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Application of Operational Data Analysis in the Optimization and Enhancement of Logistics Process Safety

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Abstract:

Purpose: *The purpose of this article is to evaluate the efficiency of transport processes and operational safety levels based on a set of logistics and operational indicators obtained from the Logistics Information System (LIS) and telematics systems for a selected fleet of 10 vehicles. The analysis demonstrates how combining technical and economic indicators allows for the diagnosis of logistics processes and the formulation of recommendations in the context of variability and risk.*
Design/Methodology/Approach: *The study was conducted in a logistics and transport company implementing LIS and vehicle telematics. Quantitative analysis was used to evaluate operational indicators such as the number of deliveries, vehicle load utilization, waiting time, number and causes of delays, the OTIF index, and* T_{AU} *representing the unit value of the utilized vehicle load capacity. Data were collected from telematics and CRM systems and aggregated into the central LIS database. Non-parametric DEA (Data Envelopment Analysis) and indicator analysis methods were applied.*
Findings: *The conducted analysis demonstrated that the highest efficiency and safety of the logistics process were achieved by vehicles exhibiting low delay rates and high values of the unit indicator for utilized vehicle load capacity. The lowest OTIF (On-Time In-Full) values characterized vehicles with the highest share of logistics delays. The findings also indicated that the number of completed deliveries alone does not guarantee high process efficiency or operational safety.*
Practical Implications: *The results draw fleet managers' attention to the need for continuous data analytics to quickly identify weak points and implement corrective measures. It emphasizes the importance of conducting regular statistical analyses of delay causes and managing operational risk within a dynamically changing transport environment. Raising the level of safety requires not only responding to threats but also prediction and prevention based on LIS and telematics data.*
Originality/Value: *This article presents a practical application of advanced LIS and telematics tools in a comprehensive assessment of transport fleet efficiency and safety. The findings provide actionable recommendations for managers on how data analysis can directly enhance competitiveness, operational performance, and resilience to disruptions.*

Keywords: *Logistics Information System (LIS), OTIF, Safety in Logistics, Fleet Management.*

JEL classification: *C15, R41.*
Paper type: *Research article.*

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1. Introduction

Contemporary logistics and transport processes operate in an environment of increasing complexity, global competition, and dynamic market conditions. In recent years, supply chains have become increasingly exposed to various types of disruptions — from transport delays caused by adverse weather and road conditions to interruptions in resource availability driven by unforeseen demand fluctuations, infrastructure failures, or socio-economic crises. Maintaining high transport efficiency while ensuring the required level of operational safety has become one of the key challenges for fleet managers and logistics professionals

Logistics safety should be understood both in the operational dimension as the assurance of process continuity and reliability and in the strategic dimension, which encompasses risk management, contingency planning, and the minimisation of disruption impacts. Effective response to uncertainty and change requires the application of methods that enable continuous process monitoring, early detection of deviations, and decision-making based on rigorous data analysis.

Delivery delays lead directly to the risk of interrupting the continuity of logistics processes, resulting in supply gaps and reduced product availability. A lack of flexibility in responding to changes negatively affects all areas of business activity. Systems with limited adaptability demonstrate lower resilience to unpredictable threats, such as sudden demand shifts, extreme weather events, or technical failures. The absence of agile solutions constrains effective risk management, making the consequences of delays more significant for operational safety.

In the era of digitalisation, real-time analytics and the effective use of information derived from telematics systems, fleet management platforms, and Business Intelligence tools have become key sources of competitive advantage. Monitoring parameters such as delivery timeliness, inventory levels, vehicle waiting times, transport unit utilisation rates, and customer transaction values not only supports cost optimisation but also enhances the overall resilience of the logistics system to disruptions.

The integration of Logistics Information Systems (LIS) with agile management approaches is crucial for increasing supply chain resilience. This combination links the advantages of advanced data monitoring and information management (LIS) with flexibility and rapid responsiveness to change (agile), thus enabling immediate adaptation to disruptions and unforeseen events.

LIS systems integrate operational data from multiple sources routes, warehouses, shipment statuses, demand forecasts, and transport conditions into a coherent platform, enhancing visibility, monitoring accuracy, and decision-making efficiency (Gong, 2025). Through LIS, managers gain access to real-time data and analytics, enabling early risk identification, trend analysis, and the implementation of preventive measures, such as rerouting in case of disruptions or ensuring appropriate resource allocation.

The objective of this article is to evaluate the efficiency of transport processes and the level of operational safety based on a set of logistics and operational indicators collected for a selected fleet of ten vehicles. The analysis encompasses both operational factors — such as waiting time and frequency of delays and economic indicators related to customer transaction values. Combining these two perspectives operational efficiency and safety — allows for a comprehensive diagnosis of the examined processes and the formulation of recommendations for optimising them under conditions of variability and uncertainty.

2. State of Research in the Studied Area

Managing safety in logistics in the era of industrial digitalization is a complex process, as the concept of Industry 4.0 integrates people, machines, and diverse production processes into one cohesive system. Modern technologies enable the operation of machines and equipment based on mutual communication and data exchange, resulting in an extensive network of interconnections between products, value chains, and business models.

The implementation of Industry 4.0 solutions encompasses not only technological aspects but also human interactions and work safety procedures. Ongoing digitalization opens new opportunities in workplace organization, contributing to the development of safety logistics. Advanced digital technologies exert a notably positive influence on operational safety and performance, particularly within logistics processes (Sen, 2021).

Recent studies have proposed innovative approaches for assessing logistics efficiency while integrating operational safety dimensions. (Ibrahim et al., 2024) analyzed the effectiveness of innovation-driven logistics systems and their impact on quality, safety, and competitiveness in transport operations. Employing the Network Data Envelopment Analysis (Network DEA) model, the study demonstrated that synergy among innovation, infrastructure, and logistics strengthens both the efficiency and resilience of logistics operations.

Empirical research often relies on Data Envelopment Analysis (DEA) methods combined with the Logistics Performance Index (LPI) developed by the World Bank to evaluate the logistics efficiency of various economies (Niloofar *et al.,* 2025).

Merdivenci and Erturan (2021) introduced a two-stage Network DEA model incorporating the LPI indicator to assess logistics efficiency across European countries, identifying critical determinants of transport system performance.

Contemporary research further indicates that implementing ambidextrous supply chain strategies integrating agility and flexibility significantly enhances supply chain resilience and overall business performance. Based on a survey of 215 supply chain professionals (Cao *et al.,* 2024) applied Structural Equation Modeling (SEM) to analyze the relationships between ambidexterity, operational agility, resilience, and firm performance. The authors confirmed that combining adaptive and agile capabilities is vital for maintaining operational efficiency and safety amid dynamic and unpredictable market conditions.

Similarly (Raza, 2023) demonstrated that the integration of agile practices and information systems shortens lead times, enhances process synchronization and communication, and reduces vulnerability to logistics delays.

Equally important is the advancement of digitalization, along with the widespread adoption of the Internet of Things (IoT) and Big Data Analytics (BDA), both of which are transforming fleet management and operational safety environments. Stasiak-Betlejewska and Czarczyk (2024) analyzed the impact of modern technologies on supply chain security, revealing that over 75% of enterprises consider digital solutions essential for improving reliability and responsiveness to disruptions. Their findings also highlight the growing use of IoT for monitoring transport conditions (e.g., temperature and humidity), securing transactions, and supporting predictive risk analytics.

According to Grand View Research (2023), the global logistics market is projected to grow at an annual rate of 7.2% between 2024 and 2030, with North America and the Asia-Pacific region accounting for the majority of market share due to population density and infrastructure investments. The core driver of this transformation is the Logistics Information System (LIS), which enhances operational efficiency through improved data management and decision-making processes (United Nations ESCAP, 2016).

Empirical evidence provided by Sakgasem *et al.* (2024), based on a comparative analysis of over 30 factories in Northern Thailand, confirmed that implementing an LIS as a logistics intervention tool can yield average savings of 25% in transport costs, 55% in warehousing costs, and 20% in management expenses, while significantly improving planning capacity.

The case study of the CONPAS LIS system implemented in the Port of Yokohama, Japan, demonstrated that approximately 14% of arriving trailers were reserved through the system during the pilot phase, reducing average vehicle waiting times by 10%. From the customer perspective, adopting LIS or ERP systems enhances satisfaction by more than 80% (Li and Wu, 2021).

In addition Saltanat *et al.* (2025) emphasized the importance of safety management in transport processes, analyzing key factors such as vehicle selection, route planning, carrier reliability, cargo and vehicle security, personnel training, compliance with legal regulations, and risk management. The study confirmed that these factors contribute substantially to logistics process optimization and risk mitigation.

In summary, safety management in logistics under the Industry 4.0 paradigm is characterized by high complexity due to the integration of humans, machines, and production processes into an intelligent data exchange network. Digital transformation not only streamlines work organization but also significantly improves both safety levels and operational efficiency. Emerging technologies such as the Internet of Things (IoT), Big Data Analytics (BDA), and Logistics Information Systems (LIS) enable real-time monitoring of transport parameters, predictive risk analysis, and dynamic logistics process optimization.

Research consistently confirms that implementing agility and flexibility strategies supported by advanced information systems enhances supply chain resilience, reduces lead times, and lowers operational costs (Bulhões *et al.,* 2018a). The use of LIS solutions improves process transparency, data management efficiency, and customer satisfaction. Consequently, logistics enterprises become more competitive, reliable, and resilient to the challenges of modern markets and environmental volatility.

3. Analysis of the Logistics Information System in a Transport Company

The study was conducted within a company operating in the logistics and transport services sector, providing comprehensive transport and distribution services. The enterprise specialises in road freight transport of various cargo types, including neutral goods, products requiring controlled transport conditions (e.g., temperature and humidity), as well as high-value shipments that demand an enhanced level of security.

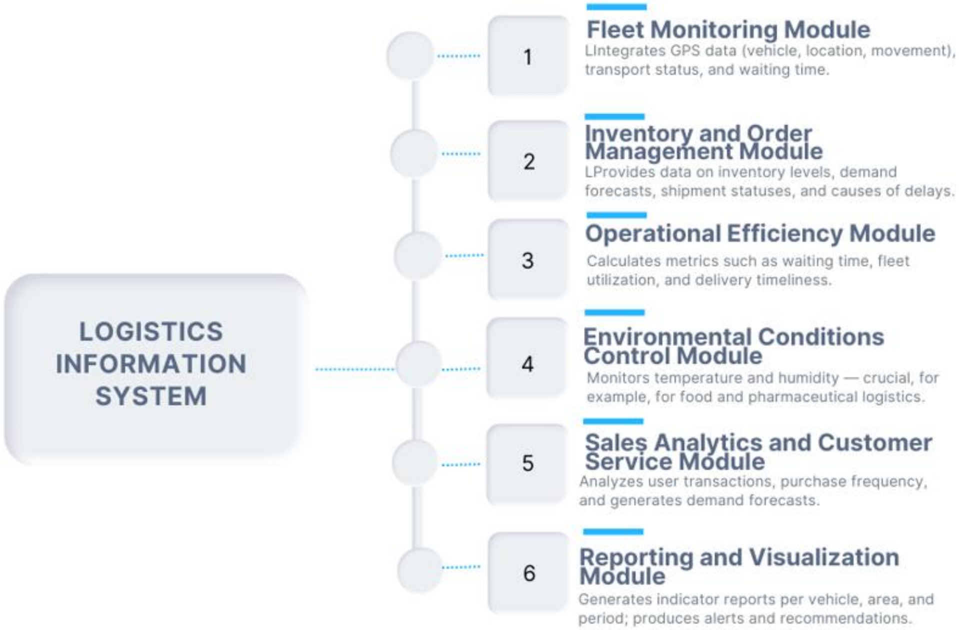
The company's operations encompass the following key areas:

1. Domestic transport and distribution – delivering goods to B2B and B2C clients within a just-in-time delivery regime.
2. International transport – conducting freight operations across the European Union and selected neighbouring non-EU countries.
3. Warehousing and fulfilment services – inventory management, order picking, and shipment execution.
4. Specialised logistics operations – transport requiring specific environmental conditions, such as those for the food and pharmaceutical industries.

The enterprise possesses a fleet of 10 trucks and delivery vehicles equipped with telematics systems, environmental sensors, and integrated modules of the Logistics Information System (LIS). The LIS functions as a digital management architecture that collects, processes, and analyses data from various subsystems to support decision-making across transport, warehousing, and customer service operations.

Figure 1 illustrates the six-module structure of the Logistics Information System implemented in the analysed company. Each module performs a specific set of tasks aimed at ensuring efficient data integration, real-time operational monitoring, and enhanced coordination between different functional areas of logistics management.

Figure 1. *Modules of the Logistics Information System*



Source: *Own elaboration.*

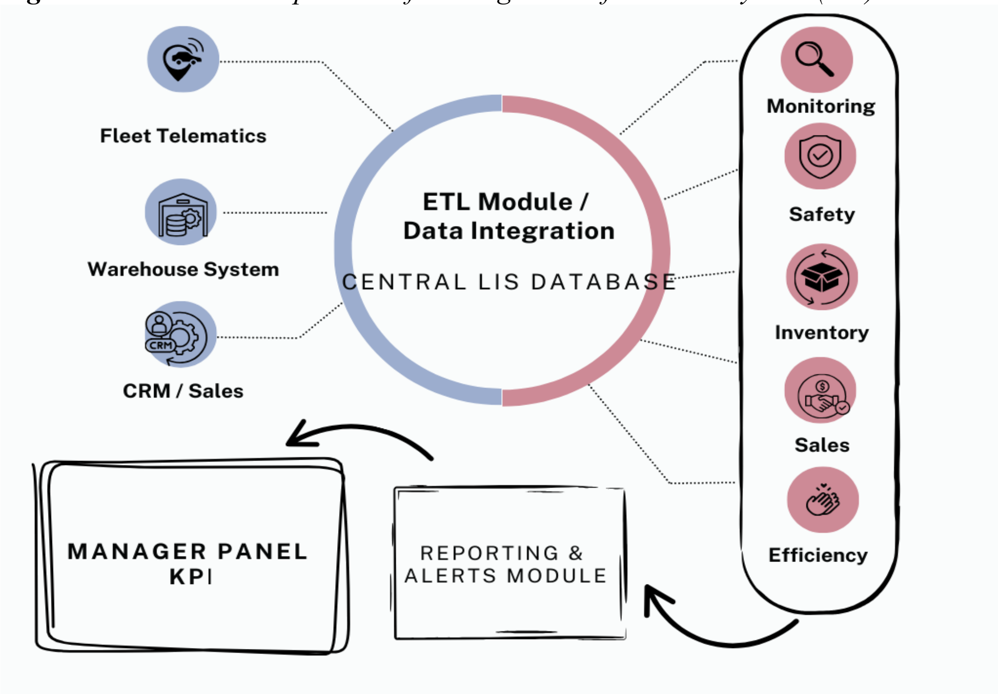
The implemented Logistics Information System (LIS) enables the continuous collection and analysis of operational data, including:

- vehicle location and performance parameters,
- inventory levels and order fulfilment rates,
- environmental transport conditions (e.g., temperature, humidity),
- shipment status and reasons for delays,
- fleet performance indicators and customer purchasing behaviour.

From a technical perspective, the LIS retrieves data from telematics sensors and devices installed in vehicles, warehouse and operational systems, as well as from the sales and customer relationship management (CRM) system. The integration of these datasets occurs through the ETL (Extract, Transform, Load) module, which is linked to the central LIS database.

The structural elements of the technical Logistics Information System are shown in Figure 2.

Figure 2. *Technical Components of the Logistics Information System (LIS)*



Source: *Own elaboration.*

The data sources for the Logistics Information System (LIS) include sensors and telematics devices installed in vehicles, as well as GPS systems, which enable the analysis of real-time parameters such as traffic status (Traffic_Status), waiting time (Waiting_Time), shipment status (Shipment_Status), and delay causes (Logistics_Delay_Reason). The Fleet Telematics system also allows for monitoring environmental conditions (Temperature, Humidity) during transport.

Warehouse management systems provide information on inventory levels (Inventory_Level) and demand forecasts (Demand_Forecast), while the CRM system offers data on customer transactions (User_Transaction_Amount) and purchase frequency (User_Purchase_Frequency).

The ETL (Extract, Transform, Load) module integrates data from multiple sources, automatically cleans and standardizes them, and serves as the foundation for LIS operations in five key areas: operational monitoring, sales management, inventory control, safety, and process efficiency.

The LIS employs a hybrid relational database architecture (SQL + NoSQL) to store current and historical operational data. These datasets support managers and supervisors in decision-making processes, verifying the efficiency of specific units, and identifying areas requiring improvement.

In this article, only selected parameters were analyzed those considered most representative of the studied area and most relevant to the research objective.

5. Evaluation of Logistics Process Efficiency and Safety

The Logistics Information System (LIS) implemented in the enterprise provides a robust foundation for analyzing and assessing the efficiency and safety of logistics processes. Monitoring real-time operational data facilitates a rapid response to unexpected events, minimizes crisis situations, enables automated calculation of performance indicators, and supports the analysis of delivery delays in terms of frequency and underlying causes.

The study focused on the area of road transport processes, carried out using a fleet of 10 vehicles that completed deliveries to customers throughout the year 2024.

The scope of the analyzed process comprised the following key areas:

1. Transport Planning and Execution
   - Route design, scheduling, vehicle allocation, and load management.
   - Monitoring the delivery execution status.
2. Route design, scheduling, vehicle allocation, and load management.
   - Measurement of delivery reliability.
   - Analysis of vehicle load capacity utilization.
   - Verification of the transport intensity ratio.
3. Operational Safety Analysis
   - Identification and frequency assessment of delays.
   - Diagnosis of disruption causes.
   - Monitoring of vehicle waiting times.

A detailed analysis of the aforementioned areas forms the basis for evaluating the studied transport process, its efficiency, and the level of operational continuity within logistics activities, for which this process constitutes a core element of an effective logistics system. This approach allowed for the objective assessment of logistics performance by combining quantitative and qualitative data sets. The selected indicators were designed to reflect operational effectiveness, delivery reliability, and process safety within real transport conditions.

Based on the available data from the Logistics Information System (LIS) and telematics systems, the following key performance and safety indicators were analyzed:

$$OTIF = \frac{D_t}{D_a} \cdot 100\% \tag{1}$$

where:
D_t – number of deliveries completed on time,

D_a − total number of deliveries.
OTIF (On-Time In-Full) is an indicator that measures delivery performance in terms of timeliness and completeness, serving as a key metric for assessing customer service quality and supply chain reliability.

$$T_{AU} = \frac{U_{ta}}{A_u} \cdot 100\% \tag{2}$$

where:
U_{ta} – user transaction value,
A_u – asset utilization,
T_{AU} (Transsaction Asset_Utilization) is an indicator that defines the unit value of the utilized vehicle load capacity.

Based on both quantitative and qualitative data, the transport process was identified and analyzed in two main areas:

1. Transport process efficiency, including the analysis of:
- Vehicle utilization intensity.
- Monitoring of implementation status (Shipment_Status).
- Measurement of delivery reliability (On-Time Delivery Rate).
- Analysis of vehicle load capacity utilization (Asset_Utilization).
- Transport intensity ratio assessment.

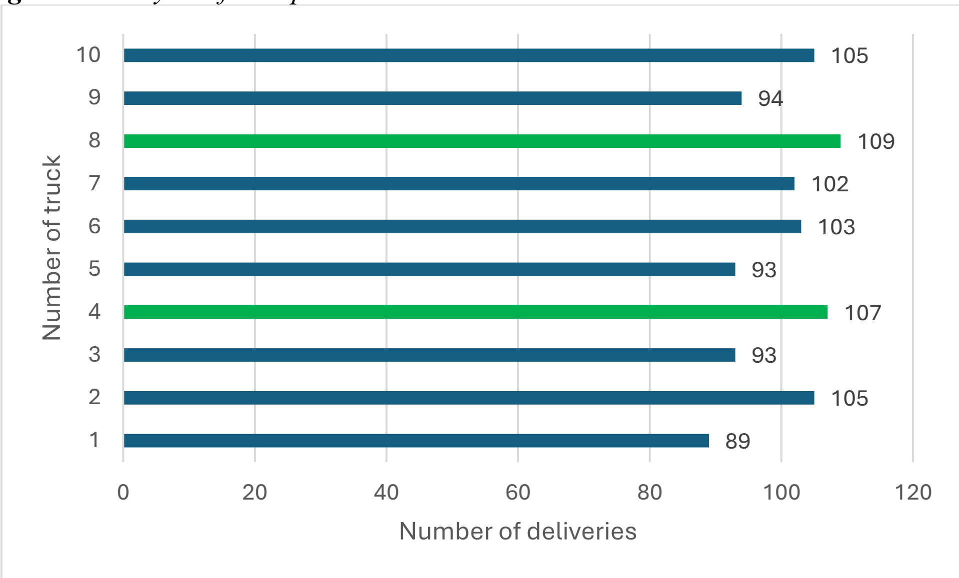
2. Operational safety, involving
- Identification and frequency analysis of delays (Delayed).
- Diagnosis of disruption causes (Logistics_Delay_Reason).
- Monitoring of vehicle waiting time (Waiting_Time).

The fundamental analysis and interpretation of the results concerning fleet vehicle efficiency reveal variations in resource utilization and highlight their impact on overall economic performance (Figure 3).

Vehicles 2, 4, 6, 8, and 10 performed the highest number of deliveries in 2024 (ranging from 103 to 109 orders), indicating the highest level of operational utilization. Vehicles 4 and 8 achieved the greatest number of deliveries 107 and 109 respectively. Vehicles 3 and 5 each completed 93 deliveries during the year. The average number of deliveries made across the entire fleet amounted to 100. The lowest utilization rate was recorded for vehicle 1, which completed 20 fewer deliveries than the fleet's most intensively used vehicle.

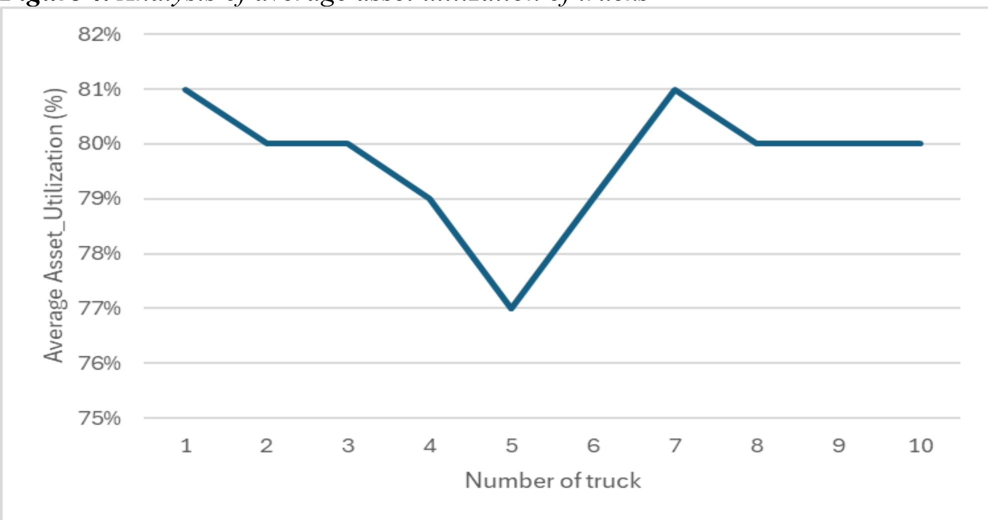
Figure 4 presents the average value of vehicle load space utilization, illustrating differences in the efficiency of cargo capacity usage and its potential influence on operational optimization.

Figure 3. *Analysis of Completed Deliveries*



Source: *Own elaboration.*

Figure 4. *Analysis of average asset utilization of trucks*

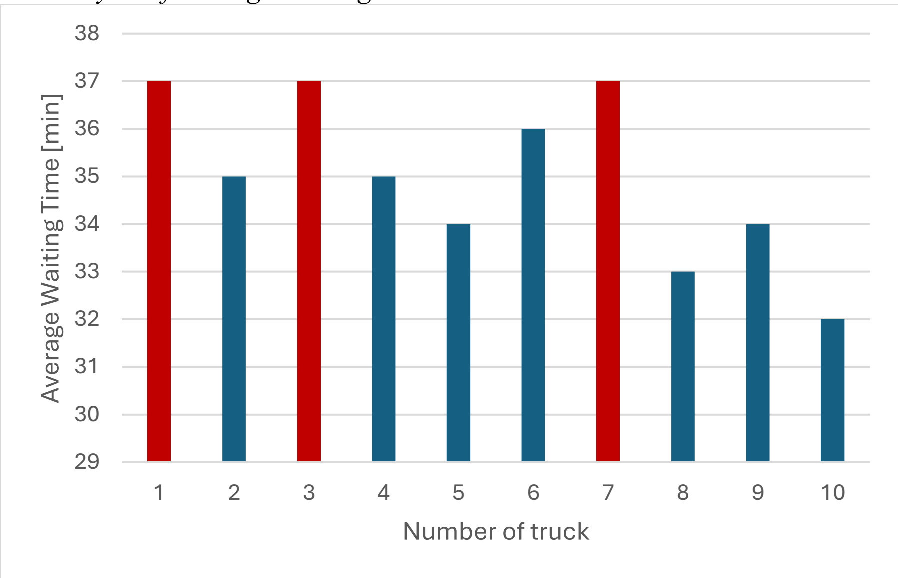


Source: *Own elaboration.*

The load space utilization rate for vehicle 5, measured at 76%, indicates that approximately three-quarters of the trailer's available volume was filled with cargo, while the remaining 24% of space was not effectively used. According to road transport logistics standards and efficiency benchmarks, this result reflects a moderately good level of capacity use. However, when compared with the rest of the fleet, vehicle 5 clearly requires improvements in delivery planning processes.

The analysis shows that this vehicle still holds significant potential for both spatial and cost optimization. Figure 5 presents the analysis of the average waiting time in transport, which may result from delays during the loading or unloading of shipments.

Figure 5. *Analysis of Average Waiting Time*



Source: *Own elaboration*

The average waiting time across the entire fleet ranges from 32 to 37 minutes, with the highest values recorded for vehicles 1, 3, and 7, and the lowest for vehicle 10. Excessive waiting times may indicate issues related to delivery coordination, cargo rotation, or insufficient planning during loading and unloading operations.

Conversely, vehicles with shorter waiting periods (5, 8, and 10) demonstrate higher rotation rates, thereby enhancing transport flexibility and operational efficiency key indicators in the analysis of logistics performance.

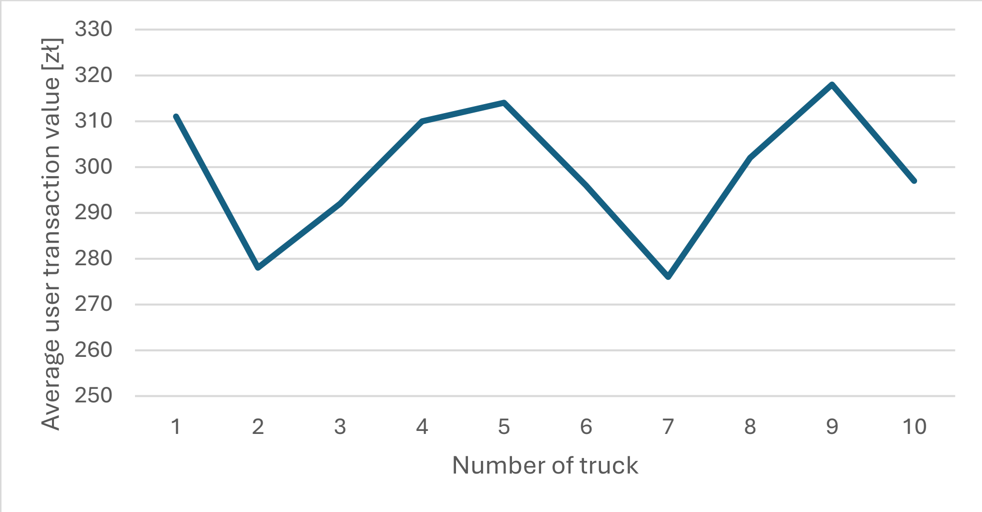
Figure 6 also presents the analysis of the user transaction value, which indicates the monetary value of the order executed for a customer by each individual vehicle.

The average transaction values for the fleet range from 275 PLN (vehicle 7) to 318 PLN (vehicle 9). It can be observed that trucks with a higher number of deliveries (e.g., 8 and 10) achieve moderate transaction values, which may suggest the distribution of products with lower unit value.

In contrast, vehicles with fewer deliveries (e.g., 9 – 94 deliveries) handle more profitable, higher-value orders. From the perspective of fleet profitability, maintaining a balance between the number of operations and the economic value of transactions is essential to achieving a high ROI (Return on Investment) and sustainable utilization of transport assets.

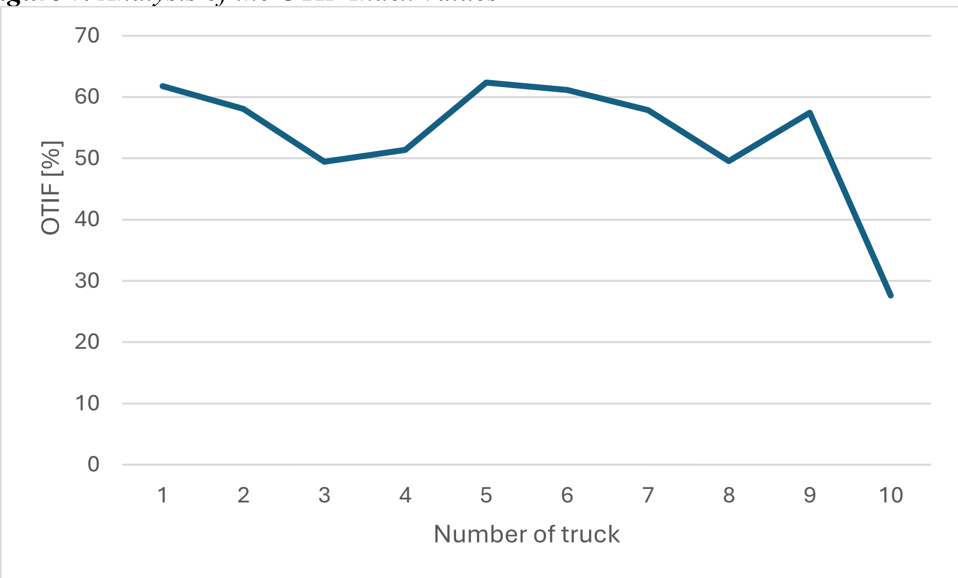
Figure 7 presents the values of the OTIF (On-Time In-Full) indicator, while Figure 8 illustrates the values of the indicator representing the unit value of the utilized vehicle load capacity.

Figure 6. *Analysis of Average User Transaction Value*



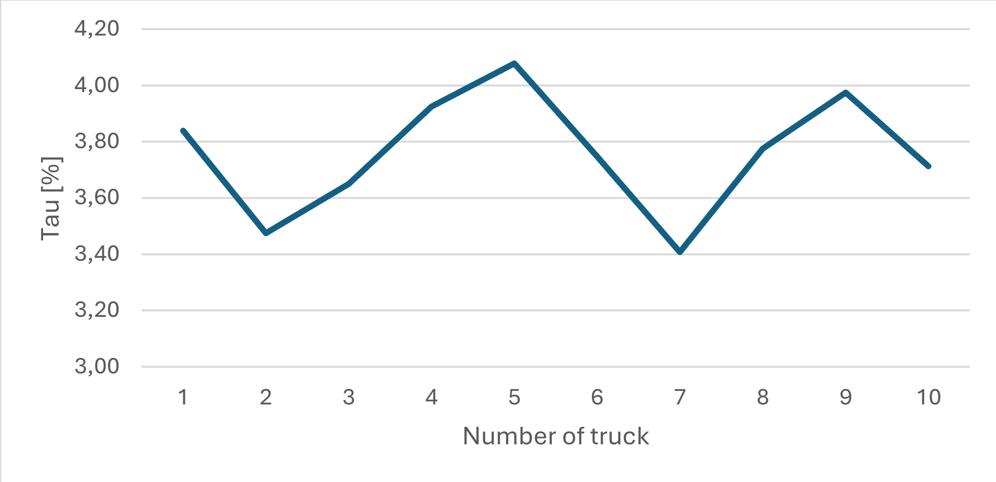
Source: *Own elaboration.*

Figure 7. *Analysis of the OTIF Index Values*



Source: *Own elaboration.*

Figure 8. *Analysis of Indicator Value* T_{AU}



Source: *Own elaboration.*

Based on the presented OTIF indicator chart for 10 vehicles, the highest value – 62% – was achieved by vehicle No. 5. Most vehicles maintained OTIF levels within the 48% to 54% range, while the lowest score – 28% – was recorded for vehicle No. 10. This may indicate issues related to delivery timeliness, completeness, or unforeseen stoppages and technical failures. As a result of these findings, a decision was made to verify the number of logistics delays defining the delivery status, which was ultimately reported by the customer upon receipt of the shipment.

Table 1 presents the dataset for each vehicle, describing the number of completed deliveries, the percentage of deliveries classified as delayed, the corresponding OTIF values, and additional performance parameters T_{AU}.

Table 1. *Analysis of Logistics Data for the Entire Fleet*

Number of truck	Number of deliveries	Logistics delay	OTIF	T_{AU}
1	89	38%	62%	3,84
2	105	42%	58%	3,48
3	93	51%	49%	3,65
4	107	49%	51%	3,92
5	93	38%	62%	4,08
6	103	39%	61%	3,75
7	102	42%	58%	3,41
8	109	50%	50%	3,78
9	94	43%	57%	3,98
10	105	72%	28%	3,71

Source: *Own elaboration.*

Based on the data presented in Table 1, it is confirmed that vehicles with the lowest level of logistics delays (1, 5, and 6) achieved the highest OTIF values (61–62%). The highest delay rate was recorded for vehicle 10 (72%), which resulted in the lowest OTIF (28%), indicating a direct negative correlation between delays and delivery quality.

Other vehicles with delay levels between 49% and 51% (e.g., 3, 4, and 8) also exhibited lower OTIF values (49–51%). Vehicle 8 completed the greatest number of deliveries (109), but due to high delays (50%), its OTIF reached only 50%. Vehicle 4, with the second-highest number of deliveries (107), also recorded a high delay rate (49%) and a low OTIF value (51%).

The highest T_{AU} indicator value (4,08) was achieved by vehicle 5, which also demonstrated one of the best OTIF values and the lowest delay ratio, indicating well-organized loading procedures and efficient vehicle utilization. In contrast, vehicle 7 recorded the lowest T_{AU} value 3,41. Despite a moderate number of deliveries (102), higher delay rate (42%), and only 58% OTIF, this suggests that improvements could be made in route planning, loading efficiency, and load space use.

The analysis clearly indicates that vehicle No. 10 represents the weakest link in the logistics process. Although it completed a substantial number of deliveries (105), as many as 72% were affected by delays, and its OTIF value stood at only 28%. Such parameters significantly increase the operational risk for the overall transport process. In the next stage of the study, the causes of logistics delays were analyzed for the two vehicles characterized by the highest share of delayed deliveries.

Table 2 presents the three main causes of logistics delays and their respective percentage shares indicating the frequency of occurrence for each factor. These categories serve to identify the key operational disruptions within the transport process, enabling further analysis and prioritization of corrective actions

Table 2. *Analysis of the Causes of Logistics Delays*

Number of truck	Logistics delay	Logistics delay reason	Value share %
10	72%	Mechanical Failure	26%
		Traffic	39%
		Weather	34%
3	51%	Mechanical Failure	21%
		Traffic	40%
		Weather	38%

Source: *Own elaboration.*

The analysis indicates that for both vehicles, the most frequent cause of logistics delays is road congestion. For vehicle No. 10, this factor accounts for 39%, while for vehicle No. 3, it represents 40%. Weather conditions ranked second in both cases, whereas mechanical failures had the lowest occurrence rate.

Considering the data presented in Table 2 on the most common causes of logistics delays, it is necessary to determine which of these factors can be directly influenced by the company or fleet managers. Corrective measures should then be implemented to reduce their frequency and impact. Only through such actions, supported by a detailed analysis, can fleet managers effectively enhance the optimization and safety of logistics processes

6. Conclusive Remarks

Systematic analysis of logistics data is crucial for ensuring a high level of efficiency and safety in transport operations. It enables the immediate identification of weak links, such as vehicle No. 10, and facilitates the implementation of corrective measures, thereby enhancing the effectiveness and operational safety of logistics processes. From a strategic perspective, this translates into reduced costs, stable customer relationships, and greater enterprise resilience to sudden disruptions.

The research findings indicated that in the case of vehicle No. 10, it is necessary to improve planning efficiency through analysis of routes, stops, unloading times, and causes of logistics delays. The low OTIF index value is most frequently associated with a high share of logistics delays, particularly for vehicles 3, 8, and dramatically for vehicle 10. High T_{AU} values and low delay times determine the highest OTIF values, as observed for vehicles 1, 5, and 6.

The study confirms that the number of completed deliveries does not necessarily determine operational efficiency. Vehicles performing the greatest number of tasks may exhibit high logistics delay rates and low unit values of utilized vehicle load capacity.

Research clearly demonstrates that systematic analysis of operational data is essential for enhancing the efficiency and safety of logistics processes. Direct monitoring of technical indicators within Logistics Information Systems (LIS) including OTIF, T_{AU}, delay rates, and resource utilization combined with root cause analysis enables rapid identification of potential risks and the implementation of effective corrective strategies.

Implementing a flexible information system that integrates data from multiple sources allows for a dynamic response to disruptions and the continuous optimization of planning processes. In practice, this leads to cost reduction, higher customer satisfaction, improved operational resilience, and greater competitiveness in the logistics sector.

Achieving the highest level of operational safety is attained through the deployment of predictive analytical tools, automated reporting, and continuous process improvement based on accurate and reliable data.

This article fully accomplishes its intended purpose by demonstrating the practical benefits of implementing LIS systems and operational analytics in modern transport logistics. Furthermore, it presents specific recommendations and insights for fleet managers operating under conditions of uncertainty, variability, and risk.

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