
CHAPTER 5

Innovative technologies and digital models in the post-war recovery of the transport and logistics system of Ukraine

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Abstract

The presented monographic study is devoted to the study of the role and significance of innovative digital technologies in the post-war recovery of Ukraine's transport and logistics system. It is noted that large-scale destruction in the transport and logistics sector as a result of the war requires not just restoration, but substantial modernization, the foundation of which must be laid on modern digital solutions and technologies. In the scientific work of the authors, morphogenesis, assessment of the current state of the transport and logistics system, as well as the corresponding infrastructure of Ukraine, has been carried out. An in-depth analysis of the prerequisites for digitalization has been conducted – including the aspiration for integration with the EU and global technological trends – and an assessment of the current level of digital development of the national transport and logistics sector is given. The work presents a comparison of Ukraine's positions in international rankings of transport and logistics digitalization with global and regional leaders. The best global practices (Europe, USA, China, etc.) regarding the implementation of digital technologies – from IoT and Big Data to unmanned systems – are considered, and the possibility of their adaptation in Ukraine is assessed. For forecasting the implementation of digital innovations, non-traditional but objective methods are used, namely Porter's Diamond Model of competitive advantages, and a simulation model of technology diffusion based on the S-curve (logistic function), which is often used in innovation theory, has been applied. As a result, practical recommendations are formulated for a "digital reboot" of Ukraine's transport and logistics system in the context of post-war recovery, consisting of a comprehensive

approach to using all the advantages of a convenient geographical location, the actually existing potential of the transport and logistics system, and the promising opportunities that open up with the implementation of advanced digital technologies.

Keywords

Post-war recovery, congruent development, transport and logistics system, digitalization, economic diagnostics, managerial decisions, forecasting, benchmarking, remediation.

5.1 Introduction

The war on the territory of Ukraine caused unprecedented destruction of transport and logistics infrastructure, which set before the country the task of its restoration in the shortest possible time [1]. After the destruction of airports (including Hostomel, Kharkiv, Mykolaiv, Zaporizhzhia) and the blockade or critical damage and disabling of key seaports (Mariupol, Berdiansk, Yuzhny, Kherson), logistics is effectively paralyzed. The destruction of more than 80 sea and river vessels, as well as dozens of airplanes and helicopters, has further aggravated the situation. The railway sector, remaining critically important for military transportation and evacuation, has suffered massive destruction: more than 120 stations and terminals have been damaged, locomotive depots destroyed, and thousands of wagons and locomotives disabled. The total cost of damage to the railway sector reaches 6.5 billion USD, not including hidden costs of logistical delays. Thus, by total losses, Ukraine's transport and logistics system has lost over 56 billion USD, which requires a systemic strategy of remediation, modernization, and re-equipment of all types of transport [2, 3].

All these facts indicate that post-war recovery to the level of "as it was" will be insufficient, as qualitative modernization of the country's transport and logistics system (TLS) is critically needed, taking into account modern technologies and global development trends. It should be acknowledged that the war simultaneously accelerated a number of processes. First, the need to increase the resilience and efficiency of logistics in crisis conditions has intensified. Second, Ukraine's integration aspirations into the European space have become more active, which requires large-scale alignment of transport and logistics with European standards. In particular, Ukraine must implement the norms of the *acquis communautaire* in the transport sector, integrate into the TEN-T network, and ensure long-term connectivity with the transport system of Europe [4]. Third, in recent years Ukraine has established itself as a digital reformer, and this momentum must be maximally expanded and utilized. This refers primarily to the creation of the Ministry of Digital Transformation in 2020 and the launch of the "Diia" application for

the provision of public services online. In the transport and logistics sphere, an important role was played by the "Shliakh" systems (electronic permit for carriers), as well as e-TTN – electronic consignment note, the implementation of which began in 2021. These tools laid the foundation for the digitalization of logistics, and therefore, the post-war recovery must use the accumulated potential to create a sustainable, transparent, and competitive transport and logistics system with corresponding infrastructure [5].

According to the authors' conviction, the expansion and multiplication of the digitalization potential, especially in the transport and logistics sector, can become a driver of economic recovery and Ukraine's integration into international transport corridors. It can and should be understood not only as an infrastructural necessity, but also as a multifunctional accelerator of territorial recovery and revitalization of the national socio-economic system. Moreover, the domestic transport and logistics system can act as a systemic transmission mechanism of economic activity, analogous to the circulatory system of an organism, providing the connection between production potential, consumer centers, and external markets.

Taking into account Ukraine's favorable geographical position at the intersection of East-West and North-South trade routes, even under conditions of limited internal production activity and even at early stages of the recovery process, transit capacities can generate revenues for the state and local budgets. This is especially critical against the background of the shortage of public resources and the urgent need to restore overall fiscal stability. However, it should be recognized that achieving a multiplicative effect from the functioning of the transport and logistics system is possible only under the condition of its prompt restoration to a competitive level, that is, taking into account the requirements of digitalization of logistics chains and the corresponding transport infrastructure.

Thus, the digitalization of the transport and logistics system must become a strategic priority, as it is not only capable of ensuring a rapid economic return on invested resources, but can also create the prerequisites for sustainable development and effective inclusion of Ukraine into global supply chains. This thesis determines the purpose and scope of this monographic study.

5.2 Prerequisites and conditions for the development of digitalization in the transport and logistics system: theoretical, methodological, and practical aspects

One of the significant stages of successful digitalization in the post-war recovery of the transport and logistics system (TLS) is a deep and comprehensive analysis of

the prerequisites and conditions that will largely determine the realism, sustainability, and effectiveness of future development scenarios. According to the authors' conviction, it is an undeniable fact that without understanding the starting point of the current state of development and existing systemic deficits, it is impossible to construct a digital model capable of implementing not only recovery, but also transformational objectives [5, 6].

The scientific exploration conducted by the authors of the monograph made it possible to identify a number of critically important theoretical, methodological, and practical prerequisites that form the objective necessity of digitalization and simultaneously create unique "windows of opportunity" for the introduction of innovative approaches. The key among them are:

1. *The scale of destruction and the need for "congruent" recovery.* The scenario that will ultimately be selected within this study as the most optimal among all possible options is based on the concept of *congruent development* – that is, a strategic choice that is maximally aligned with the current level of available resources, institutional maturity, as well as logistical constraints and external environmental factors. The term "*congruence*" in this context is borrowed from systems theory and management, and denotes a state of structural and functional alignment between a system and its environment. This approach stands in contrast to the formal replication of foreign digital strategies that are not adapted to the realities of the post-war Ukrainian context.

It is especially important to emphasize that the scale of destruction of Ukraine's transport, logistics, and warehousing infrastructure, caused by the full-scale military aggression, is so extensive in nature and magnitude that in a number of regions, post-war recovery will proceed not through modernization, but rather through a complete rethinking and reconstruction from scratch (Fig. 5.1).



Fig. 5.1 Congruent model of digitalization of Ukraine's TLS (transport and logistics system)

This provides Ukraine with a unique opportunity – to implement the principle of build back better, with an emphasis on the introduction of digital innovations based on sustainable architecture. That is, it is not just about technical reconstruction, repair, and restoration of the structural components of the transport and logistics system, but about a complete strategic restructuring on the principles of digitalization.

The above-mentioned principle Build Back Better (BBB) fits perfectly into the strategic priorities of post-war recovery of our country. Its literal translation means "to rebuild better than it was". This principle was first formulated in 2005 after the devastating tsunami in the Indian Ocean and since then has become the basis for recovery programs after natural disasters and catastrophes of various kinds, including UN initiatives and national strategies of different countries of the world that faced the need to eliminate their consequences.

Justifying its scientific significance, it should be formulated as a principle that represents a strategic approach to recovery after emergency events of various nature and scale (including military conflicts), aimed at reducing vulnerability and increasing the resilience of the territorial socio-economic system. In the context of restoring Ukraine's transport and logistics system after the destruction caused by the consequences of military actions, the BBB principle implies not merely the restoration of the former infrastructure, but its modernization taking into account modern technologies and standards. First and foremost, this includes the integration of digital solutions, sustainable and energy-efficient technologies, as well as the improvement of institutional management mechanisms (Fig. 5.2).

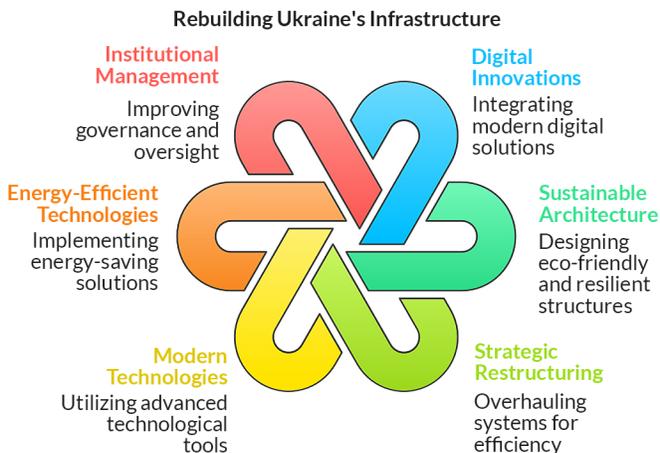


Fig. 5.2 Rebuilding Ukraine's infrastructure based on the build back better (BBB) principle

2. *The imperative of increasing efficiency and resilience: lessons from the vulnerability of transport routes and logistics chains.* Against the background of destruction caused by the war, the imperative of increasing the efficiency and resilience of logistics infrastructure becomes especially relevant. Thus, while the scale and nature of the recorded destruction form the objective necessity for a complete rethinking of infrastructure solutions (this refers to Precondition 1), the second systemic challenge is the exposure of deep-rooted weaknesses in the architecture of logistics chains, many of which existed long before the beginning of the full-scale invasion but were critically exacerbated under the current crisis conditions (Fig. 5.3).

In Fig. 5.4, two pie charts are presented, which allow for a visual assessment of how much the potential of Ukraine's transport and logistics system has decreased as a result of the war.

As is seen, the former multi-vector structure of the TLS has been distorted, which necessitates a strategic revision of national policy. Priority should be given to the restoration of key links: multimodal logistics, port recovery, warehouse modernization, as well as the relaunch and revival of the aviation sector. These steps will be critically important for economic recovery, strengthening export potential, and integration into the EU transport and logistics system.

It must be acknowledged that even before the war, Ukraine's transport sector suffered from chronic underfunding and outdated technologies, which significantly hindered economic activity. More than two-thirds of the infrastructure was morally and physically obsolete since Soviet times. In this regard, along with the renewal of the vehicle fleet and infrastructure facilities, digitalization is considered a chance to eliminate weak points: IoT solutions and sensors will allow real-time tracking of cargo and transport, identifying delays; Big Data and analytical platforms – to optimize routes and vehicle load; predictive analytics systems – to prevent breakdowns and minimize delays. It is an undeniable fact that digital technologies can significantly increase logistics efficiency, reduce fuel and time losses, which is critical for rapid economic recovery.

Moreover, it must be noted that Ukraine's digital infrastructure proved to be a rather resilient and stable structure during the war. All of the above strengthens the argument in favor of maximum digitalization of transport and logistics processes in the near future.

The link between efficiency and resilience becomes a determining factor in choosing the direction of digitalization. In this context, digitalization is no longer seen as a technological option but as a systemic tool for risk management, increased flexibility, and ensuring long-term logistics stability.

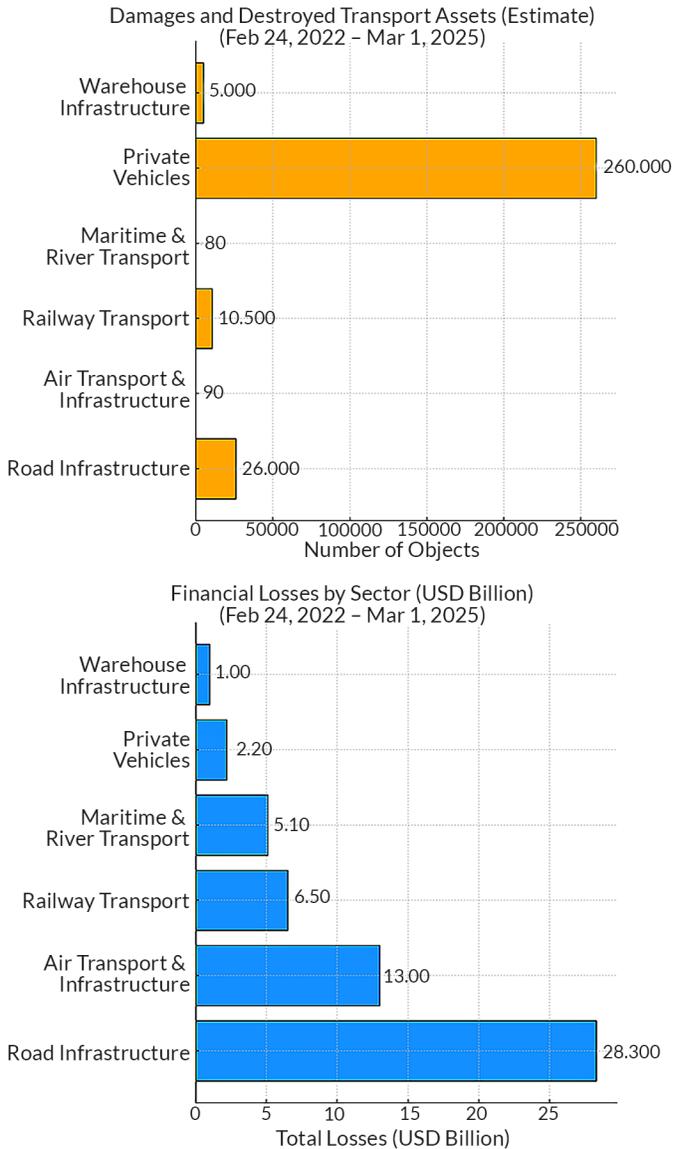


Fig. 5.3 Generalized assessment of damage and destruction to Ukraine's TLS caused by military activity

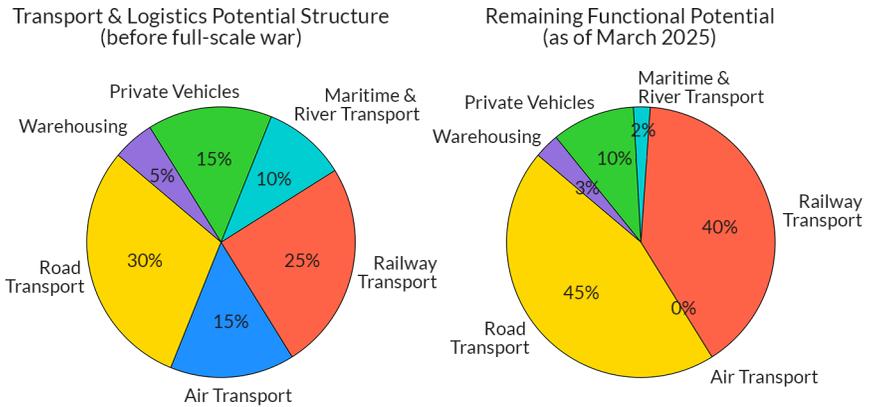


Fig. 5.4 Generalized structure of Ukraine's TLS before military actions and at present

3. *Vector of EU integration and regulatory incentives.* As previously mentioned, the development vector toward EU membership creates a strong impetus for digital transformation. The point is that, in this context, Ukraine is obliged to implement European standards in transport and logistics, many of which are linked to digitalization. For example, starting in 2025, the EU Regulation 2020/1056 on electronic freight transport information (eFTI) comes into force, requiring EU Member States to accept electronic transport documents and data. Ukraine, aiming to integrate into the single market, must harmonize its digital systems with neighboring countries – in particular, to implement electronic consignment notes (e-CMR/e-CN) and unified digital customs solutions compatible with European ones [4]. In the context of the above, it is already strategically important to pay special attention to optimizing the functioning of digital services at border crossings, including automation of passage, synchronization of data with customs services of other countries, and so on.

The published National Transport Development Strategy until 2030, updated by the government, reflects the priority of digital transformation of logistics as one of the key goals of recovery [7]. Thus, within the framework of alignment with the EU, roadmaps are being developed that include digitalization as a necessary condition for integration (including data exchange on cargo flows, compatible information systems, etc.). As is seen, the legal framework is gradually being brought in line with the requirements set by the European Union, and all this creates institutional prerequisites for the successful digitalization of the sector.

4. *The presence of strong domestic IT potential in Ukraine and society's readiness for digitalization.* The Ukrainian IT sector is one of the most developed in Eastern Europe.

The total number of IT specialists in Ukraine is estimated at 346,200 people working in 2,150 companies [8]. Significant domestic IT potential is confirmed by the fact that Ukraine ranks first in Europe in the number of developers [9]. In March 2025, IT service exports reached 598 million USD, which is 15% more than in March 2022 [10].

Ukrainian society also demonstrates a high level of readiness for digitalization, which is confirmed by the following key indicators. At the beginning of 2023, there were 28.57 million internet users in Ukraine, which accounts for 79.2% of the total population [11]. Around 78% of Ukrainians use the internet daily, and 55% of citizens used at least one electronic government service over the past year, for example, through the "Diia" application [12]. It should be noted that the "Diia" platform. Digital Education" helped almost 2 million Ukrainians improve their level of digital literacy. According to published data, Ukraine ranked 5th in the level of development of digital public services and 1st in the E-Participation indicator, which reflects citizens' readiness to participate in government processes through online platforms [13].

Thus, the digitalization of Ukraine's transport and logistics system is unfolding not only as a forced adaptation to destruction, but also as a reflection of a broader convergence dynamic. In essence, a unique point of intersection is forming – a convergence between challenges and opportunities: the destroyed infrastructure requires not just restoration, but the implementation of innovative models, while the level of digital maturity of the population, the availability of IT professionals, and political support create a favorable environment for a "leapfrogging" renewal. This situation fully corresponds to the logic of technological convergence, within which post-crisis societies can adopt and implement advanced solutions more rapidly, bypassing lengthy stages of evolutionary buildup.

The application of convergence theory in this study, according to the authors, makes it possible to more deeply interpret the uniqueness of the current historical moment. This theory explains why Ukraine, despite large-scale destruction and systemic challenges, possesses real potential for accelerated digital development and convergence with advanced models of logistics and infrastructure modernization (Fig. 5.5).

Convergence in this context is understood as a strategic "rapprochement" between the objective need for recovery, the internal digital readiness of society, and external institutional support. It is precisely this rapprochement that creates real opportunities for a breakthrough, rather than an inertial scenario of TLS recovery, within which Ukraine can not only catch up but, in many aspects, even surpass traditional development trajectories through the implementation of advanced digital technologies in transport and logistics, as well as in the service sector as a whole.

Thus, the theory of convergence lends the study not only theoretical depth but also allows the explanation of a paradox: destruction becomes a logical impetus for

renewal, and a crisis situation – an entry point for large-scale digital modernization synchronized with European standards. This makes the concept of convergence not merely theoretical but a methodological foundation for the strategic planning of Ukraine's digital recovery.

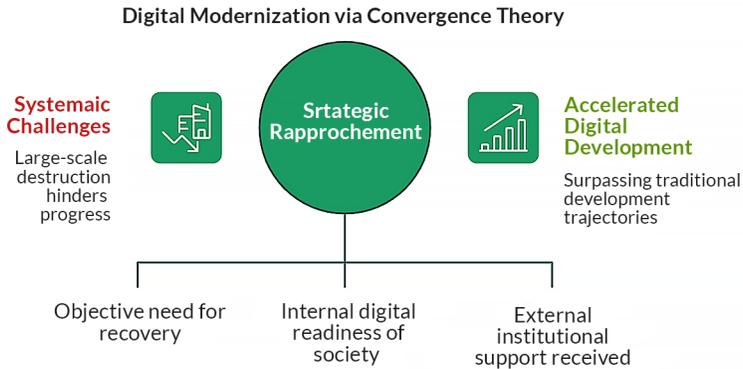


Fig. 5.5 Convergence theory in the context of digitalization of Ukraine's TLS

Further in the study, the current achievements and challenges in the digital development of Ukraine's TLS are examined, as well as how advanced global experience can be applied to overcome existing gaps.

5.3 Analytical assessment of the current state of digital development of Ukraine's transport and logistics system

Before planning the implementation of innovations, it is necessary to objectively assess the current level of digitalization of Ukraine's transport and logistics system, identify strengths and weaknesses, as well as the country's position relative to others. Below is an analytical overview of the state of Ukraine's TLS in terms of digital development at the end of the 2020s (namely, the period after the pandemic and before the start of military actions) [14].

Infrastructure and basic digital services. In terms of basic ICT infrastructure, Ukraine has a relatively good level, characterized by the following: high mobile network coverage (it should be noted that 3G/4G coverage was widespread even in rural areas before the start of military actions), a growing fiber-optic network, and fairly broad popularity of digital services among the population. In addition, as previously noted

in the study, Ukraine was rapidly developing in the direction of digitalizing the public service sector. All these achievements are important and significant for the transport and logistics sphere. For example, digital driver's licenses and vehicle registration documents in the "Diia" application simplify verification processes.

At the same time, it should be acknowledged that specialized digital solutions within Ukraine's TLS are unevenly developed.

Analysis of digital development in railway transport. The state-owned Ukrzaliznytsia (JSC "Ukrzaliznytsia") had certain digitalization elements even before the war, namely: online ticket sales for passengers, a GPS monitoring system for some locomotives and wagons, and electronic document flow for freight transportation. However, the level of process automation remained low. For example, to characterize the situation overall, it should be noted that train traffic management systems on many routes were outdated and in need of modernization to the standards of the European Rail Traffic Management System (ERTMS), and the accounting of freight wagons was often maintained in fragmented databases [15].

At the same time, international projects began to pave the way for the step-by-step development of digitalization in railway transport. For example, in 2020, Ukrzaliznytsia joined a pilot project for the implementation of the CIM/SMGS electronic consignment note for transit shipments, and in 2021 launched a mobile application for customers to track shipments. These steps, although selective, demonstrated the potential for digitalization.

After 2022, Ukrzaliznytsia was forced to become more flexible: digital passes were introduced for evacuation trains, and a freight wagon coordination system was created in real time for exports through western border crossings (referring to exports under the "Solidarity Lanes"). Nevertheless, an integrated digital system in the railway sector does not yet exist – it is under development and is expected to be implemented during the reform of Ukrzaliznytsia. One positive factor in this direction is that in March 2025, the Supreme Council introduced the Railway Transport Law, which provides for market liberalization and the stimulation of private investment [4]. In the analytical note attached to it, special attention is focused on the need to update the railway's IT systems alongside reforms of its structure. Fundamental reforms in this direction, in the authors' view, could open new opportunities for building the digital infrastructure of the TLS (including the creation of a unified digital dispatch center, a unified information system for freight transport, etc.).

Analysis of digital development in road transport. It should be immediately noted that the state of digital development in Ukrainian road transport has historically been characterized as more fragmented, primarily due to the large number of private carriers and the absence of a unified strategy. Digital initiatives were implemented in

a scattered manner, without coordination among various industry participants. However, it is worth highlighting the digital innovations that were introduced, namely, the Weight-in-Motion (WiM) system on major highways (referring to automatic weight control for trucks), as well as the electronic truck border queue system "eCherha", which was launched in 2021 [16, 17].

However, other aspects of digitalization lagged behind: for example, the electronic tolling system had only just started operating, onboard computers and telematics were not used by all companies, and data exchange on cargo between road carriers and other types of transport was quite weak.

After the war began (since 2022), accelerated transformation started to occur under the pressure of circumstances. The importance of road transport increased significantly (primarily in the context of the strategic role of road transport for humanitarian and military logistics), which stimulated rather substantial digital changes. In 2022–2023, the government began actively promoting TIR-EPD – electronic pre-declaration to simplify border crossing – and also announced the complete digitalization of the permit system for freight carriers by 2025 [18]. Large logistics companies themselves began implementing TMS (Transportation Management Systems) and tracking systems. For example, one of the largest private postal and logistics operators – Nova Poshta – received a 13 million EUR investment from the EBRD in 2021 for the automation of a sorting center and the implementation of a smart parcel logistics management system [19].

This project made it possible to double the sorting capacity and improve the efficiency of road transport use. It serves as an example of successful digitalization at the business level. However, small and medium-sized logistics firms (small and medium-sized enterprises (SMEs) make up more than 90% of logistics companies in Ukraine – these are small carriers, freight forwarders, warehouse operators who often work locally or as subcontractors for large operators) significantly lag behind [20].

According to the OECD (Organization for Economic Co-operation and Development), Ukrainian SMEs:

- weakly apply ERP, TMS, WMS, analytical and monitoring platforms;
- practically do not use AI, IoT, or eFTI (electronic freight transport information exchange);
- rarely invest in cybersecurity and the digital competencies of their personnel [21].

Thus, the war became a catalyst for the accelerated digital transformation of road transport in Ukraine, forcing industry participants to quickly adapt to new realities and seek effective solutions in crisis conditions.

Analysis of the digital development of maritime and river transport. It should be noted that before the full-scale war, digitalization of maritime and river transport in Ukraine was at an early stage, requiring a systematic approach and coordination of efforts by all interested parties. Digital initiatives were implemented in a fragmented way, without coordination among different stakeholders in the sector. For instance, in the port of Odesa, a Port Community System (PCS) was in operation for data exchange between terminals, the port administration, and customs authorities [22].

However, the level of integration was lower than in the world's leading ports. Between 2019 and 2021, digitalization of vessel call documentation processes began (including the electronic ship declaration). In river ports of the Danube region, digitalization was minimal.

The war and blockade of the country's seaports forced a reorientation toward the Danube. Thus, in the ports of Izmail and Reni, cargo flow management tools began to be widely implemented, and work on electronic data exchange with Romanian ports was actively pursued (including via the Danube Commission). The reorientation of Ukrainian exports to Izmail, Reni, and Ust-Dunaisk, in the authors' view, may become an impetus for the post-war revival of river transport. In this regard, the Ministry of Infrastructure announced plans to equip these ports with electronic document management systems and digital vessel traffic monitoring systems alongside the physical reconstruction of berths. International partners (including the Danubius Ports Administration from the EU) are ready to share software solutions with the Ukrainian side. Thus, the post-war restoration of ports is seen as a chance to immediately build "smart ports" with full digital coordination of vessel flows, cargo, and customs procedures.

It should be separately noted that the authors of this monograph have deliberately not analyzed the level of development of air transport, as it is currently completely paralyzed. The next strategically important aspect, which currently plays an extremely vital role, is customs and border logistics.

It is worth emphasizing that the digitalization of transport and logistics processes at the border is a critical element for Ukraine, considering the reorientation to EU land corridors. Even before the full-scale military actions began, Ukraine started implementing NCTS (an IT system designed to provide better management and control of goods within the framework of) its accession to the Common Transit Convention and experimented with electronic data exchange with Poland and other neighboring countries.

On October 1, 2022, Ukraine officially became the 36th participant of the Convention, which enabled Ukrainian companies to use simplified procedures for moving goods between member countries using a single electronic transit declaration and guarantee.

In 2023, Ukraine continued the digitalization of customs procedures by implementing Phase 5 of NCTS. This allowed businesses to use the latest version of the system, providing more efficient electronic data exchange and reducing customs clearance time. Ukraine became one of the first countries to implement NCTS Phase 5, despite the difficult conditions caused by the war [23, 24].

The eCherha electronic queue system was also introduced, significantly simplifying border crossing for freight transport, especially under wartime conditions and the growth of export flows. As of May 2025, eCherha operates at 23 international border checkpoints for trucks and 28 checkpoints for buses, covering borders with Poland, Romania, Hungary, Slovakia, and Moldova. In March 2025, the system was expanded to include trucks weighing from 3.5 tons, which allowed a greater number of carriers to be covered and increased the efficiency of border crossings [25].

Since its launch in 2022, more than 1.5 million border crossings have been registered through the system, 1.3 million of which were trucks.

The Ukrainian government plans further expansion and improvement of the eCherha system, including:

- integration with European data exchange systems, in particular ensuring automated exchange of information between Ukrainian and European customs authorities;
- implementation of peak load forecasting, in the context of developing mechanisms for predicting and managing peak loads at checkpoints;
- expansion of functionality, namely adding new features and capabilities to the system based on user feedback.

Thus, eCherha has become an important tool in the digitalization and modernization of Ukraine's border logistics, contributing to improved efficiency and transparency of border crossing processes.

Alongside this, within the framework of the EU-supported digital recovery program, it is planned to create a "unified data exchange system at the border" – a kind of digital corridor where declaration, certification, and permit data will be automatically transferred between the Ukrainian and European sides. This is a large-scale project, but its implementation will give Ukraine a qualitative leap in logistics efficiency at its borders. As the experience of the war has shown, the bottlenecks were the human factor and paper-based procedures at crossings; their digitalization is a matter of the competitiveness of Ukrainian exports.

It can be confidently stated that the creation of a unified data exchange system at the border is a key step toward Ukraine's integration into the European customs space. This project not only increases the efficiency of customs procedures but also contributes to strengthening economic ties with the EU, which is especially important in the context of the country's post-war recovery.

Level of digitalization: international indicators. Although a direct metric for "logistics digitalization" is absent in international statistics, indirect indicators and rankings allow an assessment of Ukraine's position relative to other countries. According to the World Bank's 2023 report, Ukraine ranked 92nd out of 139 countries in the Logistics Performance Index (LPI) with an aggregate score of 2.7 out of 5. This indicates a significant decline compared to 2018, when Ukraine held the 66th position with a score of 2.83. For comparison, Poland ranked 28th in 2023 with a score of 3.5, and Germany ranked 3rd with a score of 4.1. This highlights the lag of Ukraine's TLS in the development of logistics infrastructure and processes.

The analytical assessment of Ukraine's LPI in 2023, broken down by six components [26], is as follows:

- efficiency of customs procedures: score – 2.3;
- quality of infrastructure: score – 2.4;
- international shipments: score – 2.5;
- logistics competence: score – 2.6;
- tracking and tracing: score – 2.5;
- timeliness of delivery: score – 2.8.

The above data indicate the need for comprehensive improvement of Ukraine's TLS, including customs clearance procedures, infrastructure development, and the implementation of modern technologies for cargo tracking.

5.4 Benchmarks of global best practices and opportunities for their adaptation in Ukraine.

For the successful digital transformation of Ukraine's TLS, it will be useful to orient toward global best practices. Below are examples of innovative digital technologies and models implemented in different countries and companies, which can serve as benchmarks for further adaptation and implementation. Special emphasis is placed on those solutions that have proven effective and are potentially applicable under Ukrainian conditions. According to the authors, a deep analysis of positive international practice – especially in the context of digitalization – is critically important for the successful and fundamental transformation of Ukraine's transport and logistics system aimed at increasing its competitiveness:

1. "Digital Freight Train" (France). The state-owned railway company SNCF in France is implementing the Train Fret Digital program – "Digital Freight Train" This is a comprehensive digital solution that includes equipping wagons and locomotives with IoT sensors, as well as using automated systems for transport planning and

monitoring. As a result, SNCF can monitor trains in real time, optimize train composition and scheduling, thereby improving efficiency and reducing costs [1].

An additional effect is achieved – the reduction of CO₂ emissions through more rational use of railway transport instead of road transport. The results of this program demonstrate not only ecological impact but also market share growth. For example, despite structural changes in Fret SNCF, in the first half of 2024, the Rail Logistics Europe division increased its revenue by 9.5%, reaching 17 million EUR, and profitability (EBITDA) grew to 91 million EUR compared to 28 million EUR in the same period of the previous year [27].

According to the authors of this monograph, it would be reasonable to adapt and implement a similar project for Ukraine, specifically during the restoration of railway communication – especially along international corridors – by integrating such a program into Ukrzaliznytsia (UZ). For example, in a pilot project on the European 1435 mm gauge in the Lviv region, it would be possible to immediately introduce digital freight train management, integrated with European dispatch centers. This would help effectively utilize new opportunities for access to TEN-T and eliminate "bottle-necks" at border crossing points through schedule synchronization and load balancing.

2. *Green last mile logistics (Germany)*. The "Green Last Mile Logistics" project, implemented in Germany, is a strategic initiative aimed at significantly reducing CO₂ emissions in urban centers through the introduction of sustainable logistics solutions (this refers to the transition to environmentally friendly vehicles such as electric trucks and e-bikes for deliveries in city centers).

One of the most prominent examples is the Emission-Free Delivery model implemented by DACHSER. In 2025, the company plans to double the number of cities covered by the Emission-Free Delivery program – from 12 to 24, including Amsterdam, Barcelona, Dublin, Hamburg, Cologne, London, Malaga, Rotterdam, Stockholm, Toulouse, Warsaw, and Vienna [28].

This approach has already proven its effectiveness and can be adapted to Ukrainian conditions, especially in the post-war recovery of cities and logistics infrastructure. The implementation of the "Green Last Mile Logistics" concept in Ukraine could become an important step toward sustainable development and integration into the European logistics space.

3. *AI for forecasting and optimization of logistics operations*. Leading global logistics companies actively use artificial intelligence (AI) in transport and logistics systems. For example, DHL (Germany) uses AI for predictive maintenance, warehouse automation, and real-time data analysis. DHL's AI algorithms optimize delivery routes, predict delays, manage warehouse inventory, and improve customer service through chatbots.

As part of e-fulfillment process optimization, DHL developed IDEA software, which uses AI algorithms to optimize order picking routes and task distribution among warehouse staff. The results are impressive:

- up to 50% reduction in walking distances for workers;
- up to 30% increase in warehouse productivity;
- decreased error rates and training time for new staff [29].

In addition, DHL has introduced sorting robots capable of handling 1,000 + parcels per hour with 99% accuracy, boosting sorting center throughput by 40% [30].

UPS (USA) implemented the ORION system, which uses machine learning to determine the optimal delivery routes for each courier, saving the company millions of liters of fuel. Since its launch in 2012, UPS has achieved:

- route reductions of 6–8 miles/day per driver, equaling 100 million miles/year;
- up to 10 million gallons of fuel saved annually;
- ~100,000 metric tons of CO₂ emissions reduced/year;
- 300–400 million USD saved per year.

In 2021, UPS introduced Dynamic ORION, enabling real-time routing adjustments based on road conditions and new delivery requests (including backloads and combined deliveries), reducing routes by an additional 2–4 miles/day per driver [31].

Adapting similar solutions in Ukraine could reduce costs, lower environmental impact, and improve customer service quality. According to the authors, the UPS ORION experience could be used by Ukrposhta and Nova Poshta for urban deliveries, integrating traffic data from Ukrainian cities.

Maersk, a global leader in ocean container shipping, actively implements Internet of Things (IoT) technologies to improve the efficiency and transparency of logistics processes. One of its key solutions is remote container management (RCM), providing real-time container monitoring [32].

Maersk currently operates around 300,000 smart containers that transmit location, temperature, and condition data in real time. In addition to operational optimization and loss reduction, customer service has significantly improved – customers use the Captain Peter™ platform to access real-time cargo status [33].

The Maersk experience demonstrates the significant advantages of using IoT in logistics, and its adaptation in Ukraine could greatly enhance the efficiency and competitiveness of the national transport system – especially in container shipping.

4. *Warehouse automation and robotics (USA, China).* The company XPO Logistics (USA) is known for implementing robots in its distribution centers: automated sorters and loaders, controlled by a centralized AI system, have significantly accelerated order processing. The company has deployed over 5,000 collaborative robots (cobots) in its warehouses across North America. These robots work alongside

humans, performing tasks such as picking, packing, and sorting goods, thereby increasing both safety and productivity of operations [34].

The use of robotic systems and machine learning technologies has allowed XPO to double its productivity and improve performance by an average of 40% [35].

The Blue Yonder warehouse management system enabled XPO Logistics to achieve 99.9% inventory accuracy for some clients, and also to increase the overall efficiency of warehouse operations [36].

The next benchmark is Cainiao (China) – the logistics arm of Alibaba, which successfully uses robots and drones for deliveries, especially in last-mile rural logistics, and manages freight flows using real-time AI. It can be confidently stated that Cainiao has created some of the most advanced smart warehouses, where almost all operations are automated.

In 2023, the company announced the large-scale deployment of Level 4 autonomous vehicles for parcel delivery on public roads, demonstrating Cainiao's commitment to last-mile delivery automation [37].

During the annual Double 11 (November 11) shopping festival, the company processes billions of parcels through the use of Big Data, artificial intelligence, and machine learning, which significantly accelerates delivery [38].

It is worth noting that drone delivery is rapidly developing in China. Well-known companies such as Meituan and JD Logistics actively use drones and autonomous vehicles to deliver goods, especially in hard-to-reach areas.

In particular, Meituan reported the launch of 53 drone delivery routes in major Chinese cities, completing over 400,000 orders by December 2024 [39, 40].

According to the authors, post-war logistics recovery in Ukraine is a chance to build modern distribution centers in place of outdated warehouses. The application of robotics does not require enormous funds when building from scratch: there are already Ukrainian integrators capable of supplying warehouse conveyors, sorting lines, and more.

Therefore, the highest state authorities should motivate the creation of logistics hubs with a high level of automation (for example, through tax incentives or joint investments with international companies). This is especially relevant for multimodal nodes, which are included in Ukraine's recovery plans [4].

5.5 Forecasting the implementation of digital technologies in Ukraine's TLS

The forecast of digital technology development in the transport and logistics system (TLS) of Ukraine is a complex task due to numerous uncertainties (recovery pace,

volume of investments, external environment). To obtain an objective assessment, this study uses a combination of forecasting methods, namely:

1. The primary method is *Porter's Diamond Model*, which is used as the basic forecasting tool. Within the framework of the forecast analysis, key factors will be evaluated, including: human resources and infrastructure potential, internal demand, related industries, regulatory framework, and external support (EU, USA, etc.).

2. As a complementary method, scenario analysis (3 scenarios) was selected: *optimistic scenario* – active implementation of digital technologies with the support of the EU and investors; *realistic (baseline) scenario* – partial implementation, depending on internal reforms and external investments; *pessimistic scenario* – characterized by slow implementation of digital technologies, as well as minimal interest from economic actors and minimal government support. Within the framework of scenario analysis, a *simulation model of technology diffusion based on the S-curve (logistic function)* was applied.

3. As a third method, the authors selected a *Priority Matrix*. It is precisely the combination of these three approaches that can provide an objective vision of the future prospects for the development of digitalization in Ukraine's TLS.

Priority matrix: assessment of key digitalization directions. To begin with, the authors of the study selected and evaluated the key directions of digitalization (a 1-to-5 scale was used). Evaluation criteria:

- impact on efficiency and competitiveness;
- technological maturity;
- required costs and resources (the higher the costs – the lower the score);
- compliance with EU requirements;
- sustainability and security.

It should be noted that as a basis for assigning scores under each of the criteria, the following sources were used:

- reports by the World Bank and USAID on the digital modernization of customs checkpoints;
- European regulations on eFTI and NCTS, official EU publications on multimodality and IoT;
- analytical research by Logistics Business and logistics trends reports (World Economic Forum);
- official reports by the Ministry of Infrastructure of Ukraine on the status and plans for transport digitalization;
- reports and analytics from the We Build Ukraine platform, and research publications by DAI/USAID (**Table 5.1**).

To enhance the significance of the research, it is proposed to use weighting coefficients (from 1 to 5) for each criterion (**Table 5.2**).

The formula for calculating the final index value (I) was determined as follows

$$I = \sum(R_i \cdot W_i), \quad (5.1)$$

where R_i – score of the criterion (1–5); W_i – weight of the criterion (1–5).

The results of the final indicators calculation are collected in (Table 5.3).

Table 5.1 The overall score-based assessment of key digitalization directions

Digitalization Direction	Effectiveness and competitiveness	Technological maturity	Costs and resources	Compliance with EU requirements	Sustainability and security	Total
1. Border customs digitalization	5	5	4	5	5	24
2. IoT monitoring platforms	5	5	4	5	5	24
3. Multimodal logistics	5	4	3	5	5	22
4. Drones (UAVs)	4	3	2	3	4	16
5. AI/Big Data analytics	5	4	3	4	5	21
6. Blockchain	3	2	2	3	4	14

Table 5.2 Weighting coefficients by criteria

Criterion	Weight coefficient (W)	Justification of weight
Efficiency and competitiveness	5	Key indicator
Technological maturity	4	Important for implementation
Costs and resources	3	Medium value
Compliance with EU requirements	5	Strategically important
Sustainability and security	5	Strategically important

Table 5.3 Calculation of the final indicator – index of key digitalization directions

Direction	Calculation formula	Final score (I)
Border customs	$(5 \times 5) + (5 \times 4) + (4 \times 3) + (5 \times 5) + (5 \times 5) = 104$	104
IoT platforms	$(5 \times 5) + (5 \times 4) + (4 \times 3) + (5 \times 5) + (5 \times 5) = 104$	104
Multimodal logistics	$(5 \times 5) + (4 \times 4) + (3 \times 3) + (5 \times 5) + (5 \times 5) = 98$	98
AI and Big Data	$(5 \times 5) + (4 \times 4) + (3 \times 3) + (4 \times 5) + (5 \times 5) = 94$	94
Drones	$(4 \times 5) + (3 \times 4) + (2 \times 3) + (3 \times 5) + (4 \times 5) = 79$	79
Blockchain	$(3 \times 5) + (2 \times 4) + (2 \times 3) + (3 \times 5) + (4 \times 5) = 69$	69

As can be seen from the table data, the first two key directions of digitalization are the implementation of advanced technologies at border crossing points and the introduction of an IoT platform; in third place is the digitalization of multimodal logistics. Completing the list of digitalization priorities in Ukraine's TLS are the implementation of AI and Big Data, drones, and Blockchain.

The next stage of the study is the analysis of Ukraine's competitive advantages in the digitalization of the transport and logistics system (M. Porter's model). It should be noted that M. Porter's model (Porter's Diamond) allows for an analysis of a country's competitive advantages across four groups of factors: factor conditions, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry. In the context of digitalization of Ukraine's transport and logistics system (TLS), this model helps identify the strengths and weaknesses that influence the success of the digital transformation of transport and logistics. TLS digitalization includes the introduction of information technologies into transportation, warehousing, customs procedures, and other logistics processes to improve efficiency and integration into global supply chains.

Analysis of factor conditions. Factor conditions include, above all, the resources that form the basis of competitiveness. According to the authors, these include: human capital (availability of qualified personnel, especially in IT and engineering), infrastructure (both transport and digital), and the geographical location of the country. **Table 5.4** presents a score-based assessment of the above-mentioned factors. Due to the need for objectivity and the absence of precise data at the time of the study, it was decided to use data starting from the year 2020 as a baseline.

Demand conditions analysis. This component makes it possible to assess how much internal and external demand stimulates innovation and digital development of the TLS. In the Ukrainian context, internal demand is important (referring to the needs of the local market for modern logistics services, including e-commerce), as well as external demand (referring to export-import flows and transit), and regulatory requirements of the EU as a major trade partner and integration direction. **Table 5.5** summarizes the assessment data.

Related and supporting industries. This block analyses the presence of well-developed related industries in the country that can enhance the competitive advantages of the core industry (in our case – transport and logistics). These include, above all, the IT sector (software and service development), telecommunications (communication and internet), the transport industry itself (carriers, warehousing, etc.), as well as donor programs and investments supporting reforms in the TLS sector. **Table 5.6** presents the summarized evaluations.

Table 5.4 Score-based assessment of key factors for evaluating the competitiveness of Ukraine's TLS

Factor conditions	Score	Justification (since 2020)
Human capital	4/5 (High)	A high level of education and a strong IT sector provide Ukraine with personnel for digital transformation. According to the global innovation index (WIPO), in 2023 Ukraine ranked 55th overall, including 54th in human capital and research
Infrastructure	2/5 (Low)	According to the 2023 logistics performance index (LPI) published by the World Bank, Ukraine received the following scores, which confirm the overall assessment: overall LPI index – 2.7 out of 5, indicating a medium level of logistics performance, and the quality of trade and transport infrastructure – 2.4 out of 5, reflecting low infrastructure quality, including roads, railways, and ports. These indicators, in addition to the infrastructure destruction caused by military actions, point to the need for significant investments in the modernization and restoration of the country's transport infrastructure
Geographical location	5/5 (Very High)	Ukraine has a strategic geographical location, confirmed by the following facts: 1) transit corridor between Europe and Asia – Ukraine is part of several international transport corridors, including Pan-European Corridors No. 3, No. 5, No. 7, and No. 9, as well as the TRACECA initiative; 2) the country has access to the Black and Azov Seas; 3) Ukraine ranks 17 th in the world by the length of its railway network, which provides connections between major industrial centers and ports

Source: [41]

Note: the score in the range from 1 to 5 indicates the comparative strength of the factor: 1 – very weak point, 5 – very strong point

Table 5.5 Score-based assessment and description of external and internal demand

Demand Conditions	Score	Justification (since 2020)
Internal demand	3/5 (Medium)	Internal demand in Ukraine remains moderate despite economic challenges related to the war. For example, in 2023, private consumption accounted for 60.7% of nominal GDP, indicating a significant role of internal demand in the country's economy. However, due to ongoing military actions, real GDP data is not currently available in open sources, which led to a medium score
External (export-import) demand	4/5 (High)	Ukraine actively participates in international trade despite current challenges. In 2023, Ukraine's exports amounted to 40.3 billion USD and imports to 55.2 billion USD, reflecting a significant volume of foreign trade. As for trade turnover, in 2024 it increased by 13% compared to 2023, reaching 112.3 billion USD
EU requirements (regulatory demand)	4/5 (High)	The deep and comprehensive free trade area (DCFTA) agreement provides for the gradual harmonization of Ukrainian legislation with EU norms, including technical regulations and standards. Ukraine has adopted more than 30 technical regulations, most of which comply with EU directives, facilitating the export of Ukrainian goods to the European market

Source: [42–44]

Table 5.6 Score-based assessment of related and supporting industries of Ukraine's TLS

Related and supporting industries	Score	Justification (since 2020)
IT sector	5/5 (Bery high)	A strong domestic IT industry is a key driver of TLS digitalization
Telecom infrastructure	4/5 (High)	Developed telecommunications support digital transformation
Transport industry (basic)	3/5 (Medium)	The sector of transport companies and logistics operators in Ukraine shows a mixed level of development. A strong side is the presence of major players covering different segments: Ukrzaliznytsia (the largest railway network), Ukrposhta and private courier services, ports (Odesa, Yuzhny, and others), and tens of thousands of small freight carriers

Strategy of firms, industry structure, and competition. The final component of Porter's Diamond reflects the business environment in which TLS sector companies operate: firms' strategies and initiatives, the structure of the industry, and the level of competition, as well as state policy and the progress of reforms in the sector. This block determines to what extent internal conditions facilitate or hinder digital innovations. **Table 5.7** illustrates the situation.

Below let's present the visualization of Porter's Diamond (**Fig. 5.6**).

Table 5.7 Score-based assessment of TLS firms' strategy, industry structure, and competition

Strategy, industry structure, and competition	Score	Justification (since 2020)
	1	2
Reforms and deregulation	3/5 (Medium)	Since 2020, Ukraine has carried out a number of important reforms in the transport sector, although many of them are still unfinished
Business initiatives (firm innovation)	4/5 (High)	Ukrainian logistics businesses show flexibility and capacity for innovation, especially in response to crises. Major private companies are investing in IT: Nova Poshta has deployed its own courier IT platform and is even entering EU markets; Agri holdings are implementing grain transportation monitoring systems (GPS trackers on wagons); warehouse networks use Big Data to optimize inventory. Startups are finding applications in logistics: truck-sharing services have emerged, and Ukrainian teams are involved in developing global drone delivery solutions. During the war, businesses independently established alternative logistics chains (e.g., agricultural exports via the Danube) and quickly adapted to new requirements – many exporters mastered European electronic certification and customs systems

Continuation of Table 5.7

1	2	3
Level of competition and industry structure	3/5 (Medium)	The competitive environment in Ukraine's transport and logistics sector is heterogeneous. In some segments, competition is high (road freight, forwarding, warehousing – many players, including foreign ones), which stimulates efficiency. However, other segments are dominated by state monopolies or oligopolies: freight rail transport is almost entirely controlled by Ukrzaliznytsia, monopolistic practices were present in the port sector until recently, and the air transport market is dominated by a limited number of airlines. Insufficient competition has traditionally led to stagnation and weak customer orientation
State policy	3/5 (Medium)	In recent years, the state has shown initiative in digital transformation (creation of the Ministry of Digital Transformation, the "Diia" portal, etc.), which has had a positive impact on the TLS. Government systems have been launched: e-queues at the border, open data from Ukravtodor on road conditions, and online platforms from Ukrzaliznytsia for shippers. The National Transport Strategy until 2030 was adopted, where digitalization is named a priority. In 2023, the government announced its course toward joining the EU digital single market, which implies adapting all digital infrastructure (including logistics) to European standards. However, in the area of direct transport management, problems remain: insufficient funding for infrastructure maintenance, and complex procedures for project coordination between agencies

Radar Chart: Balance of Ukraine's Competitive Factors (Porter's Diamond)

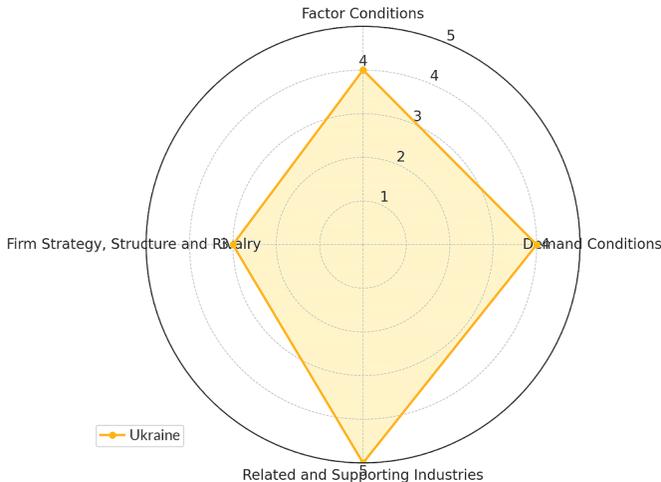


Fig. 5.6 Visualization of the results of competitive advantage analysis of Ukraine's TLS (Porter's model)

Modelling future development: S-curve of digitalization of Ukraine's transport and logistics system. Based on aggregated data, the authors conducted modelling of digitalization rates using the Python 3.10 programming language and the Matplotlib library for data visualization. The following were also used: the NumPy library for numerical calculations (creation of data arrays, calculation of function values); and the SciPy library (for precise curve visualization – in our case, the basic logistic formula was used).

Model type. As the basic function for forecasting, the logistic function of innovation diffusion (the so-called S-curve, or logistic growth) was applied. The logistic function best describes the dynamics of innovation diffusion, where growth begins slowly, then accelerates (forming an "S" shape), and eventually stabilizes at a certain level of maturity.

The formula used for the modelling

$$y(x) = \frac{L}{1 + \exp(-k \cdot (x - x_0))}, \quad (5.2)$$

where $y(x)$ – the level of digitalization maturity in year x ; L – the maximum maturity value (4.5–5.0); k – the diffusion rate coefficient (0.25–0.5); x_0 – the year of maximum acceleration in innovation diffusion; \exp – exponential function.

Forecasting horizon: 2023–2035.

The forecast graphs of the S-curve of digitalization of Ukraine's TLS are presented below (**Fig. 5.7**).

The model takes into account that the implementation of new technologies proceeds slowly at the initial stage, then accelerates upon reaching a critical mass, and finally reaches a saturation plateau. Calculations showed that under favorable conditions, the inflection point (sharp acceleration of digitalization) for Ukraine may occur in 2027–2030, and saturation – by the beginning of 2034. This quantitative assessment correlates with the optimistic and baseline scenarios, providing additional justification for the forecasts presented above. It is important to emphasize that the proposed forecast is not deterministic, but conditional. Its goal is to indicate what needs to be done to bring reality closer to the optimistic scenario, and what risks to consider in order to avoid the realization of the pessimistic one.

Interpretation of the presented forecast data:

- *optimistic scenario*: rapid acceleration of digitalization is expected, in the best case, after 2026–2027, with maturity reached by 2030;
- *baseline scenario*: moderate growth rates with maturity level ~ 4.7 expected only by 2032;

– *pessimistic scenario*: characterized by "sluggish" digitalization implementation in the transport and logistics sector, with stabilization at the level of 4.5 expected after 2034.

This fully corresponds with the historical analysis of the recovery process in other countries, which restored their transport and logistics systems over a fairly long-time horizon (**Table 5.8**).

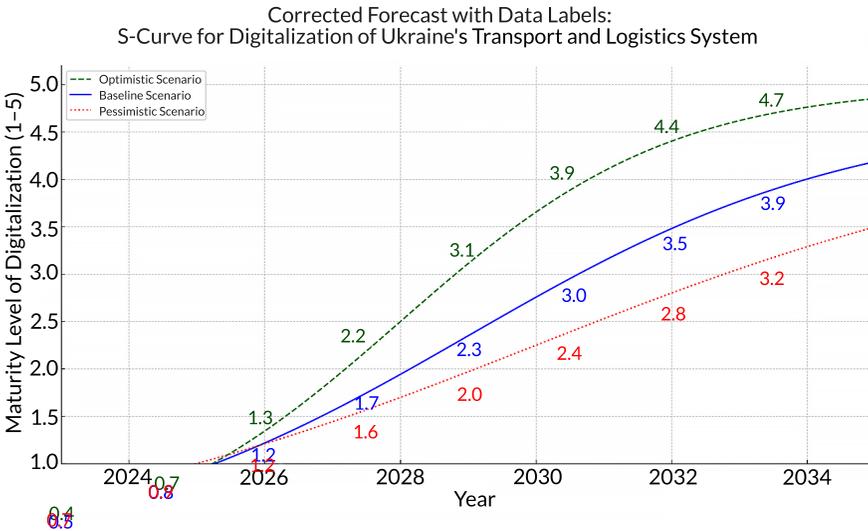


Fig. 5.7 S-Curves of digitalization forecasts for Ukraine's transport and logistics system

Table 5.8 Historical analysis of post-war recovery of the transport and logistics system

Country	TLS – recovery period	Description
Germany (Post-WWII)	10–15 years (with U.S. coordination under the Marshall Plan)	With massive international assistance
South Korea (1950s)	≈ 15 years	With large-scale U.S. assistance
Bosnia and Herzegovina (1995)	10 + years	Small country, limited resources
Iraq (2003–the present)	15 + years (unfinished)	Political instability hinders recovery

In the opinion of the authors of this study, given that Ukraine is a country with a vast territory and a complex nature of interrelated influencing factors, as well as

due to the large-scale destruction of the TLS during military activity, even under optimistic scenarios, five years will not be sufficient to achieve full digital maturity. In this regard, it will be necessary, after the end of active military operations, to implement a set of remediation measures as the initial stage, which will be able to launch a chain of positive multiplier effects across all sectors and branches of the national socio-economic system, among which the transport and logistics system (TLS) occupies a leading position [45–47].

Finally, the concluding stage, following the economic diagnostics and further forecast modelling, will be the visualization aimed at forming the "Roadmap" of the digitalization of Ukraine's TLS. According to the authors of the study, the most optimal tools that allow for the synthesis of the previously obtained results are the combination of the Layered Timeline + Heatmap Matrix (Fig. 5.8).



Fig. 5.8 "Roadmap" of the digitalization of Ukraine's TLS (2025–2034)

The above Layered Timeline + Heatmap Matrix diagram synthesizes the key results of the Diamond model, the digitalization priority matrix, the S-curve modelling, and the scenario forecast up to 2034.

The interpretation of the graph is as follows:

- the Y-axis represents the directions of TLS digitalization: from customs and IoT to drones and blockchain;
- the X-axis shows the years from 2025 to 2034;
- the color of the cells reflects the maturity level (from 1 to 5) for each direction in each year. The more saturated the color, the higher the maturity of digitalization in the respective direction.

At the conclusion of the study, special attention should be drawn to the practical significance of the visualized "Digitalization Roadmap" of Ukraine's TLS, which will undoubtedly influence managerial decisions, namely:

- the strategic drivers of digitalization – customs digitalization and IoT monitoring – reach the peak of maturity as early as 2027, and it is precisely with them that scaling should begin. These directions can ensure a quick return and compliance with EU requirements;
- multimodal logistics and AI demonstrate stable positive dynamics both in the near and long-term perspective. Their development and scaling require institutional coordination between sectors and support from the government;
- drones and blockchain demonstrate the slowest pace of implementation, which may be influenced by uncertainty in legal regulation and normative support (here the focus is primarily on their practical application in TLS), as well as certain integration barriers with international infrastructure and external funding. According to the authors of the monograph, they will require the creation of special pilot testing zones and digital "sandboxes" for trial implementation.

This visualization format has proven to be the most effective for assessing which directions require urgent governmental intervention and support, international technical assistance, as well as the application of a set of focused management measures.

5.6 Conclusion

Thus, it is possible to summarize that under conditions of severe resource constraints and extended investment horizons, traditional and linear approaches to restoring transport and logistics potential lose their effectiveness. They imply the recreation of the past, whereas the congruent model of digitalization is a movement forward, taking into account the experience gained as well as the transformation of internal and external environmental conditions. Within this model, the new domestic transport and logistics infrastructure will be designed from the outset as digitally integrated, automated, energy-efficient, and sustainable – which not only meets the

challenges of modernity but also positions Ukraine competitively within the future system of European logistics and smart routes.

The digitalization of Ukraine's transport and logistics system by 2030 and beyond is a complex, multi-stage process, dependent on a number of conditions. Analysis through the lens of Porter's model shows that the country possesses potential and drivers for success (strong factor conditions in IT, high demand for efficient logistics, partner support, and competition that stimulates innovation). The assessment of six priority areas of digitalization revealed that the greatest immediate impact will come from projects focused on digitalizing borders and multimodal logistics, as well as pervasive IoT monitoring. These areas form the foundation upon which more advanced technologies are deployed – Big Data analytics, artificial intelligence, drones, and blockchain.

The scenario forecast demonstrates a wide range of possible outcomes – from a breakthrough transformation of Ukraine into a digital logistics hub of Europe (under an optimistic set of circumstances) to slowed, partial progress (in the case of prolonged crises). The baseline scenario will most likely lead to gradual development and the achievement of key goals set for 2034 in the existing strategies. A crucial prerequisite for all scenarios remains the establishment of lasting peace and the attraction of investment for recovery. Nevertheless, even in the most favorable case, realizing the digital potential will require Ukraine to make consistent efforts: investing in education and human resources, strengthening cybersecurity, improving legislation and standards. It is necessary to ensure coordination between the state and business, project transparency, and a focus on the best global practices.

It is extremely important to shift from isolated IT initiatives to a comprehensive strategy covering the entire transport and logistics system. If all key elements come together, Ukraine will not only restore what was lost but also create a new, competitive, and resilient logistics infrastructure. As experts note, only such a comprehensive approach will allow for the formation of next-generation logistics, strategically oriented toward integration into the global economy. The digital transformation of transport will become one of the pillars of economic growth, increase investment attractiveness, and strengthen Ukraine's role as a transit bridge between Europe and Asia. Even today, despite all the difficulties, steps are being taken in this direction and the success of their implementation in the coming years will determine the country's logistics future by 2030 and beyond.

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