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Development of a Strategic Accounting and Control System for Freight Forwarding Services in the Industry 4.0 Environment: Opportunities and Challenges

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Abstract

The article investigates the development of accounting and control systems for freight forwarding enterprises amidst the implementation of Industry 4.0 technologies. The study analyzes the fragmentation of scientific research regarding the impact of digitalization on forwarding activities and identifies a lack of systematic approaches to assessing implementation risks. Three key benefits of utilizing Internet of Things (IoT), Artificial Intelligence (AI), and Big Data are revealed: 1) Visibility (ensuring real-time supply chain transparency); 2) Optimization (increasing resource efficiency); 3) Analytics (strategic data-driven planning). The directions for transforming the accounting and control system are defined by transitioning from periodic documentation to continuous monitoring, replacing simplified cost allocation methods with precise costing based on sensor data, and evolving from retrospective reporting to predictive analytics. The main challenges of digitalization are systematized into: 1) Technological (scalability, device incompatibility, data security); 2) Organizational (staff resistance, competency deficits, low implementation success rates); 3) Regulatory (absence of accounting standards for new business models). Strategies to overcome these barriers include investing in training, engaging consultants, implementing iteratively, and developing an organizational culture. Perspectives for further research include unifying digital asset accounting methods and transforming professional competencies for accounting personnel.

Keywords: sustainable development; global supply chains; freight forwarding services; Industry 4.0; strategic accounting and control system; customs control; costing, depreciation of digital assets; non-financial reporting; environmental indicators; Internet of Things; Artificial Intelligence; Big Data; blockchain; digital transformation.

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1. Introduction

The transition to Industry 4.0 fundamentally transforms the approach to organizing and maintaining accounting at enterprises providing freight forwarding services. Traditional accounting systems, which reflect business transactions with significant time lags from the time of their occurrence, fail to support effective management of logistics and transport enterprises amid high global economic turbulence. Specifically, they do not provide adequate control within the dynamic, complex modern logistics chains, leading to an inability to respond promptly to disruptions and deteriorated financial performance.

One significant trend in development accounting systems is the integration the accounting modules of information systems with transport management systems, IoT-based cargo tracking, and customs platforms. This integration allows you to switch to cargo accounting, where every change in route, temperature, humidity, or customs status is recognized as a condition change, triggering the recording of new business transactions and eliminating the time lag between the physical movement of cargo and its reflection in the accounting system. This allows management to receive up-to-date information on transportation status at any time, increasing the validity and efficiency of management decisions, and, on the other hand, reducing costs and minimizing the negative impact on the environment, ensuring the achievement of sustainable development goals. Thus, the relevance of the topic is enhanced not only by the technological turbulence of the global economy but also by changes in public policy (in particular, the strengthening of environmental standards and transparency requirements). The new strategic accounting system becomes a «bridge» between the interests of private business and the requirements of the state in matters of customs control, preparation, and publication of non-financial reporting, etc.

Industry 4.0 transforms the control system from a tool for fixing deviations into a powerful tool for predicting and preventing them. The introduction of AI tools into the accounting and control processes of freight forwarding companies opens up opportunities to analyze large datasets on fuel costs, port dues, seasonal fluctuations, and the reliability of counterparties. This enables predictive modeling of voyage costs at the planning stage and the detection of anomalies in real time, thereby increasing the efficiency of risk management in freight forwarding companies.

Along with the above advantages, implementing accounting and control systems that integrate Industry 4.0 technologies poses serious challenges. Firstly, this is the problem of the quality of primary identification and data processing by Internet of Things devices, ensuring their transfer to cloud storage. Secondly, these are security threats to the instant formation and transfer of data to the accounting information system, which can lead to violations and failures of the entire system. Thirdly, the need to overcome resistance, expand the competencies of accounting employees to provide interpretation and analytical support for management decision-making, and foster active interaction with IT employees. Overcoming these challenges will improve the functioning of the enterprise management system, increasing transparency, reliability, and the analytical value of information for various stakeholder groups.

2. Literature Review

Global supply chains, particularly in freight forwarding services, are facing unprecedented challenges, including inefficiency, opacity, demand fluctuations, and the aftermath of geopolitical conflicts (Islam et al., 2023). The traditional freight forwarder model remains «stunningly analog», with manual processes and isolated information systems, a problem that is especially acute in the fragmented road freight market (Heinbach et al., 2022). The answer to these challenges is a statistical digital transformation, driven by the Internet of Things, artificial intelligence, and Big Data analytics, which can provide the necessary transparency and efficiency. As A.Garg and S.Vemaraju point out (2025), the integration of these technologies is a breakthrough solution that changes the rules of the game, enabling a shift from reactive responses to proactive management of logistics processes.

Despite the revolutionary potential of these technologies, scientific and academic understanding of their impact remains fragmented and limited (Wang et al., 2021). Most existing research focuses either on specific technologies or application areas, or on related sectors (shipping, customers, etc.), without providing a broad, systematic overview of the current state of implementation of new technologies. According to C.Dong et al. (2021), such isolation of existing research does not allow for the formation of holistic recommendations for industry experts in the era of digital evolution. An essential contribution to understanding the practical aspects of digitalization was made by C.Heinbach et al. (2022), who proposed a three-dimensional model of the benefits of digital platforms (visibility, optimization, analytics), which served as the theoretical basis for many applied studies.

The lack of systematic research on the specifics of perception and implementation of digital solutions in freight forwarding companies is particularly acute. As noted by L.Lapinskaitė et al. (2024), there is currently no systematic approach to assessing the risks of digitalization for this specific group of the transport sector. Despite container transportation dominating world trade and the shipping industry itself being characterized as conservative and slow to adopt digital tools (Dowling et al., 2025), the opinions and experiences of freight forwarders remain understudied compared to those of other market participants.

M.Ben-Daya et al. (2019) systematized the key problems in the digitalization of forwarding companies, including network scalability, device identification, security, and energy efficiency. And the social and regulatory barriers to digitalization, in particular the risks of cyberattacks, privacy, and employee safety, were analyzed in detail by O.Maiboroda et al. (2021).

Thus, today there is an urgent need to study the impact of Industry 4.0 technologies on the freight forwarding sector. Therefore, this study aims to fill the existing gap by systematizing the key drivers and barriers to the digitalization of the

freight forwarding sector using Industry 4.0 technologies, and by identifying areas for transforming the accounting and control systems of freight forwarding companies under their influence.

3. The identification of previously unresolved issues and the formulation of research hypotheses

Despite the revolutionary potential of Industry 4.0 technologies, the scientific understanding of their impact on freight forwarding companies' operations remains fragmented and limited. Analysis of the professional literature and practice of implementing digital solutions allows us to highlight several previously unresolved issues that are at the intersection of accounting disciplines, management, digitalization and public policy, in particular: 1) the presence of institutional and regulatory gaps; 2) the obsolescence of approaches to primary accounting and depreciation; 3) the peculiarities of accounting and customs control in global supply chains; 4) the need to integrate environmental indicators into the management accounting system; 5) the necessity of transforming accounting competencies.

Based on the identified gaps, this study formulates the following hypotheses.

1. The transition of freight forwarding companies from periodic documentation to continuous monitoring based on the integration of accounting modules with Internet of Things systems and customs platforms allows for the elimination of information asymmetry in global supply chains. It forms a qualitatively new, strategic accounting and control system.

2. Replacing simplified methods of cost allocation and linear depreciation with calculations based on actual data from sensors (depreciation accrual by the production method) critically increases the accuracy of determining the cost of each trip and the objectivity of financial results.

3. Digitalization of logistics processes (route optimization, digital twins) creates a technological basis for fulfilling state regulatory requirements for sustainable development, turning CO_2 emissions accounting into an integral part of the management accounting and non-financial reporting system of freight forwarding companies.

4. The low level of success of digital transformation in the freight forwarding industry is due not so much to technological limitations as to institutional gaps, lack of legislative regulation, and personnel resistance, which requires iterative implementation of changes and evolution of accountants' competencies.

4. Research methodology and method

The theoretical and methodological basis of the study is the fundamental principles of accounting theory, global supply chain management, and the concepts of Industry 4.0 and sustainable development. Given the interdisciplinary nature of the problem, the work employs a comprehensive approach that draws on general scientific and specific research methods.

Systematic analysis and synthesis were used to critically evaluate a fragmented array of scientific publications on the digitalization of the freight forwarding industry, which enabled us to identify key challenges and the lack of holistic research on risk assessment and the transformation of the accounting system.

The theoretical modeling and conceptualization method were used to structure the impact of Industry 4.0 technologies on the accounting and control system. The three-dimensional model of the advantages of digital platforms, proposed by C.Heinbach et al. (2022), served as a basis for justifying the transition of the accounting system from retrospective fixation to strategic planning.

To analyze the impact of public policy and the regulatory environment on the development of accounting, an institutional approach was used, which investigated the contradictions between traditional accounting standards and new business models of platform logistics, and also identified barriers in the form of the lack of legislative regulation of privacy and data security of IoT sensors.

To move from general trends in the use of artificial intelligence and the Internet of Things to specific changes in the foundations of accounting, induction and deduction methods were used.

To verify the theoretical provisions and hypotheses of the study, the practical experience of leading companies and digital platforms was analyzed (using examples from Danone, the Transfix platform, and the Disruption Navigator tool from Project44), and empirical generalizations were conducted.

The information base for the study was scientific works by leading domestic and foreign scientists in the field of logistics and accounting, analytical reports of international consulting companies, industry materials, as well as data from empirical studies on the implementation of Internet of Things, artificial intelligence, and blockchain technologies in the activities of freight forwarding companies.

5. The purpose of the study

The purpose of the study is to substantiate the theoretical foundations and practical recommendations for developing the accounting and control systems of freight forwarding enterprises in the context of Industry 4.0 technologies.

6. Main results

In the context of the deployment of Industry 4.0, new challenges are emerging for the field of freight forwarding services (technological, infrastructure, security and confidentiality challenges, organizational, regulatory, legal, ethical), which are most clearly manifested as a result of the application of Internet of Things, artificial intelligence, and Big Data technologies. At the

same time, new opportunities are emerging to use these technologies to improve existing business models, create new ones, enhance interaction between enterprises, transform the systemic principles of the freight forwarding services field, and develop e-commerce and new types of digital services. The existence of such a trend has led to increased interest among stakeholders in understanding the impact of revolutionary technologies on freight transportation, as well as in improving the decision-making system in the field of transport and logistics management (Dong et al., 2021; Wang, 2021).

The modern freight forwarding industry is undergoing a fundamental transformation, driven by Industry 4.0 technologies. The integration of the Internet of Things, artificial intelligence, and Big Data opens unprecedented opportunities for this area, overcoming traditional limitations such as process opacity, inefficient planning, and high operating costs. As E.Hofmann and M.Rüsch note (2017), the pure vision of Industry 4.0 can become a reality only if logistics provides production systems with the necessary resources at the right time and in the right quality. That is why the implementation of Industry 4.0 technologies is not just a competitive advantage, but a necessary condition for the survival and development of freight forwarding companies in today's dynamic environment.

According to C.Heinbach et al. (2022), the use of Industry 4.0 technologies allows for three main benefits: 1) visibility, which provides the ability to see and control the cargo at every stage of the journey; 2) optimization, which allows using this visibility to instantly improve routes and resource utilization; 3) analytics, which opens the way to strategic planning based on deep data analysis, leading to long-term sustainability and reduced operating costs (Fig. 1).

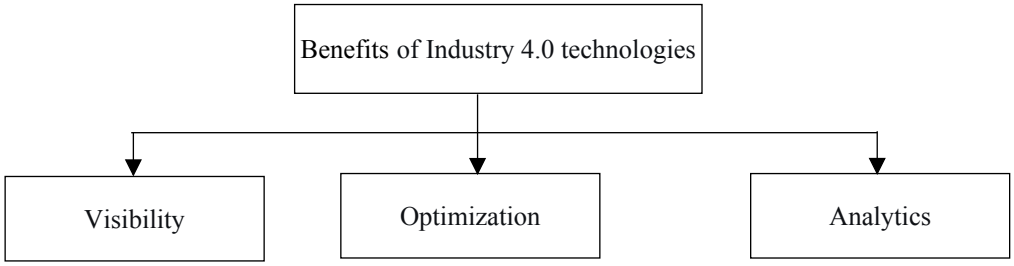

Fig. 1. Benefits of Industry 4.0 Technologies for Freight Transportation Management According to C.Heinbach et al. (2022)

It is at the intersection of these benefits (Fig. 1) that specific business advantages emerge, confirmed by modern research. Each of these advantages acquires specific practical significance through the integration of Internet of Things, artificial intelligence, and Big Data technologies. Moving from the most fundamental level - visibility, through the tactical level of optimization to the strategic capabilities of analytics, digitalization ensures the creation of value for freight forwarding companies, helping them not only save money, but also become more flexible and successful in the long term.

1. *Visibility – ensuring transparency and control in real time.* The defining consequence of implementing Industry 4.0 technologies is unprecedented transparency in supply chains. The integration of cyber-physical systems and the Internet of Things into logistics systems promises to provide real-time tracking of material flows (Hofmann et al., 2017). This directly transforms the freight forwarder's accounting system, as the accounting for the movement of goods and materials ceases to be purely retrospective and becomes real-time, synchronized with the physical movement of cargo.

IoT devices, especially when interacting with blockchain, enable continuous monitoring of cargo location and condition. This is critically important for goods sensitive to transportation conditions (e.g., temperature and humidity) and for dangerous or high-value cargo, such as food, medicines, or chemicals (Dong et al., 2021). Blockchain-compatible sensors enable real-time notifications of potential damage or deviations from the norm, enabling immediate response to incidents (Garg et al., 2025). For the control system, this means moving from periodic inventories and inspections to continuous automated monitoring of cargo quality and safety, enabling the precise recording of the moment of loss of quality or damage for subsequent claims against the responsible parties. Practical cases from leading companies, in particular Danone, demonstrate that the use of Big Data in combination with AI tools provides visibility into hidden risks at the second- and third-tier supplier level, which was previously impossible with traditional monitoring approaches (Everstream, 2025).

Access to reliable, real-time data promotes better communication and cooperation among all stakeholders – freight forwarders, carriers, customs brokers, and customers. This facilitates the execution of tasks and processes, eliminating information asymmetry, which has traditionally been a source of inefficiency and conflict (Islam et al., 2023). In the accounting context, this eliminates the need for multiple reconciliations and agreements between parties, as all participants use a single, reliable set of data, thereby speeding up document flow and financial period closure. Empirical studies confirm that end-to-end visibility into information flows achieved through data consolidation is highly correlated with the accuracy of demand forecasting, as eliminating information gaps enables the construction of more relevant forecasting models (Ooi et al., 2025).

Thus, visibility, as the first fundamental advantage of Industry 4.0 technologies, lays the foundation for all subsequent transformations in freight forwarding. The integration of the Internet of Things and blockchain eliminates the traditional opacity of supply chains, turning them into transparent and controllable systems. The ability to track the location and condition of cargo in real time, especially for sensitive and high-value goods (pharmaceuticals and medical products, perishable food products, premium goods, high-tech products and electronics, chemical and hazardous products, etc.), not only minimizes the risks of damage or loss, but also allows for an instant response to emergencies. From the perspective of the accounting and

control system, the achieved level of transparency provides a basis for improved automation of primary accounting, reducing the time required to document business transactions and increasing the reliability of accounting information. In addition, reliable data available to all participants in the process eliminates information asymmetry, fostering transparent communication and strengthening trust among forwarders, carriers, and customers. The achieved level of transparency becomes a necessary prerequisite for moving to the next stage – meaningful optimization of logistics processes based on the collected data.

2. *Optimization, which ensures increased efficiency and sustainability of forwarding companies.* The second dimension concerns the use of collected data to improve existing business processes. Artificial intelligence and machine learning transform raw data into tools for making optimal decisions (Garg et al., 2025). This allows forwarding companies to move from reactive response to problems to proactive management of logistics processes, which becomes a significant competitive advantage in a dynamic market. In the accounting and control system, this is manifested through the automation of routine operations, in particular, the automatic generation of acts of work performed and invoices based on telematics data, the control of compliance with planned routes to prevent the inappropriate use of fuel, etc. In particular, modern practical cases demonstrate that automating data-driven processes can save more than 1000 person-hours annually in report preparation alone, freeing up resources to solve strategic tasks (Jessen, 2025).

Artificial intelligence algorithms can dynamically adjust routes based on current road conditions, weather, port congestion, and other factors. This not only reduces delivery time and fuel consumption but also increases logistics predictability (Garg et al., 2025; Islam et al., 2023). Such dynamic routing allows freight forwarders to significantly reduce operating costs while simultaneously improving customer service by ensuring more accurate adherence to delivery deadlines. From a control point of view, algorithmic recording of deviations from optimal routes enables you to identify inefficient actions by drivers or dispatchers. It provides an objective basis for motivating personnel.

Modern research also confirms that integrating adaptive learning algorithms with Internet of Things and digital twin technologies enables the simultaneous achievement of three conflicting goals – minimizing costs, reducing delivery time, and reducing carbon emissions - while maximizing the operational flexibility of the enterprise (Nozari et al., 2025). In addition, the implementation of intelligent document processing systems based on AI tools enables optimizing port operations and reducing vessel overtime downtime, thereby minimizing both financial losses and additional CO_2 emissions associated with delay compensation (Jessen, 2025). Here, accounting directly serves public policy goals for greening business.

Route optimization and fuel use directly contribute to reducing the carbon footprint. In addition, technologies enable reducing waste by optimizing the use of materials and packaging. The use of digital twins allows the simulation of different scenarios and the identification of the most environmentally friendly and resource-saving solutions even before their physical implementation (Garg et al., 2025). The modeling results of Y.Liu, S.Pan, and E.Ballot (2025) demonstrate that integrating federated digital twins with knowledge-based approaches reduces costs by more than 50% and emissions by more than 30%. Thus, freight forwarders receive tools not only for voluntary reduction of environmental burden, but also for preparation for more stringent regulatory requirements for reporting on emissions and environmental friendliness of logistics operations. In the context of developing the accounting system, this requires integrating environmental indicators into the management accounting system, enabling non-financial reporting and accounting for environmental factors when calculating transportation costs.

Analysis of data from IoT sensors on vehicles enables the prediction of equipment failures before they occur. This minimizes downtime, extends the service life of assets, and reduces the cost of unplanned repairs (Islam et al., 2023). In fixed asset accounting, this means moving to depreciation based on actual use of the asset, i.e., based on the production method, using sensor data, rather than on the linear process, which increases the accuracy of forming the cost of each voyage.

Unlike traditional logistics planning, which relies on static assumptions, modern approaches based on digital twins adapt to real-time constraints, continuously receiving information about assets and integrating logistics knowledge into operations management (Liu et al., 2025). Leading companies also use AI tools to automate contract processing (charter parties) and extract key data from documents, thereby speeding up operations and reducing the risk of human error in freight administration (Jessen, 2025).

Thus, optimization, as the second main advantage of digitalization, demonstrates how the collected data is transformed into a direct increase in the operational efficiency of freight forwarding companies. Thanks to artificial intelligence and machine learning algorithms, companies cannot only reduce costs through dynamic route planning, rational fuel use, and optimization of warehouse stock levels, but also significantly increase the predictability and reliability of logistics processes. The control system receives tools for automated monitoring of resource efficiency, and the accounting system gains higher-level analytics and greater efficiency in providing accounting information. Of particular importance is the contribution of these technologies to achieving sustainable development goals through reducing CO_2 emissions, minimizing waste, and modeling environmentally friendly solutions using digital twins. The implementation of predictive maintenance using IoT sensors further reduces the risk of unplanned downtime and extends asset lifecycles. In general, Industry 4.0 technologies lay the foundation for a flexible, cost-effective, and environmentally responsible logistics system that meets modern market requirements and customer expectations.

3. *Analytics (new analytical tools) that provide Data-oriented strategic planning of activities.* The third advantage concerns the strategic use of Industry 4.0 technologies, where data serves as the basis for long-term planning and decision-making.

Machine learning models that analyze historical data alongside external market factors significantly outperform traditional forecasting methods (Islam et al., 2023). This allows freight forwarders and their customers to better plan purchases, production, and logistics, thereby increasing supply chain resilience to demand fluctuations. As emphasized in the analytical

materials of «Transfix», predictive analytics based on Big Data enables companies to anticipate demand spikes, price volatility, and potential failures long before they occur, allowing them to act proactively rather than reactively (Ruiz, 2025).

The synergy of machine learning and blockchain allows you to automate complex compliance, customs clearance, and document verification procedures. Analytical AI tools optimize workflows, and blockchain provides an immutable, transparent record of all transactions, significantly reducing reliance on outdated paper systems and minimizing human error (Islam et al., 2023). For the accounting system, this serves as a basis for creating a single, reliable source for all financial and operational data, thereby preventing manipulation of accounting statements, simplifying auditing, and increasing the level of interaction between companies' accounting systems and government regulators.

A key aspect of analytics is its ability to transform basic visibility into effective strategy implementation. First, the use of Big Data provides better visibility, and then analytical AI tools transform this data into forecasts and strategic decisions. For example, the Disruption Navigator tool can predict failure risks 75% faster than traditional methods, allowing you to significantly reduce costs associated with unforeseen events (FreightWaves, 2025).

According to D.Phillips (2025), modern analytical tools go beyond simple data collection, providing deep integration into daily operations. Leading logistics companies use business analytics to optimize carrier selection and cost management. Such strategies include analyzing hidden fees, optimizing transport modes, and routing based on a combination of historical data and current market conditions. This allows you to make informed decisions that simultaneously increase economic efficiency and operational flexibility. The emergence of these new analytical capabilities enables the management accounting system to move to a multidimensional analysis of profitability by various factors (customers, cargo types, modes of transport, geographical destinations), enabling it to identify hidden factors that affect financial efficiency.

That is, analytics, as the third main advantage of using Industry 4.0 technologies, turns data into an active tool for strategic management, allowing freight forwarding companies not only to understand the current situation but also to predict future trends, manage risks, and make informed strategic decisions that ensure long-term competitiveness in a dynamic market. And the accounting system, from a passive recorder of past events, becomes a proactive strategic planning tool (strategic accounting system) capable of modeling various event scenarios and their financial consequences. Thus, the implementation of Industry 4.0 technologies is not just a gradual improvement in freight forwarding companies' operations, but a paradigm shift towards automated, data-driven decision-making in transport and forwarding services. Their integration increases operational efficiency, flexibility, security, and sustainability of global trade operations. It enables stakeholders to access reliable, relevant, and timely data and make informed, up-to-date, and strategic decisions, ultimately reducing costs and increasing customer satisfaction. For the accounting and control system, this means a fundamental transformation, characterized by the following changes: 1) the rejection of periodic documentation of completed operations in favor of continuous monitoring in real time; 2) the replacement of simplified cost allocation methods with accurate calculations based on actual data from IoT sensors; 3) the evolution from retrospective reporting to predictive analytics and scenario modeling of the financial consequences of various logistics scenarios (profitability of alternative routes, assessment of the impact of carrier choice on transportation costs, determination of financial results for different volumes of demand, etc.), the results of which are disclosed in management reporting.

Despite the significant potential of Industry 4.0 technologies to increase the efficiency and transparency of logistics operations, their integration into freight forwarding companies' operations poses several serious challenges and barriers. As E.Hofmann and M.Rüsch (2017) note in this regard. However, the idea of a self-realized «Fourth Industrial Revolution» may seem promising at first glance; it is essential to recognize that there are many challenges, risks, and barriers to its implementation.

A separate group of challenges is problems in the accounting and control system, which are not only not automatically resolved with the introduction of new technologies, but can also be exacerbated. First, an institutional gap arises from the contradiction between traditional cost calculation methods and new business models. In modern logistics operations, costs such as asset sharing or differences in delivery time are difficult to allocate using conventional methods. Secondly, there is a problem of valuation and depreciation of new digital assets. Investments in robotic systems, IoT sensors, or software quickly become obsolete, and traditional depreciation methods do not account for the pace of technological progress, distorting the real value of freight forwarding companies' assets and the cost of the services they provide. It should be noted that without a change in public policy regarding accounting standardization, Industry 4.0 technologies will not achieve their full potential.

The freight forwarding industry is becoming increasingly digital, and companies are being forced to implement new technologies to remain competitive. However, the implementation process itself is a difficult task that requires companies to invest significantly in personnel training and infrastructure development, because only under these conditions can the full return on new technologies be achieved (Rajesh et al., 2023). Compared to other industries, international logistics demonstrates a slower pace of innovation, due to both the complexity of the ecosystem and the fragmented scientific understanding of these processes. As noted by Y.Wang and J.Sarkis (2021), academic knowledge of the impact of digital technologies on land transport remains limited, and the negative consequences of their application have received insufficient attention. This creates a gap between rapid technological development and science's ability to provide practical recommendations for freight forwarding companies.

One of the key challenges is the low success rate of implementing digital solutions. Despite a wide range of tools – from blockchain to financial settlement automation – the success rate of such projects does not exceed 30% (Lapinskaitė et al., 2024). Among the main obstacles, researchers identify staff resistance, a shortage of necessary competencies, the absence of unified standards, and cybersecurity risks. The highest probability of occurrence was assigned to employee resistance, which, in the first month of implementation, can cause losses of 2,500-5,000

euros (Lapinskaitė et al., 2024). In the field of accounting and control, this resistance is often exacerbated by the fact that automation threatens the usual roles and functions of accountants, transforming them from classic accounting workers into accountant-analysts. In addition, the transition from periodic reporting to continuous real-time monitoring requires fundamentally different competencies that are lacking in existing accounting staff.

No less acute is the shortage of qualified specialists who can work with the latest technologies and integrate them into business processes. Thus, companies that have achieved significant progress in implementing AI tools, as a rule, did so through iterative adoption of changes. Still, this progress requires strong cross-functional cooperation, investment in digital skills, and a reliable data infrastructure (Cooper, 2025). Therefore, according to E. Hofmann and M.Rüsch (2017), the key issues to be resolved on the path to Industry 4.0 are defining appropriate infrastructure and standards, ensuring data security, and providing employee training.

Technological barriers also remain a significant obstacle to the effective digitalization of freight forwarding activities. According to the summary by M.Ben-Daya, E.Hassini, and Z.Bahroun (2019), the implementation of the Internet of Things faces problems of network scalability, the identification of millions of connected devices, their heterogeneity, and issues of security, privacy, and energy efficiency. Separately, the authors also point out limitations in computing power, the high cost of machine learning in logistics networks, and the low throughput of the blockchain when processing large volumes of transactions, which remain bottlenecks to scaling solutions in global supply chains.

For the accounting system, these technological limitations create additional risks. Thus, the blockchain's low throughput can lead to delays in recording transactions, rendering real-time accounting impossible. In addition, the incompatibility of IoT devices and the variety of data formats make it difficult to integrate them into a single accounting system, leading to information loss or distortion. Data security issues are critical, as distortions in accounting data can have serious financial and legal consequences for freight forwarding companies.

Social and regulatory barriers also play an essential role. Process automation, including robotics, autonomous trucks, and drones, creates new safety requirements for workers and the public. O.Maiboroda et al. (2021) emphasize the risks of cyberattacks, which increase with the mass distribution of digital devices, as well as the threat of using incorrect data, when a failure at the level of an individual device can cause large-scale violations. The mass use of sensors to record images, sounds, and movements requires precise legislative regulation of privacy issues. In addition, trade unions can actively oppose job reductions due to automation, and governments can seek to increase taxes while reducing working hours.

Strategies proposed by L.Dowling and A.Haddud (2025) aim to overcome these challenges. To compensate for the lack of internal expertise, it is recommended to engage specialized consultants to help select technologies and train staff, because technologies are only effective «in the right hands». Overcoming cultural resistance requires active employee engagement through surveys, focus groups, and training to demonstrate the personal benefits of digitalization and allay fears of job loss. Challenges related to IT infrastructure and budget constraints require additional funding and pilot testing before making long-term commitments. Finally, strong management and a clear digital transformation strategy are crucial, as management must define goals, communicate them effectively, and ensure support at all levels, recognizing that successful transformation requires comprehensive changes to the business model and the enterprise's organizational culture.

Thus, the digital transformation of freight forwarding companies using Industry 4.0 technologies faces a complex of organizational, technological, and social challenges. The low implementation success rate indicates a lack of technological readiness, with key barriers including staff resistance, skills shortages, lack of standards, infrastructure limitations, and cybersecurity risks. Overcoming these barriers requires a comprehensive approach through investments in training and infrastructure, engagement of external experts, iterative implementation through pilots, and active work on organizational culture.

7. Concluding remarks

The study shows that the introduction of Industry 4.0 technologies (the Internet of Things, artificial intelligence, and Big Data) into the operations of transport and forwarding companies leads to a fundamental transformation of their accounting and control systems. The key advantages of such a transformation are achieving supply chain transparency (visibility), increasing the efficiency of resource use (optimization), and transitioning to strategic data-oriented planning (analytics). For the accounting system, this means abandoning periodic documentation of completed operations in favor of continuous real-time monitoring, replacing simplified cost allocation methods with accurate calculations based on actual data from Internet of Things sensors, as well as the evolution from retrospective reporting to predictive analytics and scenario modeling of the financial consequences of various logistics decisions. The presence of such changes is convincing evidence of the transition to the formation of a strategic accounting system in forwarding companies. The control system, in turn, is transformed from a tool for correcting deviations into a powerful tool for predicting and preventing them, providing automated monitoring of quality, cargo safety, and the efficient use of enterprise assets.

At the same time, the integration of Industry 4.0 technologies into the accounting and control processes of freight forwarding companies is accompanied by the emergence of serious challenges: 1) there is a contradiction between traditional cost calculation methods and new business models (shared use of assets, platform logistics), which complicates the distribution of costs; 2) the problem of assessing and amortizing digital assets, which quickly become obsolete, distorts the real value of the enterprise's property and the cost of services; 3) technological limitations, in particular, low blockchain bandwidth and incompatibility of various Internet of Things devices, complicate the integration of data into a single accounting system and create risks of information loss or distortion.

Further scientific research in this area should focus on developing unified methods for accounting for transactions in the context of platform logistics and asset sharing, as well as on establishing standards for the valuation and depreciation of assets that account for the pace of technological obsolescence. Another critical area is the study of the impact of Internet of Things and blockchain technologies on the organization of internal control, particularly in developing procedures for automated verification of primary data and for preventing cyber threats to the accounting system. The issues of transforming the professional competencies of accounting personnel and developing models of interaction among accountants, analysts, and IT specialists during the digital transformation of forwarding companies also require further study. Research aimed at developing recommendations for government agencies to inform public policy on adapting national and international accounting standards to the conditions of platform logistics, thereby overcoming existing regulatory barriers, is also considered essential.

References:

1. Ben-Daya, M., Hassini, E. and Bahroun, Z. (2019), «Internet of things and supply chain management: a literature review», *International Journal of Production Research*, Vol. 57 (15–16), pp. 4719–4742.
2. Cooper, M. (2025), «Barriers to AI Adoption in Supply Chain Management: Perspectives from Industry Leaders», *Preprints.org*, doi: 10.20944/preprints202504.0581.v1.
3. Dong, C., Akram, A., Andersson, D., Arnäs, P. and Stefansson, G. (2021), «The impact of emerging and disruptive technologies on freight transportation in the digital era: current state and future trends», *The International Journal of Logistics Management*, Vol. 32 (2), pp. 386–412.
4. Dowling, L. and Haddud, A. (2025), «The Impacts of Digitisation on Freight Forwarders within the Shipping Industry», *Operations and Supply Chain Management an International Journal*, Vol. 18 (2), pp. 240–255.
5. «Danone - Everstream Analytics», *Everstream Analytics*, [Online], available at: https://www.everstream.ai/case-study/danone-real-time-risk-visibility/
6. «Project44's Movement and Disruption Navigator are transforming visibility», *FreightWaves*, [Online], available at: https://www.freightwaves.com/news/project44s-movement-and-disruption-navigator-are-transform
7. Garg, A. and Vemaraju, S. (2025), «Integrating IoT and smart AI for Enhanced Sustainability in freight forwarding companies Performance», *Journal of Intelligent Systems and Internet of Things*, Vol. 16 (1), pp. 49–60.
8. Heinbach, C., Beinke, J., Kammler, F. and Thomas, O. (2022), «Data-driven forwarding: a typology of digital platforms for road freight transport management», *Electronic Markets*, Vol. 32 (2), pp. 807–828.
9. Hofmann, E. and Rüsch, M. (2017), «Industry 4.0 and the current status as well as future prospects on logistics», *Computers in Industry*, Vol. 89, pp. 23–34.
10. Islam, M.A., Hasan, M.A.R., Zaman, S. and Haque, S. (2023), «Revolutionizing supply chain, logistics, shipping, and freight forwarding operations with machine learning and blockchain», *American Journal of Scholarly Research and Innovation*, Vol. 2 (1), pp. 79–103.
11. «How AWS & Cargill unlock sustainability data for shipping», *Sustainability Magazine*, [Online], available at: https://sustainabilitymag.com/news/cargill-aws-carbon-neutral-shipping
12. Lapinskaitė, I., Ingaunytė, N., Zemlickienė, V. and Martinkutė-Kaulienė, R. (2024), «Navigating the digital landscape: situation and risk assessment of digital solutions in forwarding companies», *Technological and Economic Development of Economy*, Vol. 30 (4), pp. 976–1008.
13. Liu, Y., Pan, S. and Ballot, E. (2025), «Federated digital twins platform for smart city logistics: A knowledge-driven approach», *International Journal of Production Economics*, Vol. 290, 109772.
14. Maiboroda, O., Bezuhla, L., Gukaliuk, A., Shymanska, V., Momont, T. and Ilchenko, T. (2021), «Assessment of Perspective Development of Transport and Logistics Systems at Macro and Micro Level under the Conditions of Industry 4.0 Integration», *International Journal of Computer Science and Network Security*, Vol. 21 (3), pp. 235–244.
15. Nozari, H., Szmelter-Jarosz, A. and Weiland, D. (2025), «A Fuzzy Multi-Objective Sustainable and Agile Supply Chain Model Based on Digital Twin and Internet of Things with Adaptive Learning Under Environmental Uncertainty», *Applied Sciences*, Vol. 15 (19), 10399.
16. Ooi, T.K., Hsieh, C., Wang, S. and Huang, Y. (2025), «Orchestrating agile omnichannel supply chain planning through big data analytics and end-to-end visibility», *The Asian Journal of Shipping and Logistics*, Vol. 41 (2), pp. 110–117.
17. «Data-Driven freight management strategies that work», *Transportation Insight*, [Online], available at: https://transportationinsight.com/resources/data-driven-freight-management-strategies-that-work/
18. Rajesh, D., Gupta, S.K., Ilinich, S. and Singh, N. (2023), «An assessment of challenges and factor influencing the freight forwarding business in the logistics industry», *Economics Finance And Management Review*, Vol. 2, pp. 4–23.
19. «Advanced Freight Data & Analytics», *Transfix*, [Online], available at: https://transfix.io/insights/advanced-freight-data-amp-analytics
20. Wang, Y. and Sarkis, J. (2021), «Emerging digitalisation technologies in freight transport and logistics: Current trends and future directions», *Transportation Research Part E: Logistics and Transportation Review*, Vol. 148, 102291.

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