

Industry 4.0: Implementation of Digital Technologies to Improve Production and Economic Efficiency

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Abstract- The paper investigates the relationship between Industry 4.0 technologies and the competitiveness of manufacturing enterprises. Industry 4.0, which integrates digital technologies such as artificial intelligence, big data, robotics, and the Internet of Things, is transforming production processes and business models, fostering innovation, and enhancing global competitiveness. The study aims to explore how these technologies influence manufacturing efficiency, flexibility, and product quality, and to identify the main motivations and barriers faced by companies in adopting Industry 4.0 technologies. The research employs several methodologies: systematic literature review - to summarize existing research on Industry 4.0 and its impact on competitiveness, identifying key innovations and trends in manufacturing; bibliometric analysis - analysing scientific publications to map the research landscape, identify influential works, and discern key technological trends in Industry 4.0; survey method - a survey of 100 Ukrainian manufacturing enterprises was conducted to assess the main motivations and barriers for adopting Industry 4.0 technologies. The results show that Industry 4.0 allows companies to significantly improve productivity, reduce costs and adapt to changing market conditions. However, the introduction of new technologies is accompanied by a number of risks, including economic, technical problems, including high initial investments, cyber security, and the need for new skills of employees. The challenges associated with the introduction of these technologies, including financial, technical and organisational costs, as well as problems associated with resistance to change, are considered. The reasons for this resistance are analysed, including personal interests of employees, distrust and uncertainty. Effective methods of managing resistance to change, such as communication, training and active participation of employees in the change

process, are proposed. The importance of clear communication, support and skills development for successful technology adoption is emphasised.

Key words- Automation, Digital transformation, Innovation management, Industry 4.0, Production processes, Productivity, Resource savings,.

I. INTRODUCTION

In the context of globalisation and rapid technological change, the modern economy is undergoing a period of transformation, the main feature of which is the rapid development of the latest technologies. Industry 4.0, or the Fourth Industrial Revolution, is the undisputed leader among these changes, as it changes not only production processes but also the way of doing business and creating competitive advantages in global markets. Industry 4.0 technologies, such as automation, artificial intelligence, the Internet of Things, big data and robotics, have a huge potential to increase production efficiency, reduce costs and accelerate time-to-market for new products.

Industry 4.0 has a significant impact on the competitiveness of manufacturing companies, especially in the innovation economy, where technology and innovation have become the main drivers of economic growth. Therefore, the study of the relationship between Industry 4.0 and the competitiveness of companies is extremely important for modern enterprises.

II. MATERIALS AND METHODS

A variety of methods and materials were used in the course of researching the topic to achieve objective and reliable results.

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Systematic literature review - this method allows for a detailed analysis of existing research on Industry 4.0, its impact on the competitiveness of enterprises, as well as current innovations within manufacturing companies. It involves the study of articles, books, reports, papers and other publications to systemise and summarise knowledge on the topic. The main stages of a systematic literature review are: identifying the topic and formulating research questions, searching for and selecting publications, analysing and synthesising the data obtained; structuring and summarising knowledge; writing conclusions and practical recommendations for businesses on the implementation of Industry 4.0 technologies.

Bibliometric analysis is a method that combines bibliometric and computational tools to analyse scientific publications. This allows for the estimation of the number of publications on Industry 4.0, identification of the main research areas, key scientific works, and influential authors in this field, as well as the identification of the main trends in the development of technologies in the innovation economy. The main stages of bibliometric analysis include data collection, data processing and analysis, and interpretation of the results. Bibliometrics enables the coverage of a large volume of scientific publications, which makes it possible to draw more accurate conclusions about important trends in the development of technologies and scientific approaches in the field of Industry 4.0.

The survey method is one of the main tools for collecting data in scientific research, in particular in the study of Industry 4.0. During a survey, respondents (the target audience) fill out questionnaires or questionnaires. Surveys in our research can help us find out how representatives of different companies feel about the concept of Industry 4.0, what benefits and challenges they see in implementing these technologies. Questionnaires allow us to interview a large number of respondents, which makes it possible to obtain representative data.

Research materials: scientific publications - articles from scientific journals, books, conference reports describing the theoretical and practical aspects of Industry 4.0; reports of international organisations analysing the implementation of Industry 4.0 technologies in different countries; publications and information from open sources - statistics, materials from company websites, as well as media interviews covering the implementation of Industry 4.0 at enterprises, results of a survey of enterprises.

The use of these methods and materials allows us to form a comprehensive view of the impact of Industry 4.0 on the competitiveness of enterprises and determine how innovative technologies are changing the structure and efficiency of manufacturing companies in the modern economy.

III. RESULTS AND DISCUSSION

Industry 4.0 (I4) is defined as the use of digital technologies to integrate production processes, enabling

greater flexibility, automation and intelligent solutions. It is based on technologies such as:

- *Internet of Things (IoT)*. This is a technology that allows various devices to connect to the Internet and exchange data in real time. It makes it possible to monitor and control production processes remotely, improving efficiency.

- *Artificial intelligence (AI)* and machine learning. AI is used to analyse large amounts of data, predict and optimise production processes. With machine learning, companies can improve their strategies based on automated recommendations.

- *Big data*. Huge volumes of data generated during production processes can be used to make decisions, optimise workflows, and forecast market needs.

- *Robotics*. The use of robots to automate physical tasks in production can improve accuracy, reduce human error, and cut costs.

- *3D printing*. A technology that allows for rapid prototyping of products, which reduces the time and cost of their development [1].

The integration of these technologies into production processes allows companies to significantly increase productivity, product quality and adaptability to changing market conditions.

The innovation economy is an economy that is based on the use of innovative technologies to increase productivity, create new goods and services, and attract new investment. It relies on knowledge, research and development, and the ability of businesses to adapt to rapid change.

Industry 4.0 is one of the key factors driving the development of the innovation economy. Thanks to I4 technologies, businesses can significantly improve their efficiency and create competitive advantages. The competitiveness of an enterprise is its ability to successfully compete in the market, ensuring sustainable growth and profitability. In an innovative economy, companies must constantly introduce new technologies to maintain and increase their market share.

Industry 4.0 is already being actively implemented in various manufacturing sectors. For example, robotic car assembly lines are widely used in the automotive industry, and automated systems for product testing and quality control are used in electronics. In pharmaceuticals, big data is used to forecast demand for medicines and analyse market trends.

Scientists have developed a model [2] based on the literature on organisational motivation, resources/capabilities, and technology acceptance, as shown in Figure 1. The main part of the model examines the influence of external/reactive motives (pressure from competitors, suppliers and customers) and internal/proactive motives (efficiency and expected competitive advantage) on the intention to use I4

technologies, as well as the influence of the latter on the actual use of I4 technologies.

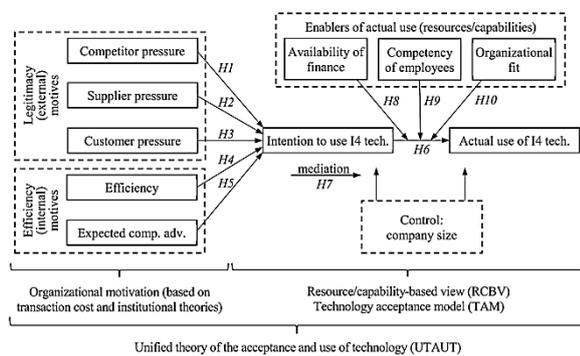


Fig. 1. Model of motivation for organisations to implement Industry 4.0 technologies.

Source: [2]

This study identifies five main groups of motivations for the adoption of I4 technologies: competitor pressure, supplier pressure, consumer pressure, efficiency and expected competitive advantage.

The first three categories - competitor pressure, supplier pressure, consumer pressure - are considered external motivations, as they arise under the influence of external factors, such as changes in the market or consumer needs. At the same time, the last two motives - efficiency and expected competitive advantage - are internal, as their main goal is to improve internal processes and achieve the company's strategic goals. Pressure from competitors, suppliers and consumers can be seen as reactive motives that encourage companies to change under the influence of the external environment. Instead, the desire for efficiency and competitive advantage are defined as proactive motives that focus on internal improvement and achievement of long-term strategic goals [2].

Industry 4.0 offers a wide range of the latest technologies for the digitalisation of business processes, including automation, the Internet of Things, artificial intelligence and big data, which are significantly transforming modern production and management [1]. The introduction of I4 technologies can significantly increase productivity and reduce costs, improve production quality and end-user convenience, as well as increase process transparency and create more sustainable business models. By integrating digital and physical systems, companies can achieve significant improvements in resource savings and develop more flexible organisational structures [4].

The introduction of I4 technologies is accompanied by a number of positive aspects, as illustrated in Figure 2, developed by the authors.

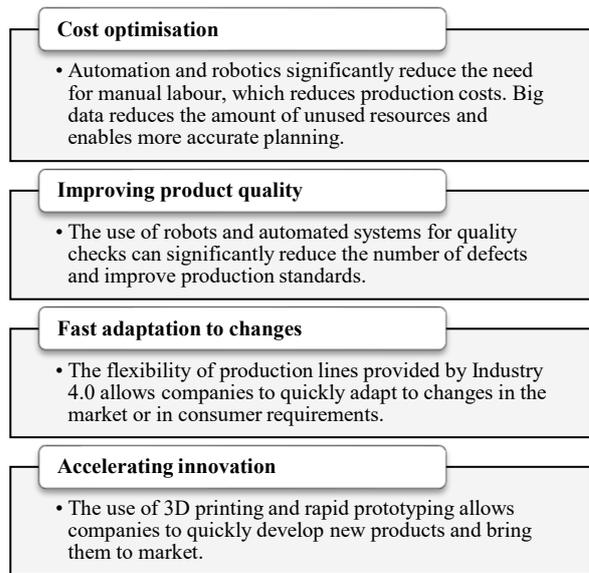


Fig. 2. The role of Industry 4.0 in improving the competitiveness of enterprises.

Efficiency motivations are the basis for the adoption of new technologies in organisations, as process efficiency gains are an important factor in making such decisions [3]. Rationalistic approaches to technology adoption are considered important as organisations expect significant productivity gains, cost reductions and improved performance through innovation. The motivation for technology adoption is based on the desire to improve the overall performance of the company, which is becoming an important factor in ensuring its competitiveness in the context of digital transformation.

On the other hand, the introduction of I4 technologies creates new challenges for organisations. In particular, there are difficulties in ensuring cyber security and data protection, organising new work processes, and adapting staff to new conditions [5]. The need for new skills and qualifications of employees, as well as the creation of an effective infrastructure for digital technologies, are urgent issues that need to be addressed to ensure the successful integration of new solutions. The problems of standardisation and integration of different technologies also remain significant on the way to the full realisation of the potential of I4 [2].

Thus, while the benefits of I4 technologies are clear, organisations must be prepared for the new challenges that arise on the way to their implementation, which includes not only technical but also organisational and human factors that determine the success of digital transformations.

Industry 4.0, or the Fourth Industrial Revolution, is characterised by the integration of digital technologies into production processes, which ensures automation, increased efficiency and flexibility of production. However, the introduction of these technologies is accompanied by a number of risks and challenges that

may affect the success of the transformation of enterprises, as shown by the authors in Table 1.

TABLE 1 RISKS OF IMPLEMENTING INDUSTRY 4.0 TECHNOLOGIES

Type of risk	Risk description
High initial investment	Implementing I4 requires significant financial investments in the latest technologies, which can be burdensome for SMEs.
Uncertainty of economic benefits	Businesses may not have a clear idea of the potential economic benefits of I4, which can lead to excessive investment without a guaranteed return.
Replacement of jobs	Automation and the use of robots may lead to job losses, especially for low-skilled workers, causing social tensions.
Growing gender inequality	The introduction of new technologies may increase gender inequalities, as women are less represented in industries related to I4.
Lack of regulation and standards	An insufficient regulatory framework and lack of common standards can complicate the implementation of I4 and create legal uncertainty for businesses.
Cybersecurity issues	The increase in the number of connected devices and systems increases the risk of cyber-attacks, which can lead to data loss, financial loss and damage to the company's reputation.
Insufficient staff qualifications	Lack of necessary skills and knowledge among employees can complicate the digitalisation process and reduce the effectiveness of new technologies.
Resistance to change	Resistance to change from employees and management can delay or complicate the transformation process.
Integration of new technologies	The difficulty of integrating new digital technologies with existing systems can lead to technical problems and disruptions in production processes.
Dependence on technology providers	Businesses can become dependent on technology providers, which can limit their flexibility.
Increase in e-waste	The rapid development of technology can lead to an increase in the amount of e-waste, which requires effective disposal and recycling systems.
Energy consumption	The use of new technologies can increase energy consumption, which requires the development of efficient and sustainable energy solutions.

Thus, the implementation of I4 is a complex and multifaceted process, accompanied by numerous risks and challenges. For a successful transformation, businesses need to develop risk management strategies, invest in staff development, ensure cyber security, and adapt their organisational structure to new requirements. It is also important to cooperate with government agencies to develop an appropriate regulatory framework and standards that will facilitate the effective implementation of I4.

Given the risks and opportunities that accompany the introduction of new technologies, it is necessary to better understand the main driving forces that determine their integration and use in organisations. Based on studies such as [6], it can be argued that a company's openness to I4 can be measured by two parameters: breadth (the number of technologies integrated into production processes) and depth (the number of stages at which these technologies are used).

Industry 4.0 technologies require deeper scientific expertise and closer integration into the operational structures of companies [2].

The main characteristics of such technologies are interaction through wireless networks, assistance in decision-making at all levels, and strong interdependence between different technological elements. As a result, machines, devices, sensors, and people can interact in real time, creating transparency and allowing participants to access information instantly and make decentralised decisions. In such environments, humans are supported by technology to perform physical and intellectual tasks, while robots perform complex or hazardous operations, thereby reducing health risks and increasing efficiency [7].

At the same time, the integration of I4 involves significant financial, technical and organisational costs, requiring companies to take a strategic approach to planning and adaptation. Thus, the adoption of such technologies should be justified, taking into account not only potential benefits but also possible risks and challenges on the way to implementation.

Industry 4.0 is focused on the integration of digital technologies that fundamentally change the way organisations create value. At the same time, a key feature is the deep interaction between the physical and virtual worlds, which allows for the creation of new business models and optimisation of production processes. Although the technologies underpinning I4 are technocentric, focusing on innovation and technological advancement, their interconnected nature indicates that their potential can only be maximised in the context of inter-organisational value chains, not within individual enterprises [8].

The most important aspects of I4 are the application of technologies that offer a new operating paradigm for industry. They can significantly increase efficiency and productivity, which, in turn, contributes to the creation of so-called 'smart factories' through the digitalisation and automation of production processes. Industry 4.0 is based on the principles of integration, decentralisation of decisions, information transparency and technical support at every stage of production [9].

The changes caused by the implementation of the I4 concept should have a positive impact on the competitiveness of enterprises; increase the flexibility of production processes, which generally contributes to the improvement of companies' market positions through increased efficiency.

Based on the results of a survey of 100 Ukrainian industrial enterprises, we assessed the main motivations that encourage companies to implement the I4 concept. The main results of the survey are shown in Figure 3.

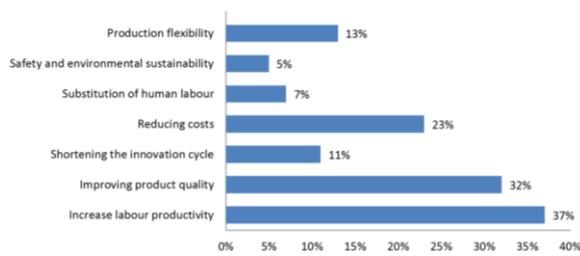


Fig. 3. Motives that encourage companies to implement the Industry 4.0 concept.

As can be seen from Figure 3, the main factors contributing to the implementation of I4 elements in organisations are visualised, with the most common factors for implementing the I4 concept being increase labour productivity, improving product quality, reducing costs, production flexibility and shortening the innovation cycle.

We have already shown that Industry 4.0 offers tremendous benefits for businesses that have managed to implement and adapt the latest technologies into their daily operational processes. But there is always a downside when companies fail to implement Industry 4.0 technologies in their business. We conducted a survey among 100 industrial enterprises in Ukraine to investigate the main barriers to digital transformation. The survey results are shown in Table 2.

TABLE 2 THE MAIN BARRIERS TO THE IMPLEMENTATION OF INDUSTRY 4.0 IN THE PRACTICE OF INDUSTRIAL ENTERPRISES

Main barriers	Disagree	Neutral	Agree
Resistance to change	21%	24%	55%
Lack of qualified personnel	23%	26%	51%
High initial investment	19%	39%	42%
Poor quality of management	17%	33%	50%
Cybersecurity and data risks	42%	27%	31%

The table shows that the majority of respondents consider the factor ‘Resistance to change’ (55%) to be an important obstacle to the implementation of Industry 4.0 benefits. This is the highest figure among the other reasons. However, there are also significant barriers, such as ‘Lack of qualified personnel’ (51%) and ‘Poor quality of management’ (50%), which also hinder digital transformation.

However, despite the potential of I4 technologies, their successful implementation at the industrial level requires consideration of soft factors such as organizational strategies, company structure, corporate culture, and workforce training during the transition to the I4 era [10].

However, even when change appears to be ‘rational’ or ‘positive’, it always carries with it an element of uncertainty that can cause emotional discomfort among employees and those involved in the change process. Uncertainty often causes resistance to change, which is a natural human reaction to the loss of stability and the

desire to maintain the status quo. When faced with uncertainty, people often try to avoid change, as it allows them to maintain a sense of control and security in the face of new challenges [9].

Kotter and Schlesinger identify four main reasons for resistance to change: personal interests, misunderstanding or lack of trust, different assessments of the situation, and low tolerance for change. According to them, people often resist when they believe that they may lose something that is important to them; when they do not trust those who are implementing the changes; when they do not understand the reasons for the changes and do not believe in their ability to adapt to new conditions. According to other research, resistance can also be the result of uncertainty or fear of future change [11].

However, resistance is not always a purely negative reaction to change. Resistance can be a tool for identifying shortcomings in change plans or information provided, giving the organisation the opportunity to adjust strategies to achieve better results. As a result, the proper management of resistance can lead to significant organisational gains, as it helps to identify weaknesses in the change process.

Thus, effective management strategies, including communication, employee participation in the change process, as well as training and negotiation, contribute to a smoother implementation of the change and increase employee acceptance. As a result, these strategies help to reduce the level of resistance and ensure the successful transition of the organization through the change.

In this context, it is important to consider different approaches to dealing with employee resistance when implementing I4 technologies. Since the implementation of such technologies is often accompanied by significant changes in organizational processes, it is necessary to consider strategies that minimize resistance and ensure the successful adaptation of employees to new conditions. The following will analyse the main methods of managing resistance, in particular through effective communication, employee participation in the change process and providing clear explanations for the implementation of new technologies.

1. Communication. Communication is a key aspect in the process of digital transformation of organizations. Satisfactory communication allows for a positive perception of changes among employees by explaining to them the benefits of the implemented technologies. When employees understand why and how a specific I4 technology is being implemented in the organization, this significantly reduces the level of resistance. Leaders should provide evidence of positive outcomes from the use of technology to confirm its effectiveness and minimize fears that may arise due to uncertainty [9].

According to a study [12], presenting a clear strategy for implementing and using new technologies is another important step to reduce resistance. Employees should be informed in detail about the stages of change and the

possible side effects of implementing new technologies. Unclear communication or lack of information can lead to negative rumors, which can seriously complicate the change process. Therefore, it is important for managers to provide accurate and understandable information, answering employees' questions and explaining all aspects of the change, even if they have certain shortcomings or difficulties. Another important component of an effective communication strategy is constant feedback. Employees should feel that their feedback is important and that they can influence the change processes.

2. *Training.* Training is a critical factor for the successful implementation of I4 technologies. With the implementation of I4 technologies, there is a need for new technical skills, such as data analysis, data modelling, knowledge of cyber-physical systems, the Internet of Things, and robotic manufacturing. In addition, soft skills, such as the ability to solve problems, work in a team, implement change, and adapt to new conditions, are necessary for the successful application of new technologies [13].

Training provides employees with the opportunity not only to update their knowledge but also to gain experience in using new technologies. In addition, training programs allow them to demonstrate the value of new technologies by providing employees with a clear understanding of their functions and potential opportunities for implementation within the organization. Therefore, investments in training are becoming an important component of the strategy for the successful implementation of I4 in organizations.

Successful implementation of training for I4 requires efforts not only from the industrial sector, but also significant participation from academic institutions. Research institutes and universities should be involved in the development and updating of educational programs that meet the requirements of new technologies. An important aspect is the close cooperation between manufacturing companies and educational institutions to create specialized programs that will contribute to the training of a skilled workforce [9].

3. *Participation.* To increase employee involvement in the implementation of new technologies, it is important to encourage their active participation in the process. This allows employees not only to understand more deeply the principles of how the technology works, but also to realize its real benefits in the context of expected results. Interaction with new technologies through direct participation helps people develop a more positive attitude towards them and, thus, increase their commitment to innovation.

Furthermore, when employees are involved in the process of developing and implementing technology, they can influence its adaptation to their specific needs and constraints, which contributes to the formation of a sense of ownership and responsibility for innovation.

IV. CONCLUSIONS

Industry 4.0, through the integration of digital technologies into production processes, has a powerful impact on the competitiveness of enterprises. However, this process is accompanied by a number of risks, including economic, social, political and technical. For a successful digital transformation, companies need to address cyber security issues, develop risk management strategies, adapt HR policies and develop infrastructure.

The introduction of I4 creates new opportunities for the development of an innovative economy, but requires a comprehensive approach and readiness for challenges. The introduction of I4 technologies opens up new opportunities for organizations, but is accompanied by significant challenges. Assessing a company's openness to these technologies through the parameters of breadth and depth allows you to better understand the scale of integration and the potential of technologies. Industry 4.0 technologies require deep scientific expertise and close integration into companies' operational processes. They provide transparency, increase efficiency and reduce risks for employees. However, successful implementation requires significant investments in technology, as well as consideration of organizational, financial and human factors.

An important aspect is change management, in particular combating employee resistance. Effective change management strategies include communication, training and employee participation in the adaptation process. Through clear communication, providing the necessary knowledge and involving employees in decision-making, the level of resistance can be significantly reduced and ensure the successful implementation of new technologies. Investment in education, cooperation between companies and educational institutions are also key to preparing a skilled workforce. Therefore, to achieve success in the era of I4, it is important to combine technological innovations with an effective management approach, focusing on employee participation and development.

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