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System and Technology Integration for Tracking Shipments in Rail Transport on the New Silk Road: Research Results

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Abstract:

Purpose: *The objective of this paper is to analyse the possibilities of improving logistics processes in the import of goods from China to Poland within the New Silk Road by applying GS1 standards, with particular emphasis on radio frequency identification (RFID) technology in rail transport. The research focuses on the integration of the identification of transport units, goods, and transactions, as well as on indicating the potential of these solutions for improving logistics processes efficiency in supply chains.*
Design/Methodology/Approach: *The paper presents a functional and informational analysis of transport processes and customs procedures along the New Silk Road, taking into account the transport document flow (CIM, SMGS), identification standards (GTIN, SSCC, GSIN, GIAI), as well as IT systems used by the postal operator and its partners (EN, IPS, ZST, Microsoft Dynamics AX). On this basis, a logical model for RFID implementation in accordance with GS1 standards was proposed, enabling automatic identification and real-time monitoring of transport units.*
Findings: *The results indicate that current rolling stock and container marking systems are limited in terms of automatic identification and require expert knowledge. The RFID application allows for the creation of a globally unique identification system based on GIAI, linked to the EVN number and container numbers. The equipment requirements for a train consisting of a locomotive, 40 wagons, and 40 containers were estimated, indicating the need to install 81 passive tags and 48 trackside readers, which enables effective tracking of transport over a distance of approximately 9,500 km.*
Practical implications: *The proposed model integrates identification and monitoring processes, supports the digitization of customs procedures, increases the transparency of goods flows, and enhances the competitiveness of Polish logistics operators in global supply chains. This solution can be used by postal operators, rail carriers, shipment consolidators, customs services, and transport safety supervisory institutions.*
Originality value: *The paper contributes to the literature by proposing an integrated, empirical model for the application of GS1 standards in international logistics, combining RFID, GIAI, and the EVN numbering system. This approach enables a quantitative assessment of the transport units flow, enhances system interoperability, and provides a starting point for ongoing research on the digitization and automation of rail transport in Poland in the context of the New Silk Road.*

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1. Introduction

Rail transport is the core of modern logistics systems, acting as a strategic link in international supply chains. It's a driver of economic integration and a catalyst for sustainable transport development – helping to reduce emissions, optimise transport costs and improve the safety of logistics operations (EC, 2025). In the context of increasing globalisation and intensification of international trade, the role of rail transport in transcontinental transport corridors, such as the New Silk Road, is growing (GFDC, 2021).

From the perspective of Europe, and Poland in particular, the New Silk Road not only strengthens the geopolitical dimension of trade, but also poses a number of challenges for logistics in terms of interoperability, transport documents flow and automatic identification for transport units.

The scale and complexity of logistics processes performed as part of the New Silk Road require the creation of integrated information management mechanisms based on uniform standards.

Poland, as a key hub and point of arrival for the European section of the route, plays a particularly important role in the flow of goods between Asia and Europe. This responsibility entails the need to improve customs procedures, the transport documents flow and the implementation of identification technologies, including RFID and GS1 standards.

At the institutional and operational level, both international regulations – including the use of CIM and SMGS consignment notes – and national rolling stock and container identification systems are of significant importance. Their effective use requires close integration of the IT systems of logistics operators, rail carriers, customs administrations and infrastructure managers. Only then it becomes possible to fully control the freight flow and transport information in real time, thereby increasing the transparency and security of the entire process.

The aim of this paper is to analyse the possibilities of improving logistics processes in the import of goods from China to Poland within the New Silk Road by applying GS1 standards, with the use of RFID technology in rail transport. The research focused on the integration of the identification of transport units, goods and transactions, and the assessment of the potential of these solutions to improve the logistics efficiency in Poland.

The analysis adopted a model and conceptual approach, including mapping the transport document flow, identifying the process locations responsible for marking and monitoring transport units, and assessing the readiness of supply chain entities to implement the proposed solutions. Expert knowledge was used to estimate the real possibilities of applying GS1 standards and RFID technology in logistics practice.

This approach not only identifies limitations and barriers, but also sets out directions for the development of supply chains with a view to increasing the efficiency, safety and transparency of the flow of goods on international routes using rail transport.

2. Literature Review

The literature on rail freight transport is dominated by the perspective of seeking ways to increase the competitiveness of railways vis-à-vis other modes of transport. Analyses indicate that both infrastructural and organisational factors are of key importance, as is the integration of logistics processes on a European and global scale (Islam, 2014a; 2014b; Bueno and Alencar, 2016).

It should be noted that the main barriers to development are the lack of interoperability, the low quality of door-to-door services and the fragmentation of the market, which continue to limit the possibilities for complete integration of railways into multimodal supply chains (Lewis, Semeijn, and Vellenga, 2002; Potter, Soroka, and Naim, 2022).

An important area of research is the role of rail transport in sustainable mobility policy. The literature emphasises that rail has the potential to significantly reduce CO_2 emissions and support green transport corridors, making it a key element of European environmental strategies (Islam and Blinge, 2017; Aditjandra, Zunder, and Palacin, 2022). For this reason, research is being conducted into energy efficiency and the adaptation of railways to new market segments in urban environments, following high-speed rail for low-density, high-value freight transport (Vajihi and Ricci, 2021; Boehm, Arnz, and Winter, 2021).

Long-term analyses indicate that achieving the targeted modal shift indicators requires consistent regulatory and investment measures, as well as regional transport systems that are resilient to economic and political disruptions. (Islam, Jackson, and Burgess, 2015; Potter, Soroka, and Naim, 2022). Strategic and operational planning issues are also an important area of research. Great emphasis is placed on optimising the location of logistics hubs and designing intermodal networks that enable cost reduction and shorter transport times (Li *et al.,* 2023).

Pricing strategies for high-speed rail services are also being developed, taking into account the perspectives of both rail carriers and logistics operators (Yue *et al.,* 2025). Predictive models and machine learning algorithms are becoming increasingly important, enabling dynamic journey time forecasting and better railway network management (Kumar, Sharma, and Kumar, 2025).

The area of digitisation and automation of rail transport processes is developing extremely rapidly. Research focuses on the implementation of solutions based on artificial intelligence, digital twins and ERP information systems, which enable more precise planning and control of operations (Lekarev *et al.,* 2020; Sarp, Kuzlu, and Guler, 2024; Felder, Bataleblu, Grünbacher, and Rauch, 2025).

Particular attention is given to the development of digital tools for intermodal route planning and emissions monitoring, with a special focus on the challenges faced by small and medium-sized enterprises (Zajac, Rožić, Swieboda-Kutera, and Starčević, 2025; Pham, 2021).

Identification and monitoring technologies play an important role in this research. RFID, IoT systems and automatic data collection enable precise freight tracking, improve operational transparency and support real-time analysis (Hompel, Masoudinejad, and Roidl, 2018; Kodym and Unucka, 2016; Ravi, Seetharaman, and Jayaraman, 2023).

Innovative solutions are also being developed in the field of train positioning and automatic analysis of railway route plan compliance, which helps to minimise operational and planning risks (Olaby, Hamadache, Soper, Winship, and Dixon, 2022; Porto, Falcão, Franco, Porto, and Nunes, 2015).

At the same time, research is being conducted on the managerial and institutional challenges accompanying the digitisation of railways. Analyses indicate that the successful implementation of advanced traffic management systems, such as ERTMS, remote control and automatic driving, depends not only on technology, but also on effective change management and the involvement of all stakeholders (Morin, Olsson, and Lau, 2024).

The need to adapt academic and vocational education to the requirements of modern railway logistics and to develop methods for assessing the quality and services efficiency is discussed in the works of Tanaino, Yugrina, and Zharikova, (2018), and Marinov and Fraszczyk, (2014).

International literature also shows wide regional diversity – from mature rail services in Europe, through infrastructure challenges in Brazil and Turkey, to market niches related to Eurasian corridors (Bueno and Alencar, 2016; Çelebi, 2023; Zhang and Schramm, 2020). In addition, research indicates the growing importance of the Logistics 4.0 concept, in which intermodality, digitalisation and automation are treated as the fundamental elements of the future competitiveness of railways (Vida, Illés and Bányainé-Tóth, 2022; Lehmacher, 2021; Faustov, Chemeris, and Halada, 2023).

The literature therefore presents freight rail as a sector with great potential for sustainable development and digital transformation, but one that faces significant organisational and structural barriers. The development of this area requires a systemic approach that combines technological innovation, process integration, an appropriate regulatory framework and investment in human skills.

Despite the wide scope of research, previous publications have rarely taken a comprehensive approach to all elements of the New Silk Road logistics chain in the context of data integration and IT system interoperability. In particular, there is a lack of empirical research showing the practical possibilities of standardising the information and document flow, implementing RFID and EPCIS systems, and integrating data for stakeholders.

The research gap that this paper fills therefore concerns the practical analysis of the integration of IT systems of operators, carriers and customs authorities in rail transport on the New Silk Road and the identification of critical points of information flow.

The research conducted not only allows for mapping existing processes and data exchange processes, but also indicates directions for the development of data and information flow digitisation, the use of GS1 standards in the identification of rolling stock and containers, and the implementation of real-time monitoring systems. As a result, the paper provides new practical knowledge to increase the efficiency and transparency of rail transport between Asia and Europe.

3. Research Methodology

The research was conducted based on a model and conceptual approach, enabling systematic analysis of logistics processes and assessment of the possibilities of integrating RFID technology and GS1 standards into the Polish rail transport system as part of the New Silk Road. The focus was on the identification and monitoring of transport units, freight and transactions, as well as the assessment of the readiness of entities involved in the supply chain to implement the proposed solutions.

The first stage of the research involved analysing documents and applicable procedures, including international regulations such as CIM and SMGS consignment notes, customs regulations and national standards for identifying rolling stock and containers.

The functioning of Polish IT systems supporting logistics operations was also analysed to identify limitations in the automatic identification of transport units and information flow.

The second stage involved modelling and conceptualising logistics processes, including mapping the transport document flow, freight and transactions along the New Silk Road. Based on the collected data, a logical model of process locations responsible for marking and monitoring transport units was developed.

The model took into account both GS1 standards, in particular the Global Individual Asset Identifier (GIAI), which was linked to EVN numbers for railway vehicles and container numbers, enabling unambiguous identification of transport objects.

An integral part of the research was expert knowledge obtained from logistics operators, representatives of the postal operator, infrastructure managers, and international transport specialists. The expert assessment not only allowed for an evaluation of the readiness of entities to implement RFID technology, but also identified organizational, technological, and operational barriers.

Based on the information gathered, an estimate was also made of the hardware requirements, such as the number of tags and readers necessary for effective monitoring of a train composition with a specific configuration of wagons and containers.

This methodology not only allows for the identification of limitations in the current logistics system, but also for the determination of potential directions for its development, increasing the process efficiency, improving safety, and transparency of the goods flow in Polish rail logistics in the context of international transport corridors.

4. Research Results and Discussion

Research examined the information and system processes necessary for effective shipment monitoring, with particular emphasis on data flow in rail transport between Asia and Europe, customs procedures and distribution to the end customer. The research covered not only the information needs of operators, carriers and terminals, but also the system readiness of the postal operator and business partners to integrate data in real time, using GS1 standards, EDI and ERP/WMS systems.

The aim was to identify opportunities for standardising the identification of shipments and freight, optimising the transport document flow and ensuring full interoperability in the global supply chain.

An assessment of information requirements for the integration platform showed that postal operators and partners in the New Silk Road logistics chain use diverse data exchange channels, which need to be standardised in order to enable efficient shipment monitoring. The research included observation of shipping and transport processes involving intermodal operators, rail carriers, terminals and the Customs Office.

As part of the railway process, it was found that the intermodal operator sends wagon orders and consignment notes to the railway carrier mainly by e-mail, EDI or on paper, depending on the carrier's system. Confirmation of wagon availability and the transit schedule is provided to the operator, terminals and forwarders, and the transport documents (CIM and SMGS) contain varying amounts of data depending on the legislative and geographical system.

The lack of a single standard makes it difficult to automate processes and exchange data in real time, especially when shipments are transferred between the CIM and SMGS communication standards. Integrating CIM/SMGS solutions are only now appearing.

In terms of distribution to the end customer, data flow was observed through the EN (in polish Elektroniczny Nadawca - Electronic Sender) application, which enables both the generation of labels and reports in web form and integration with external customer ERP/WMS systems using WebAPI.

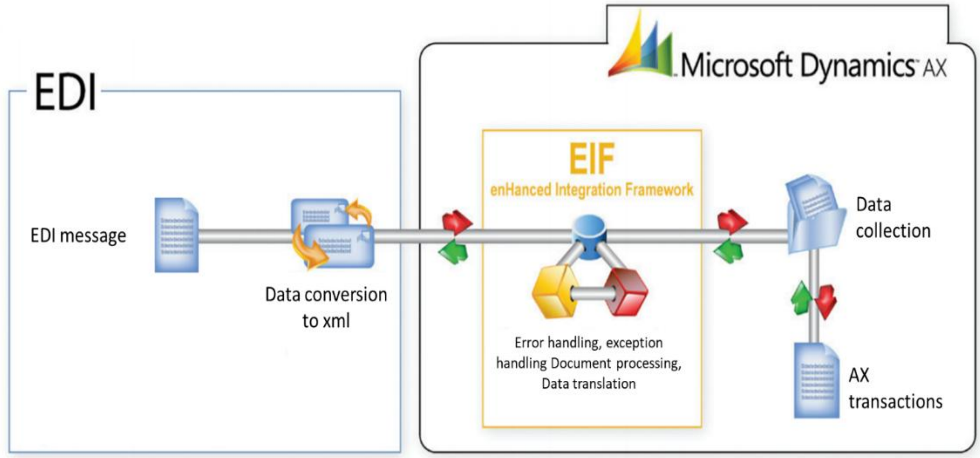
The functionning of the IPS (International Postal System) and ZST (in polish Zintegrowany System Informatyczny - Integrated Information System) systems showed that shipment data is entered and verified in the postal operator's systems, freight lists and reports are generated, and the registration and scanning process is carried out systematically.

The most important element of the research was the assessment of postal operators' readiness for information integration in the context of data sharing. Integration tests with Microsoft Dynamics AX showed that centralising processes within ERP enables the exchange of documents in EDI standards (EDIFACT and XML) with external systems.

Figure 1 shows a diagram of EDI integration with Microsoft Dynamics AX, illustrating the flow of transport data, loading reports and shipment statuses between the postal operator and its business partners. Centralisation and system integration significantly reduce the risk of errors, enable quick response to discrepancies and support real-time shipment monitoring.

The research confirmed that effective implementation of GS1 standards and integration of IT systems can ensure full interoperability in the information flow, both at the level of operators, carriers and terminals, as well as in relations with the end customer. The implementation of a core ERP system and the use of EDI as a data exchange tool provide real added value, increasing the efficiency and transparency of the entire logistics process along the New Silk Road.

Figure 1. *EDI integration with Microsoft Dynamics AX*



Source: *Own study based on Microsoft Dynamics AX (Envista) documentation.*

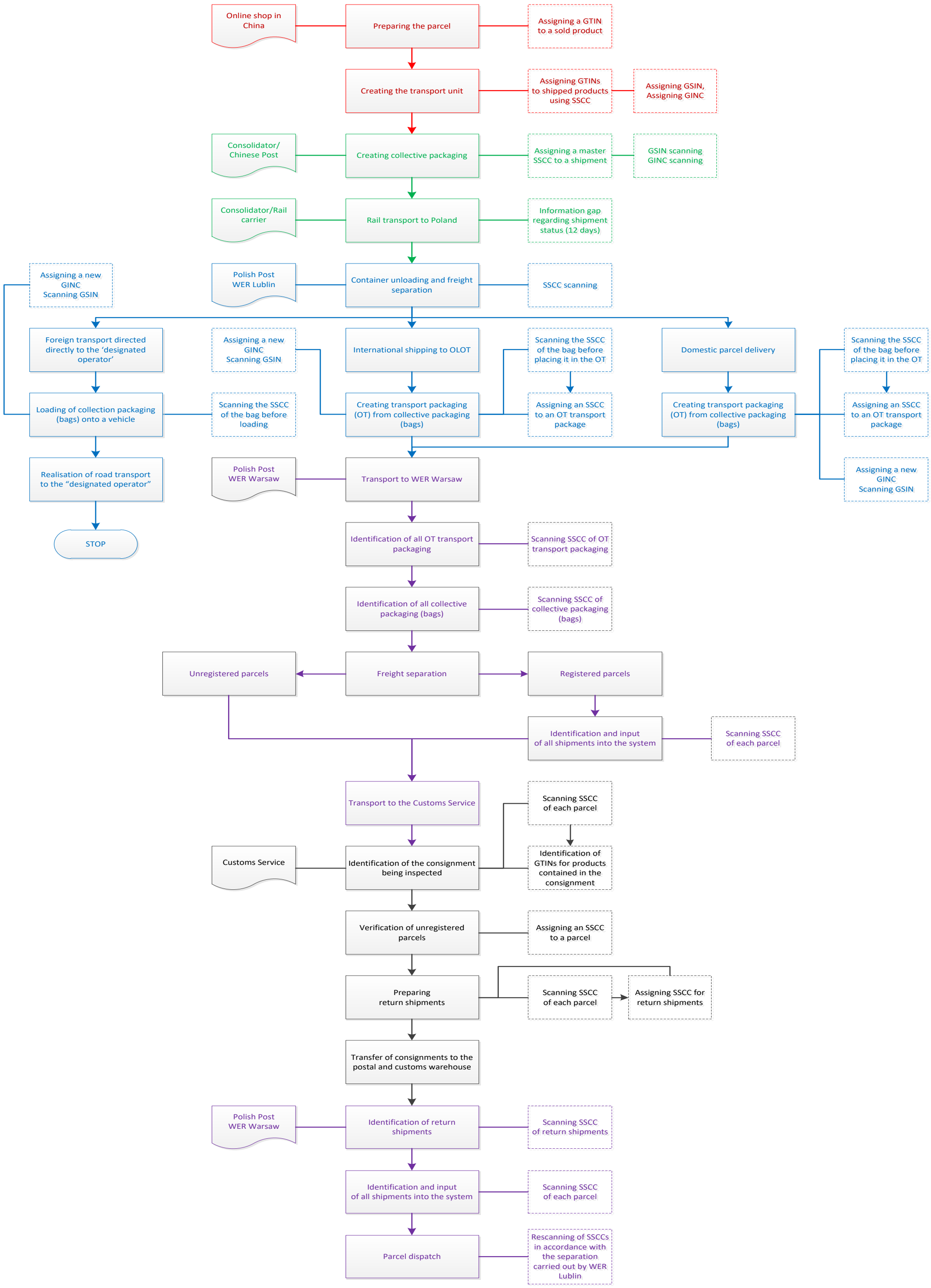
The next stage of research focused on the possibilities of applying RFID technology in rail transport on the New Silk Road route. The research began with a review of the markings used on rolling stock, including locomotives and freight wagons, as well as transport containers, which are an integral part of the transport process. During the observation, the applicable standards for marking railway vehicles were identified, including the European Vehicle Number (EVN) and national markings used in Poland by PKP S.A (Polish State Railways).

The EVN consists of 12 digits that clearly identify the type of rolling stock, interoperability capability, country of the carrier, technical characteristics of the vehicle and serial number, with the last digit serving as a check digit. Similarly, PKP national markings use a combination of letters and digits to specify the type of traction, purpose, axle arrangement, drive transmission method and vehicle inventory number. Although both systems allow for full identification of the object, they are primarily read visually and require knowledge of the numbering schemes used.

Therefore, the next stage of research was to assess the applicability of GS1 standards in the automatic identification of rolling stock and transport containers (Figure 2). The Global Individual Asset Identifier (GIAI) was adopted, which uses a 12-digit EVN number as part of the reference number for railway vehicles.

This makes it possible to read basic data about the resource even when there is no Internet access. For containers, the GIAI identifier number contains the container code and allows it to be linked to the loading unit, wagon and locomotive, creating a coherent structure for tracking the shipment from the collective packaging level to the entire train composition.

Figure 2. *Model for applying GS1 standards in the New Silk Road Model for applying GS1 standards in the New Silk Road*



Source: *Own study based on a research project for GS1 Poland.*

From a pragmatic perspective, RFID tags are installed at two points on opposite sides of the vehicle, enabling the signal to be read by trackside readers. For the estimated system assessment, the New Silk Road was adopted, with a distance of approximately 9,500 km, a train length of up to 600 m, and a composition including a locomotive, 40 flat wagons and 40 40-foot containers.

The estimated number of required passive tags and track-side readers is 81 and 48, which allows for the recording of incidents such as train passing every 500 km and entry and exit from border crossings.

Through the use of RFID in connection with GS1 standards and the integration of postal operator systems, it is possible to effectively monitor shipments in real time and respond quickly to any potential irregularities.

The final stage of the research was to assess the possibility of using the EPCIS standard to monitor rolling stock on the New Silk Road. EPCIS, as a standard for tracking logistics events, allows for the collection and information exchange about the location and status of resources, but requires the separation of interface specifications from RFID technology.

In practice, this means that the RFID system transmits location and other data as part of EPCIS events, while the standard does not impose a method for capturing them – EPCIS only indicates what information should be recorded, and consistent event structures enable data exchange between railway entities.

The need to monitor rolling stock applies to both domestic and cross-border operations, enabling better planning of operations and optimal use of vehicles. The observation concerns the level of individual transport units – wagons and locomotives – and includes the location and status of rolling stock throughout the entire transport process. Several potential applications of EPCIS have been identified: real-time freight tracking, estimating the distance travelled by a vehicle for preventive maintenance planning, and monitoring vehicle availability.

Ongoing possibilities include the use of EPCIS to obtain data on the condition of rolling stock and its components in order to improve preventive maintenance. In this context, Wayside Train Monitoring Systems (WTMS) play an important role, monitoring the condition of rolling stock during movement, enabling the detection of irregularities and improving the reliability of rail transport. Through the EPCIS integration, it is possible to monitor, among other things:

- detection of overheated axles – measuring the temperature of wheels and axle bearings for early failure detection,
- detection of wheel impact loads – measuring static and dynamic forces to identify defects and incorrect loads,

- acoustic monitoring of axle bearings – assessment of degradation using acoustic sensors,
- pantograph – use of high-speed cameras and image analysis to detect broken carbon strips.

Research has confirmed that the use of EPCIS in rail transport on the New Silk Road has great potential for real-time rolling stock monitoring. The system allows for shipment tracking, ongoing assessment of the technical condition of vehicles, preventive maintenance planning and effective management of rolling stock availability, which significantly increases the safety and efficiency of the entire logistics chain.

5. Conclusions, Proposals, Recommendations

The analysis clearly shows that Poland has the opportunity to play a strategic role in the development of rail logistics within the New Silk Road. Its geographical location makes it a natural gateway to Europe and, at the same time, an area where challenges related to the integration of transport, documentation and customs systems accumulate.

The results of the research show that one of the key factors determining the transport processes efficiency is the integration of CIM and SMGS communication standards. The standardisation of these documents within a digital platform offers a real opportunity to reduce the risk of errors, reduce handling time and increase the transparency of commercial transactions.

Customs procedures also play an important role in improving rail transport. As a border country of the European Union, Poland is responsible for the proper realisation of import and export clearance, which directly affects the agility of the entire logistics process. The implementation of modern digital solutions, such as the integration of operators' IT systems with customs administration tools, has proven to be an effective way to quicken and simplify customs clearance.

The example of the solution's implementation at a postal operator shows that digitisation is not only a tool for improving efficiency, but also an element of building competitive advantage in the logistics sector.

Another finding is the growing importance of automatic identification technology in rail transport. The implementation of RFID systems based on GS1 standards allows for the clear identification of containers, wagons and entire trains. A hierarchical labelling system involving loading units, vehicles and infrastructure enables real-time tracking of shipments regardless of their physical location. Integration with central databases allows for real-time verification and information updates, which increases the reliability of monitoring processes and reduces susceptibility to disruptions.

Furthermore, the use of the EPCIS standard allows for effective tracking of railway assets at the level of individual wagons and locomotives, as well as predicting maintenance needs and planning rolling stock availability.

Monitoring systems such as WTMS, in combination with EPCIS, enable the detection of critical conditions such as overheated axles or pantograph damage, which contributes to improved transport safety and supply chain reliability.

These findings point to three key directions for the development of Polish rail transport processes in the context of the New Silk Road:

1) Digitisation and standardisation of documents and procedures (unification of transport documentation and customs procedures; centralisation of processes within IT systems enabling automatic data exchange; standardisation of information flow between operators, customs offices and terminals),

2) Development of monitoring and identification systems (implementation of RFID technology and hierarchical identification systems enabling real-time tracking of shipments; integration of GS1 and EVN standards in the identification of rolling stock and containers; use of EPCIS to monitor the location and technical condition of rolling stock in real time; use of data for preventive maintenance planning and operational optimisation),

3) International cooperation and interoperability (standardisation of data exchange between railway operators, logistics partners, customs and phytosanitary services; training and support for all participants in the transport process in the use of new systems and standards; deepening cross-border cooperation for full integration of data and logistics processes).

The realisation of the above measures allows Poland to fully exploit its potential as a major logistics hub for rail transport between Asia and Europe, increases the efficiency, safety and transparency of the entire supply chain, and strengthens the competitiveness of the domestic logistics sector.

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