article 5 of Regulation No 1071/2009. This provision mandated

that vehicles engaged in international transport return to an operational center in their Member State of the establishment at least once every eight weeks. The ECJ ruled that the measure violated the principle of proportionality, lacked sufficient justification and conflicted with EU environmental policies [12].

General Advocate Giovanni Pitruzzella's Opinion, delivered on November 14, 2023, played a crucial role in the ECJ reasoning. He argued that the rule imposed disproportionate economic and environmental burdens on transport operators and that the EU legislature failed to justify its necessity [24].

ECJ's legal assessment of the provision was based on three primary considerations: 1) Lack of an adequate impact assessment. The ECJ concluded that the European Parliament and Council had not thoroughly assessed the economic, environmental and operational impacts of the vehicle return obligation. 2) The EU legislature did not sufficiently evaluate the measure's consequences, particularly its impact on the single market, competition and the environment [12]. 3) The obligation was introduced late in the legislative process without adequate analysis or consultation with affected stakeholders [12].

From a legal perspective, the failure to conduct a comprehensive ex-ante assessment before implementing a restrictive provision raises concerns about legislative transparency.

Disproportionate Burden on Peripheral and Smaller Member States. It was acknowledged that the return of the vehicle rule disproportionately affected transport companies based in peripheral EU Member States, such as Lithuania, Bulgaria, Romania and Malta. These businesses argued that the measure imposes significant operational costs, limits their ability to compete in central and western European markets and creates an unfair competitive disadvantage [12].

This finding matches concerns from industry groups, who say that uniform rules unfairly harm transport companies from Eastern European countries. The ruling highlights an ongoing structural problem in EU policymaking - the tendency to favor larger, centrally located economies at the expense of smaller or peripheral ones.

The ECJ also focused on the environmental impact of the rule. The return obligation would increase empty trips, fuel consumption and CO_2 emissions, contradicting the EU's Green Deal objectives. The ECJ cited evidence showing:

"According to the Republic of Poland's assessments, the additional empty runs imposed by the obligation for vehicles to return, applicable to the Polish vehicle fleet of over 2.5 tones active in international transport, generate 672,024 tones of CO_2" [12].

"The European Commission's study estimated that compulsory vehicle returns "would generate up to 100,000 additional tones of CO_2 emissions per year" [12].

The ECJ ultimately determined that the rule exceeded what was necessary to achieve its objectives, violating the principle of proportionality under Article 5(4) TEU: The measure imposes excessive restrictions on transport operators without demonstrating that less restrictive alternatives were considered [12].

ECJ annulled the return of the vehicle rule, given these considerations.

This case highlights a fundamental tension in EU transport policy - how to balance market regulation with economic freedom. The annulment of the rule suggests a growing judicial skepticism toward restrictive regulations that disproportionately harm specific Member States. Based on the analysis, future actions of EU institutions should focus on (authors' insights):

- Conduct thorough ex-ante impact assessments before implementing restrictive transport rules.
- Align economic regulations with environmental priorities to ensure internal consistency in EU law.
- Ensure Compliance with EU Primary Law to Prevent Institutional Overreach in Decision-Making.

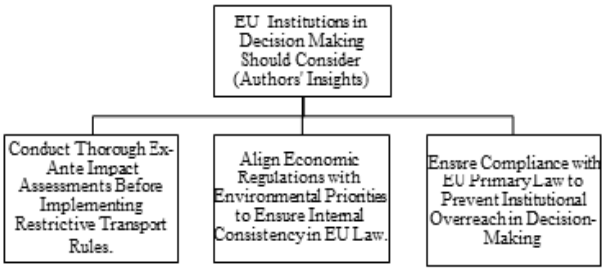

Fig. 3. EU Regulatory Strategies: Authors' Insight on Balancing Economy and Environment.

Fig. 3 illustrates a holistic regulatory strategy that integrating environmental sustainability into economic policies.

The ECJ's annulment of the return of the vehicle rule highlights the importance of proportionality, economic fairness and environmental policy coherence in EU law. Advocate General Pitruzzella's Opinion provided an additional layer of scrutiny, reinforcing concerns about overreach and lack of justification.

According to the authors, this case sets an important precedent for future EU transport regulations, emphasizing that:

EU policymakers must base regulatory measures on empirical evidence and comprehensive impact assessments.

Legislation should not disproportionately burden businesses from specific Member States.

IV. Conclusions

The EU Mobility Package's vehicle return requirement conflicts with the Green Deal, Fit for 55 objectives, and climate neutrality goals by increasing road freight emissions. The ECJ annulled the provision due to its disproportionate economic and environmental impact and lack of an ex-ante impact assessment.

Despite efforts to reduce empty runs, data shows an increase from 20% in 2020 to 21.8% in 2023, with national transport (25.9%) more affected than international transport (13.1%). This indicates that the policy has failed to improve transport efficiency and instead worsened logistical inefficiencies.

The environmental impact is significant. In 2023, CO_2 emissions possibly increased by up to 2.9 million tons, contributing to a 4.6% rise in international road freight emissions. Air pollution costs from NO_x and PM2.5 emissions may have reached EUR 25.9 million, while additional freight transport potentially added 2.5 million extra vehicle kilometers, further exacerbating fuel consumption, congestion, and emissions.

The research findings highlight both practical and theoretical implications for EU transport policy. Practically, ex-ante impact assessments are essential to prevent unintended economic and environmental consequences, ensuring that future regulations align with sustainability goals. Reducing empty runs is a key priority for improving freight efficiency and lowering emissions. Theoretically, the study underscores the importance of compliance with EU primary law to maintain regulatory proportionality and prevent institutional overreach. A data-driven, evidence-based approach is necessary to develop transport policies that balance economic efficiency, legal consistency, and environmental sustainability.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 563-569

Development of a Sustainability Strategy for a Road Construction Company in Latvia

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***Abstract*— The Corporate Sustainability Reporting Directive (CSRD) entered into force on 5 January 2023. This new directive updates the rules on the social and environmental information that companies must report. Companies covered by the CSRD will be required to report in accordance with the European Sustainability Reporting Standards (ESRS). The unclear direction of the industry's development, unstable and unpredictable funding, limited innovation capacity due to regulatory enactments and various customer-created regulations are significant limitations for future plans. All these challenges, supplemented by the principle of the lowest price, complicate and make it difficult to develop new sustainable development strategies. While the selection criterion is the lowest price, large-scale sustainable innovations can put the company in an uncompetitive market position. Road construction companies need to develop a sustainability strategy that both complies with the new regulatory framework, and is in line with the market reality of the industry, and minimizes future risks that may arise from specifying sustainability goals and principles. A sustainability strategy for the road construction company has been developed. This strategy aims to enhance the company's competitiveness by reducing production costs and minimizing environmental impact. It ensures compliance with future sustainability requirements and mitigates risks associated with the loss of competitiveness. The strategy also incorporates the development of management skills necessary for the successful and efficient implementation of strategic directions and for the further development or adjustment of the sustainability strategy in response to policy changes.**

Keywords*— *CSRD, ESRS, sustainability, strategy, competitiveness, environmental impact, construction

I. Introduction

On 5 January 2023, the Corporate Sustainability Reporting Directive (CSRD) entered into force. Similar initiatives aiming to contribute to the transition toward a more circular economy (CE) are increasingly numerous.

There are many debates about indicators and its interpretation – how to represent and what to represent [1], [2], [3]. Several recent papers have demonstrated high disagreement among existing social, environmental, and governance (ESG) rankings (e.g., [4], [5], [6], [7], [8]).

In financiarized economy, decisions are driven by financial interests [9]. As the future environment is constantly changing, [10] suggest that countries and companies need to develop a vision for the future, take short-term actions, and create a theoretical model to guide future decisions in the face of changing circumstances.

Michael Porter argues that many companies narrowly focus on creating value and optimizing short-term financial performance, disregarding the most critical customer needs and ignoring the broader determinants of long-term success [11]. Therefore, the integration of sustainability in a long term-strategy is critically important through the implementation of CSRD, which enable the management to correctly address the sustainability challenges in the construction industry.

It is important to mention that evolution of CSRD is requiring company to adapt its performance indicators to keep pace with new investments to circular economy. Thus there is a vast range of indicators (e.g. over 200 [12]) which is necessary to consider and address all specific needs.

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8668
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CSRD requires also a broad set of large companies, as well as listed SMEs to disclose information on ESG issues with the first reports to be published in 2025.

The outcomes of this analysis suggest that better understanding of CSRD framework is important, as requirement pressures could affect voluntary earnings guidance, which is subject to the cost–benefit trade-off for companies. Therefore, [5] it is necessary to explain what constitutes good and bad ESG performance.

The additional administrative burden to ensure compliance with the reporting requirements will result in significant administrative costs. According to the European Commission, the average reporting costs per company are estimated at around €106,000 per year [13]. However, in the construction sector, given the complexity of supply chains and the various business and environmental factors, these costs are expected to be higher in the authors' opinion.

TABLE 1 CONSTRUCTION OUTPUT AT CURRENT PRICES BY ECONOMIC ACTIVITY, THOUSAND EURO – ECONOMIC ACTIVITY (NACE REV. 2) [14]

Economic activity	**2021**	**2022**	**2023**	**2024**
F Construction	2 435 574	2 592 242	3 230 926	3 138 459
F4211 Construction of roads and motor ways	440 205	477 072	406 925	466505
Share, %	18.1%	18.4%	12.6%	14,9%

The volume of the road and motorway construction sector constitutes a significant part of the volume of the construction sector. Despite the significant decline in 2023, the volume reported in 2024 years is almost 15% of the total production volume of the construction sector (see Table 1).

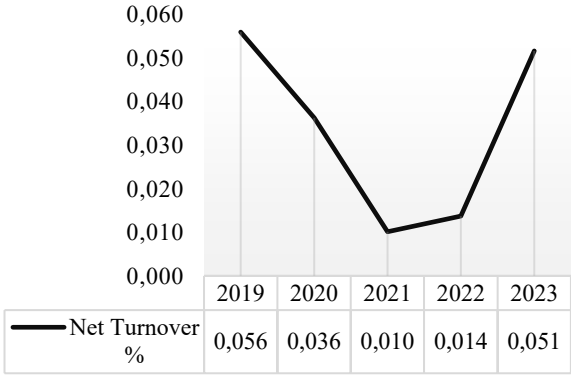

Fig. 1. Net turnover of merchants by type of activity (F42 Civil Engineering) [15].

The above-mentioned Table 1, which summarizes the production output of construction and road and motorway construction, shows that while the volume has almost constantly fallen to 2023, in the period from 2019 to 2022, the net profit of the civil engineering sector has also decreased significantly, reaching its lowest point in 2021, stopping at the 1.0% mark (see Fig. 1). The rapid recovery of profits seen in 2023 can be explained by the fact that in 2023 many companies may have received a share of the income received as a result of indexation for projects that were implemented in previous years. Accordingly, profit figures from previous years should also be viewed over several years.

Overall, the situation in the sector remains unclear, and the expected amount of funding is also divided among different customers – Latvian State Roads, municipalities, Rail Baltica, VAMOIC. Each of these customers has its own specifics of the construction work required, which also means other necessary skills, equipment and construction methods to be implemented. In such situation, it is especially difficult to make decisions about capital investments in development, because it is difficult to predict the investment return in long-term. Therefore, it is necessary to consider peculiarities of the construction industry and its investment strategy for a equipment and processes that are universal or make a decision on specialization in long-term ESG, but this will almost certainly lead to a reduction in the output and operations limits of current needs.

II. METHODS AND RESEARCH DESIGN

To assess the main factors interpretation in strategy development from the perspective of the company's management, an expert method was used, surveying 6 members of the company's top management. The study was conducted in stages:

- The interviews identified the main development directions in the opinion of each manager;
- They were summarized and 10 main directions were proposed;
- Each manager was asked to rank them in order of importance from 1 to 10;
- The results obtained were summarized and analyzed.

The research was conducted using an expert survey method, in which the top management of the road construction company. The survey was conducted in two rounds, in the first round, factors were identified by discussing current industry and company issues, the improvement of which would contribute to the company's competitiveness, as a result of which 10 factors were selected. In the second round, each representative of the company's top management was asked to rank these factors by priority from highest to lowest. Statistical and analytical methods were used to analyze the results, including the Fishburne formula, which was used to determine the importance of the factors. To assess the coherence of the company's management's views, it was tested by calculating Kendall's W coefficient [16].

As it was mentioned various literature sources list vast number of factors that affect the growth of a company. To rank the factors in order of their importance, the authors of this table have used the relative importance index (RII). The relative importance index method is used to prioritize factors based on the answers provided by the respondents. Respondents rate the factors from 1 to 5, with 1 being the least important and 5 being the most important. The RII is then calculated using the following formula (1) [17]

$$RII = \sum \frac{w}{A \times N}, \quad (1)$$

where RII – relative importance index;
w – importance of the factor;
A – the highest importance indicator;
N – sample size.

TABLE 2 LIST OF FACTORS FOR BUSINESS GROWTH [18]

Growth factor (F)	∑w	RII	Place
Good corporate governance	479	0.9392	1
Good cash flow management	459	0.9000	2
Sufficient knowledge and experience	456	0.8941	3
Good team of employees	453	0.8882	4
Technical knowledge	452	0.8862	5
Good project management	449	0.8803	6
Efforts to ensure customer requirements are met	447	0.8764	7
Capital availability	446	0.8745	8
Availability of qualified labor	444	0.8705	9
Good customer relations	441	0.8647	10
Internal efficiency	439	0.8607	11
Product quality	439	0.8607	12
Availability of loans and credit lines	432	0.8471	13
Political stability and peaceful environment	431	0.8450	14
Effective organizational structure	430	0.8431	15
Competitive prices	428	0.8392	16
Market specialization	418	0.8196	17
Open government economic policy	416	0.8156	18
Government support, tax policy	406	0.7960	19
Technological advantages	403	0.7901	20
Employee development and training	396	0.7764	21
Use of new technologies and automation	394	0.7725	22
Work safety	389	0.7627	23
Searching for innovation	382	0.7490	24
Research and development	374	0.7333	25
Knowledge diversification	370	0.7254	26
Formation of full societies	349	0.6843	27

The factors, based on the calculated index, are ranked in order of importance (see Table 2). It can be seen that the first places are occupied by such factors as good corporate governance, good cash flow management, sufficient knowledge and experience, a good team of employees and technical knowledge. In turn, job security, the search for innovations, research and development, diversification of knowledge and the formation of full societies are mentioned as less important factors.

The authors conclude that the key factor identified in this study is good corporate governance, which directly resonates with the conclusion of the study "Understanding the impact of ESG practices in corporate finance" that improving governance by implementing ESG principles contributes most to the ability of companies to increase profits [19]. In addition, there is a need to integrate efforts to achieve global sustainability goals with goals aimed at the company's economic growth. This is particularly important in the road and motorway construction industry, as it is subject to many different regulations and restrictions related to products, which also limits the ability to innovate.

III. DATA ANALYSIS

The factors used in the survey and the factor assessments provided by management can be seen in Table 3.

TABLE 3 SUMMARY OF SURVEY FACTORS AND RESULTS (TABLE CREATED BY THE AUTHORS)

	Factor (F)	V1	V2	V3	V4	V5	V6
1	Improve and modernize the company's equipment fleet to meet modern requirements.	3	2	2	3	1	3
2	Focus on the development of road construction and asphalt concrete production processes	1	9	1	9	9	10
3	Reduce equipment downtime and use resources more efficiently.12	2	1	3	1	4	1
4	Develop leadership skills and implement a strategic approach to business management.30	10	5	8	2	3	2
5	Develop digitalization projects more quickly, implement innovative solutions.	6	4	7	7	7	5
6	To introduce the latest technologies and automation solutions in road construction.	4	3	5	4	2	4
7	Increase cooperation with policymakers to create a desirable regulatory framework.	7	8	9	6	8	9
8	Develop opportunities for material reuse, thereby reducing the risk of material price increases	9	10	10	10	10	6
9	Implement cost-effective sustainability initiatives that promote low costs and high efficiency.	5	6	4	5	5	7
10	Develop innovations and environmentally friendly solutions, such as reducing CO2 emissions.	8	7	6	8	6	8

Calculation of the importance of factors was using the Fishburne formula. The general formula is as follows (2) [20].

$$S_i = \sum_{j=1}^{n} \omega_j \times \mu_{ij}, \quad (2)$$

where S_i - the total outcome or utility for option *I*;
ω_j- the weight of factor - *j*, reflecting its importance;
μ_{ij}- the utility or performance of option *i* according; to criterion *j*;
n - total number of criteria, n=10

The first step is to calculate the relative importance of each criterion. This is done using the following formula (3), for each criterion value.

$$\omega\ (R_i) = \omega_i = \frac{2(m-j(R_i)+1)}{m(m+1)}, \qquad (3)$$

where *j(Ri)* - factor *Fi* position number in a ranking sequence. See the calculated relative weights in Table 4.

TABLE 4 RELATIVE WEIGHTS OF CRITERIA (TABLE CREATED BY THE AUTHORS)

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
relative weight	0.19	0.16	0.15	0.15	0.10	0.08	0.07	0.05	0.04	0.01

In the next step, we replace the factor ranking with the calculated relative weight and calculate the average value between the managers. See the calculated indicators in Table 5.

TABLE 5 CALCULATED TOTAL IMPORTANCE OF CRITERIA (TABLE CREATED BY THE AUTHORS)

Factor	**Average weight**	**Importance**
Improve and modernize the company's equipment fleet to meet modern requirements.	0.164	2
Focus on the development of road construction and asphalt concrete production processes	0.073	7
Reduce equipment downtime and use resources more efficiently.	0.182	1
Develop leadership skills and implement a strategic approach to business management.	0.127	4
Develop digitalization projects more quickly, implement innovative solutions.	0.091	6
To introduce the latest technologies and automation solutions in road construction.	0.145	3
Increase cooperation with policymakers to create a desirable regulatory framework.	0.036	9
Develop opportunities for material reuse, thereby reducing the risk of material price increases	0.018	10
Implement cost-effective sustainability initiatives that promote low costs and high efficiency.	0.109	5
Develop innovations and environmentally friendly solutions, such as reducing CO2 emissions.	0.055	8

The main three factors that would positively affect the competitiveness of the company are those related to efficiency – reduction of downtime, modernization of the technical fleet and automation. In the middle category (4th-7th place), the first place is taken by managerial and strategic management skills. The authors point out that in the study, the results of which are shown in Table 3, good corporate governance, which is related to management skills and a strategic approach, is the main factor strengthening competitiveness. This statement also appears in other scientific studies considered within the framework of this work. Accordingly, it can be assumed that the fact that this factor remains behind the first three may indicate an incomplete understanding on the part of the company's management, the cause of which may be precisely the lack of management skills. The difference in opinions is also shown by the difference in the ratings of this factor, which ranges from 2nd to 10th place.

TABLE 6 THE SUM OF SQUARED DEVIATIONS (TABLE CREATED BY THE AUTHORS)

Factor	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**Sum**	**D**
Improve and modernize the company's equipment fleet to meet modern requirements.	3	2	2	3	1	3	14	361
Focus on the development of road construction and asphalt concrete production processes	1	9	1	9	9	10	39	36
Reduce equipment downtime and use resources more efficiently.	2	1	3	1	4	1	12	441
Develop leadership skills and implement a strategic approach to business management.	10	5	8	2	3	2	30	9
Develop digitalization projects more quickly, implement innovative solutions.	6	4	7	7	7	5	36	9
To introduce the latest technologies and automation solutions in road construction.	4	3	5	4	2	4	22	121
Increase cooperation with policymakers to create a desirable regulatory framework.	7	8	9	6	8	9	47	196
Develop opportunities for material reuse, thereby reducing the risk of material price increases	9	10	10	10	10	6	55	484
Implement cost-effective sustainability initiatives that promote low costs and high efficiency.	5	6	4	5	5	7	32	1
Develop innovations and environmentally friendly solutions, such as reducing CO2 emissions.	8	7	6	8	6	8	43	100
						Average		**33**
						Sum of squared deviations from the overall rank mean (*S*)		**1758**

Therefore, to assess the overall consensus of the company's management, the Kendall W coefficient will be calculated. It is calculated according to the following formula (4).

$$W = \frac{12 \times S}{m^2(n^3-n)}, \qquad (4)$$

where S - sum of squared deviations (D) from the overall rank mean;

m - number of evaluators;
n-number of factors.

The calculated results can be seen in Table 6

By inserting the calculated numbers into the formula, we obtain the following result

$$\frac{12 \times 1758}{6^2(10^3 - 10)} = 0.592$$

The results obtained can be categorized as follows:

- Weak agreement – below 0.20
- Moderate agreement – 0.21 – 0.40
- Average agreement – 0.41 – 0.60
- Good agreement – 0.61 – 0.80
- Very good agreement – 0.81 – 1.00

Therefore, the obtained result can be interpreted as an average or moderate coherence of opinions. This may indicate that the management has an agreement on the basic development directions, but taking into account the factors in different directions, fundamental differences are also observed. This further justifies the need to develop and implement a unified strategy to prevent uncoordinated prioritization of development directions, which can significantly hinder the development of the company.

IV. Conclusions

The findings of this study provide the analysis of the key factors interpretation by the management to consider when developing a sustainability strategy in changing environment. The strategy approach draws on research that assesses the impact of a sustainability strategy on a company's financial performance, risk management, the role of management and stakeholders in setting and implementing the strategy, and potential reporting challenges. The authors emphasise that a successful sustainability strategy is, first and foremost, a successful business strategy that integrates ESG factors to ensure multi-faceted decision-making that is acceptable to all stakeholders.

At a time when sustainability-related requirements are not assessed by industry customers or the assessment of such requirements is very minimal, the developed strategy must consider the promotion of long-term competitiveness and reduce risks. The specifics of the industry create prerequisites or targets that the company can achieve, but at present they can only be mentioned. For this reason, the authors combine the growth factors of companies highlighted in various studies, the impact of various sections of sustainability (environmental, social and governance) on company results, potential procurement requirements and the opinion of company management in order to create a strategy concept that contributes to the improvement of both the short-term and long-term results of the company by interpreting vast number of CSRD metrics.

The competitiveness of a company is, of course, determined by many complex factors, and the company should pay attention to all of them. Taking into account the CSRD integration, significant attention should also be paid to participation in the development of regulatory enactments, representation of its interests in industry associations and the development of innovations. However, the strategy proposed by the authors is based on three main directions, which are the most important:

- Cost-effectiveness;
- Reducing environmental impact;
- Development of management skills.

The implementation of these three directions will allow the company to both reduce its direct costs, thereby gaining a competitive advantage in the lowest-price procurement, and reduce its environmental impact and prepare for the introduction of sustainability requirements in procurement, thereby reducing the risks of loss of competitiveness, and by developing management skills, ensure that the company and its management are able to implement and manage changes, which is also related to this sustainability strategy.

The construction of the main road is a technically intensive work, which means that a large part of the work can be done only using construction machinery and automation solutions without a large human workforce. Therefore, the renewal of the technical fleet can not only open up the opportunity to take an active part in the implementation of the project, but also gain competitive advantages over local competitors, and maintain competitiveness against foreign infrastructure construction companies.

In general, the benefits to be achieved from making such investments can be seen in conceptual model for the strategy ranking and interpretation example on Figure 2.

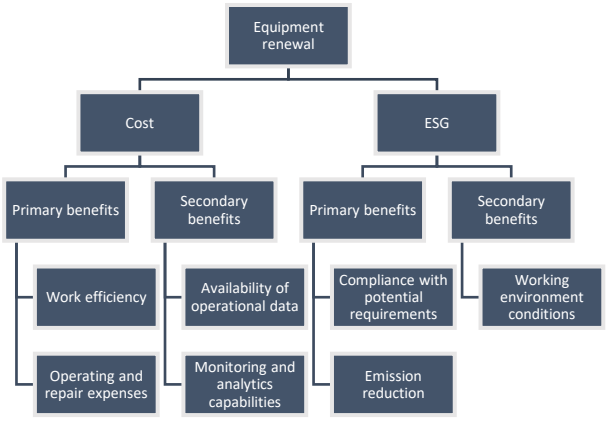

Fig. 2. Example interpretation of benefits of technical renewal for ESG (image created by the authors).

The main primary benefit of renewing the equipment fleet could be an increase in work efficiency and thus competitiveness. Different sources differ in data that allow comparing the performance of new and old equipment

units, because the total performance, expressed as the amount of work performed in a certain unit of time, and which is used to calculate the cost of work, depends on many factors, including:

- Technical performance;
- Operator skills;
- For planning and performance of other construction machines;
- The specifics of the construction project and the work to be performed;

However, industry estimates, comparing new equipment with equipment that is 10 years or more old, indicate an average efficiency improvement of 15%.

In the field of ESG and CSRD, the primary benefit is the reduction of the risk that the equipment will not meet future environmental requirements. This effectively reduces the risk that the company's fixed assets will no longer be usable for the company's core business. There is reason to believe that such a practice will also be adopted in projects of other customers, even if it is implemented in a different way, for example, when assessing direct CO2 emissions, new equipment has lower CO2 emissions and particulate emissions due to fuel economy and engine efficiency.

Summarizing the strategy described in the calculation part of the paper and based on the calculations, the author conclude that the chosen ESG strategy should consider the specifics of the industry capital requirements, there are currently no clear requirements related to sustainability factors that would be used to evaluate offers according to the principle of economic benefit.

The developed strategy contributes to the short-term and long-term competitiveness, while at the same time preparing the company for the development of sustainability requirements, the chosen strategic directions not only contribute to cost efficiency, but also have a beneficial effect on the working environment of employees and promote the strategic development of the company, promoting the development of management skills. In this way, an improvement in the company's results is achieved in all areas of sustainability - environmental, social and governance, while providing economic benefits and reducing risks.

Overall, the conceptual strategy successfully balances the company's goals in terms of profit generation with the need to prepare for and meet external demands. The strategy provides a clear but flexible framework, and ensures that it is adaptable to changing market conditions and can be used or projected down to each of the company's structural units.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 571-576

The Concept of the Reporting Entity and Dual Materiality in Sustainable Reporting

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***Abstract*- To determine the boundaries of the reporting entity in good faith, it is necessary to consider the rights of stakeholders. The sustainability report applies to the same reporting entity as the financial statements. Financial statements are prepared from the perspective of investors using financial materiality criteria. The inclusion of the direct and indirect business relationships of the entity allows for the expansion of the scope of materiality by assessing the significant impacts, risks, and opportunities associated with its activities. They require assessment and justification of the decision to include them in the determination of materiality, which is differentiated into impact materiality and financial materiality. These circumstances are considered upstream and/or downstream in the value chain of the entity. There is a need to document the decision to include information about the value chain only in relation to the parts of this chain for which the issue is material. For sustainability reporting, the materiality principle is transformed into the principle of double materiality. Accordingly, the financial statements include a new component – a sustainability report, part of the organization's annual report. There is a transformation of the financial reporting related to sustainability into a separate, structured sustainability report, part of the organization's annual activity report. Resources for preparing quality sustainability reports are found in using accounting methods for current reporting through a certain analytical approach and assessment of significant impacts, risks, and opportunities. The methods of analysis and synthesis, observation and comparison, analogy, documentation, and modeling are used. The implementation of the proposed analytical accounting facilitates the preparation of the sustainability report. The documents prepared to include information on the value chain provide evidentiary value of the decisions made for the organization's sustainability.**

Keywords- reporting entity, dual materiality, accounting, sustainability, report.

I. INTRODUCTION

Sustainability requires the responsibility of today's management to future generations. Sustainable development is often defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [15] Sustainability reporting requires not only formal contractual relationships with suppliers, customers, and employees, but also the informal and indirect business relationships of the enterprise. There are blurred boundaries of relationships, creating a mesoenvironment that operates at the boundaries between the micro and macro environments of the enterprise. The mesoenvironment creates an opportunity to expand the scope of the reporting organization to include the impact of actual and potential business relationships on sustainability.

The concept of the accountable enterprise finds its origin in the need for everyone to be responsible for their activities and to receive a reward or profit for the work done by them. In this sense, the organization has an interest in differentiating and addressing its efforts in a way that allows for both costs and assets, as well as revenues and liabilities, to be accounted for in the process of forming and maintaining sustainability. Sustainability in the channel for sustainable solutions is created and maintained by the rights and obligations of interested parties. In this regard, for the mesoenvironment, public accountability "is expressed in the obligations of individuals and organizations, including state-owned enterprises, to which state funds are provided, to bear fiscal responsibility, managerial responsibility and responsibility for the implementation of programs, as well as to be accountable to those who have provided them with these responsibilities." [2, 20-21] Therefore, the concept of the reporting enterprise applied in the mesoenvironment of the

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8649
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organization provides a distribution channel for sustainable solutions.

The nature of a reporting entity is defined in the 2018 Conceptual Framework (the Framework), which states that "A reporting entity is an entity that is required, or chooses, to prepare financial statements. A reporting entity can be a single entity or a portion of an entity or can comprise more than one entity. A reporting entity is not necessarily a legal entity." [21, par. 3.10] The determination of sustainability requires taking into account the influence of the communicative nature of the activities performed by the organization not only from suppliers, customers and appointed persons, but also from the end users of the production organizations' output. The path to reach the end users is defined as the marketing distribution channel for the organization. Stern and El-Ansari define marketing channels as "a set of interdependent organizations involved in moving a product or service to the consumer." [9] Sustainability, formed by the relationships between the participants in the distribution channel, finds expression as a marketing dialogue that "emphasizes the communicative nature of all activities of sellers and buyers."[6] The commitment of each of the participants in the distribution channel requires responsible business behavior, which finds expression in the Global Reporting Initiative (GRI), founded in Boston (USA) in 1997 [24].

TABLE 1 COSTS FOR ENVIROMENTAL, SOCIAL AND GOVERNANCE SUSTAINABILITY

№	Costs For Sustainability		
	№	*Scope of classification*	*Classification*
1.	1.1.	For the purpose of control from the point of view of occurrence	Costs for restoring a disturbed ecological balance
	1.2.	For the purpose of control from the point of view of occurrence	Costs for preventing the disturbance of the ecological balance
2.	2.1.	For the accounting purposes and the relationship of expenses to the financial statements of the entity	Internal environmental costs
	2.2.	For the accounting purposes and the relationship of expenses to the financial statements of the entity	External environmental costs

From the beginning, GRI's goal has been to "work to further publicize information that goes beyond a simple sustainability perspective to include social, economic and governance issues."[5] The contribution of GRI is that it "creates a global common language for organizations to report their impacts - which enables informed dialogue and decision making around those impacts."[24]Twenty-five years later, the sought-after sustainability of business relationships finds a natural expression in CSRD and ESRS as a value chain formed both between the individual objects of an enterprise and between enterprises created on the basis of capital, contractual or consumer relationships. Both financial and non-financial information on the impacts, risks and opportunities formed in the meso environment is necessary for sustainability reporting. Therefore, "when determining at what level (within its own activities and down and up the value chain) a given material sustainability issue arises, the enterprise uses the assessment of impacts, risks and opportunities that it has made, observing the principle of double materiality."[17, par. 66] As a concept providing a comprehensive view of environmental costs, applicable also to social and management sustainability costs, the classification of B. Yonkova (1, p. 174), presented in Table 1, can be accepted.

By searching for the relationships in environmental, social and governance sustainability, a new concept is defined "as the "triple bottom line", considering simultaneously environmental, social and financial results" (8, 77).

II. MATERIALS AND METODS

The availability of financial and non-financial information on environmental, managerial and social sustainability allows for a better explanation of social processes through the sociological theory of structural functionalism [11], (H. Spencer, M. Durkheim, T. Parsons), explaining the structures and functions of society. From the point of view of the economic aspect of the behavior of individuals and organizations, the sociological theory of exchange is applicable, the subject of study of which is the normative-value side of the exchange processes. [11] At each level in the value chain, a basic activity-behavioral model can be organized in control, with which two effects of influence can be used - the effect of the coercive order and the effect of creative expression, which, taken together, will lead to a greater overall effect of the functioning of the organization. The basis of the activity-behavioral model "is the idea of the dual nature of labor - as activity and behavior." [4] The activity-behavioral approach proposed in the model is the result of a comparison of two other approaches to management – the institutional-activity and the motivational-behavioral. The first of these is characterized by the fact that it institutionalizes relations and regulates the rules. It applies the concept of typical design and in controlling the organization it is characteristic to introduce a completely new management, strict regulatory control by the regulator and strong bureaucracy. In the motivational-behavioral approach, centralization is displaced and modern marketing management tools are applied, concretizing in "social management".

Financial statements are prepared from the perspective of investors using financial materiality criteria. The inclusion of the direct and indirect business relationships of the enterprise allows for the expansion of the scope of materiality by assessing the significant impacts, risks and opportunities associated with its activities. They need evaluation and justification of a decision for their inclusion in determining materiality, which is differentiated into materiality of impact and financial materiality. These circumstances are considered

upstream and/or downstream of the enterprise's value chain. There is a need to document the decision to include information about the value chain only in relation to the parts of this chain for which the issue is material. For sustainability reporting, the materiality principle is transformed into the principle of double materiality. In DR (EU) 2023/2772, the concept of dual materiality is defined and it is determined that dual materiality has two dimensions, namely: impact materiality and financial materiality (16, ESRS 1, par. 37). The impact needs up-to-date reporting tools. A sustainability issue is material from an impact perspective when it relates to the significant actual or potential, positive or negative impacts of the entity related to its own activities, upstream and downstream of its value chain. (16, ESRS 1, par. 3.4). The financial materiality of a sustainability issue is not limited to matters that are under the control of the entity, but includes information on significant risks and opportunities arising from business relationships outside the scope of consolidation used in the preparation of the financial statements. Dependencies on natural, human and social resources may be a source of financial risks or opportunities. The significance of risks and opportunities is assessed based on a combination of the likelihood of occurrence and the potential magnitude of the financial consequences (16, ESRS 1, par. 3.5).

The problem of sustainability in the value chain is directly related to the "transformation" of a company's potentials in markets and segments in them, making up its company strength. Under the concept of "transformation" we take the meaning of the word "transformatio" in the sense of "art of changing some values with others".[10] With certain changes in strategy, size of organizations, management technology and the surrounding environment, the value chain is restructured, and accordingly restructures the structures involved in the organizational units. System dynamics and structural sustainability of relationships are of interest for the long-term, mid-term and operational sustainability reporting. Certain difficulties may arise in the accumulation of information in connection with sustainability reporting. These difficulties may be caused by a lack of analytical accounting or market information. According to the ESRS, the reporting entity is relieved during the first three years of sustainability reporting. In this case, "the entity explains what efforts it has made to obtain the necessary information for its value chain upstream and downstream, the reasons why it could not obtain all the information, as well as its plans to obtain the necessary information in the future." [16, par.132] As can be seen, non-financial information for sustainability reporting is descriptive in nature. It, as well as the information included "in the annex to the Annual Financial Statements, descriptive information means descriptive, non-financial information that complements and enriches the financial information in the components of the financial statements." [13]

The annual report of the organization includes a new component – a sustainability report, part of the annual report of the organization. There is a transformation of the financial reporting related to sustainability with a separate, structured sustainability report. Resources for preparing quality sustainability reports are found in the use of accounting methods for current reporting through certain sub-accounts and analytical and assessment of significant impacts, risks and opportunities. Analytical reporting should be directed in accordance with the requirements of the sustainability report according to ESRS, and the sub-accounts and analytical accounting accounts for costs and revenues related to environmental, social and governance sustainability should be described in the accounting policy of the organization.

III. Results and discussion

When identifying and assessing impacts, risks and opportunities along its value chain to determine their materiality, an enterprise shall focus on areas where impacts, risks and opportunities are considered likely to arise, based on the nature of the activity, business relationships, geography or other factors. In line with the requirements of the CSRD, the list of sustainability issues on which enterprises are required to disclose information should be aligned as closely as possible with the definition of 'sustainability factors' set out in Regulation (EU) 2019/2088 and avoid any inconsistency between the information required by data users and the information that enterprises should report. [18, par. 28] 'Sustainability factors' means environmental, social and employee-related issues, as well as issues related to respect for human rights and the fight against corruption and bribery. [19] It is evident that the marketing dialogue model supports the definition of the value chain and plays an important role in determining the materiality of the impact. The threshold and compensating factors also serve to define the "sustainability factors". The result is a model of the marketing dialogue between manufacturer, distributor and retailer, supporting the assessment of the materiality of the impact, shown in in Fig. 1 [15] Reporting of sustainability is carried out in compliance with the accounting principle of priority of substance over form. First, costs are accrued by economic elements (by content), then the costs are transferred by types of activities (by form). The risks associated with receivables and payables require the use of the principle of caution - maintaining increased attention when making judgments under conditions of uncertainty. Issues related to deviations from environmental standards may have an impact on the recognition, measurement and reporting of liabilities in the financial statements, which are applied in accordance with IAS 37 Provisions, Contingent Assets and Contingent Liabilities. According to IAS 37, it is necessary to disclose the nature of provisions or contingent liabilities and indicate the uncertainty about the amount or timing of the related economic flows (IAS 37, para. 85-

86). Costs by economic elements are incurred for materials, external services, depreciation, payroll, social security and others. Sustainability costs are also incurred for the purchase of long-term assets used to ensure environmental, social and management sustainability. According to the degree of aggregation of accounting data, accounting accounts for sustainability reporting are divided into synthetic and analytical. Synthetic accounts reflect information on the prevailing common properties of homogeneous groups of assets, liabilities, income and expenses. To account for the functional purpose of the objects generating environmental, management and social sustainability and in order to support the preparation of sustainability reports, it is necessary to create decomposed, more detailed accounting information. "This is achieved by maintaining analytical accounting accounts to a given synthetic main accounting account." [3] Along with monetary ones, natural measures can also be used. In order to introduce differentiated information on sustainability, sub-accounts can also be used, which "are introduced when, within a synthetic account, it is necessary to perform an additional (intermediate) grouping of reporting objects." [12] In addition to the expenses incurred on a cash basis for the period, it is necessary to create accounting information for sustainability through analytical reporting on the receivables and payables of enterprises on an accrual basis.

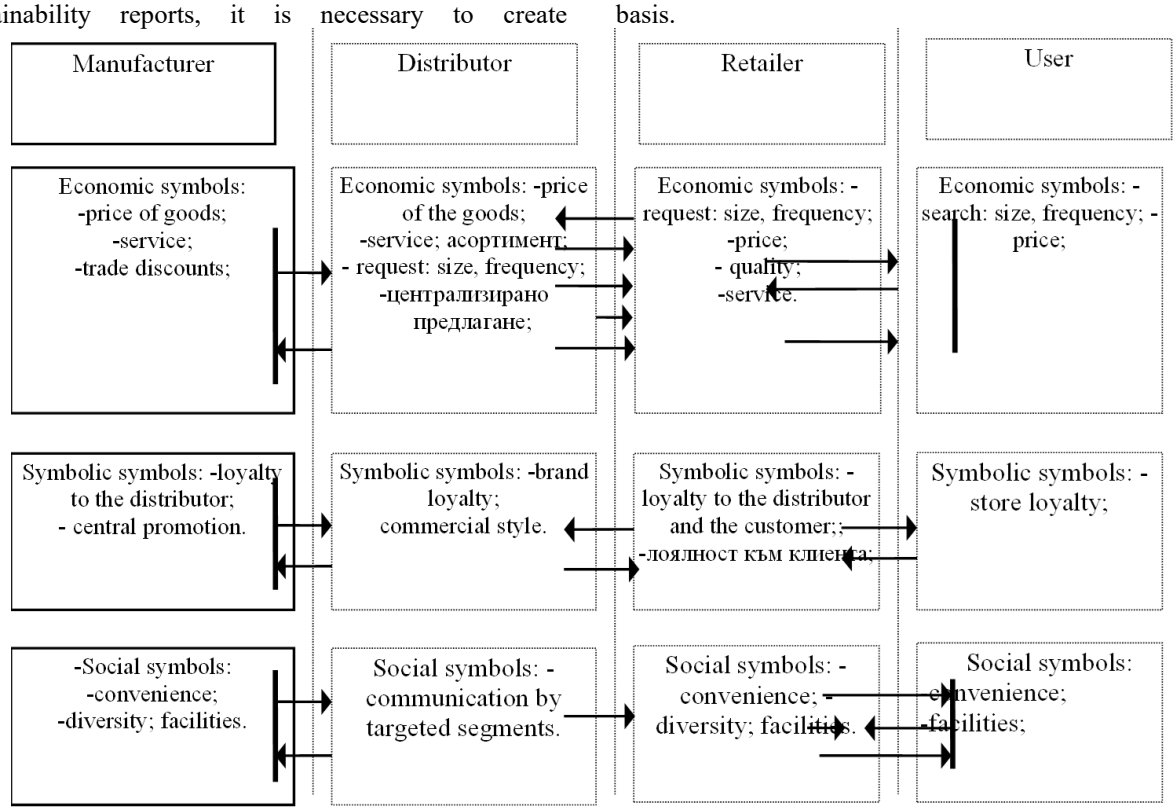

Fig. 1. Marketing dialogue model in the distribution channel.

For receivables reported with the active accounting account "Receivables", accrual can be illustrated with the example shown in Table 2. Analytical reporting can also be organized by clients, by payment terms, by client country, etc. For liabilities, sustainability analytics is also created, as they are reported on a synthetic passive accounting account "Payables to suppliers".

To account for sustainability, the system of analytical accounts to the synthetic account "Receivables" has the form shown in Table 3.

The sustainability report regulated by the ESRS [17, 115] is part of the annual report on the activities of organizations. In order to verify the completeness and correctness of the accounting entries regarding environmental, social and management sustainability, an analytical turnover sheet is prepared. "From the turnover sheets for analytical accounts, changes (increases or decreases) of each reporting object can be established. Therefore, they are an important source of information that is used to control and analyze business activity". [7] That is why they have an important place in providing accounting information for inclusion in the sustainability report.

In support of the claims that the enterprise is a going concern, the sustainability report includes off-account information. This information represents opinions, statements, and others that give rise to grounds for reporting specific transactions and operations in a future period, but are not accounted for and do not give rise to financial effects in the current period. For example, a concluded supply contract covering a future period should be entered into the accounting system off-balance sheet in the current period, but is not reported on the balance sheet

accounts. The information and statements should not be accounted for, but should support forecasts and projections of the organization's sustainability in different time horizons.

TABLE 2 ACTIVE SYNTETIC ACCOUNTING ACCOUNT "RESEIVABLES"

№	Synthetic Accounting Account "Receivables"		
		Debit	***Credit***
1.		Opening balance	
2.		Debit turnover – increasing	Credit turnover – deceasing
3.		Amount of debit turnover	Amount of crebit turnover
4.		Debit total	Credit total
5.		Ending balance	

TABLE 3 ANALITICAL ACCOUNTS FOR SUSTAINABILITY TO THE SYNTETIC ACCOUNTS "RECEIVABLES"

№	**Analytical Accounts For The Sustainability To The Synthetic Accounting Account "Receivables" (Separately for Materials, External Services, Depreciation, Salaries, Social Security and Others)**					
	Analitical Account "Enviromental sustainability"		***Analitical Account "Social Sustainability"***		***Analitical Account "Management Sustainability"***	
1.	Debit	Credit	Debit	Credit	Debit	Credit
…	…….		……		……	

Accountants prepare approximate accounting estimates of the effects of future business operations, through which they establish predictable financial values. The preparation of a forecast included in the sustainability report should be guided by the International Standard on Assurance Engagements 3400: Review of Prospective Financial Information, which states that "Prospective financial information" means financial information based on assumptions about events that may occur in the future and possible actions by an entity. It is highly subjective in nature and its preparation requires the exercise of considerable judgment. Prospective financial information can be in the form of a forecast, a projection or a combination of both, for example, a one year forecast plus a five year projection. (23, para. 3) In order to assess the materiality of the impact along the value chain and determine financial materiality, it is important to project the activities in operational, medium-term and long-term periods. The business relationships that have arisen should be assessed. The sustainability of the activities is also assessed. Therefore, in order to take sustainability into account, a "Projection of Future Opportunities" is prepared. „A "projection" means prospective financial information prepared on the basis of:

(a) Hypothetical assumptions about future events and management actions which are not necessarily expected to take place, such as when some entities are in a start-up phase or are considering a major change in the nature of operations.

or

(b) A mixture of best-estimate and hypothetical assumptions.

Such information illustrates the possible consequences as of the date the information is prepared if the events and actions were to occur (a "what-if" scenario)". (23, para. 5)

Therefore, the preparation of predictive and projective information supports the application of the concept of dual materiality. For example, when acquiring a company, the preparation of the organization's value chain can use an analysis of the activities ensuring its sustainability:

„1st rank: Macro-environment in the areas: "Acquired company" - Society - Ecology.

Threshold and compensatory factors for the transformation of the interest in transfer, generated by the marketing environment.

2nd rank: Analysis of the industry environment in the areas: "Acquired company" - Strategic business unit /SBU/ - Industry.

Threshold and compensatory transformation factors of the industrial environment.

3rd rank: Analysis of the company's environment in the areas: "Acquired company" - Product - Market.

Threshold coefficients for marketing transformation:

PC1= Sales by products and markets/marketing costs by products and markets

PC2= Market share by products/marketing costs by products. "(14, 88)

Company compensatory factors are also prepared. Such an analysis can be used to draw up the reporting entity's value chain and to demonstrate it as a going concern.

IV. CONCLUSIONS

Non-financial information for sustainability reporting is descriptive in nature. Transformations in the value chain occur when threshold sustainability factors are crossed. At a lower level in the value chain, there are compensating factors, the change of which does not lead to transformation, but to a change in a given local area of sustainability. For the three ranks (macro, meso and micro environment of the enterprise), threshold and compensating factors are defined, based on specific adjustable parameters and indicators. The result is a model of the marketing dialogue between the manufacturer, distributor and retailer, supporting the assessment of the materiality of the impact. The main impacts, risks and opportunities of a given enterprise are similar to the material impacts, risks and opportunities established in accordance with the principle of double materiality, reported in its sustainability report. The marketing dialogue model supports the definition of the value chain

and plays an important role in determining the materiality of the impact. The threshold and compensating factors also serve to determine the "sustainability factors". To account for the functional purpose of the sites generating environmental, management and social sustainability and in order to support the preparation of sustainability reports, it is necessary to create decomposed, more detailed, analytical accounting information. In order to verify the completeness and correctness of the accounting entries regarding environmental, social and management sustainability, an analytical turnover sheet is prepared. The preparation of predictive and projective information supports the application of the concept of dual materiality.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 577-582

The Application of the Accrual Basis Principle in Dynamic Balance Theory for Ensuring Sustainability in Bulgaria

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Abstract: **In accrual basis accounting, flows are recorded at the time economic value is created, transformed, exchanged, transferred or settled. The period between the time a payment is accrued and the time it is actually made is recorded as a receivable or payable in the financial accounts. The criterion for recognizing receivables and payables that have arisen is the right to receive or pay cash. The financial condition of the organization in the future period is presented in a resulting balance sheet, which is a function of the balance sheet in the current period and the income received and payments made in the future period. The transfer of funds to the future period for the repayment of incurred liabilities leads to a decrease in cash and a reduction in liabilities. The receipt of cash resources in connection with the receivables incurred leads to a decrease in receivables and an increase in cash. This development is described by the theory of the dynamic balance sheet. The dynamic balance sheet is an auxiliary tool for forecasting the financial result and is not part of the annual financial statement of the organization. The theory of the dynamic balance sheet was introduced by Eugen Schmallenbach, a representative of the German accounting school. E. Koisol, his follower, further developed this theory through the concept of the Patagoric balance sheet he developed. The dynamism of the information in the balance sheet reflects the effects of applying the accrual basis in statics and dynamics. The methods of analysis and synthesis, observation and comparison, analogy, modeling and accounting methods of balance sheet summarization were used. The preparation of a dynamic balance sheet allows for the expansion of the application of the accrual basis in budgeting in the private and public sectors.**

Keywords: ***accounting, accrual basis, dynamic, sustainability.***

I. INTRODUCTION

Bulgaria is a member of the European Union. In this regard, in connection with reporting to the Eurostat, the country's commitments to macroeconomic statistics have increased over the last decade. The system of national and regional accounts currently used by EU members (ESA) provides the accounting macro-framework for government and private sector statistics in the EU, which is based on current accrual. "In the European System of Accounts 2010 (referred to as "ESA 2010" or "ESA"), flows are recorded on an accrual basis; i.e. when economic value is created, transformed or lost or when receivables or payables arise, transformed or extinguish."[16] In summary, the principles of accounting are generally known and applicable. The generally known ones are observability, causality, specificity, storage, equivalence of changes, analysis, summary and others.[1] "In applied terms, accounting principles are the restrictive rules for creating accounting information for individual business transactions in the capital turnover carried out in the enterprise."[7] The principles are the basis for implementing the information function of accounting with a view to creating quality information for the reported objects. In this regard, as one of the accounting principles, "the consideration of the problem of accrual accompanies the transition of fundamental accounting concepts from concepts to the formulation of conventions and the formalization of accounting principles."[13] According to the currently effective Accounting Act in Bulgaria, the accrual principle states: "accrual - the enterprise prepares its financial statements, with the exception of statements related to cash flows, based on the accrual principle - the effects of transactions and other events are recognized at

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8700
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the time of their occurrence, regardless of the time of receipt or payment of cash or their equivalents, and are included in the financial statements for the period to which they relate."[18, art. 26, para. 1, item 4] As can be seen, the text of the accrual principle sufficiently clearly characterizes the independence of accrual from the moment of receipt or payment of cash or their equivalents, meaningfully emphasizes the right to recognize liabilities or receivables in the current and to receive or pay cash in the next reporting period. It is precisely and comprehensively explained that the effects of accrual are included in the financial statements for the period to which they relate. The application of the accrual principle is characterized by:

-1. The difference between the receipt or payment of cash and the right to receive or pay it.

-2. Accrued income and expenses arise in one reporting period, but the cash will be received or paid in a subsequent reporting period.

These circumstances also emphasize the essence of the accrual principle, which is expressed in the right to recognize receivables and payables incurred in the current reporting period as settlement relations that will be received or paid in a subsequent reporting period. The topicality of the topic is caused by the circumstances that it is impossible to recognize the currently arising receivables and obligations, reported on an accrual basis in Bulgaria as current rights and obligations in the public sector budgets. It is also relevant to submit an interim report containing an accrual and cash basis, which will present accounting information for inclusion in the sustainability report. The purpose of the study is to present a report that contains accounting information on sustainability in the private and public sectors. The study is supported by a comparison of different authors' theses on the balance sheet from the history and theory of accounting. By researching statements in various legal acts, the thesis of applying the accrual basis in a dynamic balance sheet and on this basis preparing accounting information for inclusion in the sustainability report is emphasized. In total, nineteen literary and legal sources are used.

II. Materials and Methods

The accounting balance sheet has as its theoretical and scientific basis the balance sheet summary and the double entry of business transactions (the dopika), which are the main elements of the accounting method.[4] It is a technical means for implementing the balance sheet summary of the accounting information reflected up to this point by means of current accounting. The accounting balance sheet is characterized by staticity, because it reflects the accounting information at a certain point in time. As a means and method of knowledge, the accounting balance sheet and the balance sheet summary are inextricably linked to each other. The balance sheet summary is a method by which two sides of something are compared in order to achieve equilibrium (balance) between them.[5] In accounting, achieving equality between the two sides is mandatory, since they are two sides of the same object. The two-sided manifestation of the property of the enterprise is expressed in the two sides of the balance sheet - "Asset" and "Property and liabilities". In the asset, the property is shown as a specific composition of funds (assets) with a given form of embodiment and functional purpose. In the liability, the sources of the property are designated and shown, systematized as equity and foreign sources (liabilities).

TABLE 1 O. SCHMALLENBACH'S DINAMIC BALANCE

Dynamic balance sheet	
Asset	***Property and liabilities***
Cash and non-cash assets such as expenses that have not yet become income, i.e. the organization has spent the money but has not yet absorbed it in its activities.	Capital, reserves, financial result. Income and expenses that give rise to rights and obligations, recorded through estimates.
1) cash (cash, current account, etc.) Decrease: 2) expenses, but not yet invested in production, are in stock (purchase of materials, etc.); 3) values that will become expenses after they receive cost price (semi-finished products, etc.); Increase: 4) estimates that give rise to receivables but are not yet receipts of funds (receivables); 5) values that will become income through sale (finished products, etc.);	1) capital; 2) expenses that will become values (reserves, etc.) Increase: 3) income that will become assets assets (advances received, etc.); 4) proceeds that are the result of liabilities incurred (loans received, credits, etc.); Decrease: 5) estimates that give rise to liabilities, but not yet expenses (liabilities to suppliers, salaries, etc.);

Static balance refers to the state of the object at a given moment, while dynamic balance refers to the state of the object over time. Dynamic balance is an aid to forecasting the financial result and is not part of the annual financial statement of the organization. The theory of dynamic balance was introduced by Eugen Schmallenbach (1873 - 1955), a representative of the German accounting school. If we consider the material results and material costs for a short period, then the excess of the results for this period over the costs is not equal to the financial result, since financial costs and revenues do not always correspond to the material results and costs incurred. O. Schmallenbach's dynamic balance is presented in Table. 1, adapted according to [8]. It is striking that the goal of Schmallenbach's approach is to capture the unfinished business in business operations, to try to distinguish the current moment in which the funds have not been received or paid, but after a certain action (completion of production, delivery, occurrence of dates for payment of salaries and social security contributions, etc.), in a future reporting period, the amounts will be paid or received. This controlled dynamic, launched as early as 1919 by

Schmallenbach, according to other authors, is perceived in practice "as 'accrual accounting', i.e. recording and deriving elements of the economic result based on realized "profits" (income) and the "sacrifices" made for this (expenses in the income statement)."[9] In developing the concept of the dynamic balance, "Schmallenbach based himself on a specific model, in the construction of which he proceeded from the premise that the balance sheet does not show the state of economic resources and their sources, but on the contrary, the movement of both resources and sources."[8] In this sense, the main task of the dynamic balance sheet is to obtain the financial result.

Unlike the static balance theory, representatives of the dynamic balance sheet theory consider the depreciation of assets not as depreciation (i.e., as a decrease in their value), but as the distribution of the purchase value of assets between the individual periods during which these assets will bring economic benefit to the enterprise. Representatives of the dynamic balance theory believe that "... assets are generated future costs (such as depreciation costs, material costs, etc.), which will manifest themselves as such in subsequent reporting periods." [6, 84]

The main purpose of the static balance is to establish the financial condition of the organization as of a certain date. Therefore, the dynamic balance considers this date as the beginning of the current reporting period and disposes of the future by calculating the rights to receive receivables or repay liabilities. The dynamic balance can be interim or annual. Its purpose is to support the reporting, management and control of the organization.

E. Kosiol, a follower of O. Schmalenbach, further develops the theory of the dynamic balance through the concept of the pagatoric balance developed by him. In English, pagatoric means something related to payment. The pagatoric balance is an application of both the accrual and cash basis. The dynamism of the information in the balance sheet reflects the effects of applying the accrual basis and cash basis in statics and dynamics. According to Kosiol, "the actual business operations are designated as income – an increase in economic benefits, and expenses – a decrease in economic benefits, which is different from cash inflows and outflows."[6, 86] The reason for this is that income and expenses include receivables and liabilities, recorded as estimates, which are the right to pay and receive payment in a future period. Total reflection of the benefits is achieved through business turnover for current and future reporting periods. The disadvantage is that there is no reflection of the material embodiment of the purchased assets in the balance sheet, as well as their capital source. The latter means that in the Pagatoric balance sheet the depreciation expenses reflected do not correspond to the asset to which they are accrued. This balance sheet does not include long-term assets, which may be related to environmental, social and management sustainability.

The conclusion that can be made is that O. Schmalenbach's dynamic balance sheet can be used to account for sustainability. Through this balance sheet, the accrual basis forms and maintains the sustainability of expected financial results. The balance sheet also includes long-term assets and the sources of their financing, as well as their depreciation when used to form and maintain environmental, social and management sustainability.

Sustainable development is often defined as "development that meets the needs of the present without jeopardizing the ability of future generations to meet their own needs".[11] It is understood as a comprehensive approach that unites the three pillars of environmental, social and economic sustainability.[2] Budgeting fits into the general framework of the planning, decision-making and control process. Velcho Stoyanov defines the budget as "... a digital financial expression of government policy, ... an instrument for public accountability and control over state financial resources ... and ... a means of managing the financial economy."[2] Other authors believe that "the budget is an element of a performance management system, which is a quantitative plan of dynamically changing target values, expressing the relationship between the organization's goals and the resources needed to achieve them."[10, 49] Budget planning specifies the implementation of a medium-term and long-term plan in the current accounting year. The budget serves as a tool through which the activities of the different parts of the organization are synchronized for the implementation of the overall plan. Budgets are planned, managed, reported and controlled at all management levels in the organization. Therefore, the budget is a tool for planning and controlling environmental, social and economic sustainability. In response to the static theory of balance sheets, the organization's budget planning provides a static budget as of a certain date. This budget is characterized by low flexibility and cumbersome procedures for introducing corrective parameters. In the transition from the current to the next reporting period, the identified deviations often impose significant changes in the planning of the organizational and financial goals of the business enterprise. Maya Lambovska proposes a process of budget management of the organization, which has the form shown in Fig. 1.[3] The dynamic balance is the basis for the implementation of the described corrective actions for the implementation of budgetary control in the reporting of environmental, social and governance sustainability. For the purposes of reporting through a dynamic balance, both in the management of public finances and in the economic organization, result-oriented budgeting can be used. "Result-oriented budgeting seeks to ensure the achievement of the set goals, by focusing on the optimal measures for assessing their implementation."[10, 26] Budgeting in the public sector in Bulgaria is carried out on a cash basis. The manual for the implementation of the applicable chart of accounts of budgetary organizations – introductory, general part – item

11 states that the reporting of budgetary enterprises is on an accrual basis. Nevertheless, the principles of current accrual and cash-based reporting are applied simultaneously. The Public Finance Act (PFA) legally defines that the "Cash Basis" is a budgeting and reporting system that covers all cash receipts and payments subject to recording in the bank accounts of budgetary organizations, their cash transactions, as well as transactions equated to them in accordance with the relevant provisions of the standards and guidelines for the reporting of budgetary organizations under Art. 164, para. 1."[19, § 1, item 17] of the PFA. The "cash basis" principle is also called the cash flow principle. The "cash basis" principle through the Unified Budget Classification facilitates the budget process through the possibility of planning and control over the reporting of budget revenues and expenditures, but does not take into account the receivables and liabilities formed through estimates in the state budget. There is no legally permitted methodological toolkit for reporting the state budget on an accrual basis. The Public Finance Act stipulates that the Minister of Finance shall approve accounting standards and the chart of accounts and shall issue instructions to budgetary organizations, which shall be by the requirements of the European Union for public sector reporting, statistics, and budgeting [19, Art. 164, para. 1, item 1]. The Accountancy Act does not comment on the issue of sustainability in the public sector, as this issue is regulated by a subordinate regulatory act issued by the Minister of Finance.

III. Results and Discussion.

Sustainability reporting in Bulgaria as a member of the European Union is in line with transposed directives in 2024. Regulation (EU) 2023/2772 (ESRS) provides an updated proposal for European Sustainability Reporting Standards (ESRS) and the structure of a sustainability report.[14] The European Sustainability Reporting Standards apply to all companies falling within the scope of the Corporate Sustainability Reporting Directive (CSRD) - Directive (EU) 2022/2464 of the European Parliament.[15] Specifically, the ESRS sets out the information that an enterprise must disclose about its material impacts, risks, and opportunities in relation to environmental, social, and governance sustainability issues. In response to the ESRS requirements, the term “non-financial statement” is replaced by “Sustainability Report” in the Bulgarian accounting legislation, which is part of the annual report of the organization.[18, Art. 48, para. 1-12]

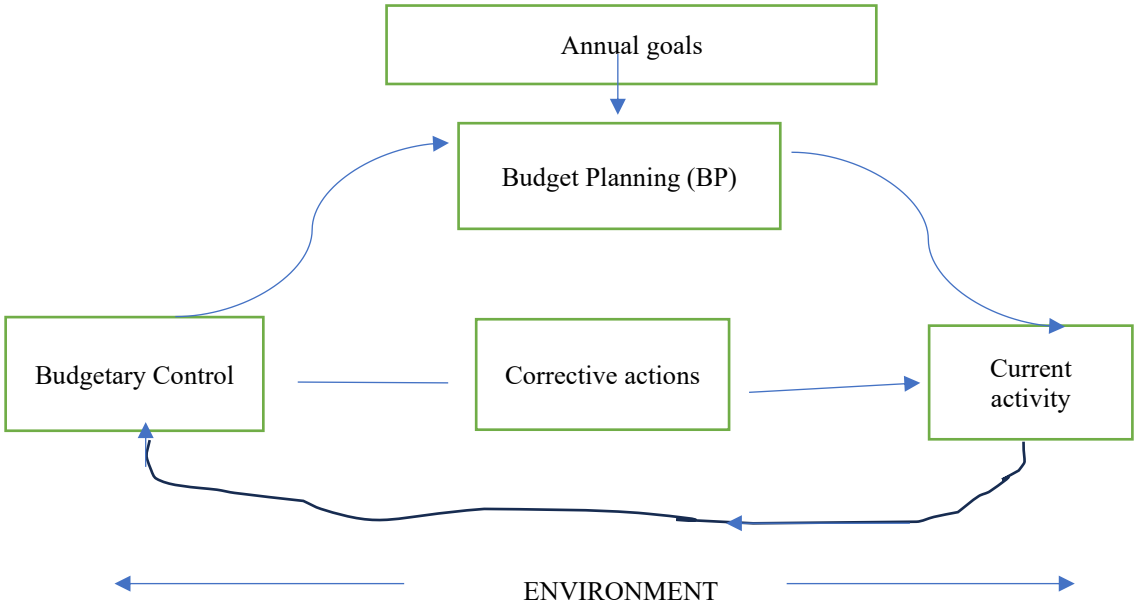

Fig. 1. Process of budget management of the organization.

The sustainability report is not a component of the annual financial report of the business organization. According to the ESRS, and in particular through Disclosure Requirement GOV–4 – Due Diligence Report, it is facilitated to understand the process of the enterprise for due diligence in relation to sustainability issues. Appendix D of the ESRS, European Sustainability Reporting Standard 1, presents the Structure of the Sustainability Report. The company structures its sustainability report in four parts, following the following

order: general information, environmental information (including the information disclosed under Article 8 of Regulation (EU) 2020/852), [17], social information and management information (management information) [14, ESRS 1 General Disclosures, par. 115].

TABLE 2 DINAMIC BALANCE SHEET FOR SUSTAINABILITY REPORTING

Dynamic balance sheet	
Asset	***Property and liabilities***
1) money (cash, current account, etc.) **Decrease** 2) expenses, but not yet invested in production, are in stock (purchase of materials, etc.); Account Materials, analytical accounts for: - environmental sustainability; - social sustainability; - manager-l sustainability. 3) values that will become expenses after they receive cost price (semi-finished products, etc.); Account Costs for main activity, analytical accounts for: - environmental sustainability; - social sustainability; - managerial sustainability. Increase 4) estimates that give rise to receivables, but are not yet receipts of funds (receivables); Account receivables from customers, analytical accounts to the Account receivables for: - environmental sustainability; - social sustainability; - management sustainability. 5) values that will be converted into income through sales (finished products, etc.); Account expenses for main activities, analytical accounts for: - environmental sustainability; - social sustainability; - management sustainability.	1) capital; 2) expenses that will become values (reserves, etc.) **Increase** 3) income that will be converted into assets assets (advances received, etc.); Account advances from customers, analytical accounts to the Advances from customers for: - environmental sustainability; - social sustainability; - management sustainability. 4) proceeds resulting from liabilities incurred (loans, credits received, etc.); Account Financing, analytical accounts to the Financing account for: - environmental sustainability; - social sustainability; - management sustainability. Decrease 5) estimates giving rise to liabilities, but not yet expenses (liabilities to suppliers, salaries, etc.); Account Liabilities to suppliers, personnel and others, analytical accounts to the Liabilities account for: - environmental sustainability; - social sustainability; - management sustainability.

The regulatory framework for the preparation of the sustainability report is complex and does not specify the requirements for the preparation of a sustainability report precisely enough. The requirements for the preparation of a sustainability report by business organizations are proposed in the Accountancy Act, but there is no methodological indication of how to prepare the accounting information in the sustainability report. An interim dynamic balance sheet needs to be proposed. The information from this balance sheet will be included in the sustainability report. The dynamic balance sheet developed by O. Schmallenbach, supported by data from synthetic and analytical current accounting on an accrual basis, for the purposes of preparing the sustainability report, may have the form shown in Table 2.

The transfer of cash in the future period to repay the liabilities incurred leads to a decrease in cash and a decrease in liabilities. The receipt of cash resources in connection with the receivables incurred leads to a decrease in receivables and an increase in cash. No change is observed in the amounts of the asset and liability of the balance sheet.

IV. CONCLUSIONS.

Accounting information obtained through current accounting and synthesized in the interim balance sheet provides reporting according to international accounting standards. Accounting information reported on an accrual basis provides current information on rights that have arisen as receivables and payables and paid in the next reporting period. These circumstances give reason to consider that information on an accrual basis supports the reporting of sustainability in the organization. The regulatory acts of the European Union governing sustainability reporting require the preparation of a sustainability report, which includes financial and non-financial accounting information. Therefore, financial information must be on an accrual basis, and non-financial information should cut off the circumstances of the rights and liabilities that have arisen, regulated in the current and future periods. Therefore, the sustainability report must correctly reflect the data on a current accrual basis. The interim dynamic balance sheet, prepared on the basis of the balance sheet of O. Schmalenbach, provides an opportunity to prepare a report for including accounting information in the sustainability report to the annual activity report. Accrual accounting through interim dynamic balance is a tool that provides a basis for budget adjustments in the public and private sectors. The dynamic balance sheet proposed by E. Koisol, with the inclusion of accounting information on an accrual basis, can be used to improve the cash statement applicable in the public sector in Bulgaria. The presentation of the cash statement in the public sector with an appendix on the rights and obligations on an accrual basis in each budget organization leads to the application of the same reporting for the state budget. For the true and accurate presentation of accounting information in the sustainability report of business organizations, it is necessary to prepare an interim financial report providing data for inclusion in the sustainability report for the implementation of the Corporate Sustainability Reporting Directive (CSRD) and in accordance with the requirements of the Delegated Regulation on the Standards of Sustainability Reporting (ESRS).

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 583-587

Numerical Simulation of Fluid Flow Through a Non-Return valve: an Integrated Approach for teaching in Fluid Mechanics and Mechatronics

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Abstract*—Non-return valve is a critical component in fluid mechanics and mechatronic systems, ensuring unidirectional flow while preventing backflow, which is essential for system efficiency and safety. These valves are widely used in hydraulic, pneumatic, and process control systems, playing a vital role in preventing pressure surges, cavitation, and mechanical failure. Understanding the fluid dynamics behavior inside a non-return valve is essential for optimizing its design and performance. However, due to the complex flow interactions within the valve, analytical solutions are often insufficient, necessitating numerical simulations for accurate analysis. This study presents a numerical simulation model of fluid flow through a non-return valve using Computational Fluid Dynamics (CFD) techniques. The primary objective is to provide an integrated learning approach that enhances students' and engineers' understanding of the interaction between fluid flow and valve dynamics. The research employs CFD simulations to visualize pressure distributions, velocity profiles, and turbulence effects under different flow conditions, offering insights into the valve's operational characteristics. The methodology includes Theoretical background on valve mechanics and fundamental fluid flow equations; Numerical modeling using ANSYS Fluent, where the valve geometry, boundary conditions, and turbulence models are defined; Simulation and analysis of pressure drop, velocity distribution, and flow separation within the valve. The results highlight how flow conditions influence valve efficiency, showing pressure losses, cavitation risks, and flow separation effects. The study demonstrates that numerical simulations provide a powerful tool for engineering education, allowing students to visualize complex flow behaviors and develop practical skills in CFD analysis. By integrating simulation-based learning into engineering curricula, this approach strengthens problem-solving abilities and prepares future engineers for real-world challenges in fluid mechanics and mechatronics

Keywords— non-Return Valve, flow simulation, CAE, education, training simulation.

I. Introduction

Check valves, also known as non-return valves (NRV), are essential components in fluid mechanics and mechatronics, ensuring unidirectional flow while preventing backflow. These valves are widely used in pumps, compressors, hydraulic and pneumatic systems, where maintaining controlled flow is critical for system efficiency, safety, and reliability. The design and performance of check valves directly impact pressure losses, flow stability, and cavitation risks, making their study crucial for engineers working in fluid transport and control applications.

The ability to model and simulate fluid flow through check valves is essential for understanding and optimizing their performance. Due to the complex interactions between turbulent flows, pressure distributions, and vortex formations, analytical methods alone are insufficient for accurate analysis. Therefore, Computational Fluid Dynamics (CFD) has become an indispensable tool for predicting flow behaviour, pressure losses, and turbulence effects within check valves.

Integrating CFD-based simulations into fluid mechanics and mechatronics provides students with practical learning experience, bridging the gap between theoretical concepts and real-world applications. This study aims to develop an integrated learning approach that enhances students' and engineers' understanding of fluid

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8641
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dynamics, numerical modelling, and control systems through numerical simulations of check valve flow.

A. Objectives of the Study

The primary objective of this research is to present a numerical simulation model for analysing fluid flow through a check valve using CFD techniques. This approach serves both as a research tool for valve optimization and an educational framework for teaching fluid mechanics and mechatronics. The key goals of this study include:

- Providing a detailed analysis of flow behaviour, pressure distribution, and turbulence effects inside a check valve.
- Demonstrating the use of CFD modelling techniques in ANSYS Fluent for valve flow simulation.
- Comparing numerical results with classical fluid mechanics principles to validate model accuracy.
- Enhancing engineering education by integrating simulation-based learning into fluid mechanics and mechatronics curricula.

By addressing these objectives, this study contributes to the optimization of check valve design, offering insights into flow regulation, energy efficiency, and system stability in fluid-based engineering applications.

A thorough review of fluid mechanics, numerical methods, and turbulence modelling is necessary to support the theoretical and computational framework of this research. The selected literature sources provide foundational knowledge on fluid flow, numerical modelling, and valve optimization:

Sources [1] and [2] provide essential background on fluid mechanics, conservation laws (mass, momentum, energy), and governing equations (Navier-Stokes equations). These principles are fundamental for understanding flow behaviour in check valves, particularly in relation to pressure variations and flow separation.

Source [8] offer an in-depth discussion on boundary layer theory, crucial for analysing flow interactions near valve walls and transition from laminar to turbulent flow.

Sources [3] and [7] provide detailed discussions on the Finite Volume Method (FVM), which is widely used in CFD solvers such as ANSYS Fluent. These sources emphasize the importance of mesh refinement, discretization techniques, and numerical accuracy in fluid flow simulations.

Sources [6] is a foundational reference in numerical heat transfer and fluid flow, introducing techniques for solving Navier-Stokes equations and turbulence modelling, both of which are crucial for CFD-based valve simulations.

Source [5] introduces computational fluid dynamics (CFD), including practical aspects of grid generation, turbulence models, and solver settings, making it a valuable resource for numerically analysing check valve flows.

Source [10] provide a comprehensive analysis of the k-ε turbulence model, which is widely used for simulating turbulent flows in engineering applications. This model is particularly relevant for checking valve simulations, where vortex shedding, flow separation, and recirculation zones play a significant role in pressure losses and performance evaluation.

Source [9] discuss aerodynamic design principles, which are applicable in the optimization of fluid systems, including valve geometry modifications to minimize pressure losses and enhance efficiency.

Source [4] explores modern control engineering, which is essential for understanding how check valves interact with mechatronic systems in fluid control applications.

Source [11] provides a practical tutorial on check valve simulation, demonstrating real-world applications of CFD tools in engineering design and analysis.

B. Importance of an Integrated Learning Approach

This research emphasizes the educational benefits of integrating numerical simulations into fluid mechanics and mechatronics training:

- Theoretical Understanding: Students develop a strong foundation in fluid mechanics through conservation equations, boundary layer effects, and turbulence modelling.
- Practical Application: By using CFD software (ANSYS Fluent), students gain hands-on experience in numerical modelling, mesh generation, and post-processing of simulation results.
- Interdisciplinary Approach: The study connects fluid dynamics with control engineering, allowing students to understand the role of check valves in automated fluid systems.

This paper presents an integrated approach for teaching fluid flow through check valves, combining theoretical foundations, numerical simulations, and practical applications. By leveraging CFD techniques, students and engineers can gain valuable insights into valve performance, turbulence effects, and energy efficiency, reinforcing the role of numerical modelling in modern engineering education.

II. MATERIALS AND METHODS

A. Preparing the CAd model for simulation

An assembly including the valve's components is part of the original shape. The fluid volume must be created before we can start a flow simulation. We will use the CAD edit functionality to accomplish this. At this point, our three primary goals are: establish an Internal Flow Volume, Eliminate the valve's solid parts, Optimize the geometry of the flow zone for simulation.

First, it is established an internal flow volume.

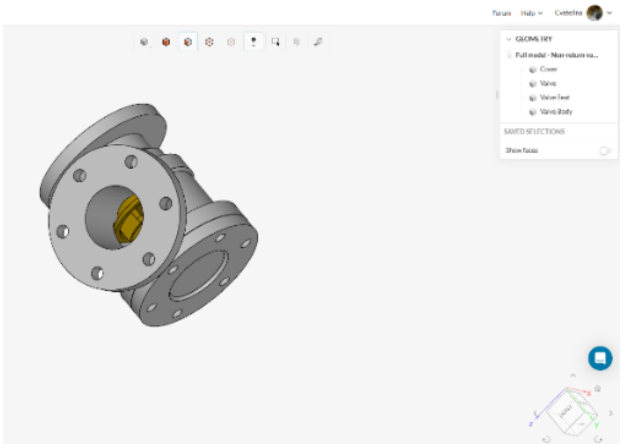

Fig. 1. Imported CAD model of non-return valve.

Fig. 1 shows the imported CAD model of non-return valve. The next step after importing the CAD model is performed elimination of the valve's solid parts. Next the geometry is optimized, and it is obtaining ned final CAD model that is used for fluid flow simulation.

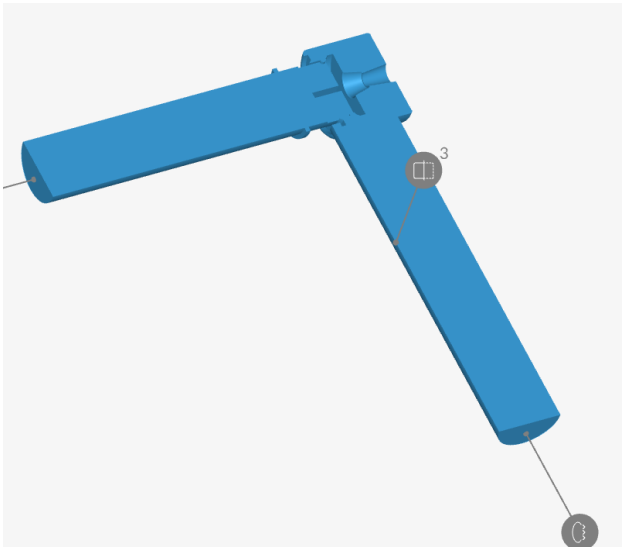

Fig. 2. Final perpared CAD model for fluid flow simulation.

B. *Creating a simulation*

The developed numerical model of non-return valve under this study is based on the relevant models of Sim Scale web, [11].

We determine the water flow through a valve in this scenario. We choose the incompressible analysis and build the simulation once the fluid speed is subsonic (Mach Number < 0.3).

C. *Assigning the material and boundary conditions*

Using [11], before assigning the boundary conditions, the material was assigned first. The assigned material for the fluid flow simulation is water with kinematic viscosity $\nu = 9.338e-7$ m^2/s, and density $\rho = 997.3$ kg/m^3.

Using [11], Fig. 3 shows an overview of boundary conditions.

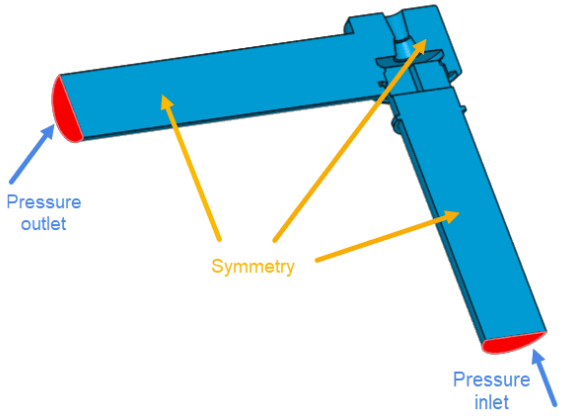

Fig. 3. Overview of the boundary conditions for the non-return valve, [11].

We assigned a pressure inlet condition with a total gauge pressure of 3e+5 Pa. Finally, we will set a pressure outlet condition to the outlet with a fixed value of 0 gauge pressure. This allows flow to easily depart by setting the outlet to atmospheric pressure. The geometry's symmetry condition can now be specified. All surfaces that are immediately on the plane of symmetry will now be given symmetry criteria. Create a new boundary condition of the Symmetry type and choose the three surfaces to do this.

D. *Numerical and simulation control*

Using the algorithm [11] under the Simulation control setting we change the End Time to 2500 seconds, and a total of 2500 iterations. Result controls can also be used to see how some things of interest behave when they converge. Let's set an Area average result control in this simulation to monitor the inflow values.

E. *Mesh*

According to [11] the Standard algorithm is recommended for creating the mesh, which is a solid choice in general because it is quite automated and produces decent results for most complex geometries, such as the non-return valve in our instance. Figure 4 depicts the geometry of a non-return valve with a produced mesh.

Frequently, just a few areas in the mesh exhibit significant variations in cell sizes. Cells rise sharply as global mesh refinements are increased.SimScale provides physics-based meshing as an alternative to the traditional Mesher. Using the specified border conditions, this method finds areas that need a finer resolution. One of the local refinement options, such local element size and region refinements, can also be used to accomplish this manually.

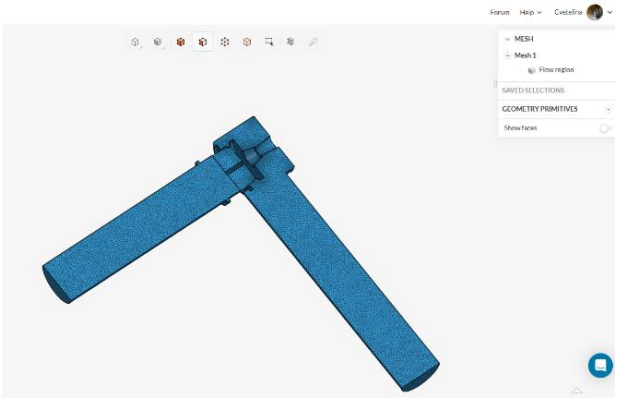

Fig. 4 View of mesh created around non-return valve.

III. Results and Discussion

Convergence is crucial for the fluid flow simulation. As the iterations go on, key parameters are expected to stop changing. At this point, the simulation is considered converged. For the flow simulation through non-return valve the key parameters for convergence that must be monitored are the pressure drops across the valve, and velocity vectors.

After your simulation run is finished, you can view the results using the online post-processor. It's a good idea to assess the simulation's convergence before using the post-processor.

Calculating the pressure drop, monitoring the velocity behavior throughout the system, and determining whether backflow occurs are all fascinating aspects of valve analysis. The outcome statistics calculator is used to calculate the pressure drop across the valve. Fig. 6 shows the pressure visualization through the non-return valve.

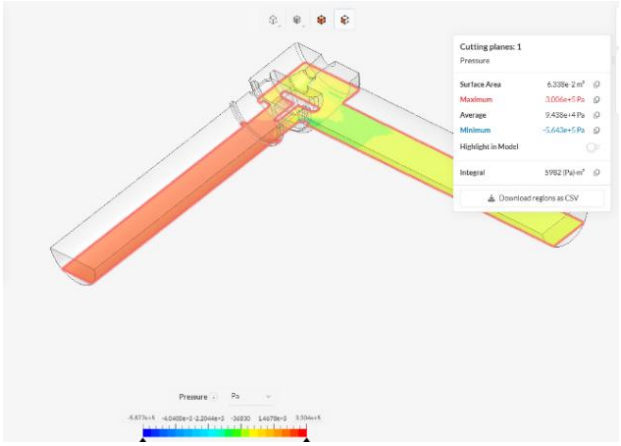

Fig. 5 The pressure visualization through the non-return valve.

From Fig. 5 we can see how the statics tool provides minimum, maxium, and average value over the selected faces from valve. You can now choose the model's inlet face and discover that the average pressure is 9.438e+4 Pa. The average pressure, which is the value imposed by our boundary condition, should be zero if you unselect the intake face and then select the outflow face. Consequently, 9.438e+4 Pa is the total pressure decrease over the valve. The pressure distribution across the valve provides information about the forces acting on the valve disc. The highest pressure is observed near the inlet, while a significant pressure drop is observed in the valve area. The valve disc experiences a force that balances the pressure differential and regulates the flow rate.

The average pressure at the inlet does not match the inlet pressure boundary condition we put in the simulation setup, as you may have noted, but it does at the outlet. You're probably thinking that something went wrong!

Actually, there isn't a mistake. We applied a total pressure condition as the boundary condition at the input, and we post-processed the static pressure as the output field. Because the dynamic pressure from the flow speed is added to the static pressure, the total pressure is higher.

Another significant occurrence to consider while assessing a valve is backflow. Fig. 6 shows the cutting plane with velocity vectors visualizing backflow.

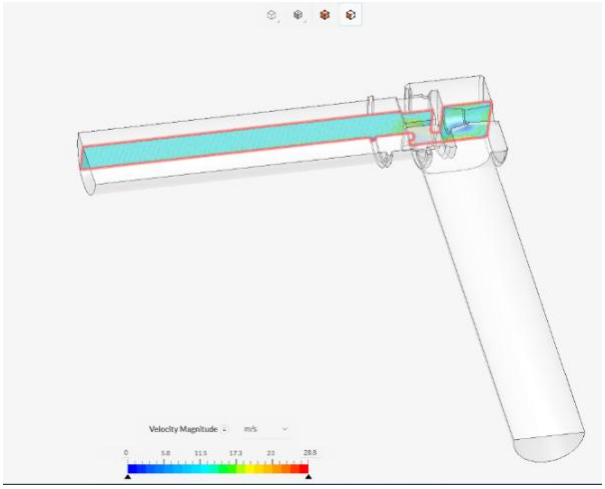

Fig. 6 Cutting plane with V vectors visualizing backflow.

The aforementioned Fig. 6 shows that there are swirls inside the valve cavity and backflow close to the valve's entrance. Because it obstructs flow patterns at crucial points and raises the pressure drop, this may affect the valve's function. The simulation shows that the check valve effectively prevents backflow when the outlet pressure exceeds that at the inlet. The valve disc closes rapidly in response to the pressure difference, preventing any backflow. This behavior highlights the reliability of check valves for maintaining unidirectional flow in fluid systems.

IV. Conclusion

This study demonstrates the effectiveness of numerical simulations in analyzing fluid flow through a non-return (check) valve, offering valuable insights into its performance, pressure distribution, and flow characteristics. The integration of Computational Fluid Dynamics (CFD) simulations in engineering education bridges the gap between theoretical understanding and

practical applications, providing an interactive learning approach for students and engineers in fluid mechanics and mechatronics

A. Theoretical Contributions

1. Validation of Fluid Mechanics Principles:

- The numerical results confirm the fundamental principles of fluid dynamics, including mass conservation, momentum balance, and energy conservation.
- The Navier-Stokes equations were successfully applied to model flow through a check valve, validating classical fluid mechanics theories such as boundary layer interactions and turbulence formation.

2. Application of Numerical Methods:

- The study employs the Finite Volume Method (FVM) for numerical discretization, demonstrating its accuracy and efficiency in simulating internal fluid flows.
- The use of turbulence models (k-ε model) effectively captures vortex formations and flow separation, which are crucial for valve performance analysis.

3. Impact of Boundary Layer Effects:

- The simulation results illustrate how boundary layers develop along the valve walls, affecting pressure distribution and velocity profiles.
- The study aligns with Schlichting & Gersten (2016) [8], reinforcing the importance of boundary layer theory in valve design and optimization.

B. Practical Applications

1. Optimization of Valve Design:

- The analysis of pressure drops, and backflow prevention helps in improving valve efficiency and reliability.
- reducing energy losses and cavitation risks in fluid transport systems.

2. Industrial Engineering Applications:

- The findings are relevant to hydraulic, pneumatic, and process control industries, where check valves are critical for maintaining unidirectional flow.
- The study provides a CFD-based framework for engineers to evaluate and optimize valve designs, improving operational efficiency in industrial applications.

3. Engineering Education and Training:

- The study highlights the importance of simulation-based learning, enabling students to visualize complex flow behaviour that are difficult to observe in experimental settings.
- The integration of ANSYS Fluent simulations into academic curricula fosters problem-solving skills and hands-on experience, preparing students for real-world engineering challenges.
- The interdisciplinary approach linking fluid mechanics and mechatronics encourages a deeper understanding of fluid-structure interactions and control systems.

By utilizing numerical simulations, this research provides a comprehensive approach to studying fluid flow in check valves, demonstrating both academic relevance and industrial significance. The integration of CFD techniques into engineering education not only enhances theoretical comprehension but also prepares future engineers for advanced computational analysis in real-world applications.

Future research can expand on this work by investigating:

- Turbulent and unsteady flow conditions in check valve.
- Comparison with experimental data to further validate simulation accuracy.

The study concludes that CFD-based modeling is an indispensable tool for optimizing engineering systems, reinforcing its role in both educational and professional engineering disciplines.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 589-593

Rapid GIS-Based Model for Vulnerability Assessment of Medicinal Plants: a Case Study of the Varna District (North-Eastern Bulgaria)

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***Abstract*—Wild medicinal and aromatic plants represent renewable natural resources and a valuable product for Bulgaria's export. Despite the appropriate regulatory framework, there is unregulated overharvesting of medicinal plants, such as collection of plants in non-permitted quantities and collection of plants included in prohibited lists. These illegal practices in combination with the negative anthropogenic impact, lead to a cumulative negative effect on natural habitats. In accordance with the Bulgarian strategy for sustainable use of biological resources, studying, assessment, and monitoring of the natural distribution, abundance, structure, and dynamics of the wild populations are required. In order to obtain correct quantitative data, it is necessary to carry out long-term studies, especially on the effect of overexploitation. Constantly changing demand and market trends for quantities and types of medicinal plants, as well as changing negative anthropogenic factors, requires establishment of dynamic models for rapid vulnerability assessment of wild medicinal and aromatic plants. The aim of the present study is to present and discuss some theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP) as well as model validation in case study of the Varna District (Noth-eastern Bulgaria). This model is based on explicit criteria and on a weighted value scheme for scoring each taxon, rather than intuitive interpretation of experts in conventional assessments. Unlike other rapid methods, which predicts vulnerability of plants to overharvesting, RMVAMP assesses more aspects and critical factors which directly affect the target medicinal species. Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using color scale. The natural habitats of herbs that should be restricted were defined.**

Keywords*— Medicinal Plants, North-Eastern Bulgaria Varna District, Vulnerability Assessment.

I. Introduction

Wild medicinal and aromatic plants represent an important component of biodiversity and renewable natural resources as well as a valuable product for Bulgaria's export [1], [2]. In recent decades, there has been an increase in the quantities of medicinal plants collected for export by herbalists, in contrast with the decreasing quantities collected for personal use. The growing need for raw materials for the pharmaceutical and cosmetic industries, and the desire for quick profits, are leading to pressure to increase the quantities collected. Despite the appropriate legal and regulatory framework, there is unregulated overharvesting of medicinal plants, such as collection of plants in non-permitted quantities or collection of plants included in prohibited lists [3]. These illegal practices in combination with the negative anthropogenic impact, lead to a cumulative negative effect on natural habitats [2], [3]. In accordance with scientific theoretical approaches [4], [5], the Bulgarian strategy for sustainable use of biological resources, studying, assessment, and monitoring of the natural distribution, abundance, structure, and dynamics of the wild populations are required [6]. In order to obtain correct quantitative data, it is necessary to carry out long-term studies, especially on the effect of overexploitation [7]. Constantly changing demand and market trends for quantities and types of medicinal plants, as well as changing negative anthropogenic factors, requires establishment of dynamic models for rapid vulnerability assessment of wild medicinal and aromatic plants [3].

One of the most used tools for assessment of the extent of existing and potential threats to the medicinal plants is Rapid Vulnerability Assessment (RVA) [8] - [11]. The RVA was tested, validated, and modified in series of studies, e. g. [1], [3], [12], [13].

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8698
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The need to assess not only individual medicinal plant species, but also their communities, habitats, and areas to which attention should be paid requires development of approaches consisting of evaluation systems. Unlike the classical models for conservation significance, they are based on cumulative criterion schemes for identification and prioritization of conservation territories with medicinal plants [3], [6].

Clearly and precisely formulated evaluation criteria of the assessments are reliable base for developing GIS-based models, which comprise dynamic geographical maps of habitats with assessment scale and associated numerous data sets [14].

The aim of the present study is to present and discuss some theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP) as well as model validation in case study of the Varna District (Noth-eastern Bulgaria). The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using color scale. The natural habitats of herbs that should be restricted were defined.

II. Material and Methods

Varna District comprises 12 municipalities with 3819.5 km^2, distributed as follows: forests - 27.8%, arable lands - 59.6%, grasslands – 5,4%, and urban zones - 7.2%. The climate inland is moderate temperate, and similar to Mediterranean climate along the Black Sea coast, with milder winters and cooler summers [15].

The studies of the spatial distribution of the plant communities were based on literature data of the distribution of plant species in the study area [14], [16], [17], [18] and were detailed and refined with data from field observations and remote sensing during the vegetation periods from 2018 to 2024 yr.

Conservation status, as well as endemics and relics were determined after [17], [19].

A regional plant species assessment scheme based on the Rapid Vulnerability Assessment [8] - [11] and concept of plant biodiversity hotspots [6], [14], [20], [21] was used. The summarized scheme modified after Vergiev [6], based on 2 groups of criteria, that comprise the distribution and conservation status of plant taxa, as well as socioeconomic criteria is presented in Table 1. In order to evaluate the vulnerability of each species, ten criteria were used. Each of the predictors has a score assignation where 0 is not applicable, 1 indicating low vulnerability, and other scores indicating ascending order of high vulnerability.

International conservation status criterion is evaluated by Annexes II and V to Council Directive 92/43 / EEC on the conservation of natural habitats and of wild fauna and flora; Annex I to the Convention on the Conservation of European Wildlife and Natural Habitats (Berne Convention), Annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

TABLE 1 SUMMARY SCHEME OF CRITERIA FOR THE ASSESSMENT OF PLANT TAXA MODIFIED AFTER [6], [13], [22].

Code	**Criterion**	
	Predictors	*Score*
C1	Presence and distribution of the species in floristic regions and subregions of Bulgaria	
	Only in the study region	5
	From 2 to 15 regions	1
	From 16 to 29 regions	0
C2	Criteria of population fragmentation	
	Highly fragmented	5
	Low fragmented	3
	Unfragmented	0
C3	Criterion "National conservation status" (Included in the Bulgarian Biological Diversity Act)	
	Included in Annex 2	3
	Included in Annex 3	3
	Included in Annex 4	2
	Not included	0
C4	Red Data Book Criterion	
	CR Critically Endangere	4
	EN Endangered	3
	VU Vulnerable	2
	NT Nearly Endangered	1
	LC Low Affected	0
	DD/NE, Insufficient Data, Not Rated	0
	N/A	0
C5	Endemics and Relics	
	Endemic to Bulgaria	5
	Endemic to Bolcan Peninsula	3
	Relics	2
	N/A	0
C6	International conservation status criterion	
	IUCN	2
	Directive 92/43/EEC	2
	Berne Convention	2
	CITES	2
	N/A	0
C7	Plant parts used	
	Whole plants	4
	Roots, Rhizome	3
	Flower, Seed, and Inflorescence	2
	Leaves	1
C8	Resource origin	
	Only from cultivation	4
	Wild and small-scale cultivation	3
	Wild and trial cultivation	2
	Only from wild	1
C9	User group	
	Local people	4
	Local people and Local exchange	3
	Local people and trade	2
	Local people, local exchange and trade	1
C10	Life forms	
	Long lived perennial	4
	Short lived perennial	3
	Biennial	2
	Annual	1

The evaluation of each individual taxon was obtained as the sum of the points of each of the criteria, after applying the relevant coefficients of significance of the criterion according to the formula:

$$Ai = 0.5xC1i + 0.5xC2i + 1.25xC3i + 1xC4i + 1.25xC5i + 1.5xC6i + 2xC7i + 0.5xC8i + 0.5xC9i + 2xC8i \quad (1)$$

where,

A*i* - general assessment of the taxon *i*

*C*1*i* - *C*610*i* - estimates by criteria C1 to C10 for taxon *i*.

A dynamic GIS-based model was built and applied using the Model Builder module of ArcView Spatial Analyst (ArcGIS v.10.0 ESRI Inc.). The study area was separated into grid cells (2500 m ×2500 m). The general assessment of each cell was calculated according to the formula:

$$E = \frac{\sum_{k=1}^{n} An}{n} \quad (2)$$

where,

E - general assessment of the territory

A - assessment of each individual taxon

n - total number of assessed taxa in the territory.

When drawing the maps, the following were used: UTM Zone 35 North map projection, WGS84 terrestrial coordinate system and the Baltic altitude system. The collected field and remote sensing data were organized in attribute tables and assigned to the layers in vector format using relational classes in a GIS environment using base maps and Digital Terrain Model (DTM).

III. Results and Discussion

The approach Rapid Vulnerability Assessment is based on the understanding that a relatively small set of factors has a disproportionate impact on the likelihood that a medicinal plant species will be used in a sustainable manner [8] - [11]. The assessment is calculated by summing the points of an average of 5 – 7 predictors. Organized in this way, the assessment provides information about species that are threatened by overexploitation easily and quickly. However, it is often necessary to make a comprehensive assessment of a certain area, and not just of individual species. In such cases, the simple sum of the species estimates does not provide reliable information, and the model needs to be upgraded.

Unlike other rapid methods, which predicts vulnerability of plants to overharvesting, Rapid Model for Vulnerability Assessment of Medicinal Plants assesses more aspects and critical factors which directly affect the targeted medicinal species in certain area.

The predictors are divided into two groups of criteria. The first group represents ecological criteria such as distribution and conservation status of the species. Distribution is predicted by presence of each species in one or more floristic regions and subregions of Bulgaria. The main hypothesis is that widely distributed species are less vulnerable than narrowly distributed species [13]. Predictor of population fragmentation shows the possibility of population recovery. In the case of high fragmentation, the species will be more vulnerable. Conservation status is assessed by four criteria for international and Bulgarian status. Cumulative assignment in more conservation categories define species as more vulnerable.

The second group represents socioeconomic status of the species. The predictors "Used parts" and "Life forms of the plants" are based on the idea that leaves harvesting is less vulnerable than those of roots, rhizome and whole plant [13]. Harvesting of the plants from only wild population is more vulnerable, as well as species with many user groups are more vulnerable than single user group [13], [22].

The assessment is based on an adequate inventory of the flora the study area. For this purpose, a list of flora was prepared based on literature data, as well as unpublished own studies.

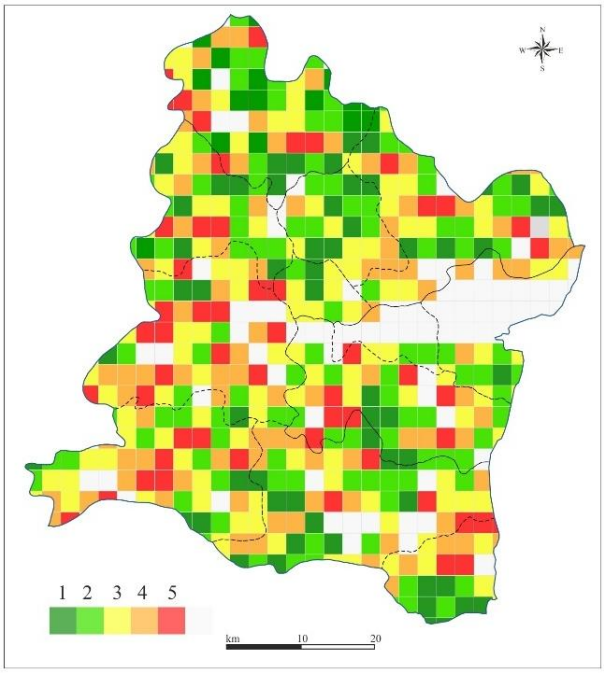

Fig. 1. Vulnerability assessment of medicinal plants. From 1 – non vulnerable to 5 – highly vulnerable. White cells represents urbanised teritories.

The established total number of plant species found in the region was 938. 467 of them were recognized as medical and aromatic plants and were assessed.

Although the model is aimed at identifying the vulnerability of individual locations, it can also be applied to identify the vulnerability of individual species. As a

result of the analysis, the following groups of medicinal plants can be identified:

1) Vulnerable species: *Frangula alnus* Mill., *Sedum acre* L. *Artemisia alba* Turra; *Galium odoratum* (L.) Scop.; *Echinops sphaerocephalus* L.; *Asarum europaeum* L.; *Galanthus nivalis* L.; *Helichrysum arenarium* (L.) Moench; *Valeriana officinalis* L.; *Glaucium flavum* Crantz; *Convallaria majalis* L.; *Cercis siliquastrum* L.; *Lilium martagon* L.;

2) Highly vulnerable species: *Paeonia peregrina* Mill.; *Primula veris* L.; *Carlina acanthifolia* All.; *Berberis vulgaris* L.; *Alchemilla vulgaris* L. ; *Leucojum aestivum* L.; *Ruscus aculeatus* L.; *Orchis morio* L.; *Orchis purpurea* Huds.; *Orchis simia* L.; *Cyclamen coum* Mill.; *Artemisia lerchiana* Weber; *Asparagus officinalis* L.; *Ephedra distachya* L.; *Platanthera bifolia* (L.) L. C. Rich.; *Ruta graveolens* L.

Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on the created map using colour scale (Fig. 1).

Applying the constructed model and as a result of the "overlay" analysis, all values within the areas of overlap of the polygons were summarized and 37 zones of high vulnerability were identified.

The identification of areas with a degree of vulnerability is only the first step in a long and tough process of protecting the habitats of medicinal and aromatic plants.

Our role as scientists is to investigate and to analyze, followed by prioritizing and using limited resources for the protection of medicinal plants. This should be accompanied by the implementation of the entire set of regulatory documents and punitive instruments for the preservation of natural habitats.

In my opinion, educational initiatives are also extremely important to inform about the available medicinal plants in each area, along with small projects for the protection and expansion of habitats.

IV. Conclusions

This study presents analysis of theoretical aspects of Rapid Model for Vulnerability Assessment of Medicinal Plants (RMVAMP). The factors that contribute to the vulnerability of medical and aromatic plants are based on two groups: ecological criteria and socioeconomic criteria. Cumulative assignment in more predictors defines species as more vulnerable.

The established total number of plant species found in the region was 938. 467 of them were recognized as medical and aromatic plants and were assessed.

Cumulative weighted values were incorporated in GIS environment. The natural habitats in the Varna District were categorised into classes of vulnerability and were indicated on map using colour scale.

Applying the constructed model and as a result of the "overlay" analysis, all values within the areas of overlap of the polygons were summarized and 37 zones of high vulnerability were identified. The natural habitats of herbs that should be restricted were defined.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 595-600

The Effect of Hand Dryers on Restroom Indoor Air Quality

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***Abstract*— The widespread use of hand-dryers in public restrooms raises concerns about hygiene and indoor air quality. Hand-dryers facilitate microbial proliferation and aerosolization, increasing infection risk and degrading indoor air quality by dispersing pathogens and allergens. This study investigates microbial growth and air contamination, advancing the field by exploring factors such as humidity, airflow mechanics, and particle count concerning various hand-dryer types. Different models of 8 warm air dryers and 2 jet dryers in ten restrooms were sampled (4 female, 4 male and 2 accessible) in an academic institution. The study involved air sampling from the hand-dryer outlet for 30 seconds directly onto agar plates and surrounding air sampling using the "SAS SUPER ISO 180" device. Microbiological samples were then cultivated on different media, manually counted and identified. Fungi were identified by native smears and safranin staining, bacteria using VITEK. Particle count was measured before and during hand dryer use with "TSI P-TRAK", while other variables such as room temperature, humidity, CO_2 levels, hand dryer air flow velocity, temperature were also recorded. The data was processed using IBM SPSS. Statistically significant correlations were found: airflow temperature negatively correlated with fungal dispersal on Sabouraud agar ($r=-0.747$, $p<0.05$), CO_2 positively correlated with bacterial dispersal on Trypticase soy agar (TSA) ($r=0.661$, $p<0.05$), and humidity showed a significant positive correlation with TSA CFU/min ($r=0.636$, $p<0.05$). Microbial contamination was detected in all restrooms. Warm air dryers consistently emitted higher bacterial loads than jet dryers across all tested media. Hand-dryer air ranged from 0 to 1360 CFU/min, while restroom air ranged from 0 to 1424 CFU/m3. Most fungi identified were molds (*Mucor spp., Penicillium spp., Aspergillus spp.*), with 22 yeast colonies. Analysis identified various opportunistic and pathogenic bacteria, including *Acinetobacter baumannii, Escherichia coli, Staphylococcus* and other species. Average particles count before use was 7831, while during use 11668. The findings indicate that while hand dryers may contribute to bacterial and fungal dispersal, factors such as airflow temperature, humidity, and CO2 levels also play significant roles in microbial behavior.**

Keywords*— *Indoor Air Quality, Hand Dryers, Microbiological contamination, Particles.

I. Introduction

Hand hygiene plays a crucial role in preventing the spread of infections, particularly in public restrooms, where microbial contamination is a concern. While proper hand drying is essential, the method of drying can significantly influence microbial dispersion. Studies have shown that warm air dryers contribute to bacterial aerosolization, potentially increasing contamination levels in restroom environments [1]. - [4.]. Jet dryers, despite their faster drying times, may also pose hygiene risks by dispersing microbes over a larger area due to their high-velocity air streams [5.], [6.].

Research indicates that hand dryers can spread various opportunistic and pathogenic bacterial species, including *Staphylococcus spp., Escherichia coli*, and *Acinetobacter baumannii,* raising concerns about their impact on indoor air quality [7.]- [9.]. Some studies suggest that jet dryers

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8678
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result in lower microbial contamination than warm air dryers, while others report greater bacterial dispersion with their use [10.], [11.]. However, comparative studies assessing different hand dryer models under real-world conditions remain limited.

A key finding in previous research is the significant role that air velocity plays in the dispersion of microorganisms [12.]. Notably, this study examined both bacterial and fungal presence while incorporating important environmental parameters such as CO_2 concentration and airflow velocity, which were often overlooked in earlier studies. Understanding how these factors influence microbial transmission is crucial, as room conditions like humidity, temperature, and air exchange rates have a direct impact on the proliferation of both bacteria and fungi [13.], [14.]. These environmental factors are critical in assessing the hygiene risks associated with hand dryers, as they help explain how microbial contamination is spread in enclosed spaces like restrooms.

This study investigates microbial growth and air contamination, advancing the field by exploring factors such as humidity, airflow mechanics, and particle count concerning various hand-dryer types. The aim of this study is to assess the impact of different hand dryers on microbial dispersion and air quality in public restrooms. By analyzing air samples from various hand dryer models in an academic setting, the relationship between airflow mechanics, microbial proliferation, and particle dispersion will be evaluated. The findings will provide insights into the hygiene risks associated with different hand drying methods and their implications for public health.

II. MATERIALS AND METHODS

This study was conducted to assess the microbiological and environmental impact of different types of hand dryers in restrooms within an academic institution, with a particular focus on indoor air quality. Indoor air quality is a critical factor influencing health and hygiene, especially in shared spaces like restrooms where microbial dispersion can occur.

TABLE 1 RESTROOM DESCRIPTION

Room Nr.	Gender and accesibility	Restroom area, m^2	Hand dryer room, m^2
1.	Female	31.9	16.5
2.	Male	30.2	
3.	Accessible	3.1	
4.	Female	12.2	6.5
5.	Male	11.1	2.7
6.	Female	11.9	4.7
7.	Accessible	3	
8.	Male	11.8	4.1
9.	Female	6.8	2.2
10.	Male	6.9	2.2

A total of ten restrooms were included in the study, comprising four female restrooms, four male restrooms, and two accessible restrooms. (Table 1.) The hand-drying devices sampled consisted of eight warm air dryers and two jet dryers, representing various models.

A. Preliminary Data Collection

Prior to the experiment, floor plans including square meter measurements and information on disinfectants and soap used in the restrooms were obtained. The disinfectants used were ethanol 70% and benzalkonium chloride 0.06%. Ethanol is effective against a broad range of bacteria, viruses, and fungi, making it a widely used disinfectant.

TABLE 2 HAND DRYER TYPES

Room Nr.	Hand dryer Type	Hand dryer model
1.	Jet	Faneco Monsun 1900W, DA1900PFW
2.	Jet	Faneco Monsun 1650W, DA1650PFS
3.	Warm air	P+L Systems Automatic Hand Dryer Value DV2100P
4.	Warm air	P+L Systems Automatic Hand Dryer Value DV2100P
5.	Warm air	P+L Systems Automatic Hand Dryer Value DV2100P
6.	Warm air	Mediflow Intelligent sensor operated hand dryer, M02A
7.	Warm air	Machflow sensor operated hand dryer M09A
8.	Warm air	Mediflow Intelligent sensor operated hand dryer, M02A
9.	Warm air	Mediflow sensor operated hand dryer, M03A
10.	Warm air	Mediflow sensor operated hand dryer, M03A

TABLE 3 HAND DRYER DESCRIPTION

Room Nr.	Manufacturer-specified hand dryer velocity, m/s	Manufacturer-specified airflow temperature, C°	Measured airflow temperature, C°
1.	95	35	31.5
2.	95	35	35
3.	20	65	30.8
4.	20	65	Exceeded limit
5.	20	65	Exceeded limit
6.	26	50	23.9
7.	55-90	45	30.4
8.	26	50	41.2
9.	26	50	45.9
10.	26	50	49.3

Benzalkonium chloride provides residual antimicrobial activity and is effective against bacteria and some viruses, but has limited efficacy against fungal spores, which may allow certain fungi to persist in the environment. Additionally, the types of hand-drying models present in the restrooms were identified. The study included two

models of jet dryers and four types of warm air hand dryers. None of the models had UV features, but both jet dryers had an antimicrobial coating. (Table 2., 3.)

B. Microbiological Sampling

Microbiological sampling involved two primary approaches: direct air sampling from the hand dryer outlets and ambient air sampling within the restroom environment. Airborne microbial contaminants emitted by the hand dryers were collected by exposing agar plates directly to the dryer's airflow for 30 seconds (representing average hand drying time) 5-15 cm from the outlet. Concurrently, the surrounding air was sampled using the SAS SUPER ISO 180 air sampler, which was placed near hand-washing stations and dryers, to assess airborne microbial load beyond the immediate dryer vicinity. Plates for fungi and bacteria were filtered through 500L of air from the restroom environment using this system. (Fig.1.)

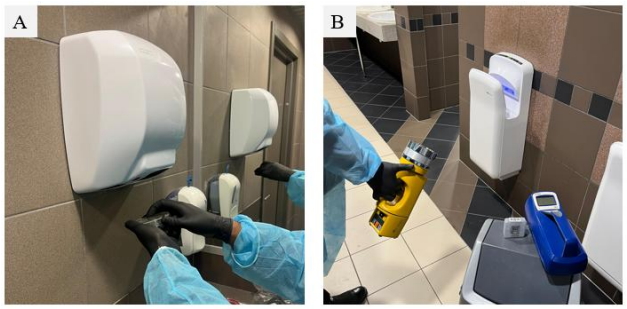

Fig.1 Microbiological sampling
A Hand dryer air sampling B. Restroom air sampling

Following collection, microbiological samples were cultivated in various culture media to facilitate the growth and identification of bacterial and fungal species. Bacterial species were cultivated on Trypticase Soy Agar (TSA) for general bacterial growth, Mannitol Salt Agar (MSA) for the selective growth of Staphylococcus species, and MacConkey Agar (MA) for the isolation of Gram-negative bacteria. Incubation was conducted for 24 hours at 37°C. Fungal species were incubated for 48 hours at 22°C on Sabouraud Agar (SA), which is designed for the selective growth of fungi and yeast. Colony-forming units (CFUs) were manually counted, and microbial identification was performed. Fungal identification was conducted using native smears and safranin staining, while bacterial identification was performed using Gram staining and the VITEK automated identification system. A total of 28 samples were analyzed using the VITEK system, identifying 21 Gram-positive (Gr+) and 7 Gram-negative (Gr-) bacterial species. However, there were limitations in the analysis, as only 28 bacteria could be identified due to technical issues.

C. Environmental and Particle Analysis

In addition to microbiological assessments, particle counts were measured both before and during hand dryer operation using the TSI P-TRAK device (particles size <1 um). This allowed for the evaluation of airborne particle concentration variations in response to dryer use. To evaluate the restroom environment, several parameters were recorded before the experiment (Table 4.) Air temperature and humidity levels were measured using the Aranet4Home monitoring system (Ltd SAF Tehnika), as these factors can influence microbial survival and dispersion. Additionally, airflow velocity and temperature of each hand dryer were measured using the Testo 400 Multimeter (Ltd Testo), as these factors could influence bacterial dispersal patterns. Carbon dioxide (CO_2) levels within the restroom environment were also monitored using the Aranet4Home system to assess ventilation efficiency, which can impact microbial persistence in the air. These measurements provided insight into the potential impact of hand dryers on indoor air quality by examining variations in airborne particle levels before and during their use. Since the restrooms remained open to users during the study, user traffic was recorded to account for potential variations in microbial load due to occupancy levels.

TABLE 4 RESTROOM ENVIRONMENT DESCRIPTION

Room Nr.	Average room airflow, m/s	Average room humidity %	Average room CO_2 levels, ppm	Average room temperature, C^o
1.	0.0183	27.2	824.8	22.8
2.	0.0100	24.8	723.4	24.3
3.	0.0050	26.8	799.6	24.5
4.	0.0017	28.1	955.5	24.4
5.	0.0033	30.2	940.3	23.7
6.	0.0033	32.2	1201.6	23.1
7.	0.0083	31.7	995.1	22.5
8.	0.0067	32.8	1125.9	22.8
9.	0.0167	31.8	963.6	24.2
10.	0.0200	41.8	1033.6	23.5

D. Data Processing and Statistical Analysis

All collected data were processed and analyzed using Excel and IBM SPSS statistical software. The correlations were assessed by Spearman's correlation test. A p value < 0.05 was considered statistically significant. For air sampling, microbial concentrations were calculated as CFU/m³, while for hand dryer air, CFU/min values were determined by doubling the observed counts, as testing was conducted for 30 seconds.

III. RESULTS AND DISCUSSION

A. Microbiology

Microbial contamination was detected in all restrooms. Hand-dryer air ranged from 0 to 1360 CFU/min, while restroom air ranged from 0 to 1424 CFU/m³. Warm air dryers consistently emitted higher bacterial loads than jet

dryers across all tested media. (Fig.2, Fig 3.) Direct air sampling showed Trypticase Soy Agar (TSA) with an average of 531 CFU/min for warm air dryers compared to 66 CFU/min for jet dryers, and similar trends were observed in MacConkey agar (15 CFU/min vs 7 CFU/min) and Mannitol Salt Agar (MSA) (195 CFU/min vs 69 CFU/min). Room air sampling also revealed higher bacterial concentrations in restrooms with warm air dryers, with TSA averaging 671 CFU/m³ and MSA averaging 300 CFU/m³, compared to 520 CFU/m³ and 159 CFU/m³ for jet dryers, respectively. MacConkey agar in room air showed 30 CFU/m³ in restrooms with warm air dryers versus 2 CFU/m³ for jet dryers, highlighting the greater bacterial dispersion associated with warm air dryers. Warm air dryers were often located in smaller and less crowded restrooms, which could limit air circulation and allow bacteria to accumulate over time. Additionally, these dryers appeared less clean, which may have contributed to the higher microbial loads observed. In contrast, jet dryers had an antimicrobial coating, which could have played a role in their lower bacterial emissions.

Gender differences were observed, particularly in MacConkey agar, where jet dryers in female restrooms showed 0 CFU/min, while male restrooms had 14 CFU/min. Conversely, warm air dryers in female restrooms had higher bacterial levels than in male restrooms, with TSA results showing 596

CFU/min in female restrooms versus 342 CFU/min in

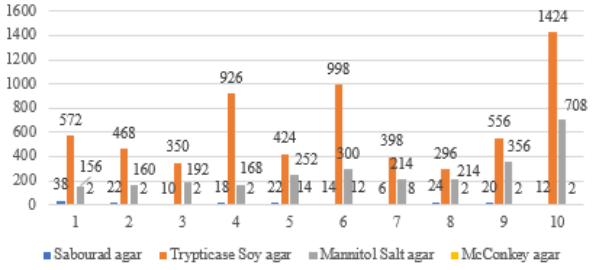

Fig.2 Microorganism concentration in restroom air, CFU/m3

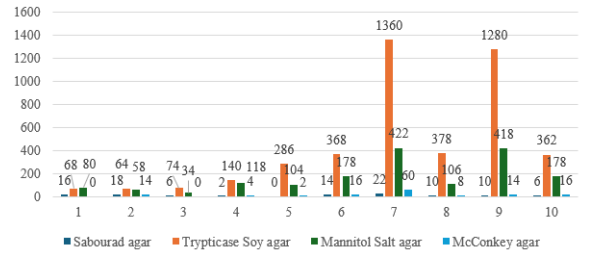

Fig.3 Microorganism concentration in hand dryer air, CFU/min

male restrooms, and MSA results at 238 CFU/min in female restrooms versus 129 CFU/min in male restrooms. These differences could be explained by user traffic patterns, as the average number of users was 6.25 for female restrooms and 2.75 for male restrooms, with peak usage reaching 10 in female restrooms and 5 in male restrooms.

A total of 28 samples were analyzed using the VITEK system, identifying 21 Gram-positive (Gr+) and 7 Gram-negative (Gr-) bacterial species. (Table 5) Among the identified species, *Staphylococcus haemolyticus, Staphylococcus saprophyticus*, and *Acinetobacter baumannii* are considered opportunistic pathogens, potentially posing a risk in vulnerable individuals. Other opportunistic bacteria such as *Escherichia coli* and *Pseudomonas fluorescens* were also identified. Notably, *Escherichia coli* was detected in a male restroom with jet dryers from direct hand dryer air, suggesting possible contamination or bacterial dispersion via the dryers. Additionally, species like *Leuconostoc mesenteroides* and *Kocuria kristinae,* while generally less harmful, can still cause infections under certain conditions. The presence of these bacteria underscores the potential health risks, particularly in environments with high microbial exposure. These findings are in line with other researches which highlighted the presence of *Staphylococcus spp*. in restroom environments [7.].

TABLE 5 IDENTIFIED BACTERIA

Identified bacteria	Count
Leuco.mesen.cremonis	2
Staph.hom.hominis	1
Koc. varians	2
Ps.oryzihabitans	1
Koc. kristinae	3
Staph.lentus	1
Staph. warneri	1
Leuco.mes.dext.	1
Staph. haemolyticus	3
Staph.saprophyticus	1
Staph.vitulinus	1
Sphomon.paucimobilis	2
Parac.yeel	1
Esch.coli	1
Ps.fluorescens	1
Aci.beumanii	1
Unidentified	6
Non/Low reac.biop.	1

Fungi were present in the air of all sampled restrooms, while only 9 out of 10 hand dryer air sampled fungal growth was detected. Regarding fungal diversity, three mold species were identified, with Aspergillus spp. being the most prevalent (40.2%), followed by Penicillium spp. (36.6%) and Mucor spp. (23.2%). Additionally, 22 yeast colonies were detected. The results indicate that the average fungal concentration in room air was 18.6 CFU/m³, while the average fungal count in hand dryer air was 10.4 CFU/min. Among the hand dryers, the jet dryers showed slightly higher average fungal levels (11 CFU/min, 24 CFU/m³) compared to the warm air dryers (8.5 CFU/min, 19.7 CFU/m³). This difference may be attributed to the moisture retention in the air from jet dryers, which could provide a more favorable environment for fungal growth and dispersal.

B. Particles

Hand dryers increase the number of airborne particles during use, with warm air dryers showing a greater impact than jet dryers. On average, the particle count in the room before dryer use was 7,831, rising to 11,668 particles/cm^3 during dryer operation. Warm air dryers had a higher average particle increase (from 8,251 to 12,806 pt/cm3) compared to jet dryers (from 6,150 to 7,115 pt/cm3), suggesting that warm air dryers contribute more to airborne particle dispersion. Additionally, dryer airflow temperature was positively correlated with particle count ($r = 0.714$, $p < 0.05$), further emphasizing that higher temperatures may increase the dispersal of particles. However, the particle count did not show a statistically significant correlation with microbial concentrations in the air, indicating that while hand dryers may increase overall particulate matter, this does not necessarily translate to higher microbial loads.

C. Other variables

There was a positive correlation between humidity and bacterial counts, particularly for MacConkey agar (MA) and Trypticase Soy Agar (TSA). The correlation was significant for TSA CFU/min ($r = 0.636$, $p<0.05$), MA CFU/min ($r = 0.699$, $p<0.05$), and MA CFU/m³ ($r = 0.815$, $p<0.05$), indicating that higher humidity levels may contribute to increased bacterial presence. The recorded humidity levels ranged from 25% to 42%, with an average of 31%. These findings suggest that variations in humidity could influence microbial survival and dispersion in restroom environments, potentially affecting indoor air quality and hygiene conditions.

Positive correlation between CO2 levels and bacterial dispersal was observed. A moderate correlation was found between CO2 and bacterial dispersal on TSA ($r = 0.661$, $p < 0.05$), and a stronger correlation was observed on Mannitol Salt Agar ($r = 0.736$, $p < 0.05$). This correlation between CO2 and bacterial dispersal could be attributed to several factors. Higher CO2 concentrations in enclosed spaces can lead to changes in air circulation patterns, potentially promoting the movement and spread of airborne particles, including bacteria. Additionally, higher CO2 levels may affect microbial metabolic activity, which could also influence bacterial proliferation and dispersion. These findings suggest that environmental factors such as CO2 levels could play a role in bacterial distribution, warranting further investigation to better understand the underlying mechanisms.

Room temperature did not show statistically significant results in relation to bacterial dispersal, but airflow temperature had a negative correlation with fungal dispersal on Sabouraud agar ($r = -0.747$, $p< 0.05$) and bacterial concentration on MacConkey agar ($r = -0.764$, $p<0.05$). These findings suggest higher airflow temperatures may reduce bacterial dispersal. However, there were issues measuring the temperatures of hand dryers, with some exceeding the maximum temperature range of the device.

IV. CONCLUSIONS

Both bacterial and fungal dispersal were observed, with warm air dryers consistently showing higher bacterial concentrations compared to jet dryers. The presence of opportunistic pathogens such as *Staphylococcus haemolyticus, Escherichia coli,* and *Acinetobacter baumannii* in hand dryer air indicates potential health risks, particularly in environments with frequent microbial exposure. Additionally, fungi were detected in all restrooms, with Aspergillus spp. being the most prevalent. Jet dryers exhibited slightly higher fungal counts, possibly due to moisture retention, which creates a more favorable environment for fungal growth.

Airborne particles were also affected by the use of hand dryers, with warm air dryers leading to a greater increase in particle concentration compared to jet dryers. The increase in airborne particles was positively correlated with airflow temperature, which may contribute to the dispersion of particulate matter. However, no statistically significant correlation was found between particle concentration and microbial counts in the air.

Environmental factors such as humidity and CO2 levels played a role in microbial dispersal. A positive correlation between humidity and bacterial counts was observed, particularly on MacConkey and Trypticase Soy agars. CO2 levels also showed a moderate to strong correlation with bacterial dispersal, suggesting that changes in air circulation and microbial metabolic activity could be influencing bacterial movement in enclosed spaces. In contrast, room temperature did not have a significant effect on microbial dispersion.

Overall, this study underscores the importance of considering both microbial and environmental factors when evaluating the impact of hand dryers on indoor air quality. The findings indicate that while hand dryers may contribute to bacterial and fungal dispersal, factors such as airflow temperature, humidity, and CO2 levels also play significant roles in microbial behavior. Further research is needed to explore the underlying mechanisms of microbial dispersal and the influence of environmental factors on air quality in public restrooms to organize appropriate hand dryers' maintenance and air quality exchange.

ACKNOWLEDGEMENTS

This study is part of Rīga Stradiņš University Vertically integrated projects that are implemented as a part of ESF co-financed project Improvement of Governance Processes and Modernization of Contents of Study Programs at Rīga Stradiņš University.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 601-604

The Importance of Social Work in Assisting Individuals: Practice, Challenges, and Solutions

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***Abstract*— Addiction to psychoactive substances or other harmful habits is often linked to social, psychological, and economic issues, making social work a complex field that provides emotional, informational, and practical support. This article examines social work practices in assisting individuals facing challenges, highlighting key professional difficulties such as stigma, lack of motivation, limited resources, and emotional burnout. The analysis of social workers' experiences in working with individuals struggling with alcohol addiction highlights the key challenges they encounter. Many clients enter treatment not by personal choice but due to external pressures, frequently exhibit skepticism and defensiveness, refusing help or denying their problems. Possible solutions include interdisciplinary collaboration, innovative working methods, and improved accessibility of social services. Based on practical examples and scientific research, the article identifies the most effective strategies that help social workers address addiction-related issues more efficiently and promote sustainable rehabilitation and reintegration. Social workers play a crucial role in guiding clients toward self-awareness, recognizing the need for change, and preparing them for recovery. However, the clients' motivation and willingness to cooperate remain essential factors for achieving lasting positive outcomes**

Keywords*— *persons with alcohol addiction, reintegration, social worker.

I. INTRODUCTION

The use of alcohol and other narcotic substances is integrated into the social customs and cultures of many countries. Most individuals who consume such substances do so without harming themselves or others. However, some people face problems that can negatively affect their own health and well-being, as well as that of their family members, friends, and the community. Alcoholism is often associated with serious life difficulties – lost jobs, broken relationships, mental health issues, legal problems, and even death from alcohol-related diseases or accidents. Furthermore, alcoholism often impacts the loved ones of the dependent individuals, who experience emotional stress, violence, social isolation, and other issues. Due to these severe consequences, the treatment of alcoholism requires long-term support, which can only be provided by specialists from various fields, including social workers, therapists, doctors, and psychologists. Social workers play a crucial role as they not only help individuals address addiction issues but also support them on an emotional and social level.

Research aim: The aim of the research was to explore the challenges faced by social workers when working with individuals who have alcohol addiction.

Research objective: The aim of the research is to investigate the challenges faced by social workers when working with individuals with alcohol dependence.

The study involved 5 social workers working with individuals with alcohol dependence.

A qualitative research method was chosen for the study, and a semi-structured interview instrument was used to collect data, the obtained research data were processed and presented using the principle of content analysis.

The qualitative research was conducted in accordance with the ethical principles of research, ensuring the rights of the participants specified in [3],[4]. The participants of the study were informed about the purpose of the study and the methods of data collection, their right to privacy and security were ensured (no questions were asked that could harm the well-being of the participants). All participants voluntarily agreed to participate in the study, confidentiality was guaranteed, and their names were coded and replaced with numbers to ensure anonymity.

Research problem: What challenges do social workers face when working with individuals who engage in harmful alcohol consumption, and how do they address these challenges?

Research sample: The study used purposive sampling, and participants were social workers who hold a social worker qualification and are or have been employed in roles working with individuals with alcohol addiction. Six social workers participated

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8696
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in the study. These social workers, who work directly with individuals affected by alcohol dependency, are professionals who maintain regular contact with their clients. To ensure effective service delivery, it is important to thoroughly examine the challenges these specialists face in their work. By identifying these challenges and applying effective strategies to address them, social workers will be able to improve the quality of their services and contribute to reducing the number of individuals affected by alcohol addiction.

II. MATERIALS AND METHODS

The goal of social work when working with individuals suffering from addiction is to provide comprehensive assistance that helps not only overcome addiction but also ensures long-term recovery and reintegration into society. The main objectives of social work are described in table 1.

TABLE 1 THE MAIN OBJECTIVES OF SOCIAL WORK

Acknowledgment of addiction problems	Recognition of alcoholism and understanding it as a chronic illness is the first step. The social worker helps the individual identify the addiction, understand its consequences, and make the decision to seek help.
Motivation to change	Social workers use motivational methods to help individuals discover their internal motivation to change their behavior. This can be achieved through motivational interviewing, where the person's values and desires to live a life free from alcohol are highlighted.
Psychosocial support	Social workers provide emotional support and assist individuals in addressing issues related to the causes of addiction, such as family relationships, employment problems, mental health disorders, and other contributing factors. They help clients explore these underlying issues, develop healthier coping strategies, and improve their overall well-being, which is crucial for overcoming addiction and achieving long-term recovery.
Involving the family and community	Social workers collaborate with family members to help them understand the dynamics of addiction, providing support and guidance. Involving the community can help create a healthy environment and establish preventive measures, further supporting the recovery process and reducing the risk of relapse.
Long-term support	Addiction is a chronic condition that requires long-term care. Social workers provide support even after the intensive treatment process, ensuring that the individual has continuous assistance to prevent a relapse into alcohol use.

Social workers constantly deal with complex life issues. Alcohol and substance use often form part of this mix, frequently occurring alongside mental health disorders, poverty, and domestic violence. These issues span all areas of social work and become not only an individual's problem but a societal one.

Alcoholism is one of the most common forms of addiction, with serious consequences for the individual, their family, the community, and society at large. It is a chronic disease that often leads to physical, mental, and social difficulties. Lithuanian Department of Drug and Alcohol Control's report [14] states that "alcohol consumption can negatively affect not only the individual but also others in their close environment, family, and work. In 2023, 36.2% of all families requiring case management needed these services due to potential or existing parental alcohol addiction (35.6% in 2022)." Problems with relationships, employment, finances, and housing are often the reasons why individuals with unhealthy alcohol use seek advice and help from health and welfare services [6]. Treating this disease and providing support for people with addiction is a key social work task. Social work with individuals suffering from alcohol addiction not only includes treating the illness but also providing comprehensive support to the individual and their family to ensure sustainable recovery and reintegration into society. Social workers consistently work with individuals who have substance use problems, making their role essential in assessing the issue, carrying out prevention, intervention, and organizing effective practices [5]. Given the complexity of the phenomenon, a systemic approach is necessary, and the work should focus on promoting social acceptance and long-term aspects of the individual's life: personal (social skills and daily living quality), biological (referral to medical institutions), and environmental (work habits, lifestyle) [8]. According to [10], [6], [11], social workers are not only tasked by the state but should actively engage with the most vulnerable individuals who require the greatest support. Their duty is to provide comprehensive social support, helping the individual reintegrate into society.

According to [13], social workers operate in a constantly changing social, political, and cultural environment, directly interacting with individuals from diverse social backgrounds, behaviours, and various social issues. Since addiction is a complex phenomenon, a systemic approach is essential, and social work can become a crucial long-term healthy factor, influencing personal (social and daily living skills), biological (e.g., referral to medical institutions), and environmental (work habits, quality of life) aspects [9]. [1] notes that social workers are almost always involved when there is an alcohol consumption issue. This is not only their legal responsibility but also part of broader areas of work, such as domestic violence, family crises, or working with individuals facing mental health difficulties. According to [1], social workers' activities related to substance use encompass three main roles. First, they must integrate the topic of addiction into their work to ensure appropriate assistance for clients, their families, and loved ones. Second, their task is to encourage individuals to change consumption habits and harmful behaviours, both for themselves and their relatives in the process. Third, social workers must support individuals in striving to adopt and maintain healthier consumption habits, ensuring long-term support. Research shows that social workers face numerous challenges when working with individuals with addictions: lack of client motivation, emotional burnout, lack of services, and intersectoral cooperation, as well as the societal stigma surrounding alcohol. Studies also emphasize that in order to improve the effectiveness of these professionals' work, it is necessary to ensure better professional preparation, increase the availability of social services, and strengthen emotional support. According to social learning theory, alcohol addiction could be a learned behaviour influenced by others and to overcome this it is very important to strengthen skills, create alternatives and support positive social activities [15].

III. RESULTS AND DISCUSSION

The study investigated the challenges faced by social workers when providing services to people with alcohol addiction. It was found that social workers face challenges when providing assistance to people with alcohol addiction. The researchers divided the challenges experienced by social workers into three subcategories of challenges: frequent forced treatment, refusal of help, denial of problems and lack of motivation. When talking about forced treatment, the study participants mentioned: "*Rarely does a person come to the institution for treatment on their own"* (2). "*Often the court requires treatment" (3). "Sometimes, when relatives can no longer stand it, they bring them by force,*

threatening them; at that time, they agree, but later they often bring them with the police" (4).

According to the participants, a major challenge for social workers working with individuals suffering from alcohol dependency is that they typically come for treatment not of their own accord, but due to pressure from law enforcement or family members. They often deny having any problems, claiming that they have no issues. In these cases, achieving positive results becomes extremely difficult. As one of the study participants stated: *"They say nothing happened to them, they were just told to come here" (1). "A major problem is people's defensiveness and isolation" (3). "Many individuals are sceptical about treatment and do not want help" (6).*

After analysing the data provided by the study participants, it can be concluded that social workers face several fundamental challenges when working with individuals with alcohol addiction. First, many of these individuals enter treatment institutions not of their own free will, but due to external factors, such as law enforcement or family pressure. This causes constant resistance, and their motivation to change is often low. Second, individuals with addiction often demonstrate a defensive and sceptical attitude, which complicates the task of the social worker. Some deny that they have a problem, others distance themselves from the offered help and do not engage in the treatment process. These situations emphasize that successful work with individuals requires not only professional help, but also the use of individualized motivational methods in order to reduce resistance and promote constructive cooperation.

Challenges Social Workers Face in Motivating Clients with Addiction Problems. The study participants emphasized that social workers working with individuals who have addictions often notice a lack of motivation among their clients. It was observed that many clients arrive at the treatment facility not because they genuinely want to seek help, but due to external obligations, such as court or police requirements. Only a small proportion of clients truly have the motivation to change and undergo treatment. As the participants stated: *"It's very easy and goes well when working with a motivated person" (1). "But when someone comes in who has no motivation to change, you can do whatever you want with them, they still don't want anything and reject any help" (3). "Motivation is often fake... there is often no real desire, just pretension" (4).*

The participants noted: *"There are cases when a person comes and asks for help, but that's very rare" (5). "Often they leave, going to the store on their way home, and everything starts over. Sometimes, even in the hospital, they manage to use substances" (6).*

According to the participants, individuals with addictions often fail to understand the extent of their problems, refuse help, and lack the internal motivation to change. Some come only for formalities, just to "check-in," but as soon as they leave, they return to their old habits. There are also cases where people use psychoactive substances even within treatment facilities, which further complicates their situation. These challenges present significant difficulties for specialists, as effective help can only occur when individuals genuinely want to make changes. Social workers not only need to provide the necessary support but also continuously search for ways to encourage clients' motivation to seek treatment and change their lifestyles.

The second identified category – "Challenges related to social workers' collaboration" – includes three subcategories: communication challenges, participation and effectiveness challenges, and attitude challenges. *"As I said, sometimes it is very difficult to reach an agreement with child protection services." (1); "<…> sometimes I wish doctors were more active, I would like to have consultations and more specific guidelines." (3); "Sometimes it feels like we are speaking different languages<…>."(6)* Regarding communication challenges, the study participants emphasize that one of the difficulties is collaboration between institutions. While collaboration occurs, each institution often focuses only on its own area or specific aspects, which can cause difficulties, especially in child protection, where coordination of actions from various institutions is required. Participants also mentioned communication problems with doctors, noting that sometimes it is difficult to communicate and discuss the patient's situation. They emphasize that doctors lack initiative, especially when detailed consultations are needed for certain conditions that would require closer collaboration with social workers. This leads to situations where social workers have to perform tasks not directly related to their main activities, which may create an additional workload. Communication challenges arise due to the autonomy of institutions, lack of cooperation, insufficient initiative, and the absence of inter-institutional collaboration. When discussing attitude challenges, the study participants emphasize that each institution often tends to "pull" towards itself, defending its own perspective or limiting its actions only to its area of responsibility. This causes problems, especially in matters concerning children's rights or cooperation with the police. The participants point out that some institutions are too strict or misjudge clients' situations. They also express the opinion that the role of the doctor and their recommendations regarding treatment should be respected, rather than imposing decisions or opinions. Furthermore, in some situations, collaboration with the police could be beneficial, but it doesn't always happen effectively – the police sometimes act too harshly, rather than focusing on mutual information sharing and control, without aiming for punitive measures.

The third category – "The service provision process for individuals with alcohol addiction in addiction centers" – includes three subcategories: counseling, treatment, and information. When discussing counseling, the study participants emphasize that individuals first approach a doctor, who provides counseling on alcohol addiction and determines the level of addiction, as well as what treatment plan should be applied. The doctor also offers consultations and educates patients about the effects of alcohol on their mental health. When describing the treatment process, participants note that the treatment plan may include doctor visits at specific intervals, such as after one week, one month, or three months. During treatment, medications may be prescribed, and inpatient treatment may be offered, which involves intensive care and monitoring. Additionally, doctors aim to involve the patient in the recovery process and monitor how they accept help and adhere to the treatment plan. Psychosocial motivational programs, rehabilitation, and the Minnesota program may also be offered to help patients achieve recovery.

Regarding information provision, the study participants emphasize that social workers are the first to provide information to patients, discussing the negative consequences of alcohol consumption. This information includes not only physical but also social, legal, financial, and even spiritual consequences.

IV. CONCLUSIONS

Social work with individuals suffering from alcohol addiction is a complex and important process that requires a holistic approach to addiction treatment and rehabilitation. This involves not only direct support for individuals with addiction but also assistance and support for their families to ensure a sustainable recovery and reintegration process into society. Recognizing addiction as a chronic disease and applying appropriately tailored interventions can significantly improve the quality of life for individuals with alcohol addiction and enable them to successfully integrate into society. It is essential for social workers to possess the necessary knowledge and skills to provide support and foster changes that help individuals cope with addiction and ensure long-term recovery.

The analysis of social workers' experiences in working with individuals struggling with alcohol addiction highlights the key challenges they encounter. One of the most significant difficulties is that many clients enter treatment not by personal choice but due to external pressures, such as legal obligations or family influence. This lack of voluntary participation often leads to resistance and diminished motivation to engage in the recovery process.

People with addiction frequently exhibit skepticism and defensiveness, refusing help or denying their problems, which makes it harder for social workers to involve them in treatment. Some clients may misrepresent their situation or deny their struggles, even when clear evidence of addiction is present. This behavior, often rooted in self-defense or an attempt to navigate the system, further complicates the efforts of social workers, requiring them to employ specialized skills to help clients acknowledge and accept their condition.

Additionally, individuals who show no progress or actively resist help pose further challenges, as their unwillingness to engage meaningfully in treatment increases the likelihood of relapsing. Social workers play a crucial role in guiding clients toward self-awareness, recognizing the need for change, and preparing them for recovery. However, without the clients' motivation and willingness to cooperate, achieving lasting positive outcomes remains difficult.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 605-609

Assessment of Blackcurrant Twigs Potential as a Renewable Source of Proanthocyanidins in Latvia

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***Abstract*— Blackcurrant (Ribes Nigrum L.) is one of the most common shrubs in Latvia, in addition to fruits and leaves, twigs cut in spring and autumn are rich in oligomeric polyphenols - proanthocyanidins, which have powerful antioxidant, antimicrobial, anti-inflammatory properties. The yield of proanthocyanidin-containing extracts ranged from 12 to 22%/DM. At the same time, the twigs cut in autumn were richer in proanthocyanidin than in spring. The strong antimicrobial properties of the extracts showed their effectiveness against a wide range of bacteria, which makes the extracts promising for use in medicine and the food industry. All extracts introduced into the lipid-based cosmetic cream showed antioxidant activity comparable to reference samples. This indicates the potential for using these extracts as active ingredients in cosmetics aimed at protecting the skin from the negative effects of free radicals. The results obtained open up new opportunities for developing innovative cosmetic formulations with improved antioxidant properties that help slow down the ageing process of the skin and maintain its health. The use of blackcurrant twigs is a sustainable and cost-effective source of valuable bioactive compounds.**

***Keywords*—Blackcurrant, extract, polyphenols, proanthocyanidins, twigs.**

I. INTRODUCTION

Blackcurrant (Latin: *Ríbes nígrum*), growing in temperate regions of Central and Northern Europe and Northern Asia, is one of the most widespread shrubs, the fruits and leaves of which are rich in biologically active compounds of polyphenolic nature, possessing antimicrobial, antioxidant and health-improving properties. According to FAOSTAT, Poland ranks first among European countries in blackcurrant production [1]. Numerous studies confirm that blackcurrant fruits are a valuable source of vitamin C, P, BB, potassium, γ-linolenic acid and antioxidants such as anthocyanins, and quercetin, and have a positive effect on human health [2]-[4]. Currant extracts are widely used in the food, pharmaceutical and cosmetic industries. The high nutritional value and wide range of health properties make blackcurrant an important component of healthy nutrition and a promising raw material for developing functional foods and drugs. However, in recent years, several works have been published on using other anatomical parts of currants, in addition to the fruits, as a source of biologically active substances. Studies of the potential of leaves, which are plant waste of blackcurrant, have shown that leaves are the main source of phenolic acids or flavonoids [5].

Currently, special attention is paid to the complex and waste-free processing of fruit bushes with maximum extraction of biologically active substances and expansion of the range of preparations from them. Chemical characterization of blackcurrant branch extracts is relevant and will help to create a waste-free processing scheme for blackcurrant cultivation. Our preliminary studies reported

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8697
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that blackcurrant twigs contain a complex of polyphenolic compounds, including oligomeric polyphenols – proanthocyanidins [6]. The proanthocyanidins also known as condensed tannins are present in various plants, as a defence against biotic and abiotic stressors. Proanthocyanidins are oligomeric or polymeric products of the flavonoid biosynthetic pathway. The building blocks of proanthocyanidins include catechin and epicatechin. Proanthocyanidin's degree of polymerization can range between 2 and 11 [7].

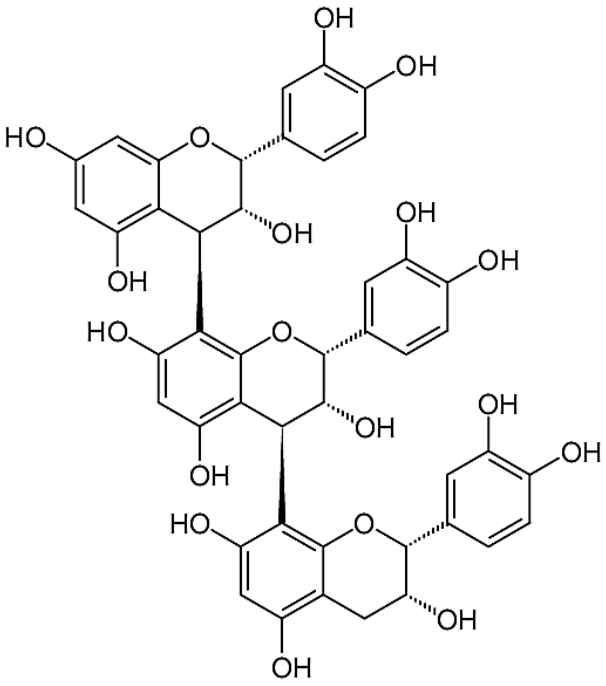

Fig 1. Chemical structure of B-type proanthocyanidins [7].

A review of the literature and our studies shows that oligomeric proanthocyanidins are highly active compounds with a wide spectrum of biological activity, which is determined by their polyphenolic structure [8]. Proanthocyanidins have antioxidant, antimutagenic, anticarcinogenic, anti-inflammatory and antiviral properties [9]. The interest in these substances in the world is extremely high due to their various biological effects and almost complete absence of toxicity.

The purpose of this work was to evaluate the twigs of black currant, collected in the spring and autumn seasons, as a raw material for obtaining proanthocyanidins. Additionally, the study was aimed at testing the proanthocyanidins-rich fraction's antimicrobial activity and antioxidant activity, for assessment of the practical application possibilities.

II. Materials and Methods

A. Collection of Blackcurrant Material

The twigs of blackcurrant were collected from the blackcurrant plantation area in Baldone parish, Kekava county of Latvia, in March and October of 2022, 2023 and 2024.

Fig. 2. Blackcurrant plantation area in Baldone parish.

The twigs were dried at room temperature, and ground with a knife mill Retsch SM100 (Retsch, Haan, Germany) and Retch SM200 (Retsch, Haan, Germany). These fractions were stored at −8 °C.

B. Hydrophilic Extract Isolation from Biomass

Extracts from the twigs' biomass of the black- currant were isolated by extraction at 60 °C for 30 and 60 min with distilled water and ethanol-water (1:1, v/v) solution. The extracts after ethanol evaporation were freeze-dried to yield a brown solid. The yield of the extracts is presented as a percentage per dry mass (DM).

C. Determination of Total Phenol Content in the Extract

The total polyphenol (TP) content in all extracts was quantified by the Folin-Ciocalteu method using gallic acid as a reference compound. An aliquot (1 mL) of the extract was transferred into the test tube and addition of 5 mL Folin-Ciocalteu reagent and 4 mL 7% aqueous sodium carbonate solution, the tube was vortexed and placed into a water bath at 30 °C for 1 h. Then absorbance of the mixture was recorded at 760 nm with a UV/VIS spectrometer Lambda 650 (Perkin Elmer, Inc., Waltham, USA) against a blank containing 1 mL of extraction solvent. The content of total phenolics was calculated as a gallic acid equivalent (GAE) from the standard curve and expressed as mg GAE/g extract. All measurements were done in triplicate. The final values were expressed as gallic acid gram equivalent (GAE). The confidence interval (CI) for the results did not exceed 3% at α=0.05).

D. Determination of Proanthocyanidins in the Extract

The content of proanthocyanidins was measured by the butanol-HCl method using procyanidin dimer B2 as a reference compound. An aliquot (1 mL) of the extract was transferred into the test tube and the addition of 6 mL of acid butanol (5% (v/v) concentrated HCl in n-butanol) and 0.2 mL of iron reagent (w/v) ($FeNH_4(SO_4)_2 \cdot 12\ H_2O$ in 2 N HCl), the tube was vortexed and placed into a water bath at 80 °C for 50 minutes. Then absorbance of the mixture was recorded at 550 nm with a UV/VIS spectrometer Lambda 650 (Perkin Elmer, Inc., Waltham, USA) against a blank containing 1 mL of extraction solvent. Each extract was analyzed in triplicate, and assay results were expressed as a percentage per dry extract (DE). The CI for the results did not exceed 3% at α=0.05).

E. Determination of Antimicrobial Activity of Extract

Antimicrobial activity was studied in 96-well plates by the two-fold serial broth microdilution method, which allowed the determination of the minimum inhibitory (MIC) and minimum bactericidal/fungicidal concentrations (MBC/MFC), as described by Andersone [10].

F. Determination of Antioxidant Activity of Extract

The effect of extracts on the oxidative stability of the lipid based system was performed with cosmetic cream (basic compositions without antioxidant additives), and were studied with the Oxipress apparatus (Mikrolab Aarhus) [11]. The oxidative stability was determined under the optimum conditions: 20 g of the reaction mixture (corresponding to 5 g of the lipid phase), oxygen pressure of 0.5 MPa, at 120°C. Ascorbic acid and gallic acid served as a reference antioxidant. The lipid-based systems without antioxidants were used as a control. First, 0.01–0.4 g of antioxidant was mixed in the reaction vessel with the lipid-based substrate (5 g in terms of lipids), and then thoroughly mixed for 30 min under an inert atmosphere. Then the reaction vessel was filled with O2 to 0.5 MPa, and placed into a furnace at 120°C and the changes of O_2 pressure were recorded as a function of time. Protection factor (PF) of samples was calculated: PF = IPx /IPc where IPx and IPc are the induction period of substrate oxidation in the presence of samples and that of the control, respectively.

G. Statistical Analysis

All measurements were conducted in triplicate (n=3). The results are presented as the mean value ± standard deviation (SD). Statistical analyses were performed using Microsoft Excel 2016. Confidence intervals (CI) were calculated for a mean using a Student's T distribution at a significance level $\alpha = 0.05$. For a yield of extractives: CI≤1.2% at $\alpha = 0.05$; for total phenolic content in the extract: CI≤3 mg GAE/g at $\alpha = 0.05$; for proanthocyanidins content in the extract: CI≤1.5% at $\alpha = 0.05$; for antioxidant activity: CI≤0.3 mg/L at $\alpha = 0.05$.

III. Results and Discussion

A. Chemical Characterization of Blackcurrant Twigs

The yield of the hydrophilic extracts isolated from blackcurrant twigs samples from both seasons varied from 12 to 20%/DM. Higher extract content was isolated using 50% EtOH from twigs samples collected in autumn (Fig. 3).

The proanthocyanidin content in the extracts was quite similar and varied from 12 to 36%/DM (Fig.4). The total polyphenols content in extracts varied from 14 to 38 GSEg/100g DM. The blackcurrant twigs collected in autumn have the highest PACs content in the extract in all years.

Compared to other berry bushes, blackcurrant is poorer than chokeberry and sea buckthorn in terms of proanthocyanidin content. Our previous studies have shown that the proanthocyanidin content in *Hippopae rhamnoides* L. and *Aronia melanocarpa* extracts isolated with 50% EtOH was ~40 and ~70% per DM [12].

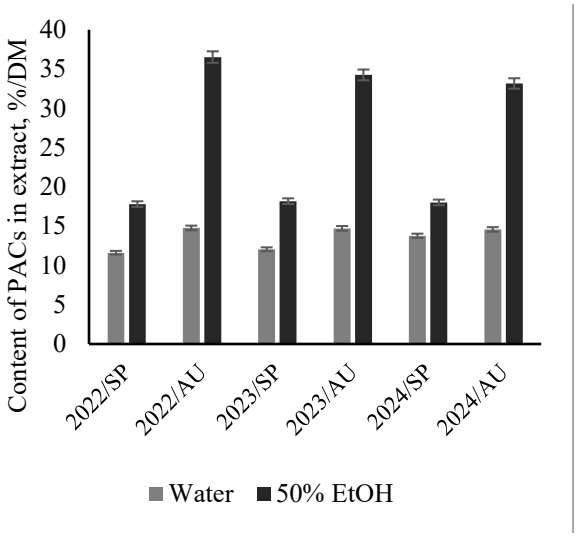

Fig. 3. Yield of extract from blackcurrant twigs biomass.

In this regard, proanthocyanidins will not be isolated from the extract but will be studied in the extract composition. This will allow us to evaluate their potential as a preservative and antimicrobial agent.

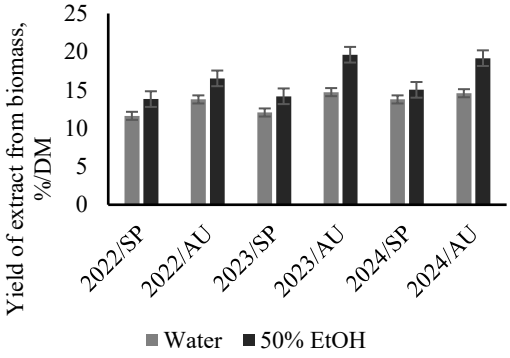

Fig. 4. Characterization extract isolated from blackcurrant twigs by water and 50% EtOH.

B. Antimicrobial Activity of Blackcurrant Extracts

The antimicrobial activity of hydrophilic extracts of blackcurrant extract was studied against four pathogenic bacteria: P. aeruginosa, S. aureus, E. coli, B. cereus. The MIC and MBC of extracts ranged from 0.6 to 5 mg mL^{-1} (Table 1).

The observed antimicrobial activity may be due not only to the presence of proanthocyanidins but also to the presence of other polyphenolic compounds in the extract. The relatively low MIC and MBC values suggest that blackcurrant extracts have potent antimicrobial activity. This is especially important given the growing concern about antibiotic resistance, with traditional antibiotics becoming less effective against certain bacterial strains.

TABLE 1. ANTIMICROBIAL ACTIVITY OF BLACKCURRANT EXTRACTS

Sample	***B. cereus* 330**	***E. coli* 332**	***P. aeruginosa* 331**	***S. aureus* (MRSA) 993**
	MIC/MBC, mg/mL			
E/SP/W	1.25/>5.0	5.0/5.0	1.25/1.25	0.31/>5.0
E/SP/50Et	1.25/>5.0	2.5/2.5	0.63/1.25	2.5/>5.0
E/AU/W	1.25/1.25	2.5/>5	1.25/>5	0.63/0.63
E/AU/50Et	0.63/>5	2.5/5	1.25/5	0.63/0.63

E/SP/W - extract isolated by water from blackcurrant twigs collected in spring, 2023
E/SP/50Et - extract isolated by 50% EtOH from black currant twigs collected in spring, 2023
E/AU/W - extract isolated by water from black currant twigs collected in autumn, 2023
E/AU/50Et - extract isolated by 50% EtOH from black currant twigs collected in autumn, 2023

The extracts offer a potential alternative or complementary approach to combat bacterial infections. The potential of blackcurrant extracts as antimicrobial agents requires further study and development. The extracts may be incorporated into new medicinal formulations, wound dressings or other antimicrobial products.

C. Antioxidant Activity of Blackcurrant Extracts

The antioxidant activity of the samples was assesmed by determining the protection factor (PF) for lipid-containing cosmetic cream from oxidation. For this purpose, the Oxipress method was used. The antioxidant activity of the studied samples was expressed as the induction period (IP), for which the antioxidant can delay the oxidation of the substrate. Ascorbic acid and gallic acid were used as references.

TABLE 2. ANTIOXIDANT ACTIVITY OF BLACKCURRANT EXTRACTS

AO concentration, %	**Sample**	**IP, h**	**AP**
1	LC without AO	1.3±0.1	-
	Blackcurrant extract isolated by 50% EtOH	2.3±0.1	1.8±0.1
	Blackcurrant extract isolated by water	1.9±0.1	1.7±0.1
	Ascorbic acid	1.9±0.1	1.5±0.1
	Gallic acid	2.0±0.1	1.5±0.1
2	Blackcurrant extract isolated by 50% EtOH	2.7±0.1	2.1±0.1

The antioxidant activities show that the extracts in focus are promising agents for stabilisation of lipid-based systems.

When comparing the results obtained, at an antioxidant concentration of 1%, the 50% EtOH extract showed the best results.

In turn, the water extract, taking into account the lower proanthocyanidin content (10.2% per dry extract), had a lower protection factor than the 50% EtOH extract. By increasing the antioxidant concentration in the cream suspension to 2%, the protection factor increased only 1.2 times, which means that the cream suspension was saturated with the studied extract, preventing the sample from dissolving further in the given system.

CONCLUSIONS

In this study, blackcurrant twigs collected in spring and autumn and extracted with 50% EtOH solution showed high antioxidant and antimicrobial activity. Blackcurrant lignocellulosic biomass is a valuable source of proanthocyanidin-containing extracts for the creation of antibacterial and antioxidant drugs for health care, food industry and cosmetics.

ACKNOWLEDGMENTS

Project No. lzp-2022/1-0599, Innovative anti-inflammatory and antipathogenic systems based on proanthocyanidins isolated from fruit shrubs agricultural lignocellulosic waste is greatly acknowledged.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 611-621

Corporate Sustainability Reporting in Public Healthcare Institutions: Relevance, Challenges, and Legal Perspectives

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***Abstract*—Corporate sustainability reporting by public healthcare institutions is essential not only for addressing environmental and social issues but also for ensuring long-term economic stability. This study analyses the implementation requirements of the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) in the healthcare sector, with a particular focus on large hospitals. Furthermore, the study compares the transposition of the CSRD into the national laws of Latvia, France, and Germany, highlighting key differences, such as sanctioning mechanisms. The research employs comparative legal analysis, content analysis, and legal norm interpretation methods. The results indicate that, unlike Latvia, France and Germany have adopted strict penalties for companies and their managers for non-compliance with CSRD requirements to promote accurate and reliable sustainability reporting. The study finds that Latvian healthcare institutions meeting the CSRD criteria, such as Pauls Stradiņš Clinical University Hospital, will be required to establish sustainability reporting systems by 2026. Consequently, the study's findings are applicable to other CSRD member states when assessing the obligations of various companies or institutions to provide sustainability reports. In addition to challenges, the study emphasizes potential benefits for businesses, including enhanced reputation. These findings also provide valuable insights for policymakers working on the development of effective regulations and the implementation of sustainability reporting in the healthcare sector.**

Keywords*— *Corporate Sustainability Reporting, Environmental, Social, and Governance (ESG) Reporting, Healthcare Sector

I. INTRODUCTION

Sustainable healthcare is crucial for safeguarding public health and mitigating climate change. This article examines the requirements of the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), with a particular focus on the obligation of Latvian hospitals to provide sustainability reports. The article explores the legal aspects, as well as the challenges and opportunities this process presents for the healthcare sector.

Although discussions about climate change and its consequences began as early as the previous century—for instance, Swedish scientist Svante Arrhenius published a study in 1896 on the impact of carbon dioxide in the atmosphere on Earth's temperature[1] — the issue of mitigating the effects of climate change has gained particular prominence in the past decade. Consequently, several international and European-level regulatory acts have been adopted, including documents related to the European Green Deal.

The Non-Financial Reporting Directive (NFRD), adopted in 2014, aimed to improve the transparency of non-financial indicators for large companies. This directive[2] required large entities with more than 500 employees to report on their impact on the environment, social issues, human rights, and corporate governance. However, the NFRD covered only a limited number of companies and was often criticized for being too general and insufficient to effectively address sustainability challenges. In contrast, the European Green Deal, introduced in 2019, set the goal for the European Union to become a climate-neutral continent by 2050, thereby demanding greater transparency and accountability from companies. Addressing the shortcomings of the NFRD, in April 2021, the European Commission proposed a new directive—the Corporate Sustainability Reporting Directive (CSRD)[3] — which expands reporting obligations and enhances the quality and

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8664
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accessibility of sustainability information, covering a broader range of companies, including certain small and medium-sized enterprises.

With growing interest in climate change and its consequences, as well as efforts to mitigate them, the issue of corporate sustainability reporting has also evolved, becoming increasingly significant in promoting transparency, accountability, and sustainability in business operations, particularly within the European Union. As society increasingly demands corporate responsibility for their impact on the environment and communities, several regulatory acts have been developed, the most notable being the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS).[4] These legal instruments aim to enhance companies' reporting on their impact regarding environmental, social, and governance (ESG) factors.

Thus, corporate sustainability reporting has become one of the key elements in advancing global sustainability. Since the European Green Deal was incorporated into the EU's framework, with its primary goal of achieving climate neutrality by 2050, EU member states have been subjected to stricter requirements regarding sustainability reporting. The CSRD, which also amends the Non-Financial Reporting Directive, introduces new and specific requirements for companies across all sectors, including healthcare institutions. At the same time, this directive not only mandates companies to report on their impact on the environment, society, and corporate governance, thereby increasing transparency, but it also requires companies to assess how environmental factors affect their own operations. This article will also compare the approaches of different EU member states in transposing the CSRD into their national laws, such as in France and Germany. It is observed that the varying approaches of these countries lead to differences in the application of the CSRD, reflecting each nation's unique national and social structures. The authors have chosen to compare the experiences of France, Germany, and Latvia in implementing the CSRD, as France and Germany have placed significant emphasis on penalizing companies for non-compliance with the CSRD and ESRS requirements. In contrast, Latvia has taken a more cautious approach, refraining from imposing direct sanctions for failure to meet reporting obligations. Germany and France were specifically selected for comparative analysis because these countries represent advanced economies within the EU, and they have established clear and stringent sanctioning mechanisms. Additionally, the availability of comprehensive legal documentation and their distinct legislative approaches provided a strong basis for comparison. A limitation of the methodology used is that it primarily relies on document-based legal analysis, potentially overlooking practical implementation challenges not captured in official documents.

According to Recital 13 of the CSRD preamble, there is substantial evidence that many companies fail to disclose significant information on key sustainability-related issues. This includes climate-related matters such as greenhouse gas (GHG) emissions and factors impacting biodiversity. The report also highlights the problem of limited comparability and reliability of sustainability information. Furthermore, many companies from which users require such information are not obligated to make it public. This creates a clear need for a robust and cost-effective reporting framework, complemented by efficient audit practices to ensure data reliability and prevent greenwashing and double-counting.[3] As noted by KPMG in its report, the implementation of the CSRD in Europe significantly increases companies' obligations to report on their sustainability.[5]

The concept of corporate sustainability encompasses companies' efforts to reduce their negative impact on the environment and society while promoting transparency and responsible governance. Sustainability is essential in corporate operations to enhance accountability and trustworthiness.[6] In the European Union, including Latvia, this area is becoming increasingly significant, particularly in connection with the new EU regulatory framework.

The aim of this article is to analyse these documents and legal acts, as well as to assess their impact on companies, particularly healthcare institutions in Latvia, by comparing the experiences of different EU countries in transposing the CSRD.

II. Materials and Methods

This study examines how the Corporate Sustainability Reporting Directive (CSRD) has been integrated within the European Green Deal framework in Latvia and other European Union (EU) countries. The research involves a comparative legal analysis of the CSRD and European Sustainability Reporting Standards (ESRS) in relation to Latvian legislation. Additionally, the study contrasts the Latvian legal framework with that of other EU member states, specifically France and Germany, with a focus on the sanctions imposed for non-compliance with CSRD requirements. The research also incorporates an analysis of expert opinions provided by leading law firms on the implementation and compliance challenges associated with CSRD. Furthermore, the study identifies which Latvian healthcare institutions will be subject to mandatory sustainability reporting obligations.

A combination of qualitative and quantitative research methods was applied. The primary method used was a comparative legal analysis to evaluate the alignment of Latvian laws with CSRD and ESRS, as well as to identify differences between Latvia’s approach and that of France and Germany. The study also employed content analysis to assess legal provisions, regulatory frameworks, and sustainability reports. To gain further insights, the research utilized legal norm interpretation methods to assess the applicability of CSRD provisions in national contexts, focusing on systemic, grammatical, and teleological interpretations. The findings contribute to understanding the legal and regulatory landscape of sustainability

reporting in the Latvian healthcare sector and provide a basis for assessing future policy developments.

III. Results and Discussion

A. The Legal Framework for Corporate Sustainability Reporting

a) The Concept of Sustainability in the Healthcare Sector

The concept of "sustainability" has become a fundamental principle in today's world, applied across economic, environmental, and social contexts. From a legal perspective, sustainability signifies responsible actions that preserve resources and quality of life for future generations while balancing economic interests, social well-being, and environmental protection. In the healthcare sector, the concept of sustainability holds particular importance as it directly influences not only the operations of healthcare institutions but also public health as a whole. Sustainability is traditionally divided into three main pillars: environmental sustainability, social sustainability, and economic sustainability. These pillars are interconnected, and their balance is essential to ensure that the healthcare system can deliver quality services in the long term without causing negative consequences in the future.[7] In the context of healthcare, sustainability is especially critical as institutions must consider their impact on the environment, public health, and economic viability.

Similarly, another study highlights that the implementation of sustainable practices in the healthcare sector is based on three dimensions—environmental, social, and economic. It further emphasizes that the environmental dimension is the most critical, encompassing initiatives such as circular resource practices, waste reduction and recycling, and sustainable procurement policies. The integration of these initiatives into the operations of healthcare institutions reduces their environmental impact and enhances public health, particularly by lowering pollution and promoting efficient resource use. At the same time, these practices not only foster environmental sustainability but also deliver economic benefits, such as cost reduction and improved operational efficiency.[8]

The economic dimension places special emphasis on promoting research and innovation, as well as local production, with studies revealing these factors as key drivers influencing all other dimensions of sustainability. For instance, innovations in diagnostic and care models not only enhance the quality of services but also improve the accessibility and efficiency of healthcare. Additionally, employee and patient satisfaction, which forms part of the social dimension, is a critical aspect that impacts the overall sustainability of the healthcare system, creating a positive effect on service quality and the improvement of public health outcomes.[8]

Healthcare institutions must consider their environmental impact and comply with various regulatory acts that mandate measures to reduce harm to the environment. Waste management is a critical issue, as hospitals are required to adhere to regulations on hazardous and medical waste management to ensure proper disposal and prevent threats to the environment and public health.[20] Similarly, healthcare institutions must ensure energy efficiency by utilizing energy-efficient technologies and reducing energy consumption, which not only lowers costs but also promotes environmental sustainability. Mitigating the effects of climate change is another essential aspect, requiring hospitals and other healthcare institutions to ensure their operations do not exacerbate climate change through carbon emissions or inefficient resource use. Sustainable infrastructure and energy management are vital tools for minimizing the negative environmental impact.[9]

Social sustainability in healthcare primarily pertains to equity, respect for human rights, and the promotion of public health. Healthcare institutions have a legal obligation to ensure good working conditions for their employees by complying with occupational safety standards and providing fair compensation. Employee health and well-being are critical factors that influence both staff satisfaction and their ability to deliver quality services to patients. Healthcare institutions must also ensure equal access to healthcare services, prohibiting discrimination based on gender, race, religion, or social status. Healthcare is a fundamental right, and sustainable healthcare means that services are accessible to all members of society, regardless of their personal or social circumstances. Sustainable healthcare systems also contribute to public health by not only treating illnesses but actively engaging in public education and preventive programs. Healthcare institutions must work to improve public health by providing information on healthy lifestyles and disease prevention, which, in the long term, helps reduce the burden on the healthcare system.[9]

Economic sustainability means that healthcare institutions must ensure long-term financial stability to continue providing high-quality services. Sustainable financing is a crucial element to enable hospitals and other healthcare institutions to operate efficiently while maintaining a high standard of service. Healthcare institutions also have a responsibility to carefully manage public funds if they receive state financing. Legally, hospitals are accountable for ensuring that public resources are used efficiently and responsibly to deliver the best possible services to society. At the same time, they must ensure that the healthcare system remains financially sustainable and capable of continuing its operations in the future.

EU legislation, such as the CSRD and ESRS, mandates that large healthcare institutions, including hospitals, provide detailed reports on their sustainability policies and practices. This means healthcare institutions have a legal obligation to report on how they ensure sustainability across all three dimensions: economic, social, and environmental. In addition to EU regulations, healthcare institutions must also comply with national legal frameworks governing areas such as waste management, labor rights, human rights, and public health protection.

Hospitals are responsible for operating in accordance with these legal requirements and ensuring that their activities align with sustainability principles. Sustainability in healthcare legally encompasses responsible resource management, social equity, respect for human rights, and long-term economic viability. Hospitals and other healthcare institutions play a critical role in promoting sustainability, not only by providing treatment but also by contributing to public health, environmental protection, and economic stability. The sustainability of healthcare systems is essential to ensure they can continue delivering quality services and positively impacting society over the long term.

TABLE 1 OVERVIEW OF REGULATORY FRAMEWORK FOR CORPORATE SUSTAINABILITY REPORTING IN THE HEALTHCARE SECTOR

Source	Information
Corporate Sustainability Reporting Directive (CSRD)	Information on legal requirements for sustainability reporting applicable to large companies and healthcare institutions
European Sustainability Reporting Standards (ESRS)	Information on specific sustainability reporting standards applicable to various sectors, including healthcare
European Union and National Legislation	General principles on environmental protection, labor rights, human rights, and public health protection
Documentation in Healthcare and Sustainability Sectors	General information on the implementation of sustainability principles in healthcare, including waste management, energy efficiency, and resource management

b) Analysis of the Corporate Sustainability Reporting Directive

The CSRD is considered a crucial element in achieving the goals of the European Green Deal and climate neutrality by 2050. This directive replaced the Non-Financial Reporting Directive (2014/95/EU) and introduced stricter requirements for sustainability reporting in companies, while also expanding the range of entities obligated to report. Under the CSRD, companies are required to provide detailed information about their impact on the environment, society, and governance.[5]

The CSRD mandates the application of a double materiality perspective, requiring companies to report both on their impact on the environment and society and on how these factors affect the company's operations.[3] This approach ensures that businesses provide an accurate and truthful account of their sustainability performance, reflecting the actual situation.

The implementation of the CSRD will occur gradually, starting with large undertakings in 2025 and extending to small and medium-sized enterprises by 2027 (and in certain cases, until 2029). The CSRD aims to enhance corporate transparency and accountability, which benefits not only society as a whole but also the businesses themselves. Article 1(4) of the CSRD defines the scope of sustainability reporting, stipulating that the report must include information necessary to understand the company's impact on sustainability issues, as well as information needed to understand how sustainability issues affect the company's development, performance, and financial position.[3]

The report must include a concise description of the company's business model and strategy, as well as information on the sustainability-related targets set by the company to be achieved within a specific timeframe. This includes, where applicable, absolute greenhouse gas emission reduction targets for at least 2030 and 2050. The company must also provide a description of its progress toward achieving these targets and a statement on whether the environmental targets are based on robust scientific evidence.[3]

The report must also include a description of the role of the administrative management and supervisory structures in managing sustainability issues, the company's policies regarding sustainability matters, and whether there are any incentive schemes related to sustainability. Additionally, the company must provide an overview of the due diligence processes implemented for sustainability issues, key actual or potential adverse impacts related to its operations and value chain, and any measures taken to prevent, mitigate, or eliminate these impacts, along with the results of such actions. Furthermore, the company must describe the main risks associated with sustainability issues that could jeopardize its operations.[3]

Article 19a(6) of Directive 2013/34/EU, as amended by Article 1(4) of the CSRD, now stipulates that, by way of derogation from paragraphs 2 to 4 of this article, small and medium-sized enterprises (SMEs) and small and non-complex entities may limit their sustainability reporting to the following information: a brief description of the company's business model and strategy; a description of the company's policies related to sustainability matters; the main actual or potential adverse impacts of the company on sustainability matters and the actions taken to identify, monitor, prevent, mitigate, or remedy such adverse impacts; the principal risks related to sustainability matters that the company faces and their management; and the key indicators necessary to disclose the aforementioned information.[3]

In essence, the CSRD mandates that companies comply with the ESRS, which provides detailed guidelines on the content of reporting, such as climate change, human rights, and governance structures. Meanwhile, the CSRD broadly outlines the key components of the report and defines the scope of companies for which reporting is mandatory.

Particular attention must be paid to the provisions of Article 3 of the CSRD regarding the assurance of the accuracy and reliability of annual and consolidated sustainability reports. This assurance must be carried out by an independent, professional, and trained third party, thereby ensuring the precision and credibility of the data. Studies indicate that while the implementation of the CSRD will significantly enhance the reporting system, additional training and support are also necessary,

particularly for small and medium-sized enterprises (SMEs), to enable them to meet the new requirements.[10]

It is important to emphasize that the goal of corporate sustainability reporting is not to require businesses to disclose information about intellectual capital, intellectual property, know-how, or innovation outcomes that would qualify as trade secrets.[3]

The international business law firm "Sorainen" (hereinafter referred to as Sorainen) has pointed out that the CSRD significantly expands exceptional reporting obligations. The directive not only sets requirements for reporting on environmental and social issues but also emphasizes the double materiality approach, which requires companies to report both on their impact on the environment and national sustainability and on how environmental and social issues may affect their operations or financial position. This approach ensures that companies are fully accountable for their impact on the environment and society. Additionally, it provides a comprehensive overview of a company's sustainability strategy and its potential impact on the long-term development of the business.[11]

In addition, Sorainen emphasizes that the implementation of the CSRD requires not only a narrow report on a company's impact on environmental factors but also on how its operations affect society, such as respecting human rights and ensuring fair working conditions for employees.[11] Applied to healthcare institutions, such as hospitals, this means they will also need to report on social factors, including employee health and safety, patient rights and access to healthcare, as well as the institution's contributions to strengthening the community.

Regarding third-party audits and verification of corporate sustainability reports, Sorainen emphasizes that one of the primary requirements for corporate sustainability reporting is the need for third-party audits. These audits ensure that the submitted reports accurately reflect the company's actual practices and are reliable. This is particularly relevant for large companies facing complex sustainability reporting requirements. Independent and certified auditors review whether the company's reported data complies with the CSRD and ESRS standards. The verification of reports by certified auditors helps mitigate various risks, such as greenwashing—where companies may provide misleading information about their sustainability efforts to enhance their reputation without making genuine efforts to promote sustainability.[11]

Thus, third-party auditing is considered a crucial element to ensure that corporate sustainability reports provided by companies are truthful and reliable. As noted by Sorainen, the quality of sustainability reporting improves only when such reports are verified and certified with the involvement of independent auditors. This process compels companies to provide more detailed and accurate information, which can then serve as a trustworthy resource for investors and society as a whole.

c) Analysis of the European Sustainability Reporting Standards (ESRS)

To assist companies in meeting the requirements of the CSRD, the European Commission has developed the European Sustainability Reporting Standards (ESRS), outlined in Commission Delegated Regulation (EU) 2023/2772. These standards ensure that companies systematically reflect their impact on environmental, social, and governance (ESG) factors. The ESRS covers areas such as climate change, pollution, biodiversity, and human rights.[4]

The ESRS aims to clarify the sustainability-related information that companies must disclose under the CSRD. In essence, the ESRS specifies the details companies must provide about their material impacts, risks, and opportunities concerning environmental, social, and governance (ESG) sustainability issues.[4]

An important aspect of the ESRS framework is that it encourages companies to analyse and report not only on their direct impact on the environment and society but also on their value chain, requiring an assessment of the sustainability practices of suppliers and other partners. This approach helps companies manage risks and mitigate negative impacts. As noted by Sigurt Vitols in his research, such an approach is crucial for establishing an integrated and comprehensive reporting system that prevents the weakening of sustainability reporting due to corporate lobbying.[12]

The ESRS establishes specific indicators and targets, including those related to greenhouse gas emissions and their reduction. This is a critical element in achieving the EU's Green Deal objective of ensuring climate neutrality by 2050.

d) The Unified Electronic Format for Sustainability Reporting: iXBRL

Sorainen has also emphasized the significance of iXBRL (inline eXtensible Business Reporting Language) technology for enabling companies to meet the CSRD requirements for corporate sustainability reporting. This technology allows companies to prepare financial and sustainability reports in a machine-readable format that complies with the ESRS. The primary objectives of iXBRL are to enhance data comparability, ensure corporate transparency, and provide organizations, governments, and investors with the tools to analyse these reports effectively.[11]

Sorainen has also noted that the iXBRL format enables detailed reporting on key sustainability indicators such as carbon emissions, water consumption, waste management, and respect for human rights. Furthermore, this technology facilitates the availability of accurate and comparable information. In addition, iXBRL addresses issues associated with manual reporting methods, which previously could lead to erroneous or incomplete data interpretation.[11]

The use of the iXBRL format significantly improves the organization and processing of corporate sustainability reports by enabling the automation of data processing and analysis. Sorainen has emphasized that this technology allows organizations to submit data electronically while adhering to the ESRS. Additionally, it helps reduce the likelihood of errors associated with manual data entry, as iXBRL ensures that data is input and validated in a structured and standardized format.[11]

iXBRL provides various benefits to companies, including healthcare institutions, by simplifying compliance with EU regulatory frameworks, ensuring adherence to the CSRD and ESRS, and enhancing transparency and data accuracy. The use of iXBRL improves the quality of reporting and strengthens public trust in the company.

B. The Impact of Sustainability Reporting and Consequences of Non-Reporting

Corporate sustainability reports enhance transparency and accountability in business operations, particularly concerning environmental and social issues. Such reports strengthen a company's reputation and increase trust among the public and investors.[6]

Sustainable business practices that comply with ESRS requirements are essential not only for the long-term sustainability of the company itself but also for society as a whole, as such reports help assess corporate progress in addressing climate change challenges. At the same time, potential investors receive verified information about companies, enabling them to make environmentally friendly and socially responsible decisions.

Corporate sustainability reporting is a significant tool for promoting transparency in business operations. A study has indicated that companies reporting on their impact on the environment and society gain greater public trust and are better equipped to manage risks related to environmental and social factors.[13] Such a reporting system also helps companies better understand their obligations and responsibilities toward society and the environment. It enhances their reputation and attractiveness in the eyes of investors.

Given that the CSRD mandates specific companies to report on their corporate sustainability, it is essential to understand the consequences of non-compliance with these reporting requirements. Article 5(1) of the CSRD stipulates that member states must enact the necessary legislative and administrative measures to comply with Articles 1 to 3 of the directive by July 6, 2024.[3] In Latvia, this directive has been implemented through the Sustainability Information Disclosure Law. However, an analysis of this law reveals that Latvia has not established specific sanctions for failing to fulfil reporting obligations.[22]

Thus, at first glance, companies failing to fulfil their obligation to report on corporate sustainability may not face traditional sanctions, such as fines. However, their operations are likely to be adversely affected. Specifically, companies that do not report on sustainability aspects may lose investor trust, be excluded from access to certain markets, or fail to attract funding from sustainable investment streams. This, in turn, could negatively impact their market value. At the same time, it must be acknowledged that the number of companies in Latvia obligated under the CSRD to provide corporate sustainability reports is relatively small. Consequently, this legal issue is not as pressing in Latvia as it is in countries like France or Germany, where the number of such companies is significantly higher.

The CSRD itself does not directly specify the types or amounts of penalties for non-compliance with reporting obligations. However, it amends existing directives, such as the Accounting Directive (2013/34/EU), which requires member states to establish effective, proportionate, and dissuasive penalties. This obligation arises from Article 51 of the Accounting Directive, which stipulates that "Member States shall provide for penalties applicable to infringements of the national provisions adopted in accordance with this Directive and shall take all the measures necessary to ensure that those penalties are enforced. The penalties provided for shall be effective, proportionate and dissuasive".[2] Therefore, it can be concluded that each member state has the discretion to determine the types of penalties (e.g., fines, administrative sanctions, or other measures) to ensure compliance with the CSRD requirements. However, these penalties must be sufficiently stringent to ensure compliance and reduce violations.

Examining how the CSRD has been transposed into French national legislation reveals that companies failing to submit corporate sustainability reports may face fines and restrictions on certain rights, such as being prohibited from participating in public procurement procedures. Moreover, French laws include penalties for any legal entity or organizational leader who fails to provide the necessary information for external auditors to certify reports in compliance with CSRD requirements or who obstructs the auditors' work. In such cases, penalties may include fines of up to €75,000 and prison sentences of up to five years.[23]

Summaries indicate that the consequences of non-compliance with CSRD obligations can be legal, financial, and restrictive to a company's operations. For example, a company’s reputation may be jeopardized, and future opportunities, such as the ability to participate in public procurement procedures, may be limited.[14]

Examining Germany's approach reveals its legislative proposal for transposing the CSRD into national law. In Germany, penalties for non-compliance with CSRD requirements are explicitly outlined through amendments to the national Commercial Code.[15] These amendments provide for both administrative and criminal sanctions for companies failing to meet CSRD obligations, thereby promoting compliance with corporate sustainability reporting requirements.[15]

Administrative liability is specifically detailed in the amendments to the HGB, particularly in § 341n. If a

company fails to submit properly prepared or complete sustainability reports in accordance with the requirements of this law, it can be classified as an administrative offense. Penalties for such violations include fines, the amount of which depends on the severity of the violation and the economic impact of the company.[15]

In cases of more severe violations, such as the deliberate provision of false information, harsher penalties are stipulated under § 331a(1). These penalties can include imprisonment of up to five years or larger fines. Such sanctions are applied when violations directly undermine the credibility and transparency of the reports.[15]

In addition to these penalties, the legislative proposal includes measures to strengthen oversight and improve the quality of reports. The aim of the sanctions is not only to penalize non-compliance but also to encourage companies to prepare their reports responsibly and accurately, in alignment with the objectives and principles of EU legislation.[15]

Comparing the transposition of the CSRD into Latvian law with its implementation in other EU countries reveals that the Latvian legislature has not established specific sanctions for non-submission of reports. However, it is plausible that future regulations could introduce measures such as revoking certain rights or privileges for non-compliant companies. These could include bans on receiving subsidies, participating in public procurement procedures, accessing tax benefits, or similar penalties.

Penalizing companies for environmental violations serves both as a preventive mechanism and as a means to ensure compliance with laws. While the monetary value of fines is often relatively small compared to a company's income, they can cause significant reputational damage, thereby encouraging compliance with environmental requirements. Although financial penalties may frequently be insufficient to materially impact a company's financial performance, they can motivate the establishment of internal environmental compliance programs and the implementation of independent monitoring mechanisms. Furthermore, the reputational harm caused by public accusations often exceeds the economic impact of fines, making it a powerful incentive to adhere to environmental regulations.[16]

Comparing the experiences of Germany, France, and Latvia in transposing the CSRD into national legislation reveals significant differences in the approach to enforcing sanctions for non-compliance with the directive's requirements. Germany and France have already incorporated or plan to incorporate specific penalties into their national laws for companies that fail to meet CSRD obligations. In contrast, Latvia has not yet fully developed such mechanisms. The authors emphasize that sanctions are a crucial tool for ensuring the preparation of accurate and reliable corporate sustainability reports, as they incentivize companies to comply with the regulations and enhance the effectiveness of the CSRD. However, given that the CSRD was adopted relatively recently, member states have not yet had the opportunity to address practical cases of non-compliance. It is likely that various sanctions will be introduced over time, based on identified violations and international experiences, thereby strengthening sustainability reporting practices and advancing the goals of the CSRD.

C. Application of Reporting Obligations in the Healthcare Sector

a) What and When Must Be Reported Under CSRD and ESRS

Under the CSRD, reporting requirements apply to a broad range of entities, including large undertakings with more than 500 employees and small and medium-sized enterprises (SMEs) that qualify as public interest entities. Large undertakings must begin reporting in 2025 for the 2024 financial year, while SMEs are required to start reporting in 2027 for the 2026 financial year. However, SMEs may postpone reporting until 2029 by providing specific reasons for the delay. Additionally, starting in 2026, corporate sustainability reporting will also be required from large undertakings that are not public interest entities but meet the criteria outlined in Article 3(4) of Directive 2013/34/EU.[3] Large undertakings are defined as entities exceeding at least two of the following three thresholds on the balance sheet date: a) Balance sheet total: EUR 20,000,000; b) Net turnover: EUR 40,000,000; c) Average number of employees during the financial year: 250.[2]

These reporting requirements encompass information on environmental, social, and governance (ESG) factors, as well as the company's strategy, risk management, and sustainability objectives. In the healthcare sector, this means that healthcare institutions meeting the CSRD criteria will be required to provide comprehensive reporting on their impact on the environment and society.

This section focuses specifically on Latvian healthcare institutions and their future obligation to provide corporate sustainability reports. However, the principles discussed here are applicable to all countries subject to the CSRD. Consequently, this article provides guidance on how to evaluate whether an entity is subject to the CSRD and required to submit a corporate sustainability report, with particular emphasis on large hospitals, which may be state-owned enterprises (SOEs) operating as state owned public limited companies or state joint-stock companies, and whose transferable securities are not traded on a regulated market in any member state. Thus, the Latvian case discussed in this article can serve as a model for other countries subject to the CSRD.

b) Latvian Healthcare Institutions and Their compliance with Reporting Requirements

To determine which Latvian healthcare institutions will be required to provide corporate sustainability reports, it is essential to understand the rationale and scope of the legal framework established by EU directives. As previously discussed, under Article 5(2) of the CSRD, corporate sustainability reporting will be mandatory for large, medium-sized, and small undertakings classified as public

interest entities. According to Article 2(1)(a) of Directive 2013/34/EU, public interest entities are defined as undertakings governed by a member state's laws whose transferable securities are permitted to trade on a regulated market in any member state.[2]

According to Article 2(1)(n) of Directive 2009/65/EC of the European Parliament and Council, "transferable securities" are defined as shares in companies and other securities equivalent to shares in companies (shares); bonds and other forms of securitised debt (debt securities); any other negotiable securities which carry the right to acquire any such transferable securities by subscription or exchange.) The term "regulated" refers to an official rule or the act of controlling something.[17] From this, it follows that hospitals in Latvia do not meet the definition of public interest entities. However, it should be noted that there are companies in Latvia, specifically joint-stock companies, which are listed on the stock exchange and operate in the healthcare or pharmaceutical sectors. For example, the joint-stock company "Latvijas Jūras medicīnas centrs" and the joint-stock company "Grindeks". These companies, if they qualify as small, medium, or large undertakings, will be required to submit corporate sustainability reports in the future.

At the same time, it is necessary to consider the provisions of Article 5(2)(b)(i) of the CSRD, which specifies that for financial years beginning on or after January 1, 2025, corporate sustainability reports must be submitted by large undertakings that are not public interest entities but meet the criteria outlined in Article 3(4) of Directive 2013/34/EU.[3]

The CSRD applies to large undertakings and organizations with a significant public role. To determine whether a hospital is subject to the CSRD requirements, the following criteria are considered:

- Is the hospital a large organization? (Defined as an organization with more than 250 employees, more than €40 million in revenue, or more than €20 million in total assets)
- Is the hospital a publicly listed company or operates in a state-controlled sector (e.g., state-managed hospitals)?
- Is the hospital part of a larger healthcare network that meets these criteria?

If the hospital or healthcare institution meets these criteria, it will be subject to the reporting requirements.[3]

Examining hospitals under Article 5 of the CSRD, it can be concluded that hospitals such as the Pauls Stradiņš Clinical University Hospital will be required to submit corporate sustainability reports starting in 2026. According to its annual report for 2023, the balance sheet of VSIA Pauls Stradiņš Clinical University Hospital amounts to €272,783,196, with a net turnover of €179,307,436.[18] Additionally, it is stated that approximately 3,000 employees work at the hospital.[19] It can be concluded that Pauls Stradiņš Clinical University Hospital meets all three criteria of the directive. Using this approach, other Latvian hospitals can also be assessed. If a hospital meets two out of the three criteria, it will be required to submit a corporate sustainability report starting in 2026.

Specifically, under the CSRD, only large hospitals in Latvia (those meeting at least two of three criteria: more than 250 employees, net turnover exceeding €40 million, or total assets exceeding €20 million) must provide comprehensive sustainability reports including full disclosure on environmental impact, social responsibility practices, governance, and supply-chain management. Small and medium-sized hospitals that do not meet these thresholds are not obligated to comply with the CSRD and thus face no changes to their existing sustainability reporting practices. Adopting corporate sustainability reporting for large hospitals implies significant changes, including increased transparency, potential resource allocation to data management systems, staff training for compliance, and establishment of internal governance mechanisms to ensure adherence to the new reporting standards. However, these changes may also lead to enhanced reputation, greater public trust, improved access to sustainable financing, and overall operational efficiencies in the long run.

c) Corporate Sustainability Reporting in Hospitals

1. Hospitals subject to CSRD requirements must report on the following sustainability aspects:
    - Environmental Impact: Hospitals must report on their impact on the environment, such as energy consumption, carbon dioxide emissions, water usage, and waste management. This may also include measures taken by hospitals to reduce their environmental impact and promote environmental protection.
    - Social Impact: Hospitals must report on social factors, including employee working conditions, employee health and safety, patient rights and data protection, as well as their contribution to society.
    - Governance: Sustainability reports must include information on governance structures, risk management policies, ethical standards, and internal control mechanisms.
2. The ESRS outlines how hospitals and other healthcare institutions must structure and present sustainability data. This includes:
    - Compliance with Industry-Specific Standards: Hospitals may need to adhere to specific standards within the healthcare sector, which may require reporting on particular healthcare aspects, such as resource efficiency or patient safety.
    - Data Transparency and Reliability: Hospitals must provide reliable and verifiable sustainability data, similar to the requirements for other undertakings, and this data may be subject to third-party verification (auditing).
3. Sustainability Impact of Supply Chains:

- The CSRD and ESRS stipulate that organizations, including hospitals, must report not only on the impact of their direct operations but also on the impact related to their supply chains. This means hospitals will need to provide information about their suppliers, manufacturers of medical equipment and pharmaceuticals, and whether these supply chains comply with sustainability standards (such as responsible resource sourcing, respect for human rights, etc.).

4. Audit and Verification Obligations:
   - Similar to other organizations, hospitals subject to the CSRD will be required to undergo third-party verification and audits of the sustainability information provided. This means that sustainability reports must be certified, similar to financial statements, to ensure that the data is transparent and accurate.
5. Publication and Accountability to the Public:
   - Hospitals subject to the CSRD will be required to make their sustainability reports publicly available. This can enhance transparency regarding the hospitals' impact on the environment and society, as well as promote trust with patients and the public in general.
6. CSRD Articles Applicable to Hospitals:
   - Article 19a of the CSRD: This pertains to management reports, which must include information on environmental, social, and governance (ESG) aspects. For hospitals, this means they will need to prepare detailed reports on their operational impact in these areas.
   - Article 29a of the CSRD: This sets out consolidated reporting requirements for larger hospital groups that are part of healthcare networks.[3]

d) Challenges in Corporate Sustainability Reporting in Public Healthcare Institutions

Data Collection and Management: Companies will need to establish or improve systems for collecting and analysing data on sustainability indicators. Many companies, especially small and medium-sized enterprises, may not be prepared for such data management.

Acquiring high-quality, verifiable, and comparable data: Especially in complex areas such as climate impact or human rights in the supply chain, obtaining data will be a challenge.

Lack of capacity and resources: Smaller organizations may have limited access to resources and expertise to meet the detailed reporting requirements. Additionally, companies will need to invest in capacity building, ensuring appropriate human resources and IT infrastructure.

Interpretation and adaptation of sustainability standards: Although the ESRS standards provide certainty, their interpretation and adaptation to different business models and sectors can be challenging. Different companies may interpret the standards differently, which can create confusion and inequality in report comparisons.

Reporting integrity and reliability: Ensuring that sustainability reports are objective and reliable will be a challenge. There is a risk that some companies may engage in "greenwashing" if they fail to adequately reflect their actual impact on the environment and society.

Supply chain transparency: Companies will also need to report on sustainability aspects within their supply chains, which can be challenging, especially if suppliers are located outside the EU. This may create additional difficulties in ensuring transparency and accountability.

e) Benefits and Prospects of Sustainability Reporting in Business Development

Promoting sustainability in business: The implementation of the CSRD and ESRS will help foster sustainable practices throughout business operations. Companies will be required to actively work on sustainability to improve their impact on the environment, social groups, and the economy.

Comparability and transparency: One of the biggest benefits will be unified and comparable sustainability reporting standards across the EU, which will allow investors, consumers, and other stakeholders to make informed decisions based on accurate data.

Climate governance and attracting investment: Greater transparency about a company's sustainability performance will help investors identify and invest in companies actively addressing climate and sustainability issues. Sustainable companies will be able to gain advantages in terms of investment, access to funding, and enhanced reputation.

Sustainability innovation and competitiveness: The CSRD can serve as an incentive for companies to develop new sustainability innovations, which could create competitive advantages in the long term. Companies that adapt to the new requirements earlier will be able to more effectively leverage the potential of the sustainability market.

Increasing consumer and investor trust: Increased transparency and accountability will foster greater trust in companies from consumers and investors. Companies that stand out for their openness and positive impact on sustainability will be more attractive.

IV. CONCLUSIONS

The implementation of the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) is a significant

step towards promoting transparency and accountability in business operations within the EU. These requirements oblige companies to report on their impact on the environment, society, and governance, thereby helping society and investors make informed decisions. While Latvia currently does not have specific sanctions for non-compliance with these reporting obligations, regulations could be introduced in the future to revoke certain rights or privileges from companies, such as prohibiting participation in public procurement procedures or receiving subsidies.

The healthcare sector in Latvia plays a crucial role in the sustainability reporting process, as it contributes to the management of both environmental and social issues. For example, Pauls Stradiņš Clinical University Hospital, which meets all the criteria outlined in Article 3(4) of Directive 2013/34/EU, will be one of the first hospitals required to submit corporate sustainability reports starting in 2026. This process will help promote sustainable development and improve governance solutions in the healthcare sector.

In summary, the implementation of the CSRD and ESRS regulations is not only a regulatory step but also an opportunity for companies to enhance their reputation, increase trust, and gain access to sustainable investment flows. This is particularly relevant for those companies that successfully adapt to the new standards and promote transparency in their operations, thus ensuring long-term benefits for both society and investors who make environmentally friendly and socially responsible decisions.

In addition, the implementation of the CSRD and ESRS establishes new standards for public awareness and engagement in corporate sustainability issues. Public trust in companies and active participation in analysing and using the provided information is essential for promoting the integration of sustainability principles into business practices. Studies indicate that increased awareness motivates both the public and the private sector to collaborate in addressing climate change and social issues.

Furthermore, the integration of CSRD regulations into business operations fosters innovation and enhances competitiveness, particularly in sectors related to environmental protection and the improvement of public health. Companies that adopt the new standards early in their operations can gain strategic advantages by attracting investments and improving their market position.

The authors, while comparing the experiences of Latvia, France, and Germany, identified significant differences in the transposition of the CSRD into national legislation. While Germany and France have introduced or plan to introduce specific sanctions for non-compliance, such mechanisms are currently absent in Latvia. However, it is expected that future developments and international experience will promote the adoption of stricter regulations, strengthening sustainability reporting practices and supporting the achievement of long-term goals.

ACKNOWLEDGMENTS

Funding institution: Latvian Council of Science. Funding number: lzp-2023/1-0341. Acronym: lzp-2023/1. This research was funded by the Latvian Council of Science, project Socially responsible green transition: strengthening governance solutions to empower Homo Climaticus in the healthcare sector, project No. lzp-2023/1-0341.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume I, 623-630

The Main Aspects Of Successful Management of Reorganization and Restructuring Processes for Real Estate Management Companies in Latvia

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***Abstract*— Research background: Changes in global political processes, the impact of geopolitically unstable conditions, rapidly changing circumstances, globalization in business is the growth in movement across national borders, intensifies competition between companies, which forces companies to think about expanding their business. Companies can use mergers and acquisitions to improve competitive advantages, however, achieving the expected success through mergers and acquisitions in many cases poses serious challenges for company management and does not provide the expected value from these transactions. Acquisitions and mergers without successful management of reorganization and restructuring may not provide the expected benefits. The purpose of the article: to introduce about reorganization transactions and restructuring processes to help Latvian real estate services companies implement acquisitions and mergers and company restructuring to achieve better business results. Methods: The monographic and descriptive method was used to analyse the theoretical aspects of the management of company reorganization transactions and restructuring processes, secondary data analysis and expert interviews were used to characterize the situation in the real estate management services industry, but the quantitative research method, for example, the analysis of statistical data on reorganization transactions, was used in conjunction with the comparative, analytical, deductive, logical research method. Findings and added value: Real estate management companies in Latvia face the conditions that arise for every company, that its successful development is impossible if reorganization or company restructuring is not carried out. Companies, their managers do not have sufficient knowledge about the reorganization process and other factors for correctly conducted reorganization transactions, therefore companies need to correctly and professionally manage reorganization transactions and restructuring processes.**

Keywords — Latvian real estate service companies, mergers and acquisitions, reorganization and restructuring, successful management of reorganization and restructuring processes.

I. INTRODUCTION

Specifics of the development opportunities of Latvian real estate companies, such as: limited expansion in the local market, insufficient knowledge in expanding services and improving competitiveness, lack of experience in implementing reorganization, as well changes in global political processes, the impact of geopolitically unstable conditions, rapidly changing circumstances, globalization in business is the growth in movement across national borders, intensifies competition between companies, which forces companies to think about expanding their business.

Companies can use mergers and acquisitions to improve competitive advantages, however, achieving the expected success through mergers and acquisitions in many cases poses serious challenges for company management and does not provide the expected value from these transactions. Mergers and acquisitions without successful

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8642
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management of reorganization and restructuring may not provide the expected benefits.

The purpose of this research is to introduce about mergers and acquisitions transactions and their reorganization and restructuring processes to help Latvian real estate services companies implement acquisitions and mergers and company restructuring to achieve better business results.

Initially a review of competitiveness of companies will be presented in line in the context of the reorganization process. This topic has been dealt with by a number of authors in the competitiveness of companies, such as Michael Porter [36], who created the foundations of modern competition theory and the concept of competitiveness, so much so that today the volume of literature and researches about competitiveness is continuing to grow [6], [31]. This paper seeks to retrieve the importance of reorganization for companies in order to better adapt to competition changes [16], [17].

Despite those worldwide studies [6], [7], [18], [20], [21], [44] show that approximately 80% of transactions do not meet expectations, acquisitions and mergers are complicated transaction projects, therefore mismanaged they may not deliver the expected benefits [3], [5], [27], [31].

Before describing mergers and acquisitions transaction, management of reorganization and restructuring process, based on several findings [5], [27], [29], [31], [37], the authors present research results on the competitiveness that small and medium-sized real estate service provider companies in Latvia can improve competitiveness if they choose a product market expansion strategy [40], [44], which can be implemented through mergers and acquisitions. This means that real estate service provider companies in Latvia can more successfully improve their competitiveness directly through mergers and acquisitions, if they do not develop a new product or service by own, but, as it is stated in [40], [44], implement it directly through reorganization transactions.

In addition to the basic characteristics of the main aspects successful management of reorganization and restructuring processes for real estate management companies in Latvia, the description of Latvian real estate management companies will be presented in scope what are the main reasons that deter companies to carry out merger and acquisition transactions and how successfully to manage reorganization transactions and corporate restructuring, based on an expert interview.

II. Materials and Methods

The purpose of this research is to introduce about reorganization transactions and restructuring processes to help Latvian real estate services companies implement acquisitions and mergers and company restructuring to achieve better business results.

To achieve the goal of the research, four tasks were set:

a) to analyse the theoretical basis of competitiveness and efectivness of companies in the context of the reorganization and restructuring process;

b) to describe the companies operating in the industry of real estate management services in Latvia;

c) to define the main aspects of successful management of reorganization and restructuring processes for real estate management companies in Latvia.

The research question: How successful management of reorganization and restructuration processes can help real estate management companies in Latvia to improve their business?

The results of the application the monographic and descriptive method were used to analyse the theoretical aspects of merger and aquation transactions and restructuring aspects, secondary data analysis and expert interview were used to describe the Real estate management service industry.

An expert interview was created as a semi-structured interview. In expert interview authors used following questions and themes for discussion:

a) are there any circumstances identified that would force real estate management companies in Latvia to carry out reorganization transactions and corporate restructuring?

b) what are the most characteristic negative factors that deter Latvian real estate management service companies from carrying out reorganization transactions and corporate restructuring?

c) what are the main aspects to be taken into account when implementing reorganization transactions and corporate restructuring of real estate management companies?

III. Results and Discussion

A. Characteristics of the competitiveness of companies in the context of reorganization transactions and restructuring processess

In [36] it is stated that in today's hyper-competition conditions, it is critical for companies to understand the dynamic of external conditions and their impact on the possibilities of increasing competitiveness [14]. Fierce competitive conditions can lead companies to liquidation, so companies must to improve efficiency and financial performance [9].

Aspects of corporate competitiveness are essential in today's economic and globalization conditions [2], [12-13], therefore, as it is stated in [45], in the era of fierce market competition, mergers and acquisitions have become the main strategy for companies that want to grow and strengthen their market competitiveness.

For large and medium-sized companies, mergers and acquisitions help develop and expand their business, without which the continuous development and

competitiveness of these large and medium-sized companies in the global market would not be possible [43].

As it is stated in [35] today`s economic freedom is good obstacles for mergers.

In turn, in [33] it is evaluated corporate mergers and the increase in corporate value, as well as the increase in competitiveness, from the success factors of post-merger integration, which, in a positive case, increases the value and competitiveness of the company.

Many authors [35], [23], [32], [24], [22], [25] have conducted scientific research on aspects of corporate reorganization, including the benefits of reorganization, mergers and acquisitions for companies, increasing their competitiveness.

The business strategy of reorganization, mergers and acquisitions can be an opportunity for companies to increase their competitive advantages [29]. In [1] it is indicated that industry growth is an opportunity for the company.

Achieving a product-based competitive advantage is the main task of any company [11] and in today's hyper-competitive environment, it is very important for companies to understand the dynamics of the environment and its role in creating competitive advantages [37].

B. Characteristics of merger and acquirance transactions and reorganization process

The most typical of the reorganization transactions are acquisition, merger, which is called "Merger and Acquisition" or abbreviated as "M&A".

Mergers and acquisitions are usually carried out to increase the value of the company, expand operations into new segments or increase market share. All this is done to increase the value of the company for shareholders.

A merger is an agreement that combines two existing companies into one new company [8].

A merger is the combination of two companies, which then forms a new legal entity with a single company name and logo. A merger involves two companies joining forces to continue operating as a single new company.

Mergers and acquisitions in the global market have become a strategic alliance for business, product and geographical expansion [22].

The merger process allows firms to increase their intangible assets by increasing their knowledge capital. A key component of this model is the asymmetric knowledge transfer effect between a firm's technological centrality and its decision to participate in mergers [23].

Companies undergo reorganization for various reasons, but most often the reorganization is carried out so that the company can gain even greater competitiveness through such a transaction, achieve better business and financial results, start implementing a new business direction or market new products.

The goal of reorganization can also be to make a profit by separating and selling part of the business.

A company that acquires another company can use this transaction with the aim of subsequently eliminating the existence of the acquiring company [8].

An acquisition is a strategic decision by one company to acquire a stake in another company. Most often, companies acquire an existing business to gain access to its customer base, business practices and market penetration. This is one of the most popular ways to expand a business [42].

When implementing M&A transactions, reorganizations and restructurings, if the company doesn`t have its own internal expert for merger and acquisitions transactions with appropriate experience, then it should consider using the services of external consultants. It is important for companies to foresee a role for external consultants in their strategy, who will help successfully manage the M&A transaction, reorganization and restructuring of the company with their professionalism. The involved M&A consultants create value for the owners of the company, because they help the buyer determine the goals that have greater synergy with the buyer's company.

As it is visible in Table 1, each party to the transaction can have their own external consultant.

TABLE 1 STEPS IN M&A PROCESS

Steps in the M&A process	Procedure for implementing the steps of the M&A process and Transaction Documents
Defining the criteria for the purchasing company	Based on the Company's strategy, the company should define the criteria that the acquiring company must meet.
Selection of external consultants	• Consulting services are offered on the market by service providers in various fields: - Specialized M & A transaction brokerage firms - Law firms - Auditors or reviewers - Credit institutions
Searching for potential acquisitions	According to the criteria set by the company, external consultants approach potential acquisition companies
Evaluating potential acquisition targets	•Full list of potential acquisition companies •External consultants conduct research on potential companies based on publicly available information •Shortlist (3-5 most interesting companies)
Selection of the object of purchase	• The company, together with external consultants, carefully evaluates one potential acquisition company from the shortlist

As it is visible in Table 1, the reorganization management bases on several key aspects and covers all steps of the process, and the steps leading up to the initiation of an M&A transaction are depicted in Table 1.

C. The Real estate maintenance service industry of Latvia

Real estate management services in Latvia are offered by several types of merchants:

a) Providers of housing management services, for which the management of apartment buildings is the main type of business;

b) Premises and territory cleaning service providers who have expanded their range of services with real estate - apartment building management service;

c) Real estate brokerage service providers who have expanded their range of services with apartment building management services;

d) Real estate developer companies that build multi-apartment houses of the new project and continue to manage these houses.

When studying the building management industry in Latvia 46% are municipal companies that provide building management services at the regional level for their local municipality's apartment buildings, 21% are private management companies, and 33% are made up of others, which can be associations founded by the apartment buildings themselves, cooperatives, or other forms of management companies, as seen in Figure 1.

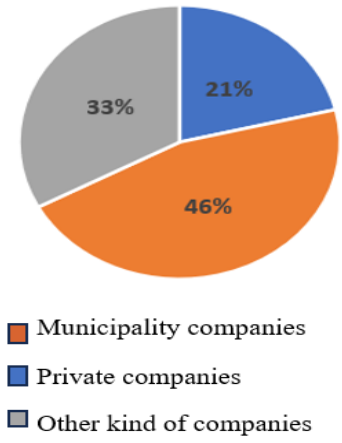

Fig.1. Kinds of apartment management service providers companies (created by authors [30]).

The data in Figure 1 shows that a significant number of building management service providers are companies owned by municipalities, but building management is a private commercial activity and not a municipal function, therefore the authors emphasize the need to develop recommendations for amendments to regulatory enactments, providing that the duty of building management is transferred only to private, licensed building management companies, removing this duty from municipal companies.

D. The successful management of reorganization transactions and restructuring processes for Real estate management companies in Latvia

Acquisition and merger transactions are complicated, mismanaged they may not deliver the expected benefits. Several authors [3-6], [15], [18], [20-21], [26], [28], [34], [39], [41] indicates that a large number of reorganization deals fail and companies do not expect the expected benefits, while a McKinsey study shows that 80% of reorganizations fail and about 10% cause serious damage to the company [6], [7], [10], [18], [20-21], [41].

After studying various sources of literature, it can be concluded that reorganization and restructuring are sometimes confused together or incompletely explained. Reorganization and restructuring are not the same thing, the goals and implementation procedures of these two processes differ.

Restructuring can be implemented together with reorganization, where the company being merged is restructured and included in the structure and management of the merging company.

It would be important for companies, their managers and leading employees to first understand the process of reorganization transactions, the course of its implementation, which could help to avoid failures, as well as the planning of the reorganization process should be done correctly, starting with the development of the reorganization strategy and its implementation plan.

After the reorganization managers begin to deal with the burning problems that need to be solved urgently, but if solving only the problems, the managers don`t focus on business development. One of the biggest success factors is to create company`s strategy and not focus only on the problems [38].

Authors chose the expert interview as a method for the research to evaluate the real estate service companies' industry, to find out industry essential main problems and to understand companies' possibilities to expand their business and necessity to expand their services.

As expert was chosen a professional expert in the field of real estate management service industry, who has worked for several years in the largest building management companies in Latvia. During the interview authors tried to find answers to following questions:

a) are there any circumstances identified that would force real estate management companies in Latvia to carry out reorganization transactions and corporate restructuring?

b) what are the most characteristic negative factors that deter Latvian real estate management service companies from carrying out reorganization transactions and corporate restructuring?

c) what are the main aspects to be taken into account when implementing reorganization transactions and corporate restructuring of real estate management companies?

In order to develop the aspects necessary for the management of reorganization and restructuring businesses, the authors conducted experts' interviews. The experts who participated in the expert interviews were from building management company industry.

The experts were selected from 4 different areas representing the company:

1) finance, 2) management, 3) administrative management and 4) a production manager who is familiar with the services provided by the company. This selection of experts ensured that the experts involved would be able to provide expert advice on each of their areas of representation - financial management, overall company management, company administrative processes and most importantly - a manager representing the company's building management services department.

An expert interview shows following results:

Description of the companies used in the study and where experts took part during reorganisation and restructuration:

Building management companies operating in Latvia - 1 company operating in Riga and Jurmala, and 4 regional companies providing services outside Riga. The reorganization process of the building management companies operating in Latvia described in the study took place from July 1, 2022 to September 30, 2023.

The expert interview revealed that restructuring requires temporarily attracting specialists who are only engaged in restructuring or hiring additional employees on a temporary basis in order to be able to complete both current work and new work related to restructuring. The biggest mistake is that companies want to save money and do more work with existing resources, but in that case the results will not be achieved quickly.

In point of view of experts the most characteristic negative factors that deter Latvian real estate management service companies from carrying out reorganization transactions and corporate restructuring are lack of experience in implementing reorganization transactions, planning and managing corporate restructuring, as well as a lack of understanding of the importance of in-depth research, as well as the fact that sufficient resources will have to be allocated for the implementation of reorganization and restructuring - time, people, finances, which is not given sufficient attention

As follows from experts' interview it is recommended to create a reorganization and restructuring plan, strategy and team, and understanding that reorganization and restructuring is a long process, which can be accelerated by bringing in additional staff, even temporarily, or to dedicate a team that only works on restructuring.

Based on Experts` interview, the authors indicate that in practice there are several reasons why companies encounter problems after completing an acquisition, which are visible in Figure 2.

As it is visible in Figure 2, the most important thing is the exchange of information between those managers who manage and are involved in the reorganization transaction.

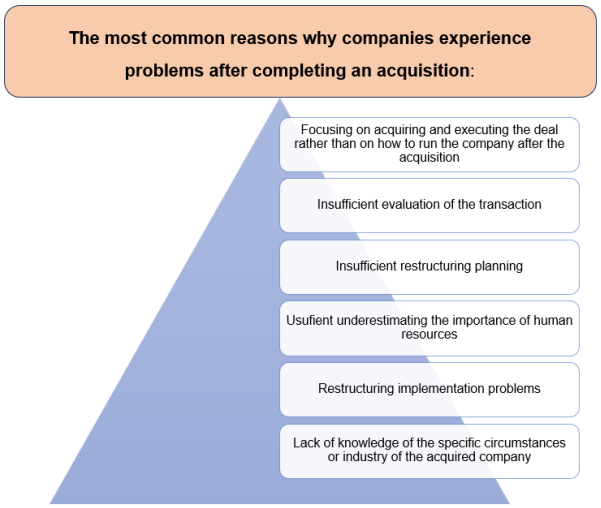

Fig.2. Reasons why companies expierence problems after reorganisations (created by authors).

Successful business management of reorganization and restructuring is based on the following basic aspects: first, the company's need for development is identified, a company strategy is developed, which defines development goals as it is visible in Figure 3.

Fig.3. M&A transactions as means to achieve goals in the strategy (created by authors).

As visible in Figure 3, one of the means for implementing which can be an M&A transaction, which serves as a means to achieve the goals set in the strategy.

After the first stage of the reorganization transaction, an important second stage follows - the post-reorganization stage as it is visible in Figure 4, which can be either the integration of the acquiring company or a complete restructuring.

Based on the findings obtained during the research, the findings obtained during the expert interview, the studies of theoretical aspects, the authors develop main aspects for the management of reorganization transactions and restructuring process, where the post reorganisation or restructuring process is described and visible in Figure 4.

As visible in Figure 4, the authors' created business management of reorganization and restructuring during the restructuring phase, which includes the importance of financial, commercial information, and integration, which is characterized by the following 5 most important factors:

Finances, Sales, Quality and processes, Clients` relationship, Effectivity, which is visible in Figure 5.

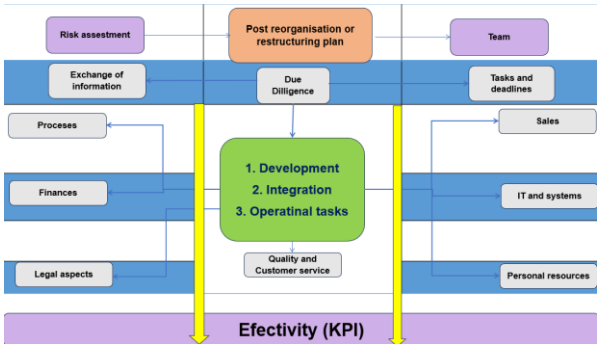

Fig.4. Sucsesfull restructuring business management (created by authors).

Fig.5. Business management of restructuring process (created by authors).

Finances:

EBITDA is gross profit before interest, taxes, depreciation and amortization and is the main KPI, because it is the debt of the company's operations (Setyopurnomo, Wiryono, Lestari, Sukarno, 2025).

For the improvement of EBIDTA, the profitability of house management services, as well as the improvement of the content and quality of the provided house management service and increase of service prices.

It is characteristic of the housing management industry that the profitability of services is formed from the profit obtained as a result of optimizing the revenues and expenses of each managed building. Another important aspect is additional income, which is in addition to basic services (management).

Sales:

A house management company must think about its development, which it can implement through sales, therefore it is important to develop a sales strategy, in which markets the company plans to develop and expand sales activities, as well as a significant role for the customer relationship management tool or CRM.

Quality and processes:

An important section of restructuring is the quality of the company and the audit of all processes, the arrangement and optimization of processes. This means that the restructuring manager must identify all processes taking place in the company, how they are implemented, responsible persons, and whether all processes are described and whether all involved understand the processes accurately.

Clients` relationship:

The building management business is based on communication with the client. The building management service is related to the consideration of apartment owners' complaints and applications, therefore, clear communication with the client is necessary on a daily basis. It is also necessary for the client to communicate easily with the manager, therefore, it is important to develop a customer service standard, plan and implement communication tools, such as a call center, a customer application.

Efectivity:

Restructuring is basically carried out to improve the company's financial performance, as well as to improve operational efficiency, therefore, within its framework, the company must transform its organizational structure, abandoning unnecessary positions or even creating new positions, so that the work proceeds effectively. It is important to conduct a function audit and personnel changes. It is also necessary to implement the streamlining and centralization of administrative functions to make the work more efficient, it is necessary to implement IT systems (accounting, document management, CRM, sales management tool, call center, quality register, repair work register and other necessary tools), which make the work more efficient and the company can save on employee costs.

IV. Conclusions

a) Reorganization transactions are serious transactions that are time and cost consuming, however, worldwide studies [4], [5], [10], [13], [15], [35] show that approximately 80% of transactions do not meet expectations.

b) The results of the research, within the information obtained during the experts` interview, show that the internal, disorganized management problems of companies can prevent managers from successfully implementing reorganization and restructuring plans.

c) To recommend the owners and managers of Real estate management companies to use aspects developed by Authors for successful management of reorganization transactions and restructuring processes.

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Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference. Volume I, 631-636

Lessons Learned from Implementing a Set of Measures to Reduce Transport Congestion

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***Abstract*—Digital technologies increasingly shape various aspects of our lives, changing tools and approaches, minds and attitudes. In this context, the transport sector plays a crucial role in improving citizens' quality of life, impacting both private and public transport systems. It is essential to recognize the steady rise in the number of vehicles on the roads. While this growth can address certain well-being needs, it also presents challenges that may impede the effective fulfilment of these needs, particularly concerning capacity and timely service. This issue is particularly acute in densely populated urban areas, where traffic congestion can lead to delays in transportation, goods delivery, and commuting. The environmental ramifications of rising vehicle numbers must also be considered, as road congestion contributes significantly to air pollution due to emissions. The objective of this study is to identify and learn lessons from the implementation of various strategies aimed at reducing transport congestion, identify opportunities for optimizing private vehicle traffic flow in large cities, and propose a model that balances the interests of private car owners, municipal authorities, and urban residents' well-being. Lessons learned might suggest further model development that would integrate a time-based financial incentive system, such as the introduction of city road tolls in designated metropolitan areas, along with recommendations for enhancing roadway infrastructure and traffic management, including intelligent transportation systems. The methodology leverages data from traffic management service providers, cartographic resources, and other relevant traffic flow and satellite information. It takes into account population movement patterns, driving habits, travel time preferences, various toll fee payment options, and motivational incentives. Additionally, the study incorporates insights and best practices derived from case studies of cities globally.**

Keywords*— congestion, intelligent transport system, lessons learned, wellbeing.

I. Introduction

As the standards of human wellbeing increases, the demands and expectations of individuals and society for higher-quality products and more efficient services also increase. Road transportation is one of those sectors that ensures people's mobility, getting to work and leisure, providing daily services and delivering goods. In conditions of economic growth, the number of cars is continuously growing. According to the forecast of research house Bernstein, it will double, reaching two billion units by 2040 [1]. Although the pace of this growth in the USA and the EU has slowed down since 2005, this growth has been taken over by emerging markets, primarily China and India.

Currently, more than half of the world's population (4.4 billion people) lives in cities, and it is estimated that by 2050, seven out of ten people will live in urban areas [2] - [3]. In the European Union (EU), around 70 percent of the population already lives and works in urban areas, generating 23 percent of all transport greenhouse gas emissions [4]. Accordingly, the constant increase in road transport units has the greatest impact on metropolitan areas and cities. The large number of vehicles is one of the most important causes of road congestion. This affects the increase in the number of road traffic accidents and victims. The streets are affected by emissions from fossil fuels, which impact air quality. Congested traffic also brings noise pollution. People are late for work, suffering both time and financial losses due to traffic congestions. According to TomTom Traffic Index ranking, in 2024, in the mega and large city category worldwide, the drivers in Baranquilla, Colombia lost the time in traffic jams during rush hours the most (130 hours per year); and in Europe, this rate was the highest in London, UK (113 hours per year) [5].

To mitigate these negative impacts, governments around the world are defining a course of action,

Online ISSN 2256-070X
https://doi.org/10.17770/etr2025vol1.8710
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developing and implementing appropriate action plans and regulations. For example, the EU plans to reduce transport greenhouse gas emissions: by 55 percent till 2030 and by 90 percent till 2050 [4]. Consequently, the EU Urban Mobility Framework initiative encourages its member states to develop public transport that is emission-free, inclusive, safe, resilient, and sustainable [6]. In order to improve air quality and reduce traffic congestion, the EU has set Urban Vehicle Access Regulations (UVARs), which would allow cities to comply with EU air quality standards [7].

The transport sector and its road transport component can be considered within the framework of the Sustainable Development Goals (SDGs), contributing to the achievement of its eleventh goal, namely "Make cities and human settlements inclusive, safe, resilient, and sustainable" [8]. Fig. 1 shows the division of the SDGs into three layers, with the 11th goal included in the infrastructure layer. The interaction of all layers contributes to the achievement of human-environmental wellbeing goals.

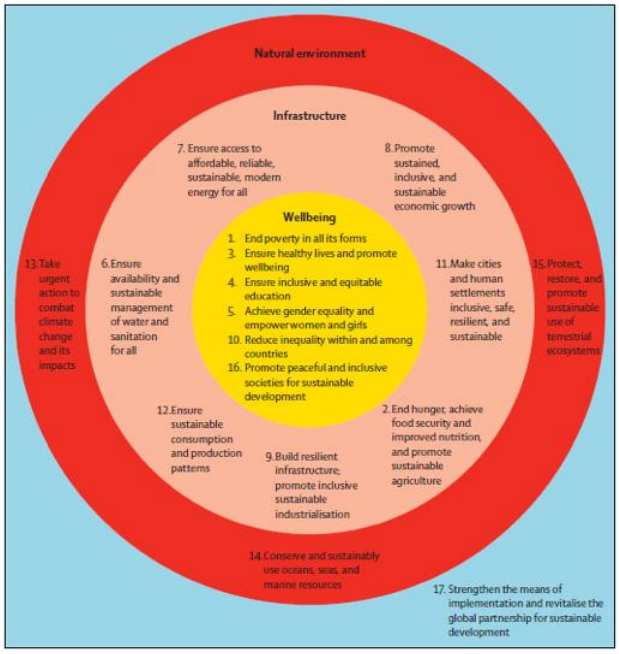

Fig. 1. Interactions framework between sustainable development goals [8].

Environmental, social and human development are important for achieving well-being goals. Several basic elements and their corresponding sectors are involved in this process, determining and directing it (Fig. 2) [9]. From the perspective of a holistic approach, it is very important to provide for the possibility of interaction and cooperation of these elements. In the field of road transport, this should apply to the delivery of goods and services to both individuals and groups of individuals and organizations. In this regard, not only the delivery of goods and services as a fact is important, but also the management of this process that ensures its efficiency, including time and route optimization, the use of smart transport infrastructure tools and technologies, and the training of people involved in the delivery process. At the same time, it should be noted that depending on the level of development of the elements indicated in Fig. 2, in specific countries and their regions their authorities can implement greater or lesser governance interventions, promoting the improvement of the relevant elements. In turn, to ensure the growth of overall well-being, the coordinated functioning of all involved elements is mandatory [9].

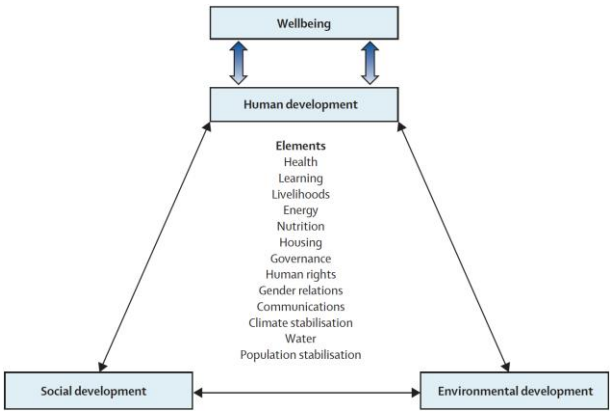

Fig. 2. Development elements contributing to human, social, and environmental development and wellbeing field [9].

In the following chapters, the study will focus on the field of road transport and the problem of road congestion, offering possible steps and recommendations to resolve the issues raised.

II. Materials and Methods

This study investigates the issues of extensive transport flows in large cities, an impact of car congestion on streets and caused environmental pollution. As a result, human and environment well-being, which is closely related to the above issues, will also be examined.

Hence, the purpose of the research is to identify and learn lessons from exponential increase in the number of road transport units in urban environments and to provide recommendations for reducing traffic congestion on the streets, and thus ensuring human-environmental well-being.

Accordingly, this study aimed to solve the following tasks:

- To find out the changes in the increasing traffic flows in cities,
- To evaluate challenges associated with the increasing number of vehicles,
- To consider various visions, regulations, activities, and measures, initiated by governments, agencies and groups,
- To develop recommendations for model development to avoid traffic jams in large cities, save the time, reduce air pollution.

In order to solve these tasks, the analysis of scientific, methodological and regulatory sources on the research topic was employed. The insights of researchers and professionals in the relevant fields, both on official websites of national government regulatory documents, and in databases recognized in the scientific community,

such as SCOPUS, Clarivate (Web of Science), and IEEE Xplore, were searched for and used as well. The methodology exploited the data from traffic management service providers, cartographic resources, as well other appropriate traffic flow and satellite information. Best practices derived from case studies globally are also taken into account.

III. Results And Discussion

A. Results

As individuals prioritize their well-being, there is an associated expectation for enhanced living standards. Addressing these evolving demands necessitates the deployment of more efficient technological solutions, especially within the transportation sector. The volume of vehicles on roadways continues to experience steady growth. While this increase may fulfil certain dimensions of well-being, it concurrently poses challenges that can hinder the effective satisfaction of these needs, particularly regarding capacity constraints and the timeliness of services. This issue is particularly pronounced in densely populated urban areas, where traffic congestion can lead to delays that adversely impact transportation efficiency, goods delivery, and daily commuting. Furthermore, the environmental repercussions of the rising vehicle numbers are considerable, as road congestion exacerbates air pollution through emissions from motor vehicles.

The challenges associated with the growth of road transport, especially in large cities, have been thoroughly analysed by Meneguette, I, et al. [10]:

- Traffic jams,
- Mobility issues,
- Roadway traffic collisions,
- Environmental sustainability,
- Financial expenditures,
- The imperative for Intelligent Transportation Systems (ITS).

The continual rise in the number of vehicles is directly associated with the growing incidence of accidents on roads. Consequently, road congestion adversely impacts travel times, leading to longer durations for the delivery of goods and the provision of services. This generates frustration among drivers and passengers, leading to heightened tension and conflicts that could be avoided in vehicles caught in traffic congestion. Furthermore, the rising number of vehicles contributes to traffic congestion, establishing a cycle that is challenging to resolve.

The significant rise in the number of road transport units is impacting mobility. While the increasing number of vehicles may initially suggest improved movement of people within urban areas, it is also leading to congestion and overburdened streets in major cities. This situation results in traffic jams and road accidents, ultimately hindering overall mobility. The high volume of vehicles on the roads contributes to significant traffic congestion, which adversely affects the efficiency of public transportation systems. This can lead to increased overcrowding on public transport options. As a result, passengers may find themselves spending prolonged periods in traffic, which can discourage them from utilizing these services. Consequently, many residents opt for personal vehicles, which exacerbates traffic congestion and contributes to environmental pollution from vehicle emissions.

The rise in the number of vehicles results in heightened traffic congestion, which subsequently contributes to an increase in road traffic accidents. These incidents not only exacerbate traffic delays but also pose significant risks to the safety of drivers, passengers, and pedestrians involved.

An increase in the number of vehicles on roads leads to a higher level of harmful emissions. This deterioration in air quality adversely affects our health and contributes to the challenges of global climate change.

Time spent in traffic has a direct correlation with financial implications, impacting both productivity and profitability. Municipalities must focus on the planning and management of transport flows, as well as maintaining, updating, and modernising roads and associated infrastructure. Additionally, they need to implement environmental protection measures, all of which necessitate considerable financial resources.

To address the challenges mentioned earlier, there is an urgent requirement for the implementation of advanced technologies and services, including Intelligent Transportation Systems (ITS). The relevance of ITS has been recognized for many years, with its initial concept being proposed in the last century [11]. The fundamental objectives and strategic directions of this initiative remain under consideration: ITS are designed to enhance road safety through the deployment of video surveillance cameras, which enable real-time monitoring of traffic conditions and facilitate the management of significant transport flows. Additionally, ITS aim to mitigate environmental impact by leveraging vehicle networks and employing data dissemination and exchange methodologies.

Over time, municipalities recognize emerging challenges and collaborate with researchers to develop and implement enhanced ITS capabilities. For instance, in order to improve road safety and optimize traffic management, the exploration of Vehicular Ad hoc Network (VANET) technology is being conducted for applications such as traffic flow detection, vehicle coordination, and locating various road services [12] - [13]. Concurrently, efforts are being made to identify solutions that safeguard VANETs against potential cyberattacks [14].

Artificial intelligence algorithms integrated within ITS offer drivers the valuable insights on road congestion, enabling them to adjust their routes and optimize travel plans. This leads to time and fuel savings, ultimately contributing to lower emissions and reinforcing sustainability initiatives [15] - [16].

The European Telecommunications Standards Institute has established a European standard for Intelligent Transportation System (ITS) architecture, which includes

four ITS subsystems: the Vehicle ITS Subsystem, Roadside ITS Subsystem, Personal ITS Subsystem, and Central ITS Subsystem [17]. These subsystems facilitate multi-layer peer-to-peer communication and data exchange among one another (Fig. 3).

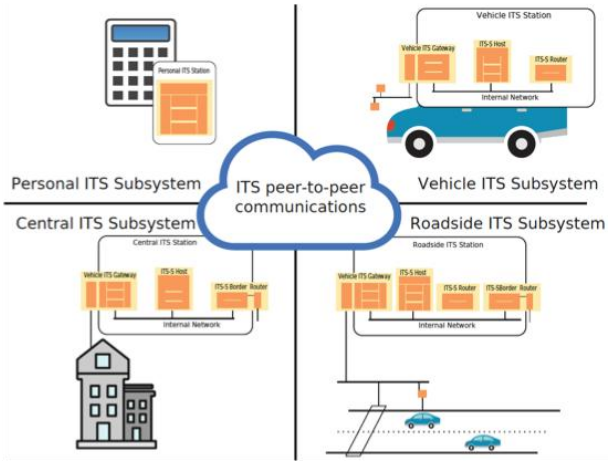

Fig. 3. European ITS architecture [17].

The European Union (EU) has recognized the importance of sustainable and smart human mobility as a critical component of overall well-being [4]. In response, it has developed appropriate regulations and established various working groups, organizations, and initiatives that are currently functioning effectively:

- Sustainable urban mobility / Urban Mobility Framework Initiative,
- Trans-European Transport Network (TEN-T),
- Sustainable urban mobility: planning and monitoring,
- Urban public transport and shared mobility,
- Active mobility: walking and cycling,
- Urban Vehicle Access Regulations,
- Zero-emission urban freight logistics and last-mile delivery,
- Urban mobility and climate-neutral cities,
- EU Urban Mobility Observatory,
- European Alternative Fuels Observatory,
- European mobility week,
- CIVITAS Initiative,
- Expert Group on urban mobility.

The European Union countries are also implementing measures to achieve the aforementioned goals. For example, the Latvian Ministry of Transport has carried out an assessment of transport sector policy and determination of future perspectives [18] and developed a plan of measures to ensure sustainable mobility [19].

B. Discussion

Taking into account the considerations presented in the previous chapters, we might propose and recommend possible solutions for model development to avoid traffic jams in large cities, save citizens' time, and reduce air pollution. Consequently, these solutions can contribute to improving human-environmental well-being.

These possible solutions can be set out in the form of recommendations:

a) Review and change the regulations in which vehicles can enter the central part of the metropolis.

This recommendation may ask municipality authorities to activate several measures:

- Access regulation,
- Permits issued on residential basis (paid passes),
- Permits issued depending on time of day and peak hours (paid passes – mobile payments),
- Offering multiple incentives to drivers to discourage them from using private cars in the city centre (central part of the city or designated districts and areas),
- Improvement of public transportation system (new routes, more busses, trams and trolleybuses, their frequency, quality, safety).

b) Mobility planning and facilitation on regular basis.

c) To enhance the mobility of residents and faster access to the desired location in the city, the creation of public transport lanes in large cities must be clarified and improved.

d) Public transportation lanes must be controlled so that others do not travel on them.

e) Create and implement reverse lanes.

f) Organize delivery of goods and waste removal only at night and off-peak hours.

g) Consider shifting working hours by one hour for employees in state and local government institutions.

h) Creation (if it is not done before) and launching Intelligent Transportation System (ITS) in order to monitor and manage traffic flow, improve safety, reduce environmental impacts.

This may include appropriate smart technologies, incorporated in the common joint ITS, for example:

- Sensors,
- Smart, i.e. intelligent traffic, road intersection lights,
- Video surveillance equipment 24/7,
- etc.

i) ITS integration in the Smart City concept, including artificial intelligence tools and 5G/6G technologies.

j) Digital Twins and Dynamical modelling of traffic flow and road infrastructure.

k) "Vox Populi".

The advantage of this approach is that the majority of city's inhabitants may express their thoughts about more suitable solutions both for citizens-car-drivers, citizens-pedestrians, and municipality. As a result, the municipal government obtains the opinion of citizens on making transport flow more efficient, or rather, on planning the organization of traffic more successfully.

l) Municipality transportation infrastructure developers ought to take into account and need to find out following issues:

- Average travel time of 10 km during peak hours: generally, it is longer than off-peak due to congestion. For instance, according to the TomTom Traffic index, it takes 20 minutes 20 seconds to drive a 10 km section in the central part of Riga during the peak of congestion,
- Peak hour toll: reasonable amount and exact timeframe on dedicated road sections to enter a congested area,
- Off-peak toll,
- Consider a motivational component for drivers, for example, the public transport refund (vouchers) as the part of road toll payment,
- Designated area where public transport vouchers (if they are planned to be issued) can be redeemed - used to pay for public transport tickets,
- The compliance of current public transportation prices with the city's sustainability and well-being policy,
- Park and ride solutions.

m) Considerations for wider use of electric vehicles:

- The issue of increasing the number and density of electric charging stations in countries and cities where this problem exists must be addressed,
- Another challenging issue is reducing the time drivers spend waiting for their vehicles to be charged at these stations. Technologies that can reduce this time should be explored. Another solution could be to create battery swapping stations for electric vehicles that can quickly swap batteries, similar to what is done at Formula One racing stages,
- The increasing part of electric cars in urban traffic reduces the total amount of harmful emissions from all vehicles in urban traffic, contributing to the achievement of sustainability goals,
- Electric cars can relieve general vehicle lanes by moving along public transport lanes,
- However, it should be noted that as the number of electric cars increases significantly, city governments will have to make decisions both on prohibiting the use of public transport lanes for them and on reducing or even abolishing parking privileges in central parts of cities.

IV. Conclusions

The wellbeing thing encompasses a wide range of human-environment interaction issues. It must be acknowledged that today's people almost cannot imagine their daily lives without vehicles. They provide citizens with invaluable benefits in terms of fast and efficient service delivery and mobility, improving their quality of life. On the other hand, the exponential growth in the number of road vehicles is causing congestion on city streets and state highways. Furthermore, vehicles powered by fossil fuels pollute the air people breathe and significantly contribute to global warming. Hence, some kind of balance must be found between the set of all those elements that contribute to the development of human, social and environmental components within the wellbeing framework, thereby also achieving an improvement in the human well-being itself.

Governments and municipal leaders around the world have recently activated measures to reduce fossil fuel emissions, mitigate global warming, and thereby achieve sustainability goals and ensure human-environmental well-being. Organizations and target working groups are being created and are successfully working on research and drafting regulatory documents to promote population mobility, develop the environmentally safe public transport, support the use of fossil fuel free cars, as well as improve and implement intelligent transport systems.

Applying digital twin technology capabilities in road traffic modelling, testing and integrating would allow for the more effective evaluation and planning of road traffic infrastructure, avoiding potential pitfalls that affect the formation of road congestions and declining in human-environmental well-being.

The recommendations provided in the discussion section of Chapter III of this article might be used for planning and developing transport infrastructure and flows not only in mega and large cities, but also in smaller towns and villages, as well as within the road network of a country or a union of several countries.

Acknowledgement

This research has been partly funded by the European Union. Project "Twinning in Environmental Data and Dynamical Systems Modelling for Latvia," TED4LAT, No. 101079206. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

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