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Research Article

Application of Artificial Intelligence-Based Digital Technologies in Transport Logistics

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Abstract

The conducted analysis highlights that, in order to effectively stimulate and accelerate the process of digitalization in line with the functioning of different modes of transport, it is necessary to rely on technologies and systems developed on the basis of the latest achievements of scientific and technological progress. Modern experience demonstrates that the integration of such technologies can bring tangible benefits to transport operators, passengers, and society as a whole. For this purpose, it is particularly important to ensure the comprehensive integration of modern digital solutions-currently applied on a limited scale or at the project development stage in certain advanced countries-into a unified transport ecosystem. Such integration can be realized by gradually improving road and transport infrastructure across regions, as well as ensuring the digital support for urban and inter-district transport services.

In the contemporary era, marked by a rapid increase in population, accelerated urbanization, and steadily growing transport volumes, the adoption of innovative technologies acquires critical relevance. Digitalization and artificial intelligence in this context should not be viewed solely as technical instruments for optimizing transport operations. They also act as catalysts for the modernization of logistics chains, the enhancement of transport safety, and the reduction of environmental impact.

Furthermore, the consistent implementation of these measures contributes to significant improvements in citizens' quality of life, ensuring more accessible, reliable, and efficient mobility. At the same time, such progress supports the achievement of long-term sustainable development goals, particularly in terms of fostering economic competitiveness, promoting social well-being, and ensuring ecological balance. The main goal of this study is to scientifically assess the impact of the digital transformation of transport and logistics systems and the application of artificial intelligence technologies on the efficiency and sustainability of the sector.

1. Introduction

It is well known that, as a direct consequence of the rapid integration of digital technologies-developed on the basis of the most recent achievements of scientific and technological progress-into the functioning of various modes of transport worldwide, the role of transport vehicles in meeting the mobility needs of both the state and the population with high quality and efficiency has significantly increased (Əhmədov et al., 2025). This process reflects not only a technical modernization of the transport sector but also a strategic transformation that reshapes how transportation services are planned, managed, and delivered. The improvement of digital ecosystems allows for the optimization of logistics chains, enhancement of operational safety, and provision of more sustainable solutions. In order to successfully stimulate the future implementation of digitalization across different modes of transport, it is therefore essential to conduct a comprehensive examination of a wide spectrum of innovative technologies and systems. According to international practice, many of these solutions are currently at the project development stage or are being applied on a limited scale in several advanced countries. Analyzing these global experiences provides valuable insights for adapting such technologies to local conditions, ensuring their gradual integration into a unified transport system, and ultimately achieving sustainable economic and social benefits.

2. Method

2.1. Research method

Manipulators and Manipulation Technologies. At present, manipulators are widely used in such areas as providing technical maintenance and repair of transport vehicles and infrastructure facilities, aircraft refueling, and automating routine and repetitive operations in logistics (sorting, packaging, loading, unloading, etc.). In the future, with the development of multimodal transport and logistics complexes, the demand for the use of manipulators is expected to increase further.

Sensorimotor Coordination and Spatial Positioning Technologies. The main task in automating transport processes is to determine the positions and trajectories of vehicles during movement, as well as to obtain feedback and model motion in real-time modes. In cases where transport demand increases during operational processes, one of the critical areas of application will be the remote monitoring of vehicles that may pose a danger to movement. The application of these technologies provides an opportunity to address this issue.

Sensors and Data Processing Technologies. During the operation of transport systems, there is a constant flow of rapidly changing and significant amounts of data. The collection and fast processing of this data make it possible to take the necessary measures to improve the efficiency of freight and passenger transportation (Postranskyy & Vovk, 2020). Therefore, in the future, during the transition to highly automated driverless transport, the integration of advanced sensors for the collection of data from various platforms will be of great importance. Such modern sensors also make it possible to monitor the level of harmfulness of exhaust gases and ensure compliance with other environmental requirements. They are considered critical elements of diagnostic devices used for monitoring anti-icing systems for vehicle glass surfaces, controlling external lighting, detecting deficiencies in pipelines used in various systems, and monitoring the operation of transport infrastructure. Consequently, in the future development of transport systems, the role of such sensors and sensor networks in the wireless acquisition of data from diagnostic devices via internet connectivity will significantly increase (Ahmadov et al., 2025).

Wireless Communication Technology Group. It is well known that the greatest effects expected from future communication networks are associated with the fifth generation (5G) networks. The use of 5G-based Wide Area Networks (WANs) is considered one of the key elements for the full implementation of the modern urban transport environment concept (Lin et al., 2017). They belong to the main group of wireless communication technologies that will enable the operation of smart road infrastructure, intelligent transport systems, and, ultimately, driverless ground transport. Other major applications include remote monitoring of vehicles, the organization of wireless communication on high-speed trains, the operation of Vehicle-to-Everything (V2X) systems for the exchange of information about road traffic conditions from various objects, real-time collection of movement status data during operation, and the provision of all possible new services for passengers. In logistics, 5G networks also allow for the use of drones to deliver goods both to end customers and to the required logistics centers.

Wireless Local Area Network (WLAN). Currently, various types of public transport vehicles are equipped with Wi-Fi-based WLAN systems that provide passenger internet access and support the operation of auxiliary systems (video surveillance, vehicle monitoring, regular system updates, etc.). In the future, with the implementation of smart city strategies and the expansion of passenger service options, the use of WLAN networks is expected to increase.

RFID Tag Technology. Personal Area Networks (PAN) and RFID (HF- and UHF-based Radio-Frequency Identification) tag technologies is now sufficiently mature and are widely used in transport infrastructure facilities (e.g., access control and management systems for monitoring logistics processes). In the future, in order to optimize prospective costs, automation of trade and logistics processes will be possible on the basis of cargo tagging.

DHL and Smart Warehouse Technologies. DHL, one of the global leaders in express postal and logistics services, established in the USA in 1969, is currently implementing the "Smart Warehouse" concept using RFID technology and Warehouse Management Systems (WMS). One of DHL's Singapore-based hubs can track the location of every item in the warehouse in real time through RFID. The advantages created by these technologies include:

- reducing shipment errors by up to 60%;
- eliminating stock losses and shortages;
- preparing orders faster and improving customer satisfaction.

Satellite Communication Technologies (SCT). Currently, satellite technologies are used to provide access to communication networks in remote regions and areas with difficult natural and climatic conditions.

Group "Virtual and Augmented Reality (VR/AR) Technologies" (Developer Content Creation Tools and UX Enhancement Technologies). At present, the level of use of content creation tools (VR/AR) and user experience (UX) enhancement technologies in the transport sector remains relatively low, partly due to the immaturity of some of these technologies. In the future, with the growing demand for more functional solutions, particularly in the training of personnel in the skills required for managing various modes of transport, such solutions will be increasingly used, especially in the aviation sector for pilot training and for preparing personnel involved in flight safety.

Demand-Responsive Technology. The implementation of this technology will make it possible to significantly improve the quality of transport management in the field of infrastructure facility design. It can also operate as part of driver assistance systems used to assess road conditions and make decisions in real time.

Motion Capture Technologies in VR/AR and Photogrammetry. Currently, the implementation of VR/AR technology is at an initial stage. In the future, it may be used, along with other technologies, to create simulators and augmented reality applications that allow the development of skills for operating various transport modes and special equipment. Photogrammetry and object recognition algorithms can also be used for the automated construction of spatial models of objects from photographs. By enabling motion capture within VR/AR systems, as well as using photogrammetry technologies, it becomes possible to identify the characteristics of moving objects, thereby improving road traffic safety. Their application is also possible in navigation solutions based on augmented reality and in the technical service sectors of modern logistics centers.

Graphic Output Technologies. Currently, solutions based on this technology for the transport sector are characterized by insufficient functionality. In the future, as the functionality of this field expands, the use of such technologies will naturally increase. This is particularly related to the provision of visual tracking through headset devices when applying VR/AR technologies to prevent hazardous situations on the road. These glasses, used to enhance the realism of three-dimensional object representation, are intended for training drivers and pilots using interactive devices.

VR/AR Data Transfer Optimization Technologies. At present, solutions based on this technology for the transport sector are also characterized by insufficient functionality. In the future, as the functionality of this technology expands, it can be used to improve the accuracy of determining the coordinates of unmanned vehicles during VR/AR data transfer optimization processes.

Feedback Interfaces and Sensors for VR/AR. This technology is also at an early stage of application. In the future, along with other technologies, it may be used to create simulators and augmented reality applications that make it possible to train skills in operating various types of transport and special equipment. The 6D platform interface, acting as a main feedback element, can be applied in multi-channel communication systems for the higher-level training of drivers of motor vehicles and pilots in air transport, as well as for collecting feedback from drivers.

Demand-Responsive Technology. This technology is applied in the Arctic zone and sparsely populated areas. Due to the specific features of maritime transport, satellite communications are used more frequently. They are widely applied to monitor and determine the location of cargo (e.g., containers). Satellite communication systems (GLONASS, GALILEO, GPS) have broad application areas in vehicle navigation, data transmission within vehicles, monitoring the transport of hazardous and special cargo, ensuring the safety of train movements, and monitoring the condition of railway infrastructure facilities. In the future, the expansion of these technologies will be of crucial importance for the implementation of large-scale transport route projects.

Mobility-as-a-Service (MaaS) System. This technology is planned to be implemented in Moscow, aiming to develop flexible transport systems and reduce negative environmental impact by aligning demand and supply for transport services. This concept provides an integrated service that includes direct access to transport system services, real-time travel conditions, and the ability to plan and predict transfers in advance. Currently, various types of transport and logistics infrastructure facilities not only have the ability to generate significant volumes of data but also pose requirements for its rapid reception and processing. Naturally, in order to derive valuable insights from this data, the use of modern automated processing tools and technologies is considered essential. Such technologies must address the collection, recording, storage, analysis, and visualization of data, as well as the automated processing of shipping documents. In this regard, solutions for passenger communication within the development of MaaS are expected to become increasingly popular.

The "Free Flow" Concept Developed in the Russian Federation. This new technology represents an advanced solution not only for Russia but also globally. Using various devices and cameras, it monitors and analyzes traffic conditions, weather, and the state of the road surface. Based on this data, the actual cost of using a certain section of toll road is determined, and invoices are generated for payment (Avtodor, 2021; Korolkov, 2021; Mohammad, 2020).

Robotaxi in Guangzhou (China) and the MaaS Platform Implemented in Moscow. It is known that personalized robotaxis are currently being tested in Guangzhou, China. In addition, based on the MaaS concept developed in the Russian Federation, it is possible to order a personalized service and receive information about travel scenarios via the "Moscow Transport" mobile application. Furthermore, users can access other important functions, such as determining which bus stop they will reach within a 500-meter radius and at what time.

Shared Mobility System. This system is based on the joint use of various modes of transport instead of private cars. It includes mobile services where passengers share the same vehicle (e.g., taxis, minibuses) operated by a driver, as well as shared use of personal mobility devices (bicycles, motorcycles, scooters) with other individuals. Such integration of movement and the multimodal form of travel allows for seamless transfer from one mode of transport to another.

5PL (Fifth-Party Logistics) Provider System. This system represents an approach to providing logistics services that forms an ecosystem delivering a complete package of transport and logistics services based on platform solutions without possessing physical assets (Murmann, 2025).

Technology Change-on-Demand Systems. Technology change-on-demand systems are applied in the digitalization of transport logistics when implementing innovations such as voice assistants for interactive maps (authentication), transport dispatching services, interaction with various transport units, and similar features. These innovations can also be used when reorganizing the operation of service centers based on citizens' requests, including during emergencies or road traffic incidents. For example, in air transport, the future development of this technology may facilitate the acceleration of passenger voice authentication implementation.

Recommendation and Intelligent Decision-Support Systems. These systems stimulate interest in recommendation-generating solutions in response to the increasing freight turnover associated with urbanization and transport infrastructure development. For instance, such a concept is widely used to determine the need for vehicle repairs with the help of predictive maintenance systems.

Decision-Support Systems. Decision-support systems can improve the efficiency of several intra-organizational processes, including human resource management and the hiring of new employees. It is well known that there is currently a growing demand for personalized recommendation systems that use intelligent mapping to build optimal routes for passengers. The scope of decision-support application will expand further with the transition to multimodal transportation, which will take into account many interrelated factors, enabling the construction of the most optimal routes for all participants and ensuring the efficient operation of transport networks.

Technology Change Systems Adapted to Demand. Demand-adapted technology change systems support the provision of intelligent assistance for vehicle maintenance, transportation process management, and the creation of platforms for transport and logistics hubs. The primary task in this area is to ensure the integration of all elements and subsystems into a fully cyclical control system.

“Living Laboratory” Concept for Driverless Transport in Germany. In Germany, a digital testbed has been launched on the A9 federal highway in the format of a “living laboratory” (Digital Motorway Test Bed) to test digital technologies under real conditions. For this purpose, favorable technical conditions have been created on a specific road section to support intelligent infrastructure and autonomous driving, allowing tests to be conducted in both directions simultaneously (Follmer & Gruschwitz, 2017).

Technology Change-on-Demand. Quantum Computing: Quantum computing solutions are currently in the development stage. Promising areas for this technology include modeling and forecasting the development parameters of various modes of transport, taking into account regional characteristics, natural and climatic conditions, and other requirements.

Quantum Sensor Solutions: Solutions based on quantum communications are also under development. In the future, quantum sensors may be used to improve the navigation systems of vehicles in order to optimize traffic flow. In maritime transport, quantum sensors can enhance the performance of mapping systems under conditions where access to other devices and communication networks is limited. This technology is expected to see wider application in the operation of autonomous (driverless) transport.

Digital Design, Mathematical Modeling, and Product Lifecycle Management (Smart Design): At present, information modeling tools such as digital design, mathematical modeling, and product lifecycle management (smart design) are widely applied in the planning of railway and road networks as well as infrastructure facilities. The expansion of digital design usage will facilitate the implementation of large-scale projects for the construction of new surface transport routes. Demand for such systems will also drive the development of smart road surfaces designed for autonomous vehicles.

Technology Change-on-Demand: Neurotechnology and Artificial Intelligence Group: Computer vision is the main artificial intelligence technology actively used in the transport sector. Through various tracking devices that generate computer-based images, it enables the capture and analysis of three-dimensional data on operational conditions adapted to the external environment, including other vehicles, road surfaces, traffic lights, and similar elements.

Robotics Components and Sensors Group: Given the specific safety requirements that arise from interactions between autonomous vehicles and humans, sensors and other digital components from this group can be applied to address these challenges. In the future, the growing demand for such technologies will mainly be driven by the need to automate transport management processes to ensure the population’s mobility needs are met.

Neurointerfaces, Neurostimulation, and Neurosensation in Transport: Neurointerfaces are used to solve a number of small but critical tasks. In the future, vehicles with integrated neural interfaces (“neurocars”) will facilitate easier control by human operators.

Technology Change-on-Demand: It is undeniable that devices enabling the collection of data on road traffic flow, road service operations, traffic violations (photo and video evidence), emission control, and other operational parameters play a crucial role in improving transport efficiency and road safety. Currently, there is already a sufficient number of emerging technologies in this field. However, with the implementation of large-scale autonomous transport projects, the demand for more sensitive computer vision systems will continue to grow.

Speech Recognition and Synthesis:

In transport operations and logistics processes, solutions based on speech recognition and synthesis are primarily used for the automatic analysis of voice messages, enabling the identification of their content and emotional components.

Platform Solutions for Users: Currently, individual projects are being developed to create platform solutions for users. In the future, the demand for advanced VR/AR technologies will increase to enable 3D modeling of transport systems, as well as forecasting traffic conditions and transport flows.

Technology Change-on-Demand: LPWAN (Low-Power Wide-Area Network) Technologies: LPWAN technologies provide wireless access for a wide range of telemetry and Internet of Things (IoT) applications in transport. They enable the transmission of data over long distances with low power consumption and are used for remote monitoring and control of vehicles, transport infrastructure facilities, and cargo. In the future, the use of LPWAN will grow as tasks are implemented to create a unified information and telecommunication environment capable of monitoring virtually all parameters of the integrated transport ecosystem.

2.2. Problem Solution

According to data from information networks, in 2020 the demand for advanced digital technologies in the transport and logistics sector of the Russian Federation was estimated at 89.4 billion rubles based on expert survey results conducted by the Center for Statistics Research and Knowledge Economy (CEMI RAS). By 2030, this figure is projected to increase sevenfold, reaching 626.6 billion rubles (Fig. 1).

Research findings indicate that, at present, the most "digitalized" segment of the transport sector is air transport. The introduction of digital technologies in this field has been regarded as a tool even for mitigating the negative consequences of the COVID-19 crisis. Leading airlines use a wide range of digital technologies both on the ground and in the air, including cloud technologies, wireless services for crews, and automated data management systems (Əhmədov et al., 2025). Currently, PJSC Aeroflot ranks fourth globally among air carriers in terms of digitalization level.

One of the modern trends in airport digitalization is the application of biometric identification during security checks. Such initiatives are already widely implemented in the world's largest airports, including those in Germany, the United States, and the United Kingdom. In the Russian Federation, the introduction of biometric identification and authentication technologies in the largest airports is planned for the near future, with the service expected to be based on the Unified Biometric System, which has been operational since 2018.

In the field of passenger air transport, Unmanned Aerial Vehicles (UAVs) are already undergoing trials. However, according to surveys conducted in several developed countries, 58% of passengers report that they are still not ready to fly on planes controlled by artificial intelligence. According to internet data, by 2026, the number of drones used for cargo delivery worldwide is expected to exceed 1 million, compared to the current figure of approximately 20,000 (Ahmedov & Akhundov, 2025).

It is widely recognized that during the military operations conducted in the region, modern remotely operated Unmanned Aerial Vehicles (UAVs) manufactured by Turkey and Israel were used for the first time as active components of military equipment. This development represented a significant milestone in contemporary warfare, marking the first successful large-scale operational deployment of such technologies in real combat conditions.

At present, serious measures are being taken in the Republic of Azerbaijan for the development and application of digital technologies. Extensive research activities in this field are being conducted at the Azerbaijan Technical University and the National Aviation Academy. According to recent information published in digital platforms, the national defense industry of Azerbaijan has also begun the production of new UAVs that meet modern operational and technological standards.

As previously mentioned, the use of UAVs allows for the fulfillment of a wide range of tasks; however, their economic feasibility must be validated through objective quantitative indicators. In this regard, the following formula (1) can be used to evaluate economic efficiency (Kotenko, 2010):

$$E = R/C \tag{1}$$

where,

(E) – indicator of economic efficiency;

(R) – achieved result (income, savings, or prevented losses expressed in monetary units);

(C) – total capital investment, including operational costs, maintenance expenses, and personnel training.

If (E > 1), this indicates that the use of UAVs generates more benefits than costs, thus being economically justified. When (E = 1), the project is considered break-even, and when (E < 1), it is deemed economically inefficient.

Additional indicators such as Net Present Value (NPV) and Investment Profitability Index can also be applied for comprehensive assessment of UAV efficiency. Since NPV reflects the difference between discounted revenues and expenditures, it serves as a primary criterion for investment effectiveness and is determined as follows formula (2) (Rezer & Gavrilyuk, 2012):

$$X = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+r)^t} \tag{2}$$

where,

(X) – net present value;

(Rt) – expected income or savings from UAV implementation in year t (e.g., savings on fuel, maintenance costs, downtime, etc.);

(Ct) – corresponding costs in the same period;

(r) – discount rate;

(n) – project implementation period.

If (X > 0), the project is considered economically viable, as its current value of benefits exceeds costs.

If (X < 0), the project is inefficient, implying the need to reduce capital expenditures or extend the payback period, which would necessitate revising its parameters.

Another key criterion for evaluating the economic efficiency of UAV application is the Return on Investment (ROI) coefficient. This indicator reflects the project's profitability level and represents the percentage of profit earned per unit of capital invested (3) (Sveshnikova & Nemchinov, 2023):

$$R = \frac{P-I}{I} \times 100\% \tag{3}$$

where

(R) – return on investment;

(P) – total project revenue, including profit, cost savings, productivity growth, and reduction of losses;

(I) – initial investment or capital expenditure.

If (R > 0), the project is considered profitable; otherwise ((R < 0)), the investment results in losses.

A positive ROI contributes to solving the following analytical and practical tasks:

1. Comparative evaluation of different UAV application models in areas such as monitoring, safety, logistics, and emergency management;

2. Assessment of investment returns both at the national and regional levels;

3. Development of a solid foundation for attracting private and public investments into intelligent transport systems.

It should be noted that several countries have already conducted similar economic assessments regarding UAV implementation in their transportation systems. For instance, according to the report of the Department of Infrastructure, Transport, and Regional Development of Australia, the use of UAVs in transport logistics, infrastructure monitoring, and environmental control has generated significant macroeconomic benefits (fig. 1).

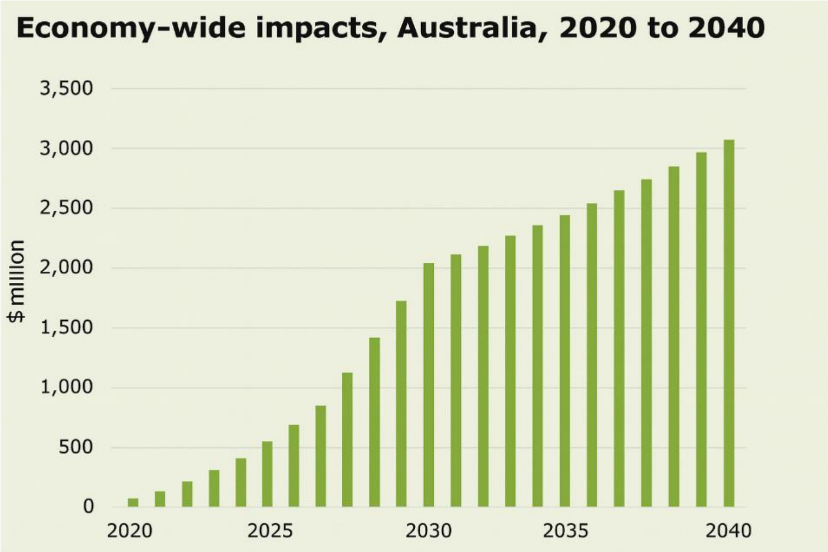

Fig. 1. The impact of UAV adoption on Australia's economy from 2020 to 2040 (Department of Infrastructure, Transport, Regional Development and Communications of Australia, 2020).

According to the analysis, the cumulative increase in Gross Domestic Product (GDP) for 2020–2040 is estimated at AUD 14.5 billion (≈ USD 9.5 billion) at a 7% discount rate. Moreover, direct savings related to reduced monitoring, maintenance, and labor costs amount to approximately AUD 9.3 billion (≈ USD 6.1 billion) (Department of Infrastructure, Transport, Regional Development, and Communications, 2020).

Beyond direct financial impact, the widespread use of unmanned technologies positively influences the labor market. Experts estimate that the development of the drone sector in Australia will create an average of 5,500 full-time equivalent (FTE) jobs annually. The eastern states-Sydney, Melbourne, and Brisbane-as well as Western Australia, where mining and transport infrastructure are actively developing, are expected to contribute most significantly to this overall economic growth (Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 2023).

Similar trends are also observed across the European Union. According to the European Union Aviation Safety Agency (EASA), the integration of UAVs into transport monitoring and logistics systems could reduce overall transport costs by 15–20% through automated inspections and real-time monitoring of bridges, tunnels, and roads (EASA, 2024).

Furthermore, the use of unmanned technologies improves the accuracy and efficiency of infrastructure monitoring, reducing the number of unplanned repairs, accidents, and transportation delays. This directly strengthens the economic sustainability of transport systems by minimizing unforeseen expenses and enhancing the transparency of logistics operations.

Therefore, conducting similar comparative research by relevant institutions in Azerbaijan would create opportunities for achieving more positive outcomes. In this regard, young researchers at the National Aviation Academy and the Azerbaijan Technical University are currently engaged in active scientific research aimed at developing safety systems for railway operations and monitoring within international transport corridors such as TRACECA and Zangezur, as well as optimizing cargo handling technologies in intermodal transport processes at the Baku International Sea Trade Port terminal-logistics complex.

In the future, once the North-South and Zangezur Corridors become fully operational, new research initiatives will continue to focus on the implementation of intelligent technologies in transport operations and logistics management processes.

It is known that the development of (UAVs) currently prioritizes their remote regulatory management. The top five countries with the most favorable regulations for the operation of driverless cars are Singapore, the United Kingdom, New Zealand, Finland, and the Netherlands (European Commission, 2019). Although Russia currently ranks relatively modestly (22nd place) in this field, in recent years the state has introduced several initiatives aimed at accelerating the development of a legislative framework for the use of unmanned transport. Specifically, preparations for testing such technologies and experimental research on public roads have been carried out. In terms of readiness for autonomous vehicle deployment, Singapore, the Netherlands, Norway, the USA, and Finland hold leading positions. Among the 30 countries evaluated in recent years, Russia ranks 26th, reflecting a relatively low level of implementation of advanced solutions in this area.

It is expected that, once a modern digital infrastructure network meeting contemporary standards is established in our country, the operation of autonomously controlled vehicles will commence.

In the maritime transport sector, Russia is also among the countries testing autonomous ships. Norway has been a leader in such trials since 2017. Further impetus has been provided by the International Maritime Organization’s 2019 guidelines on testing autonomous vessels. At present, these systems are tested only in experimental conditions. One of the world’s first fully autonomous vessels, the Yara Birkeland, had its 2020 trials postponed due to the COVID-19 pandemic.

Azerbaijan's digital transformation in the transport and logistics sector has become a cornerstone of its economic and technological development strategy. The "Digital Azerbaijan 2030" initiative, launched in 2024, aims to integrate advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and Big Data across various sectors, including transportation and logistics.

Strategic infrastructure projects like the Zangezur Corridor, the Trans-Caspian International Transport Route (TITR), and the Baku–Tbilisi–Kars railway are pivotal in enhancing regional connectivity. These corridors facilitate multimodal transportation, linking Azerbaijan to Europe and Asia, and are increasingly supported by digital solutions. Technologies such as GPS/GIS tracking, sensor networks, smart routing systems, and cloud-based logistics platforms are being implemented to improve cargo flow coordination, security monitoring, and operational efficiency (Ministry of Digital Development and Transport of the Republic of Azerbaijan, 2025).

At the Baku International Sea Trade Port, the "Smart Port Baku" concept exemplifies the application of digital technologies in port operations. The port utilizes RFID tags, IoT devices, and Big Data analytics to monitor cargo movements in real-time, optimizing port operations and minimizing delays (DHL, 2024).

The adoption of AI-driven management technologies has significantly enhanced the safety, energy efficiency, and sustainability of transportation processes. Predictive analytics, risk assessment models, autonomous control systems, and voice authentication technologies are now integral in planning and executing transportation operations across various modes, including air, sea, rail, and road.

Furthermore, the integration of intelligent transport systems (ITS) has improved transparency and coordination across different transport modes. These systems enable seamless multimodal transportation, promote eco-friendly mobility, and facilitate the management of digital services through unified platforms.

In summary, Azerbaijan's commitment to digitalizing its transport and logistics sector not only drives technological innovation but also strengthens its position in global trade networks. The country's strategic initiatives and infrastructure developments are poised to enhance its competitiveness and contribute to sustainable economic growth.

In 2020, the Russian Maritime Register of Shipping approved a set of technical measures for automatic navigation to create a regulatory framework for testing unmanned vessels. As part of this experiment, certain vessels under the Russian flag were permitted to use autonomous navigation systems until 2025. According to the latest information, specialists in this field currently favor a hybrid approach, combining traditional and new ship management systems. In this regard, in the Azerbaijan sector of the Caspian Sea, unmanned autonomous SALVO-type light vessels are already in use, equipped for combating drug trafficking, ensuring security, and protecting the sea’s resources (fig. 2).

In recent years, significant achievements have also been made in rail transport in unmanned operation. The first autonomous metro trains were deployed in Kobe, Japan, in 1981, and today such technologies account for approximately 7% of metro networks worldwide. Unlike closed underground lines, the operation of fully autonomous trains in open areas for urban and intercity connections remains in the experimental stage. Major companies such as Deutsche Bahn and SNCF have announced that semi-autonomous and fully autonomous trains will be deployed within the next few years. In 2020, China began operating the world's fastest autonomous high-speed train, capable of reaching 350 km/h (Aliyev et al., 2021).

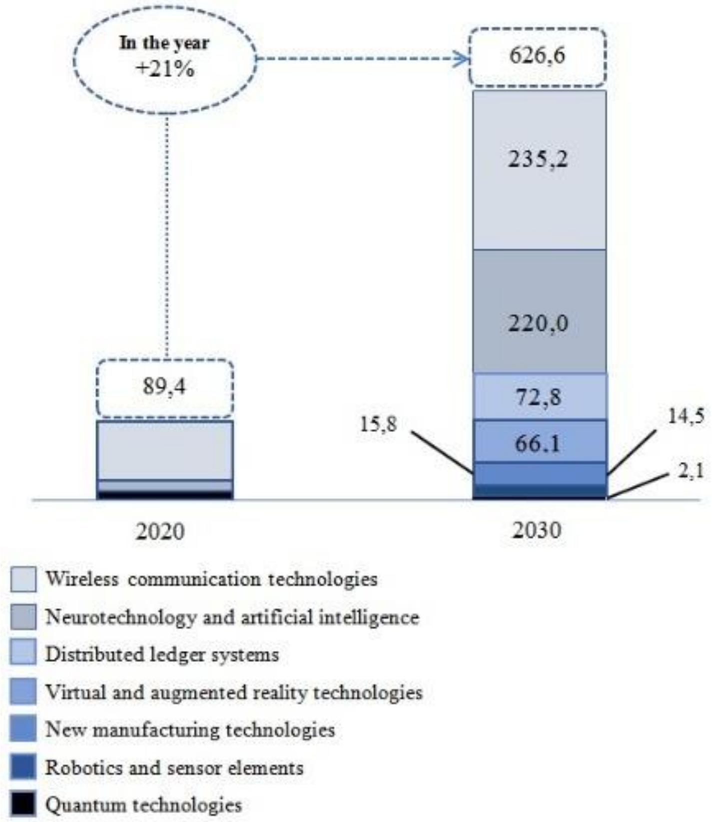

Fig. 2. Potential demand for advanced digital technologies in transport and logistics in 2020-2030, billion rubles (Institute for Statistical Research and Knowledge Economy (ISSEK), 2020)

In the recent past, certain initiatives have been undertaken in the Republic of Azerbaijan to establish networks for such modern high-speed trains (Əhmədov, 2014; Ahmedov, 2014; Ahmadov et al., 2022). Presumably, in order to meet the transportation demand of the population, the operation of autonomous high-speed trains is expected to commence in the future once a suitable railway network is constructed. These trains would provide a convenient and efficient mode of transport, while also being relatively safer in terms of operational and environmental security.

The expansion of shared mobility services (i.e., small-capacity vehicles used alongside other transport modes) into rural areas, in addition to large cities, offers several advantages in terms of enhancing population mobility. Although there are conflicting views regarding the full integration of such shared transport services into a unified urban and regional transport system, the improvement of road infrastructure across all regions makes the implementation of these technologies feasible (Postranskyy & Vovk, 2020). Nevertheless, the COVID-19 pandemic and related restrictions temporarily affected public attitudes toward shared services, particularly in major cities. Currently, in a period of rapid population growth and increasing transport demand, the broad deployment of such prospective technologies remains highly relevant.

3. Results and Discussion

The integration of Artificial Intelligence (AI) and digital technologies into Azerbaijan's transport and logistics systems has evolved from a technological modernization effort to a central component of economic and social transformation. Enhancing the efficiency of modern transport networks, improving service quality, and optimizing resources have become strategic imperatives.

Comparative analyses of Azerbaijan and regional countries indicate a direct positive correlation between the level of digitalization and logistics efficiency. According to the World Bank's 2023 Logistics Performance Index (LPI), the application of digital technologies has led to an average 15–20% improvement in logistics service quality and a 25–30% increase in the agility of transport processes. In Azerbaijan, the rise in digitalization indicators over the past five years has contributed to an increase in the transport sector's share of GDP and a growth in transit cargo volume to over 40 million tons (World Bank, 2023).

One of the most significant components of the digitalization process is the implementation of Intelligent Transport Systems (ITS). Through ITS technologies, real-time route optimization, congestion management, reduced energy consumption, and enhanced safety levels are achieved. In Baku, the "Smart City Transport" program has expanded the capabilities of transport monitoring systems, incorporating AI algorithms for voice control, automatic event detection, and video analytics.

The social and ecological impacts of digitalization are also noteworthy. Extending the operational lifespan of vehicles, reducing fuel consumption, and decreasing carbon emissions demonstrate that AI-based transport models facilitate operations aligned with "green logistics" principles. Azerbaijan plans to double the number of pilot projects for smart logistics centers and energy-efficient transportation models by 2025, directly contributing to the development of the country's ecological transport policy.

The application of AI technologies also enhances the reliability of services. For instance, intelligent maintenance scheduling and predictive technical service systems have reduced the risk of vehicle breakdowns by up to 30% and optimized operating costs by an average of 12–15%. This not only confirms the technical effectiveness but also the economic efficiency of digitalization (fig. 3).

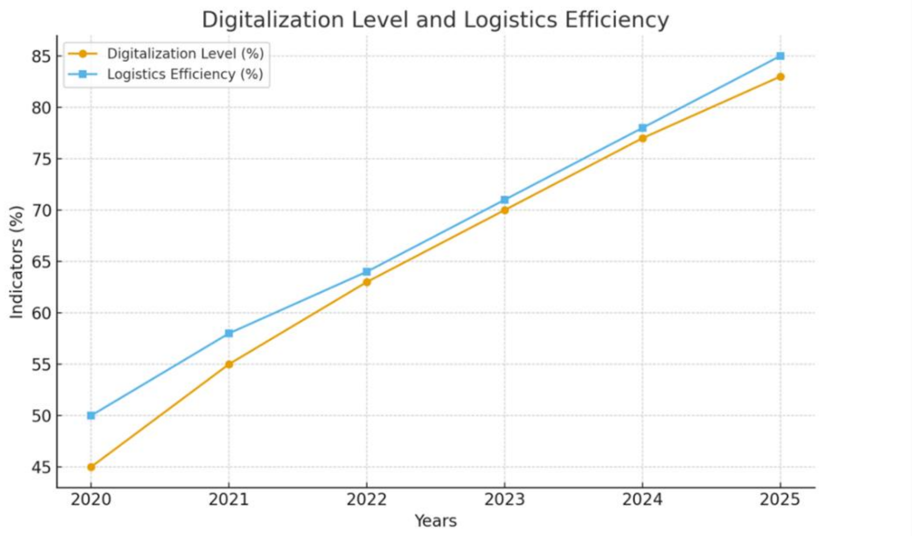

Fig. 3. The impact of the level of application of digital technologies on logistics efficiency (Azerbaijani example) (Source: Authors' own work)

Comparative analyses show that countries like Turkey, Kazakhstan, and the United Arab Emirates have implemented AI-based logistics systems with development dynamics parallel to Azerbaijan's. Specifically, the digitalization of the Zangezur and Trans-Caspian corridors facilitates the integration of multimodal coordination and data exchange platforms among these countries.

For the further digital development of the transport and logistics system, the following measures are deemed appropriate:

- **Integration with international digital platforms:** Establishing a unified information database for regional transport corridors.
- **AI-based forecasting models:** Planning cargo flows, early detection of risks in air and sea transport.
- **Strengthening human resource potential:** Teaching AI and digital logistics modules in transport engineering specialties.

- **Updating the legal and regulatory framework:** Regulating digital document circulation, drone control, and the legal status of autonomous vehicles.
- **Sustainable and ecological transport infrastructure:** Promoting green energy and alternative fuel technologies.

As a result, the integration of digitalization and AI into transport systems not only ensures technological modernization but also enhances service efficiency, safety, and social welfare. Thus, digital transformation in the transport and logistics sector serves as a key driver of Azerbaijan's economic development and the optimization of regional transit connections (Crudu & MoldStud Research Team, 2025).

4. Conclusions

In the present context of rapidly growing population and increasing transport demand, the broad deployment of such prospective technologies is of paramount relevance. In this regard, digitalization and artificial intelligence in the transport sector represent not only technological advancement but also bring about significant social welfare improvements. The implementation of these measures has a high-quality impact on citizens' daily lives and simultaneously contributes to the achievement of sustainable economic development goals.

Research findings demonstrate that the integration of Artificial Intelligence (AI) and digital technologies into transport-logistics systems plays a fundamental role in enhancing efficiency, improving service quality, and optimising resource management. This digital transformation extends beyond mere technological modernisation to strengthen social, economic and environmental sustainability.

Key findings:

1. Digitalisation and efficiency linkage: The application of digital technologies in transport systems increases operational efficiency by approximately 20–30 %, while logistics costs are reduced by around 15 %. This improves both infrastructure utilisation and service quality.
2. Impact of AI-based management systems: AI technologies (predictive analytics, routing optimisation, automated decision support) enable more agile planning of shipments, better risk management and compliance with safety indicators.
3. Regional significance of digital integration: Digital ecosystems created under projects such as the Zangezur Corridor, the Trans-Caspian International Transport Route and the Baku–Tbilisi–Kars railway accelerate Azerbaijan's emergence as an international logistics hub. This integration strengthens coordination of both intra-regional and trans-continental transport links.
4. Ecological and social outcomes: Digital transport systems enhance energy efficiency, reduce emissions and facilitate the application of "green logistics" principles. This not only minimises the environmental impact of transport but also improves urban mobility and the quality of life for the population.
5. Change in management and decision-making culture: The integration of information technologies has shifted transport management toward a data-driven decision-making model, enabling rapid coordination, transparency in reporting and novel approaches to innovation.

Future research and development directions:

- Quantum computing and neuro-technologies: Should be explored as prospective means for high-precision modelling of transport flows and real-time optimisation of decisions.
- Model for unmanned/ autonomous transport vehicles: It is important to develop local frameworks addressing legal, technological and safety aspects of autonomous systems.
- Integration of digital ecosystems: International cooperation should be expanded in order to increase the effectiveness of data-exchange hubs across regional countries.
- Human resource development: Training specialists in AI, data analytics and logistics technologies is a key condition for future success.

In conclusion, this research proves that the integration of AI and digital technologies into transport-logistics systems offers Azerbaijan not only technological renewal, but also strategic advantages in terms of economic sustainability, social welfare and regional leadership.

Abbreviations

5G : Fifth generation

WANs : Wide Area Networks

V2X : Vehicle-to-Everything

WLAN : Wireless Local Area Network

PAN : Personal Area Networks

RFID : Radio-Frequency Identification

WMS : Warehouse Management Systems

SCT : Satellite Communication Technologies

VR/AR : Virtual and Augmented Reality

UX : User experience

MaaS : Mobility-as-a-Service

5PL : Fifth-Party Logistics

UAVs : Unmanned Aerial Vehicles

DWT : Dead Weight Tonnage

IEA : International Energy Agency

IMO : International Maritime Organization

IP : Improvement Potential

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