DOI: https://doi.org/10.32782/2524-0072/2026-85-5

UDC 339.543:005.334:004

DIGITAL TRANSFORMATION OF CUSTOMS LOGISTICS IN UKRAINE: TOOLS, ARCHITECTURE, AND STRATEGIC DIRECTIONS FOR EU INTEGRATION

ЦИФРОВА ТРАНСФОРМАЦІЯ МИТНОЇ ЛОГІСТИКИ УКРАЇНИ: ІНСТРУМЕНТИ, АРХІТЕКТУРА ТА СТРАТЕГІЧНІ НАПРЯМИ ЄВРОІНТЕГРАЦІЇ

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This article systematizes modern digital tools and technologies applied in customs logistics – including electronic declaration, automated risk management systems, the single window platform, blockchain, and artificial intelligence – and evaluates their impact on the efficiency of foreign economic activity. A comprehensive conceptual architecture of digitalized customs logistics is proposed, integrating three functional levels: technological tools, risk management systems, and strategic transformation priorities. The study examines the implementation of the Multi-Annual Strategic Plan for Electronic Customs (MASP-C) in 2024-2025. Five strategic directions for digital transformation are substantiated in the context of EU integration. The findings confirm that digitalization is a necessary but not sufficient condition for improving customs efficiency.

Keywords: customs logistics, digitalization, electronic declaration, single window system, automated risk management, blockchain, artificial intelligence, EU integration, enterprise competitiveness, supply chain, foreign economic activity.

Стаття присвячена комплексному дослідженню цифрової трансформації митної логістики України в умовах євроінтеграції та сучасних викликів, зокрема воєнного стану. У роботі систематизовано ключові цифрові інструменти та технології, що застосовуються у митній сфері, серед яких електронне декларування, автоматизовані системи управління ризиками, система «єдиного вікна», блокчейн, штучний інтелект та інші інноваційні рішення. Обґрунтовано їхній вплив на підвищення ефективності зовнішньоекономічної діяльності підприємств через скорочення часу митного оформлення, зниження транзакційних витрат, підвищення прозорості процедур і зміцнення стійкості ланцюгів постачання. Особливу увагу приділено аналізу практичних ре-

зультатів впровадження цифрових рішень у 2024–2025 роках у межах реалізації Багаторічного стратегічного плану електронної митниці. Висвітлено розвиток ключових інформаційних систем, зокрема запуск нових фаз транзитної системи, розширення функціоналу «єдиного вікна» та впровадження централізованих рішень у митному оформленні. На основі узагальнення теоретичних і прикладних аспектів розроблено концептуальну архітектуру цифровізованої митної логістики, що включає три взаємопов'язані рівні: технологічний, рівень управління ризиками та стратегічний. Такий підхід дозволяє розглядати цифрову трансформацію як цілісну систему, де ефективність досягається завдяки синергії технологій, управлінських рішень і стратегічних орієнтирів. Обґрунтовано п'ять пріоритетних напрямів подальшої цифрової трансформації митної логістики: інтеграція до митного простору ЄС, повна цифровізація митних формальностей, розвиток інтелектуальних систем управління ризиками, гармонізація тарифного та правового регулювання, а також розвиток людського капіталу. Доведено, що, попри значний прогрес у цифровізації, її ефективність залежить від глибини інституційних реформ, рівня координації між органами влади та відповідності європейським стандартам. Таким чином, цифровізація розглядається як необхідна, але недостатня умова підвищення ефективності митної системи України.

Ключові слова: митна логістика, цифровізація, електронне декларування, система «єдиного вікна», автоматизована система управління ризиками, блокчейн, штучний інтелект, євроінтеграція, конкурентоспроможність підприємств, ланцюг поставок, зовнішньоекономічна діяльність.

Statement of the Problem. The rapid development of digital technologies defines the key directions of transformation of customs processes, enabling customs administrations to respond more effectively to emerging challenges and to exploit the opportunities of the digital environment [1]. As international trade volumes continue to expand, the integration of advanced information technologies, automation tools, and data analytics into customs clearance and control procedures becomes a critical factor in enhancing the competitiveness of enterprises in international markets.

For Ukraine, which is pursuing a strategic course toward European integration while simultaneously operating under the conditions of a full-scale military invasion, the digital transformation of customs logistics acquires particular importance. Under such conditions, the modernization of customs systems becomes not only an economic priority but also a strategic instrument for ensuring the resilience and efficiency of foreign economic activity, and a prerequisite for alignment with EU customs standards.

Despite notable progress in implementing digital customs solutions – including the MASP-C strategic plan and expansion of the Single Window for International Trade – the issue of a comprehensive conceptual model of digitalized customs logistics and systematic assessment of its strategic directions in the context of EU integration remains insufficiently explored. This research gap determines the relevance and scientific significance of the chosen topic.

Analysis of Recent Research and Publications. The digital transformation of customs systems has been increasingly studied in recent academic literature. International experience in risk management and the digitalization of customs procedures has been investigated by Bugarčić F. and Stanišić N. [2], as well as Alsharari N.M. [3], providing important insights into best practices and institutional approaches to modernizing customs systems. Recent studies emphasize the role of digitalization of customs logistics as a key driver of export competitiveness, especially under wartime and post-war conditions [4-10].

The implementation of electronic declaration systems, single-window platforms, and interoperable customs infrastructures has been shown to contribute to reducing clearance time and transaction costs, thereby improving firms' performance in international markets [4 -6]. The functional aspects and risk-related dimensions of customs logistics have been examined by Kostiunik O.V. and Sivashenko T.V. [11], Kushnir Yu.B. et al. [12], and Reznik N. and Verbivskyi S. [13].

At the same time, the literature consistently highlights that digitalization alone is insufficient to ensure substantial efficiency gains without effective governance mechanisms, regulatory harmonization, and system interoperability [8; 9; 14]. In the Ukrainian context, the effectiveness of customs digital transformation depends on alignment with EU standards, cybersecurity resilience, and the level of interagency coordination. Furthermore, digital customs systems are increasingly regarded as a core element of the transformation of logistics and trade infrastructure, contributing to enhanced resilience and facilitating Ukraine's integration into global value chains [15; 16; 17].

Formation of the Objectives of the Article. The aim of this study is to systematize modern digital tools and technologies applied in customs

logistics, to propose a comprehensive conceptual model of digitalized customs logistics, and to substantiate strategic directions for the digital transformation of customs systems in Ukraine in the context of EU integration.

To achieve this aim, the following research objectives are addressed: (1) to systematize modern digital tools and technologies in customs logistics and assess their impact on foreign economic activity; (2) to analyze the practical outcomes of digital customs implementation in Ukraine (2024–2025); (3) to develop a comprehensive conceptual architecture of digitalized customs logistics integrating technological tools, risk management systems, and strategic priorities; and (4) to substantiate strategic directions for the digital transformation of customs logistics in the context of EU integration.

The methodological framework of the study is based on a combination of general scientific and empirical approaches, including analysis and synthesis, a systems approach, comparative analysis, and tabular and graphical methods. The study also incorporates elements of empirical modeling, including trend analysis and the use of composite indices to assess the relationship between digitalization and customs performance.

Summary of the Main Research Material. In Ukraine, the digital customs infrastructure is based on the Unified Automated Information System of the State Customs Service, which integrates multiple subsystems, including the automated system 'Inspector', and covers the majority of customs functions at both central and regional levels [18]. The practical implementation of digital transformation is reflected in the execution of the Multi-Annual Strategic Plan for Electronic Customs (MASP-C), which establishes a roadmap for aligning national customs IT systems with EU standards.

In 2024, priority was given to the development of a centralized system architecture, including the implementation of the automated customs clearance system 'ASMO Center', the integration of risk management tools, and the deployment of NCTS Phase 5, which enabled the processing of more than 94 thousand transit declarations [19]. In 2025, these processes intensified significantly, with a strategic focus on achieving full interoperability with EU customs systems based on the EU Customs Data Model (EUCDM). The updated strategic framework emphasizes integration with core European systems (AES, ICS2, TARIC), as well as the development of service-oriented digital solutions for businesses, including API-based access to customs data and enhanced functionality of the 'Single Window for International Trade' [20].

The 'single window' system allows parties involved in trade and transport operations to submit standardized documents through a single entry point to comply with regulatory requirements for import, export, and transit. During the period 2024–2025, the functionality was significantly expanded, incorporating real-time tracking of customs procedures, electronic submission of applications, integration with guarantee management systems, and API-based access for enterprises [20; 21]. These developments enabled a higher level of digital interaction between business entities and customs authorities, contributing to increased transparency and operational efficiency.

The rapid development of digital technologies defines the key directions of transformation of customs processes. The systematization of modern digital tools and their impact on customs logistics is presented in Table 1.

The effectiveness of digital customs tools is evidenced by the practical outcomes of their implementation. In particular, in 2025 the number of transit declarations processed under the NCTS exceeded 142 thousand, while the volume of individual guarantees surpassed EUR 1 billion. These indicators reflect a substantial expansion in the scale of customs operations, increased procedural efficiency, and growing trust of businesses in digital customs solutions [20].

The implementation of advanced customs control technologies – including video surveillance systems, automatic license plate recognition, weight control systems, and scanning technologies – further enhances the effectiveness of border control and inspection processes [1]. In this context, an integrated risk management system supported by digital tools enables more targeted control, facilitates the smooth movement of goods and passengers, strengthens supply chain resilience, and reduces potential security risks.

However, the effectiveness of digital customs systems is critically dependent on the quality of institutional governance and the degree of interoperability between public authorities. Empirical evidence indicates that, in the absence of standardized data exchange protocols, coordinated regulatory frameworks, and robust cybersecurity measures, the benefits of

Table 1

Digital Tools and Technologies in Customs Logistics and Their Impact on Foreign Economic Activity

Tool / Technology	Description	Effect on Customs Logistics
Electronic Declaration	Submission of customs declarations in electronic form via the Unified Automated Information System of the State Customs Service.	Reduction in clearance time; decreased paper-based documentation.
Automated Risk Management System (ARMS)	Automated risk analysis based on risk profiles and indicators.	Targeted control; minimization of delays for compliant cargo.
Single Window System	A unified entry point for submitting documents to all regulatory and control authorities.	Reduction of transaction costs; faster interaction between FEA entities and public authorities.
Electronic Queue	Digital system for managing vehicle flows at border crossing points.	Transparency; reduction of corruption risks; decreased cargo idle time.
Scanning Systems	Non-intrusive cargo inspection systems (X-ray, gamma scanning).	Detection of concealed goods without full unloading; faster inspections.
Blockchain in Customs	Distributed ledger technology for document verification and supply chain tracking.	Immutability of records; prevention of fraud; automation of compliance procedures.
Artificial Intelligence / Big Data	Big data analytics and machine learning for risk prediction.	Proactive detection of anomalies; continuous system learning from new data.

Source: compiled by the authors based on [1; 3; 13; 18; 22]

digitalization remain limited and uneven across sectors [8; 9; 14]. In this context, alignment with EU customs standards and the development of integrated digital platforms represent key prerequisites for enhancing the efficiency of customs logistics.

The generalization of the analysed digital instruments and strategic transformation priorities allows for the conceptualization of a comprehensive architecture of digitalized customs logistics. This architecture encompasses three interrelated functional levels: technological tools, the risk management system, and strategic priorities for transformation.

As illustrated in Figure 1, the efficiency of customs and logistics processes is achieved through the integrated interaction of digital technologies (ranging from electronic declaration to artificial intelligence), a multi-level risk management system, and key strategic directions of digital transformation. Their combined implementation forms the basis for improving Ukraine's position in the Logistics Performance Index and enhancing the competitiveness of domestic enterprises in international markets.

At the technological level, the architecture integrates the full spectrum of digital tools: electronic declaration systems ensuring paperless document workflows; automated risk management systems (ARMS) enabling targeted and selective customs control; the single window system reducing transaction costs and streamlining interaction with regulatory authorities; electronic queue systems enhancing transparency at border crossing points; scanning technologies enabling non-intrusive inspection; and blockchain and AI-based solutions ensuring data integrity, fraud prevention, and predictive risk analytics.

The risk management level encompasses strategic, tactical, and operational dimensions, providing a differentiated approach to customs control calibrated to the specific risk profile of each consignment, economic operator, and trade corridor. The strategic priorities level defines the overarching direction of digital transformation, encompassing EU integration, institutional reform, regulatory harmonization, and human capital development.

Based on the analysis of theoretical approaches, international experience, and the specific features of customs logistics in Ukraine,

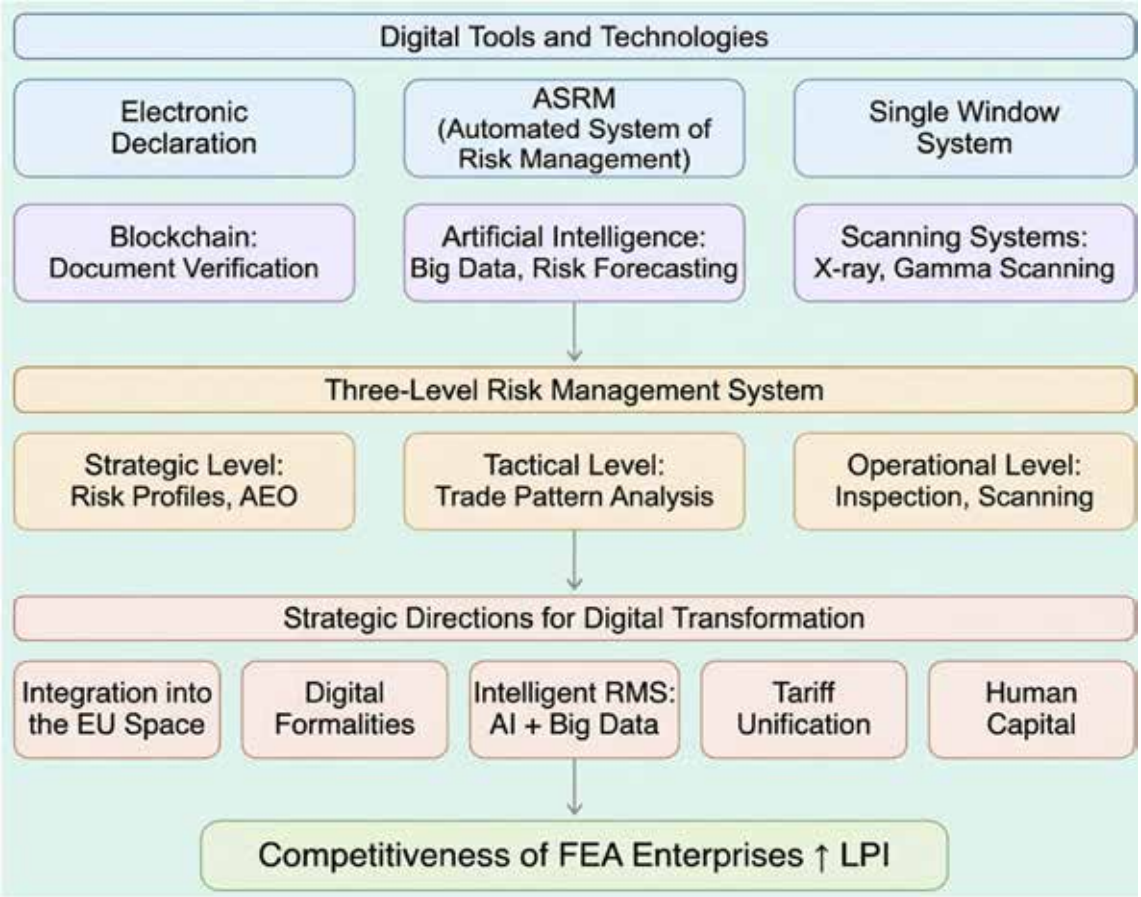

Figure 1. Comprehensive Architecture of Digitalized Customs Logistics

Source: compiled by the authors

five strategic directions for digital transformation can be identified.

Direction 1. Integration into the EU Common Customs Area. The establishment of joint border crossing points and shared data exchange systems with EU Member States can significantly accelerate customs clearance, reduce fraud risks, and minimize time and transport costs associated with cross-border procedures [23]. Integration into the common transit system via NCTS remains a key element of European integration [24]. This process is further reinforced by the implementation of MASP-C, which has enabled Ukraine to achieve a high level of alignment with EU customs IT systems, particularly in transit procedures, risk management, and electronic decision-making processes, as confirmed by the European Commission in 2025 [20; 21; 25].

Direction 2. Full Digitalization of Customs Formalities. The transition to fully digital customs procedures, including paperless document flow and the integration of customs IT systems with national databases (such as the Unified State Register, NABU, and the National Bank of Ukraine), enhances the quality, transparency, and efficiency of customs services [18]. Near-complete digitalization of declarations (over 99% by 2024) represents a significant achievement, yet further systemic integration is required to realize the full potential of digital transformation.

Direction 3. Development of Intelligent Risk Management Systems. The application of Big Data and artificial intelligence enables automated identification of risks based on historical data, profiles of economic operators, and product characteristics. A differentiated approach to customs control allows for reduced administrative burden and accelerated clearance of low-risk consignments [1]. The development of predictive analytics and machine learning capabilities represents the next frontier in customs risk management.

Direction 4. Harmonization of Tariff Policy and Legal Frameworks. The alignment of the customs tariff with international standards, including the Harmonized System and the Ukrainian Classification of Goods for Foreign Economic Activity, reduces misclassification

risks [26]. At the same time, approximation to the EU Customs Code represents a fundamental prerequisite for successful European integration [27]. Regulatory harmonization must encompass not only tariff structures but also procedural requirements, data standards, and institutional governance frameworks.

Direction 5. Development of Human Capital in the Customs Sector. Continuous training of customs personnel—particularly in risk management, digital tools, and anti-smuggling practices – is essential. The development of expertise in customs analytics and cybersecurity is of strategic importance for ensuring the sustainability of digital transformation [2]. Investment in human capital must be viewed as a complement to technological investment, ensuring that digital systems are effectively operationalized and continuously improved.

At the same time, the impact of digitalization on customs logistics efficiency remains heterogeneous. Empirical studies indicate that outcomes depend on the quality of implementation, institutional capacity, and sector-specific factors. In Ukraine, wartime conditions and infrastructure disruptions contribute to uneven effects across regions and industries [8; 10]. Furthermore, the broader trade policy environment – including free trade agreements and regulatory harmonization with the EU – plays a critical role in determining the effectiveness of digital customs reforms.

Conclusions. First, the systematization of digital tools – from electronic declaration and automated risk management systems to blockchain and artificial intelligence – confirms the formation of a comprehensive architecture of digitalized customs logistics in Ukraine. The implementation of the MASP-C strategic plan indicates that Ukraine has reached an advanced stage of digital transformation, characterized by increasing integration with EU customs systems, expansion of digital services, and gradual improvements in procedural efficiency. The processing of over 142 thousand transit declarations under NCTS in 2025 and the surpassing of EUR 1 billion in individual guarantees reflect the scale and depth of this transformation.

Second, the proposed comprehensive conceptual model (architecture) of digitalized customs logistics, integrating three functional levels – technological tools, the risk management system, and strategic priorities – provides a coherent framework for understanding and managing the digital transformation of customs processes. This architecture demonstrates that the effectiveness of digital customs systems is achieved through the integrated interaction of all three levels, not through isolated technological solutions.

Third, the five substantiated strategic directions for digital transformation – integration into the EU customs space, full digitalization of formalities, development of intelligent risk management systems, harmonization of tariff and legal frameworks, and human capital development—form a policy-relevant framework for enhancing the competitiveness of foreign economic operators. These directions are mutually reinforcing and must be implemented in a coordinated manner to achieve sustainable results.

Fourth, while near-complete digitalization of declarations (over 99% by 2024) represents a significant achievement, the nonlinear relationship between digitalization and customs efficiency suggests diminishing marginal returns from further digital expansion alone. Stagnation in LPI values despite high digitalization rates underscores that digital transformation must be accompanied by institutional reforms, process simplification, and infrastructure development.

Overall, the study confirms that digitalization is a necessary but not sufficient condition for improving customs efficiency. Future research should focus on the empirical evaluation of digital customs reforms using firm-level and sectoral data, the integration of digital and green logistics dimensions, and the development of standardized indicators for measuring customs digitalization and its impact on economic performance.

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Дата надходження статті: 30.03.2026
Дата прийняття статті: 21.04.2026
Дата публікації статті: 28.04.2026