

IMPACTS OF LOGISTICS PROCESSES IN STANDARDIZATION AND TRACEABILITY SYSTEMS

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Abstract: The research focuses on the impacts of logistics processes, especially in the field of standardization, traceability and hazardous goods supply chains. This study analyzes how international standards (ISO, GS1, ADR) and modern traceability systems contribute with safer and more efficient logistics operations. One of the most key problems is adapting to international requirements, which include regulatory harmonization, digital transformation, and economic constraints in the Hungarian industry. Technological innovations are also examined as potential tools to enhance transparency, risk management, and process optimization, such as IoT, blockchain, and artificial intelligence (AI). Furthermore, this research represents a conceptual framework to introduce the standardized traceability systems into logistics supply chain strategies. The results highlight the benefits of application harmonized standards and innovative traceability solutions to outlining barriers and opportunities for future development.

Keywords: standardization; traceability; supply chain; hazardous goods; technological innovation

1. INTRODUCTION

Logistics supply chains, standardization and traceability enable safer operations, greater transparency, and more efficient use of resources. These systems support the alignment of business models with regulatory frameworks and rapid technological innovations into the logistics processes and solutions. Based on practical application and implementation can contribute to the flexibility, resilience, and sustainability of global supply chains.

Standardization strategies are required to improve the logistics processes for dangerous goods, where safety, efficiency, reliability and compliance requirements are particularly stringent. These strategies include the integration of domestic and international standards such as ISO, GS1, and ADR. The application of advanced technologies can support these manufacturing and service processes such as IoT, blockchain, and artificial intelligence.

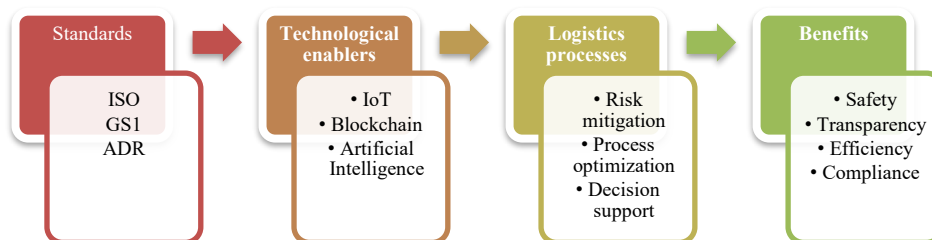


Figure 1. The role of standardization and traceability in hazardous goods logistics [Own edit]

As Fig. 1 shows, the combined application of mandatory standards and digital tools has been shown to reduce risks, improve process efficiency, and strengthen decision-making in logistics supply chains [1]. Other studies also show that blockchain-based traceability and

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standardization play a central role in improving transparency and interoperability in modern supply networks [2]. These developments not only enhance supply chain efficiency but also create standardized conditions for more transparent and secure operations.

Hungarian industry continues to struggle with adapting logistics processes to international requirements. Regulatory fragmentation, economic constraints, and technological barriers slow down the adoption of standardized traceability systems. Tackling these problems is necessary to meet global compliance, to remain competitive, and to move toward long-term sustainability. Therefore, this study examines the impacts of logistics processes in standardization and traceability to show their benefits and limitations.

2. LITERATURE REVIEW

In recent years, traceability, blockchain use, and supply chain sustainability have become key areas of scientific and political debate. This overview provides different perspectives on the topic: structural barriers to traceability systems, sector-specific applications of blockchain, new frameworks for improving efficiency, and links to sustainability and circular economy strategies.

Several authors have mentioned that structural problems often block the use of potential tools. Australian plastic companies follow the circular economy strategies with digital traceability solutions, but they also became more exposed to weaknesses in infrastructure and inconsistent regulation [3]. Compliance costs were an urgent problem for small businesses, while larger stakeholders indicated their dissatisfaction with the fragmentation of the regulations. It suggests that political instruments could better consider the different organization sizes and capacities. There are also similar concerns in the case of electronic waste management in China. It shows how extended manufacturer responsibility has encouraged the recycling companies to move towards better traceability and closed-loop systems. More radical changes are necessary to remove and replace these old approaches [4]. A Delphi-based approach was developed to identify and prioritize food supply chains in precarious situations, which is called a general framework. Transparency and cooperation consistently ranked at the top of the list, along with investment in research and clear regulatory support [5].

Several studies have explored the integration of blockchain in different industries. It has appeal to the automotive industry, because it can increase visibility and safety. Unfortunately, this progress is being slowed down by limited interoperability and a common standard [6]. Block chain has enhanced the safety and traceability of food supply chain operations, but still fragmented regulations continue to block its adoption [7]. Smart contract-based agricultural prototypes achieve more transparent transaction management, but their success still requires commonly accepted and standardized agreements [8].

Other researchers described different approaches to increase efficiency. A two-tier change management model helped to manage the product changes more flexibly and traceability [9]. The combination of blockchain and artificial intelligence led to more accurate data and faster decision-making in food supply chains, while also enabling the prediction of waste and emissions [10]. Industrial tests showed that blockchain-based data provenance can reduce the risk of centralized systems and build greater trust among supply chain partners [11].

Mathematical modeling has enabled food industry sectors to find a better solution for balancing sustainability and performance, supporting the importance of collaboration to

overcome obstacles [12]. Blockchain-based logistics supply chain has improved traceability, which enables it to generate higher profits, demonstrating that sustainability and economic performance can be synergistic [13].

European projects have developed tracking engines that have improved interoperability and data reuse across food industry sectors [14], while in maritime transport, the combination of blockchain-based auditing and standardized data exchange is seen as a way to improve global shipping efficiency [15].

In summary, the previous research has provided valuable insights into systemic barriers, blockchain adoption, efficiency-oriented frameworks and approaches in sector-specific areas. Without regulatory clarity, specific standards, and collaboration between stakeholders, technical innovations alone will not be enough to transform supply chains in a sustainable direction [16]. These relevant articles were published within the last four years. This finding highlights the scientific potential of logistics standardization and traceability processes and their developments.

3. CHALLENGES TO THE STANDARDIZATION OF LOGISTICS SUPPLY PROCESSES IN THE HUNGARIAN INDUSTRY

Standardization is an important tool in supply chain design methods, especially in manufacturing and service companies. It requires up-to-date regulation environments to support assemblies- and logistic processes in fulfilling variable customer orders.

Table I.
Challenges to the standardization of logistics processes in Hungary [Own edit]

Challenge	Description	Consequence
Regulatory fragmentation	Conflicting and inconsistent rules block harmonization	Difficult adaptation to Domestic, EU or international standards
Economic constraints	Financial and technological compliance costs	SMEs carry a large compliance burden
Technological barriers	Outdated IT infrastructure	Limited integration with IoT, RFID, blockchain
Poor interoperability	Weak data exchange and rigid systems	Reduced transparency between supply chain participants
Limited cooperation	Stakeholders hesitate to share or harmonize standards	Blocks the development of common traceability frameworks
Safety and conformity	Strict requirements in critical industry sectors (e.g., chemicals, dangerous goods)	Balancing innovation with safety remains difficult
International discrepancies	Different international interpretations of ADR/IMDG/IATA	Different packaging, labeling, documentation rules
Documentation burden	More mandatory forms and reports required	ADR declaration, MSDS, CMR waybills increase costs
Human resources and training	Specific skills and certification needed	Missing harmonized standards for staff training
Cybersecurity risks	Digital traceability systems handle sensitive data	Increased cyberattack victimization

As Table I shows, Hungarian logistics currently confronts several barriers. Regulatory fragmentation blocks harmonization and makes it difficult to adapt to domestic, EU, or international standards. Economic constraints increase compliance costs, placing a heavy burden on SMEs. Technological barriers related to outdated IT infrastructure limit to the integration of IoT, RFID, and blockchain. Poor interoperability reduces transparency between supply chain participants, while limited cooperation blocks the development of common traceability frameworks. Safety and conformity requirements make it difficult to balance innovation with compliance in critical sectors, such as chemicals- and dangerous goods. International discrepancies create different packaging, labeling and documentation rules in ADR, IMDG and IATA. The documentation burden increases costs through ADR declarations, MSDS and CMR waybills. Human resources and training are also affected, since harmonized standards for staff qualifications are missing. Finally, digital traceability systems handle sensitive data, which increases the risk of cyberattacks.

4. IMPACTS OF STANDARDIZATION AND TRACEABILITY IN LOGISTICS SUPPLY CHAIN STRATEGIES

Standardization and traceability play an important role in hazardous goods logistics processes. The application of ISO, GS1 and ADR standards increases safety, transparency and efficiency in the whole supply chain.

Table II.
Conceptual Framework of Standardization and Traceability Impacts in Logistics Systems [Own edit]

Area	Mechanism	Standards and tools	Defined indicators	Expected effect
Safety and compliance	Standards for packaging, labeling, documentation, certified training	ADR, IMDG, IATA, ISO 9001/28000, MSDS, CMR	Incident rate, penalties, compliance rate	↓ incidents, ↓ penalties, ↓ legal conformity
Process efficiency	Standard operating procedures, harmonized data formats	ISO process standards; EDI/XML	Lead time, throughput time, administrative hours	↓ admin burden, ↓ faster border, ↓ customs processing
Traceability and transparency	Full identification and status visibility	GS1 bar /QR, SSCC, RFID, IoT sensors	Scanning accuracy, reading speed, real-time tracking coverage	↑ visibility, ↑ fewer misroutes, ↑ faster exception handling
Interoperability	Common identifiers, structured master data	GS1 GLN/GTIN; standardized events	Data match % between partners	↓ data mismatches, ↓ fewer rework loops
Risk management	Digital monitoring, standardized emergency procedures	IoT datas; blockchain provenance	Probability × Loss, near-miss capture rate	↓ expected loss from incidents
Sustainability	Standardized packaging, optimized routing	ISO 14001, AI route planning	Fuel/ton-km, CO ₂ e/ton-km, packaging waste	↓ fuel and emissions, ↓ material waste

Table II represents that standardized processes also support related tasks and services, such as packaging, labeling and documentation. These can reduce the risk of accidents and ensure compliance with local, international and EU regulations. Standardized processes also support

related tasks and services, such as packaging, labeling, and documentation. The table also highlights the main areas where standardization and traceability mechanisms can affect emissions management in industrial supply chains. These practices could mitigate the risk of injuries and provide greater compliance with domestic, international, and EU regulations. It defines the relationships between impact areas, applicable standards, measurable indicators, and their expected effects, showing how coordinated practices can improve compliance, reduce risks, and lower emissions throughout the supply chain.

6. SUMMARY

The application of global systems enables better product identification and real-time monitoring, for example GS1 bar- and matrix codes and RFID traceability solutions. In addition, digital traceability tools and methods improve risk management and decision-making, including IoT sensors, blockchain and predictive analytics. These developments could reduce operation costs, increase logistics competitiveness and contribute to sustainable supply chain operations. However, the integration of standardized traceability systems enhances cooperation between stakeholders and guarantees supply chains reliability and transparency.

Hungarian industry still has challenges to adapt its logistics processes to international standard. Regulatory overlaps, high compliance costs and outdated digital infrastructure make the introduction of traceability systems slow. Poor interoperability and limited cooperation between stakeholders further reduce efficiency. Strict safety rules in hazardous goods transport, different interpretations of ADR, IMDG and IATA, and the heavy documentation requirements increase the complexity of daily operations. The lack of harmonized training and the growing cybersecurity risks also create obstacles. Solving these problems is necessary to achieve compliance, maintain competitiveness and support sustainable logistics.

The study provides a conceptual framework for integrating standardized traceability systems into logistics strategies. It describes that the harmonized standards and innovative digital tools can work together to improve security, transparency, and performance in supply chains.

In conclusion, this research underlines that standardization and traceability are key area of logistics development. Their application supports the operational- and strategic goals of supply chains decision-making processes. Through stronger cooperation and shared data frameworks between supply chain partners, these systems can gradually improve transparency and competitiveness in logistics, while also creating a foundation for future technological and regulatory development.

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