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Methodological Aspects and Limitations for Ensuring Safety in Transport Management Using Artificial Intelligence

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***Abstract*—Recently, there has been rapid technological progress in transportation, which is expressed in the field of telematics, the Internet of Things, the Internet of Vehicles, Big Data Analysis, etc. The use of information technology by drivers, including so-called smart devices, technological advances in sensor devices, autonomous vehicles, vessel telematics, cameras, etc., provides new potential for driver/operator behaviour monitoring, vehicle communication, surveillance, and incident detection in all modes of transport. The adoption of these technological advances is widespread, and the emanation of their use is the introduction of A.I. into the decision-making process. All this opens up the important topic of taking responsibility for decisions, detecting and eliminating errors in decisions and actions, and hazardous traffic management and safety processes. This article aims to examine and summarize these problems, especially when using A.I. in transport, from the point of view of ensuring safety. Methodological formulations and a general concept for a limit of admissibility in ensuring the necessary safety in transport are also proposed.**

Keywords*— *Artificial Intelligence, Internet of Vehicles, Telematics, Transport.

I. INTRODUCTION

The application of Artificial Intelligence (AI) in transport has evolved from academic theoretical concepts to real-world practical applications [1]-[6]. In the beginning, efforts focused on automating essential functions, such as signalling infrastructure management and traffic light management, as well as route planning algorithms, which laid the groundwork for the use of more advanced applications [7]-[9].

Gradually, the application of AI in transportation has increased, driven by advances in machine learning, computer vision, and sensor technologies. The most significant developments have focused on autonomous vehicles (AV) [10]-[12]. AVs using artificial intelligence have already begun to interpret the data received from their sensors, allowing them to understand and navigate the environment without human intervention [13]-[15].

AI applications have also been developed for public transport, from predictive maintenance for rolling stock to route optimization and intelligent systems for reservations, ticketing, etc. These innovations aim to improve interoperability and passenger service. AI also plays an important role in logistics and freight transport, optimizing routes and increasing supply chain efficiency [16]. Advanced AI algorithms help with predictive analysis for maintenance, load optimization, and real-time load tracking. Today's traffic management systems, as well as AI-driven autonomous vehicles, have fundamentally changed the way transportation functions.

In this regard, the primary purpose of this article is to consider and summarize these problems, especially when using artificial intelligence in transport from the point of view of ensuring safety in transport [17], [18]. Methodological formulations and a general concept for a limit of admissibility in ensuring the necessary safety in transport are also proposed.

II. MATERIALS AND METHODS

The integration of AI into transportation, especially in the form of AV, presents a new set of ethical challenges. While AVs offer many benefits, they also raise critical questions related to safety, decision-making algorithms, and, of course, public trust.

Regarding safety concerns, the determination of liability for AV accidents becomes complicated. When the

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AV is at fault, this fault can fall on the manufacturer, software developer, or even the passenger. In this regard, the risk of malfunctions increases. AVs rely heavily on software and sensors. This makes them susceptible to malfunctions, and due to software bugs and/or hacking, it also leads to safety risks [19].

In terms of decision-making algorithms, AVs must make ethical decisions in unavoidable catastrophe scenarios, which is a great challenge. In fact, the debate is around whether an AV should prioritize the safety of its occupants or pedestrians, for example. AIs are guaranteed to be free from biases leading to discriminatory navigation or pedestrian recognition practices.

Regarding public trust and acceptance, transparency is required in how AVs work and make decisions, which is challenging given the complexity of AI algorithms. From a legal point of view, establishing comprehensive legal frameworks governing AV use and safety standards is essential to gaining public trust.

AI applications in transportation are limited in their decision-making abilities, which creates serious challenges in complex situations requiring human judgment and intuition. AI systems excel at processing large amounts of data and making decisions based on predefined rules and patterns; they try to adapt to unique or unpredictable scenarios.

AI cannot make ethical judgments, raising concerns about the potential consequences of its decisions on human life and public well-being.

The implementation of AI in transportation has a social and economic impact that can lead to the loss of human jobs, especially for roles that can be automated.

The development and implementation of AI technologies in transportation also face regulatory challenges; existing laws may not adequately respond to AI decision-making.

The topic of AI limitations and strategies to overcome them is certainly both complex and fascinating. Common limitations in using AI are related to data quality, training bias, outdated infrastructure, and integration with other systems. Overcoming these limitations can help unlock the full potential of AI, making it a powerful tool for innovation and efficiency.

Overcoming these limitations and training requirements for AI systems must be carefully considered. AI algorithms need to be trained on vast amounts of data to improve their decision-making capabilities in complex situations. Additionally, ongoing research and development are needed to improve AI's decision-making abilities and overcome the ethical implications and regulatory barriers associated with its use in transportation.

III. RESULTS AND DISCUSSION

A. Cybersecurity risks

T The cybersecurity risks of using AI technologies in transport require robust safeguards to protect against potential threats [20], [21]. These AI applications increase the risk of cyber threats, including breaches, manipulation, data loss, hacking vulnerabilities, and privacy concerns. To protect itself from cyberattacks, the transportation industry must address these risks by implementing strong security measures, software updates, and hardware upgrades. The disruption of operations and the potential for hackers to steal sensitive information are the main concerns.

TABLE 1 CYBERSECURITY MEASURES DESCRIPTION

Cybersecurity Measures	Description
Encryption	Encrypting data to protect it from unauthorized access
Intrusion Detection Systems	Installing systems to detect and prevent unauthorized access
Regular System Updates	Keeping software and hardware up to date with the latest security patches
User Authentication	Implementing strong authentication protocols to ensure only authorized users have access
Employee Training	Providing training to employees on cybersecurity best practices
Incident Response Plan	Developing a plan to respond to and mitigate cyber threats

Protecting AI technology from cyber threats is crucial for maintaining the integrity and security of transportation operations. As shown in Table 1, the following security measures should be implemented to mitigate these risks.

B. Integration challenges

The application of AI technologies in transport is a complex task requiring their integration with existing systems and processes [22]. Successful integration is associated with several challenges, such as:

Compatibility issues - AI systems may not be compatible with existing infrastructure and software used in the transportation industry. This can lead to difficulties in data sharing, communication, and interoperability between different systems.

System integration - Integrating AI technology requires seamless integration with existing transportation systems and processes. This involves connecting AI algorithms to existing hardware, software, and databases, which can also be complex.

Implementation barriers - Organizations may resist implementing AI in transportation due to factors such as cost, lack of experience, and concerns about job losses. Overcoming these barriers requires careful planning, proper training, and addressing stakeholder concerns.

Addressing these integration challenges is critical to fully leveraging AI's potential benefits in transportation.

Collaboration between providers of these new technologies, industry stakeholders, and policymakers is also required. This is necessary to develop effective solutions and ensure a smooth transition to intelligent transport systems. Successfully integrating AI technology into the transportation industry also requires addressing the challenge of not having a skilled workforce capable of effectively using and managing AI systems.

C. Intelligent transportation

In recent years, various innovative applications related to transport and technology have been built. The developers of these applications focus on a process-oriented system approach, and the main goal is to create a feedback mechanism and measure the results of decisions related to transport management.

Transportation management systems (TMS) coordinate the overall transport process and the performance of individual transport operations. These systems aim to create efficient route planning, load optimization, and improved flexibility and transparency using the data in them. The data generated by users and vehicles is used to build efficient Intelligent Transportation Systems (ITS). The integration of these ITS into transport systems has provided increased productivity thanks to the collection, exchange, and integration of information between vehicles, urban infrastructure, and a range of other related activities.

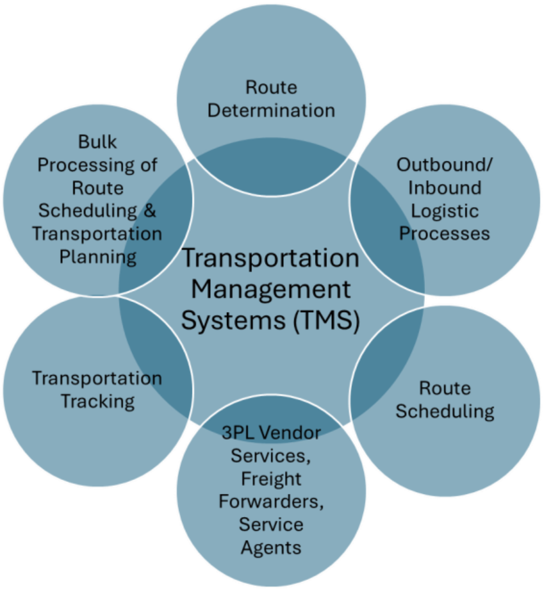

Fig. 1. Functions of TMS.

The main functions of TMS shown in Figure 1 include route definition, entry-exit logistics processes, route planning, services for Third-party logistics (3PL) suppliers, freight forwarders, service agents, transport tracking, mass processing, route planning, and comprehensive transport planning [23]. TMS-related functions relate to the transportation of goods. TMS integrates multiple transport applications into one package for better ease of use.

With the development of new technologies and cloud computing, there has also been talk of Cloud TMS, shown in Figure 2 [24].

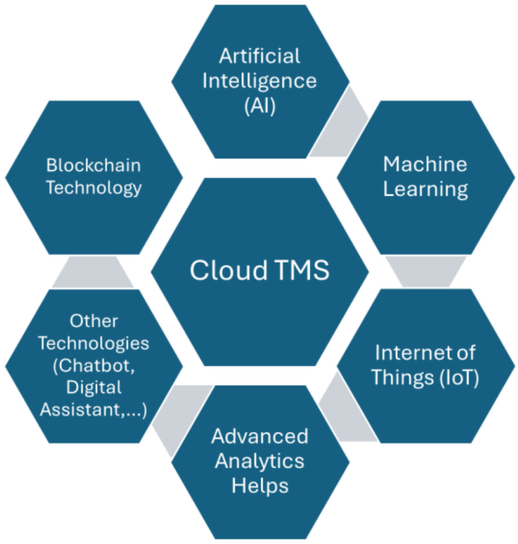

Fig. 2. Cloud TMS.

Cloud technologies make TMS systems much more accessible, which allows new capabilities and flexibility of the software used – MercuryGate, Transplace, SAP Transportation Management, Kuebix, Manhattan TMS, etc. (Source: https://www.selecthub.com/transportation-and-logistics-management/cloud-tms/).

AI brings several innovations. It handles time-consuming, routine tasks throughout the process and provides the benefits of time and cost savings.

Machine learning (ML) can quickly make accurate predictions based on massive data sets [25]. ML can help businesses manage the important trade-offs between cost savings and on-time delivery, taking into account the geographical factors of delivery in real-time, as well as direct and indirect delivery.

IoT, Internet of Vehicles (IoV). Sensors collect invaluable information that can be used to identify equipment that needs to be maintained [26]-[28]. The more equipment along the entire supply chain is equipped with sensors, the more efficient the process becomes [29].

Advanced analytics help optimize routes and delivery methods, improve delivery times, increase fuel economy, efficiency, and profitability, and adapt to changes in transport demand. As more data is generated, the role of analytics becomes even more important.

Other technologies can also make TMS systems more efficient. Chatbots or digital assistants can reduce administrative costs by handling routine customer inquiries. Blockchain technologies also provide transparency for tracking throughout the supply chain.

D. Limitation of AI Techniques

In the field of transportation, there are various criticisms of AI methods [30], with one of the main limitations of AI being the view of Artificial Neural Networks (ANN) as a "black box." [31]. ANNs are generalized in cases where some information is missing in the data. However, this limitation is overcome by combining the neural network with other traditional AI techniques and tools, such as a hybrid solution [32]-[34]. This hybridization requirement to improve performance, especially in multiple scenarios, is a common weakness [8].

Developing an efficient transport system based on artificial intelligence is very complex due to the creation of mechanical intelligence and the correct understanding of information [35]. Because of this, AI applications in transport are limited to specific applications of ITS, such as data analysis and predictions of future mobility; i.e., they are not yet able to handle the full scope of the process [36]. In order to work as stand-alone systems, it is necessary to realize the full potential of AI to develop sufficiently practical applications. It is important to introduce AI knowledge into traffic analysis, data collection and storage, and modelling and optimization decision-making [37]. AI techniques are based on data collected using loop detectors, sensors, actuators, etc., and accuracy and timely predictions are still unreliable.

Mathematical methods provide an understanding of the problem's internal structure and the nature of the solution, in contrast to the so-called - AI raster algorithms. However, in complex optimization problems, where it is impossible to use traditional mathematical techniques, the quick analysis results generated by these algorithms are better than the lack of solutions, although these algorithms arrive at a good solution in most cases, i.e., the parameters and assumptions must be adjusted and repeated many times in order to achieve the best solutions and have more insight into the problem. Another limitation has to do with the bias introduced in the training data. In most cases, this is checked by people who can introduce errors and biases into the labelling of the data.

The ability to predict short-term and long-term traffic is essential for transport, with the challenge being to predict unexpected events and adverse weather conditions, which existing artificial intelligence techniques are not yet able to address [38]. In this regard, developing incident response algorithms and forecasting schemes is important for high accuracy. In developing these algorithms, AI should increase its efficiency in online computing and improve the standardization of requirements regarding space-time coverage of data [39]. Most AI approaches, such as neural networks in time-series transport applications, rarely involve testing the properties of the error. Because of this, the model specification is considered a limitation. AI statistics should have an interdependent relationship for improvement in the development of the underlying model and suitability, as well as the ability for effective and accurate Big Data analysis [39], [40]. AI also has other common limitations, such as the high cost of development and maintenance due to its complexity, lack of customer privacy, and transparency of AI-driven technologies. Another major limitation is the computational complexity of AI algorithms. These problems require a lot of computing power to solve the complexity of increasing data density.

In general, the main task in transport includes problems such as vehicle routing and optimal planning for drivers and road users [41]. In a simple algorithm scenario, the number of input data increases, and the number of operations grows constantly. However, in real life, challenging scenarios apply, i.e., for the algorithm, the number of operations and calculations is explained in polynomial time (X^2), exponential time (2^X) and factorial time (X!). The theoretical explanation for the complexity of the algorithm is expressed in the Polynomial (P) Problem and the Nondeterministic Polynomial (NP) Problem [42]. These problems require a lot of computing power to solve the complexity problem of increasing data density. The complexity of the calculations limits the AI techniques; most algorithms are classified as NP problems and NP-complete problems. In DL, many hidden layers are built into the network architecture, and the complexity relies on the fact that Big Data contains noise and distortion from which characteristics are challenging to extract [43]. Transport data is collected from road sensors, connected devices, tolls, GPS applications, cloud applications, and other transport features [44]. These functions include traffic, speed, traffic occupancy, and the behaviour of drivers and passengers, which further complicates the computational process when solving a specific problem.

E. Alalysis

The analysis of this study's work can be classified into two aspects to ensure transport safety when using AI: transport problems when using AI and Techniques related to solving these problems.

a) Transport Issues

Population and transport traffic is constantly increasing, raising topical issues such as traffic control, air pollution, disaster and accident management, and congestion control through appropriate AI navigation systems.

Various issues focused on the literature review are summarized. Based on the study, it can be concluded that the main challenges in most of TMS's work are traffic and congestion control, as well as disaster and accident management. Air pollution, efficient traffic management, and resources are also important, and the focus on these issues is taking on new dimensions in the context of the use of AI in the transport sector. letters.

b) Techniques Involved in Solving These Issues

The specificity of the transport process is that various problems must be solved in real-time based on the dynamic information received to solve them. Technological solutions are diverse, often technologies of different generations, which must reliably and securely communicate with each other. As an example, various video surveillance cameras and sensors can be used to provide real-time information. GPS technology combines various image processing techniques for more advanced navigation systems.

Advanced AI technologies, cloud computing, and agent-based computing are being introduced to make the transportation system more efficient and intelligent. So far, the sensors and vehicle cloud computing techniques used are agent-based. Now, this is the best solution; improvements due to technological progress are expected in the future, and the use of increasingly intelligent infrastructure will support the overall process of secure and safe management of transport processes based on AI.

IV. CONCLUSIONS

The explosive growth in traffic and population density has raised various technical and environmental issues, such as air pollution, increased traffic, congestion, and accidents, which have increased interest in researching the issue.

Implementing AI in transportation is a critical issue as it solves several problems related to the transportation system [45]. The design of TMS, including AI, is essential for security and safety, and on the other hand, it improves the system of road infrastructure and traffic management [46]. Therefore, AI can be used to address these transportation-related issues. TMS with AI combine various technologies such as data collection, communication, machine learning, and data mining to provide transportation and related services. These services include intelligent traffic control, intelligent navigation and driver assistance systems, as well as fault detection systems. In addition to this, AI also makes decisions about transportation, related to issues such as disaster management, congestion control, and air pollution. Further improvement of TMS includes the addition of new techniques such as IoV, cloud computing for vehicles, and agent-based computing, which include the introduction of AI into transportation systems. By combining these techniques, TMS with AI can be more effective in solving transportation-related problems.

A systematic study of existing TMS looks at them from different perspectives, considering the pros and cons of various issues related to security and design challenges. Many review articles have been published in the context of TMS, but none of them address all aspects related to TMS with AI. The open research questions in this TMS with AI study include identifying important metrics that affect TMS performance. This should be done in the field of providing solutions for the reliability and security aspects of TMS with AI, not only in a technical context, but also in a regulatory and moral context.

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