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INTEGRATED MODEL FOR IMPROVED LOGISTICS WITH A FOCUS ON FORWARDING AND WAREHOUSING SERVICES

Nikolaj Ambrusevič

Vilniaus kolegija/Higher Education Institution, Saltoniškių Str. 58, LT-08105 Vilnius, Lithuania

E-mail: n.ambrusevic@vvf.viko.lt

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Abstract. The growing complexity of global supply chains and the increasing integration of regional economies have elevated the role of logistics as a critical link between production and consumption. Forwarding and warehousing services, as core components of logistics operations, face continuous challenges related to operational efficiency, service quality, and coordination. This study aims to develop an integrated model to enhance the performance and interconnectivity of forwarding and warehousing services. The research is based on a multi-stage methodology, combining theoretical analysis of logistics integration, identification of critical operational factors, and the construction of a systemic model framework. Key tasks include examining interdependencies between forwarding and warehousing, analysing operational challenges, and designing a model that optimises service quality, cost efficiency, and reliability. The resulting integrated model provides a structured approach to improving logistics service coordination and offers practical recommendations for implementation in real-world supply chain environments. This study contributes to both logistics theory and practice by offering a comprehensive framework for forward-looking management of forwarding and warehousing services, supporting more resilient and efficient supply chains.

Keywords: forwarding; warehousing; supply chain; risk management

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1. Introduction

The rapid advancement of economic globalisation and the strengthening of regional integration have significantly increased the importance of logistics as a vital link between production and consumption. As noted by Thui & Son (2024), the logistics sector has become a foundational component of global trade flows, ensuring that goods move efficiently across borders and markets. In this dynamic environment, forwarding and warehousing service providers face unprecedented challenges, as evolving customer expectations, technological transformation, and market uncertainties reshape the competitive landscape (Katinienė, Jezerskė & Vaičiūtė, 2021; Ndlovu, Nkondo & Manchidi, 2025).

Previous research examining the interdependence between logistics performance and economic development highlights that the logistics industry acts not only as a facilitator of supply chain operations but also as a key driver of both global economic integration and regional economic growth (Wang et al., 2021; Tubis & Grzybowska, 2022). Consequently, the effective functioning of forwarding and warehousing services plays a substantial role in the broader economic system, influencing business continuity, production stability, and national competitiveness (Naz & Ejaz, 2023; Arabelen & Kaya, 2021; Tubis, & Grzybowska, 2022).

Integrated management of forwarding and warehousing services has therefore become increasingly essential. As Struk & Karpil (2019) emphasise, the coordination of these activities is critical to ensuring seamless supply chain operations – from the early stages of production to final consumption. Issues related to product delivery, transportation, and forwarding, particularly during contract execution, remain highly relevant in both theory and practice. Such challenges can affect not only the efficiency of logistics processes but also the economic activity of entire countries, as pointed out by Sujatmiko et al. (2024).

The primary objective of this study is to develop an integrated model that enhances the effectiveness, coordination, and overall performance of forwarding and warehousing services. The model aims to identify key operational factors, reveal interdependencies between service components, and propose a structured framework to improve *service quality*, *cost efficiency*, and *operational reliability* within logistics systems. To achieve this objective, the research focuses on the following specific tasks:

1. Analyse the theoretical foundations of forwarding and warehousing services, including their roles within modern supply chains and their impact on economic development.
2. Identify key factors and challenges affecting the integration and performance of forwarding and warehousing operations.
3. Examine interdependencies between forwarding and warehousing services to understand how operational decisions in one domain affect the other.
4. Develop a conceptual integrated model that coordinates forwarding and warehousing activities to optimise service quality, cost efficiency, and operational reliability.
5. Provide practical recommendations for the implementation of the integrated model in real-world logistics systems to improve service effectiveness and supply chain performance.

To achieve the objective and fulfil the tasks, the research employs a multi-stage methodological approach. First, a theoretical analysis is conducted to synthesise existing scientific insights on logistics integration, forwarding processes, and warehousing management. This theoretical foundation enables the identification of core dimensions and critical factors relevant to the integration of forwarding and warehousing services. Subsequently, a comparative analysis and systemic modelling approach are applied to design the integrated model. The methodology includes structural interpretation of relationships among service elements, evaluation of functional compatibility, and formulation of model components based on established logistics management principles. The final stage involves conceptual model construction, ensuring that the resulting framework is coherent, practitioner-oriented, and suitable for application in real-world logistics environments.

2. The Essence and Specifics of Forwarding Services

The term "transport" is usually associated with companies that own a fleet of vehicles used for cargo transportation. In contrast, "forwarding" includes not only the organisation of cargo transportation but also additional services such as cargo escort, customs procedure handling, warehousing, and other logistics services (Skiba & Karas, 2022). Unlike direct cargo transportation, forwarding services focus on the intermediary function between cargo owners and carriers, ensuring all additional logistics stages such as warehousing, customs procedures, and cargo monitoring (Grebennikov et al., 2024). One of the most significant issues is that companies providing forwarding services operate under different terms and principles (Naz & Ejaz, 2023; Arabelen & Kaya, 2021; Tubis & Grzybowska, 2022).

Key functions of a freight forwarder include (Skiba & Karas, 2022):

- *Organising cargo transportation.* This involves planning and arranging the actual movement of goods from the sender to the recipient; the forwarder decides which transport modes (road, rail, sea, air) are most suitable, schedules shipments, and ensures the cargo reaches its destination efficiently, safely, and on time.
- *Selecting vehicles and routes.* The forwarder chooses the most appropriate vehicles (trucks, ships, planes, or trains) and plans the best routes for delivery; this requires considering factors like cost, delivery time, cargo type, road or port conditions, and potential risks along the route.

- *Coordinating the loading and unloading of cargo.* The forwarder supervises the physical handling of goods to ensure safe and proper loading and unloading; this includes making sure cargo is correctly packaged, secured, and handled according to regulations, reducing the risk of damage during transit.
- *Handling documentation (customs procedures, export-import permits).* Forwarders manage all required paperwork for international shipments; this includes customs declarations, export/import permits, certificates of origin, invoices, bills of lading, and any other legal documentation needed to comply with national and international regulations.
- *Monitoring cargo condition and quality.* Freight forwarders track the condition of the cargo throughout the journey; for sensitive or perishable goods (like food, chemicals, or electronics), they ensure temperature, humidity, or other storage requirements are maintained, and they address any problems that arise during transit.
- *Providing warehousing and cargo distribution services.* Forwarders often offer temporary storage of goods in warehouses and manage distribution to multiple destinations; this may involve consolidating shipments, splitting cargo for different recipients, and organising last-mile delivery.
- *Managing taxes and other shipping-related expenses.* They handle all financial aspects of shipping, including duties, tariffs, taxes, fuel surcharges, insurance, and other logistics-related costs; the forwarder ensures compliance with local and international regulations while optimising costs for the client.

In short, a freight forwarder is like a logistics conductor, coordinating every stage of cargo movement, from planning and paperwork to physical handling and delivery, ensuring goods move efficiently, safely, and legally.

Skiba & Karas (2022) highlight that the forwarding profession is multifaceted and has evolved historically. Initially, it focused on transport organisation on behalf of the client, occasionally including additional services related to border procedures and documentation; however, today, the forwarder is no longer just an intermediary between the sender and carrier; it becomes a key link integrating client and supplier activities within the entire supply chain (Skiba & Karas, 2022). Digitisation and automation are technological tools that facilitate the forwarder's work and help organise the entire transport process more smoothly (Bahatov, 2022). Significant changes are underway, with forwarders expanding their role from executing individual orders to coordinating and organising the entire supply chain (Kanchaveli, 2022).

3. The Role of Warehousing in the Supply Chain

Warehousing is a vital part of the supply chain, encompassing the receipt, storage, and distribution of goods until final consumption (Jarašūnienė, Čižiūnienė & Čereška, 2023). Key issues, such as lack of space, delayed orders, and insufficient advanced technologies, lead to inefficiency and high costs (Tubis & Grzybowska, 2022). Modern warehouses are complex technical structures responsible for storing, processing, and distributing materials among consumers. Proper process management and technological integration are required to prevent problems such as transport congestion, delivery delays, or excessive manual labour.

Main warehouse processes include (Jarašūnienė, Čižiūnienė & Čereška, 2023):

- *Goods receipt and quality control.* This is the first step in warehouse operations, where incoming goods are received, checked, and recorded. Key activities include:
 - Verification – confirming that the shipment matches the purchase order in terms of quantity, type, and specifications.
 - Inspection – checking for damages, defects, or discrepancies.
 - Documentation – recording goods in the warehouse management system (WMS) and updating inventory records.
 - Labelling and tagging – assigning barcodes, RFID tags, or other identifiers to track items accurately.

Proper goods receipt and quality control prevent errors, reduce losses, and ensure that only compliant products enter the warehouse.

- *Warehousing and inventory management.* This process involves storing goods efficiently and maintaining accurate inventory levels. Key tasks include:
 - Storage organisation – allocating space using techniques like racking, pallet stacking, or bin locations to maximise efficiency.

- Inventory tracking – monitoring stock levels in real-time using WMS, RFID, or barcode scanning systems.
- Stock rotation – implementing methods like FIFO (First-In-First-Out) or LIFO (Last-In-First-Out) to manage product shelf life and minimise spoilage.
- Cycle counting – regularly auditing stock to ensure accuracy and reconcile discrepancies.

Efficient inventory management minimises storage costs and ensures that products are available when needed.

- *Order picking and preparation.* This process involves retrieving products from storage to fulfil customer orders. Key activities include:
 - Order generation – receiving customer orders from ERP or WMS systems.
 - Picking – selecting items from shelves or pallets according to the order. Methods can include batch picking, zone picking, or wave picking.
 - Consolidation and checking – combining items into complete orders and verifying accuracy before packaging.

Proper picking and preparation reduce errors, improve delivery speed, and enhance customer satisfaction.

- *Packaging and dispatch.* This process ensures goods are securely packaged and sent to the correct destinations. Key activities include:
 - Packing – using appropriate materials and methods to protect goods during transit.
 - Labelling and documentation – printing shipping labels, invoices, and customs documents if applicable.
 - Loading and dispatch – coordinating with carriers, arranging transport, and ensuring timely dispatch.
 - Tracking – updating shipment status in the system to provide visibility to customers.

Effective packaging and dispatch processes reduce damage, returns, and delivery delays.

- *Returns processing.* This process handles returned goods from customers efficiently. Key steps include:
 - Inspection and assessment – checking returned items for damage, expiration, or quality issues.
 - Sorting and classification – determining if items can be restocked, repaired, recycled, or discarded.
 - Inventory update – adjusting stock records to reflect returns.
 - Refund or replacement coordination – communicating with customers or sales teams regarding replacements, exchanges, or refunds.

Efficient returns processing reduces losses, recovers value from returned items, and maintains customer trust.

According to Sy (2025), integration refers to the seamless coordination between warehouse operations (storage, inventory management, order preparation) and forwarding activities (transport planning, shipment coordination, documentation, and delivery). By connecting these two core logistics functions, businesses can manage the entire supply chain more efficiently, ensuring goods move smoothly from production to the end customer. The integration of warehousing and forwarding processes ensures a smooth flow of materials from production to the end customer (Sy, 2025; Ahmed, 2025):

- *Information sharing.* Using warehouse management systems (WMS) and transportation management systems (TMS) that communicate in real time, allowing accurate tracking of stock levels, shipment status, and delivery schedules.
- *Process synchronisation.* Aligning warehouse operations with transport schedules to minimise idle time and ensure that goods are ready for dispatch exactly when required.
- *Resource optimisation.* Coordinating labour, storage space, and transport assets to reduce redundancies and increase operational efficiency.
- *Proactive problem solving.* Forwarders and warehouse managers can anticipate delays, shortages, or disruptions and take corrective action before they impact the supply chain.

According to scientific literature, effective coordination of warehouse processes allows to achieve following results:

- *Reduced overall logistics costs.* Optimising storage space and transport routes reduces unnecessary handling, inventory holding costs, and fuel consumption.
- *Avoids duplicate operations,* such as moving goods multiple times due to poor coordination; for example, items might be moved from storage to a staging area multiple times because transport schedules or order preparation are misaligned (Struk & Karpil, 2019). Impact of avoiding duplicates:

- Reduced handling costs – avoiding unnecessary moves saves money, labour and equipment.
- Minimised risk of damage – fewer moves mean fewer chances for breakage or spoilage.
- Speeded up operations – coordinated workflows ensure that goods go directly from storage to shipment without redundant steps, reducing lead times.
- Improved accuracy – fewer transfers reduce the risk of errors such as sending the wrong items or misplacing stock.

Instead of moving pallets from one warehouse zone to another several times for different shipments, an integrated system schedules loading so items go directly from storage to the outbound truck, cutting extra moves.

- *Bulk consolidation of shipments* minimises transport costs per unit. It involves combining multiple smaller shipments into a single, larger shipment (Wang et al., 2021; Davidenko, Ristvej & Strelcova, 2020). This is a key strategy for cost efficiency in logistics. Benefits of bulk consolidation:
 - Lower transport cost per unit. Shipping a full truck, container, or shipment is generally cheaper per item than sending several smaller shipments separately.
 - Fewer trips required. Consolidation reduces the number of transport trips, saving fuel, labour, and vehicle usage.
 - Reduced environmental impact. Fewer trips mean less carbon emissions, making logistics more sustainable.
 - Better space utilisation. Larger consolidated shipments optimise truck or container capacity, avoiding wasted space.

In short, instead of sending ten partial-load shipments to different customers in the same region, the forwarder consolidates them into one full truckload, splitting the goods at the destination. This reduces overall transport costs while maintaining delivery efficiency.

- *Shortened order fulfilment time.* Orders are picked, packed, and ready for dispatch as soon as production or procurement is complete (Arabelen & Kaya, 2021); real-time inventory visibility ensures the warehouse only prepares items that are actually available, reducing delays (Jarašūnienė, Čižiūnienė & Čereška, 2023); faster response times from integrated systems allow quicker delivery to customers.
- *Improved customer service quality.* Accurate tracking and timely updates provide customers with reliable delivery information; reduced errors in orders (wrong items, missing quantities) increase customer satisfaction (Taletović, 2023); enhanced ability to meet tight deadlines and handle urgent or last-minute orders (Ahmed, 2024).
- *Increased flexibility in response to market changes.* Efficient warehouse coordination supports optimised consolidation, sorting, and staging of goods for shipment, ensuring smooth cargo organisation and flow (Sy, 2025); accurate and timely warehouse data improves route planning decisions, enabling faster and more cost-effective transportation (Bahatov, 2022); coordinated processes ensure timely and accurate preparation of transport and customs documentation, reducing delays and compliance risks (Arunkumar & Meera, 2025); proper synchronisation between warehousing and forwarding facilitates smoother customs clearance through accurate inventory and shipment information (Orłowska & Chackiewicz, 2024); integrated warehouse operations enhance communication and scheduling with carriers, improving transport reliability and capacity utilisation (Wang et al., 2021) (see summarising Table 1 below).

Table 1. Comparison of Forwarding and Warehousing Functions

Forwarding functions:	Warehousing functions:
Cargo organisation (Sy, 2025)	Inventory management (Ahmed, 2024)
Route planning (Bahatov, 2022)	Space optimisation (Taletović, 2023)
Documentation handling (Arunkumar & Meera, 2025)	Goods receipt/issue (Ahmed, 2024)
Customs procedures (Orłowska & Chackiewicz, 2024)	Packaging operations (Jarašūnienė, Čižiūnienė & Čereška, 2023)
Carrier coordination (Wang, Wen, Yip & Fan, 2021)	Order picking (Arabelen & Kaya, 2021)

In short, integration transforms warehousing and forwarding from isolated functions into a cohesive logistics network, aligning information, resources, and processes. This leads to cost savings, faster deliveries, better customer experiences, and greater adaptability – all essential for maintaining competitiveness in today's dynamic market.

4. Methods of Optimising Warehousing Processes

ABC Analysis – one of the most effective inventory management methods (Tinelli, Vivaldini, & Becker, 2012). ABC Analysis is a method used to categorise inventory items based on their value and importance, allowing businesses to prioritise management efforts on the most critical products (Abdolazimi et al., 2021). The method is based on the Pareto Principle (80/20 rule), which suggests that a small portion of items often accounts for the majority of the value or profit.

Category A: 15-20% of items, generating 70-80% of profit. Management focus:

- Close monitoring and strict control of stock levels.
- Frequent inventory checks (daily or weekly).
- Optimised reorder points to prevent stockouts.
- Use of advanced forecasting techniques.

Even though these items are few, they have a significant impact on overall profitability. Mismanagement can lead to high losses or missed sales opportunities.

Category B: Medium-priority items, 20–30% of total inventory, making approximately 15–20% of total profit. Management focus:

- Moderate control over stock levels.
- Regular review (weekly or bi-weekly).
- Balanced inventory replenishment.

These items are important but not as critical as Category A. Efficient management ensures steady profitability without over-investing resources.

Category C: 60-70% of items, generating 5-10% of profit. Management focus:

- Simplified controls and less frequent monitoring (monthly or quarterly).
- Large stock quantities can be held to prevent stockouts.
- Automated replenishment methods can be used.

These items are low-risk in terms of profitability. Over-managing them can tie up unnecessary resources (see Table 2 below).

Table 2. Application of ABC Analysis in Warehouse Management

Category	Share of Goods	Share of Profit	Management Strategy
A	15-20%	70-80%	Daily monitoring, low inventory
B	20-30%	15-20%	Weekly monitoring, medium inventory
C	60-70%	5-10%	Monthly monitoring, high inventory

Source: Abdolazimi et al. (2021)

Recently, scientific articles investigate other technological systems for warehouse management. Warehouse Management System (WMS), as a comprehensive warehouse management system, can direct a warehouse worker to the exact location of a product using the shortest path, reducing time spent searching for items and minimising handling errors (Yu et al., 2025). Using the integrated business management system of SAP S4HANA, a company can automatically adjust inventory levels based on predicted demand, ensuring that warehouses are stocked optimally and shipments are scheduled efficiently (Nendrambaka, 2023; Orłowska, 2023). Each pallet of goods in a warehouse can have an RFID (automatic goods identification) tag scanned automatically as it moves through the receiving area, updating stock levels in the system without manual input. An AGV (Automated Guided Vehicles) can autonomously transport items from the storage area to the packing station according to real-time orders from the WMS, allowing faster processing with fewer staff (Dehghan et al., 2023), see Table 3 below.

Table 3. Technological Systems for Warehouse Management

Definition:	Key Functions:	Benefits:
Warehouse Management System (WMS) is a software platform designed to control and optimise warehouse operations, from goods receipt to storage, order picking, and dispatch (Yu et al., 2025).	Real-time inventory tracking and stock visibility. Storage location optimisation and space utilisation. Order management and picking route optimisation. Integration with shipping and transport systems. Reporting and performance analytics.	Reduces errors in order fulfilment. Enhances inventory accuracy. Speeds up warehouse processes. Enables better decision-making through analytics.
SAP ERP/S4HANA is an enterprise resource planning system that integrates all core business processes, including warehouse, finance, procurement, and supply chain management, into a unified platform (Nendrambaka, 2023; Orłowska, 2023).	End-to-end visibility of inventory and supply chain. Automation of procurement, order processing, and invoicing. Real-time reporting and analytics across departments. Facilitates coordination between warehouses, suppliers, and logistics providers.	Eliminates data silos and improves communication. Supports strategic planning and forecasting. Reduces operational inefficiencies. Enhances coordination between warehouse and forwarding operations.
RFID (Radio-Frequency Identification) uses tags and scanners to automatically track and identify products within a warehouse or during transport (Zhang, Lin & Esfahbodi, 2025).	Real-time tracking of inventory items. Quick scanning for goods receipt, picking, and dispatch. Automatic updates in warehouse and transport management systems. Integration with security systems to prevent theft or misplacement.	Reduces manual scanning and paperwork. Increases accuracy and speed of inventory management. Provides better traceability for high-value or sensitive goods. Supports automated processes and analytics.
AGVs (Automated Guided Vehicles) are robotic vehicles used in warehouses to transport goods between storage areas, loading docks, and packing stations without human intervention (Dehghan et al., 2023).	Automated movement of pallets, bins, or containers. Integration with WMS to follow optimised routes. Can work continuously and safely around human operators.	Reduces labour costs and human error. Improves operational speed and throughput. Enhances warehouse safety by minimising manual handling. Supports continuous and scalable warehouse operations.

Sources: Yu et al. (2025); Nendrambaka (2023); Orłowska (2023); Dehghan et al. (2023); Zhang, Lin & Esfahbodi (2025).

In summary, together, these systems create a highly automated, efficient, and intelligent warehouse environment:

- WMS optimises daily warehouse operations.
- ERP/S4HANA connects the warehouse with the broader business ecosystem.
- RFID ensures accurate and fast inventory tracking.
- AGVs automate material handling, reducing manual labour and operational bottlenecks.

In a result it supports faster, more accurate, cost-efficient, and flexible warehouse operations that can respond dynamically to customer demands and market changes.

Choosing the right location for a warehouse is one of the most strategic decisions in logistics. It significantly influences the efficiency, cost structure, and responsiveness of the entire supply chain. Proper warehouse location directly affects (Taletović, 2023):

- Compliance with delivery deadlines – transportation usually represents the largest share of logistics expenses
- Compliance with delivery deadlines – warehouse proximity to markets and transport hubs increases delivery reliability.
- Customer service quality – warehouse location determines how quickly and accurately businesses can respond to customer needs.
- Operational flexibility – a well-chosen location allows the company to adapt to market changes more easily (see Table 4).

Table 4. Impact of Proper Warehouse Location

Affects:	Benefits:	Outcomes:
Transportation costs	Reduces the distance between suppliers, production sites, and customers. Minimises fuel consumption and vehicle operating costs. Allows consolidation of shipments and more efficient routing. Decreases the need for additional distribution centres.	Substantial cost savings and higher cost-effectiveness of logistics operations
Compliance with delivery deadlines	Shortens lead times. Enables faster order processing and dispatch. Reduces the risk of delays caused by congestion or long-distance transport. Supports just-in-time (JIT) or same-day delivery models	Higher punctuality and more consistent fulfilment of delivery promises
Customer service quality	Ensures quick delivery options (e.g., next-day or same-day). Enhances stock availability through better replenishment. Reduces errors and delays in last-mile logistics. Improves customer satisfaction and loyalty.	Better service performance and stronger competitive positioning.
Operational flexibility	Rapid scaling of operations during seasonal demand peaks. Improved access to labour markets. Greater ability to respond to supply chain disruptions. Better integration with multimodal transport networks (road, rail, air, sea).	Increased resilience and agility across the logistics system.

Sources: based on Taletović, 2023

In short, proper warehouse location enables lower transport costs, faster and more reliable deliveries, higher service quality, and greater operational flexibility.

Several scientific and analytical models support decision-makers in choosing the optimal warehouse location. These methods consider multiple criteria such as cost, distance, demand patterns, and infrastructure. Methods for selecting warehouse location (Thakkar, 2021; Houck et al., 2022):

- TOPSIS method – multi-criteria evaluation. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ranks alternatives by comparing them to an ideal (best-case) and anti-ideal (worst-case) option. It helps define criteria (cost, distance, labour availability, infrastructure, etc.), normalise and weight the criteria, calculate each location's distance from the ideal and anti-ideal solution, select the location closest to the ideal option.
- Gravity centre model – geographical optimisation. A mathematical model that identifies the optimal geographic point for a warehouse based on the distribution of customers, suppliers, and transportation flows. It plots customer/supplier locations on a coordinate map, weights each point by demand or shipment volume, and calculates the "centre of gravity" that minimises total distance or transport cost.
- AHP method – analytic hierarchy process. A structured multi-criteria decision-making method that breaks complex problems into a hierarchy of criteria and subcriteria (Manik, 2023; Bingqing & Liting, 2020). It helps define main criteria (cost, accessibility, workforce, risk, etc.), perform pairwise comparisons to determine the importance of each criterion, calculate weighted priority scores, and evaluate each potential location accordingly.

Decision methods such as TOPSIS, the Gravity Centre Model, and AHP help organisations systematically evaluate and select locations, ensuring optimal logistics performance and long-term competitiveness. TOPSIS Handles many criteria simultaneously, provides clear ranking of location alternatives, is suitable for complex decision environments; Gravity Center Model is simple and intuitive, effective for distribution networks, minimises total transportation distances, however, it does not consider qualitative factors (e.g., infrastructure, regulations), and assumes flat geography and equal transport conditions; finally, AHP method incorporates both – quantitative and qualitative – factors, captures expert judgment through pairwise comparisons, offers transparent and logical decision-making structure.

5. The Integrated Model for Improving Forwarding and Warehousing Services

Implementing recent technological capabilities creates a smarter, faster, and more efficient logistics and warehouse system – real-time data exchange, automation, reduced errors, and optimised resource use collectively improve operational performance, lower costs, and enhance customer satisfaction (Kurniadi, 2025; Kanchaveli, 2022, Zemmouvi-Ghomari, 2025), see Table 5 below.

Table 5. Technological Convergence of Forwarding and Warehousing Services

Technological advantages	Applications	Benefit
Real-time data exchange – the continuous and instantaneous sharing of information between systems, departments, and supply chain partners.	Tracking inventory levels across multiple warehouses. Monitoring shipment status during transport. Sharing updates between suppliers, logistics providers, and customers. Integration with ERP, WMS, and transport management systems.	Immediate visibility into inventory and shipment status. Faster decision-making and proactive problem-solving. Reduced delays caused by miscommunication. Enhanced coordination across the supply chain.
Automated process management - the use of software and technology to automatically perform routine logistics and warehouse tasks.	Automated order picking and sorting. Dynamic route optimisation for deliveries. Scheduling replenishment and stock transfers. Automated documentation and customs compliance.	Faster and more consistent operations. Reduced reliance on manual labour for repetitive tasks. Improved throughput and operational efficiency. Allows staff to focus on strategic or value-added activities.
Reduced human error – minimising mistakes caused by manual handling, data entry, or communication lapses through automation and digital systems.	Barcode and RFID scanning for inventory accuracy. WMS-guided picking and packing instructions. Automated reporting and documentation. AI-driven forecasting to reduce planning errors.	Fewer stock discrepancies and shipping mistakes. Increased order accuracy and customer satisfaction. Reduced operational costs associated with errors. Lower risk of compliance or safety violations.
Better resource utilisation - optimising the use of warehouse space, labour, equipment, and transportation through technology.	Dynamic storage allocation using WMS. Scheduling and routing optimisation for delivery vehicles. Real-time allocation of labour based on workload. Monitoring and maintenance of equipment to maximise uptime.	Maximised storage and transport efficiency. Reduced operational waste and costs. Improved staff productivity. Greater flexibility to respond to changes in demand.

Sources: based on Kurniadi (2025); Kanchaveli (2022)

AI technologies are increasingly integrated into logistics and warehouse operations to enhance efficiency, accuracy, and decision-making (Krnjaic et al., 2024; Rad et al., 2025), see Table 6 below.

Table 6. Applications of Artificial Intelligence Solutions in Logistics

AI solution:	Applications:	Benefit:
Demand forecasting – using AI algorithms to predict future customer demand based on historical data, market trends, and external factors	Anticipating product demand for accurate inventory planning. Optimising stock levels to reduce shortages or overstock. Supporting dynamic pricing strategies. Forecasting seasonal or regional fluctuations.	Minimises stockouts and excess inventory. Reduces holding costs and waste. Enables proactive supply chain planning.
Route optimisation – AI-powered algorithms analyse multiple factors to determine the most efficient delivery routes.	Planning optimal routes for trucks, AGVs, or drones. Adjusting routes in real-time based on traffic, weather, or delays. Coordinating multi-stop deliveries and pickups. Integrating with WMS and transport management systems.	Reduces fuel and transportation costs. Shortens delivery times and improves punctuality. Enhances driver and fleet productivity. Improves customer satisfaction with timely deliveries.

Inventory management – AI systems help manage inventory dynamically, including stock replenishment, storage allocation, and product tracking.	Predictive restocking based on demand and lead times. Automated warehouse slotting to optimise space utilisation. Identifying slow-moving, fast-moving, or seasonal items. Integrating with WMS and RFID systems for real-time updates.	Maintains optimal stock levels. Reduces carrying costs and storage inefficiencies. Minimises human error in inventory handling. Supports agile response to market changes.
Risk identification – AI analyses internal and external data to detect potential risks and disruptions in the supply chain.	Predicting delays in shipments or supplier failures. Monitoring fluctuations in fuel, material, and labour costs. Identifying regulatory or compliance risks. Detecting anomalies in warehouse or transport operations.	Enables proactive mitigation of supply chain disruptions. Improves decision-making and operational resilience. Reduces financial and reputational risks. Enhances overall supply chain reliability.

Sources: based on Krnjaic et al. (2024); Rad et al. (2025)

AI transforms logistics by providing predictive insights, real-time optimisation, and risk intelligence. Its applications in demand forecasting, route optimisation, inventory management, and risk identification allow organisations to reduce costs, improve service quality, and increase operational flexibility.

Table 7. Integrated Risk Management Strategic Guidelines

Risk Type	Forwarding Impact	Warehousing Impact	Preventive Measures
Supply delays	Route changes	Inventory shortage	Alternative suppliers, safety stock
Technical failure	Data loss	Process stoppage	Backup systems, data recovery
Demand fluctuations	Transport under/overuse	Space under/overuse	Flexible planning, dynamic management

Source: based on Singh, Chaudhary & Saxena (2018)

Common risk sources (Hanafiah et al., 2022; Kahya, Huschbeck & Marković, 2025):

- *Supply chain deficiencies* refer to weaknesses, disruptions, or inefficiencies in the flow of materials, information, or financial resources across the supply chain. These risks can arise from internal processes, external partners, or environmental factors. It includes supplier unreliability (delays, quality issues, inability to meet demand), poor coordination or lack of real-time data sharing between suppliers, manufacturers, and logistics providers, insufficient inventory, when stockouts are caused by inaccurate forecasting or inadequate safety stock, transportation issues, including carrier delays, congestion, or infrastructure failures, and, finally, even natural disasters or geopolitical events, such as floods, earthquakes, strikes, or political instability disrupting supply flows.
- *Technological disruptions* involve failures, malfunctions, or cyber-related incidents in the digital systems that support logistics operations. As warehouses and transport networks become more automated, these risks increase. It includes system failures – downtime in WMS, TMS, ERP, or barcode/RFID systems; cyberattacks, ransomware, data breaches, or hacking targeting logistics platforms; automation failures (malfunctioning AGVs, robots, conveyors, or sorting machines), integration issues or problems when connecting new technologies (IoT, AI, cloud systems) with existing infrastructure, and, communication breakdowns, that result in loss of connectivity between devices, sensors, or tracking systems.
- *Price fluctuations* involve unpredictable changes in the cost of transportation, fuel, raw materials, labour, or other logistics-related expenditures. These changes may be driven by market conditions, geopolitical tensions, or supply-demand imbalances. Fuel price volatility directly affects shipping costs for trucks, ships, and airplanes; raw material price changes affect production schedules and inventory strategies; currency exchange rate fluctuation influences cost of imports and exports; labour cost increases can raise warehousing and transport costs; seasonal demand spikes lead to higher freight rates.
- *Regulatory changes* refer to modifications in laws, standards, trade agreements, customs requirements, and industry regulations that affect logistics operations. New customs laws or tariffs affect import/export procedures and cost structures; environmental regulations put restrictions on emissions, fuel types, or packaging materials; safety standards establish requirements for handling hazardous materials or workplace safety in warehouses; labour regulations affect changes in working hours,

overtime rules, or employee protections; and finally, trade policy shifts create new free-trade agreements or trade barriers.

Based on theoretical analysis (Davidenko, Ristvej & Strelcova, 2020; Arabelen & Kaya, 2021; Fares, 2025; Unterkalmsteiner, & Gorschek, 2023), there are two main priorities for improving forwarding services – process optimisation and human resource management (see Table 8 below).

Table 8. Priorities for Improving Forwarding and Warehousing Services

Technology Implementation:	Process Optimisation:	Human Resource Development:
Development of digital platforms.	Application of “Lean” logistics principles.	Employee training.
Deployment of automation solutions.	Development of standardised procedures.	Motivation systems.
Enhancement of data analytics.	Continuous improvement.	Teamwork promotion.

Source: based on Davidenko, Ristvej & Strelcova (2020); Arabelen & Kaya (2021); Unterkalmsteiner, & Gorschek (2023); Fares (2025)

The integrated model to enhance forwarding and warehousing services through technological convergence, AI integration, risk management, and targeted improvements in processes and human resources, based by sources like Kurniadi (2025), Kanchaveli (2022), and others, emphasises real-time data exchange, automation, error reduction, and resource optimisation to boost efficiency, cut costs, and improve customer satisfaction. It highlights four core technologies (see Table 5 above):

- *Real-time data exchange* – enables tracking, monitoring, and ERP/WMS integration for immediate visibility, faster decisions, and better coordination.
- *Automated process management* – automates picking, routing, scheduling, and documentation, speeding operations and freeing staff for strategic tasks.
- *Reduced human error* – uses scanning, guided systems, and AI forecasting to minimise discrepancies, boost accuracy, and lower costs.
- *Better resource utilisation* – optimises space, labour, equipment, and transport via dynamic allocation and monitoring, enhancing flexibility and reducing waste.

Based on Krnjaic et al. (2024) and Rad et al. (2025), artificial intelligence solutions may be used to transform operations through predictive and optimisation tools (see Table 9 below).

Table 9. Integrated Model for Improving Forwarding and Warehousing Services

Artificial Intelligence Solutions:	Key Application:	Primary Benefits:
Demand forecasting	Inventory planning, dynamic pricing	Minimises stockouts/overstock, cuts holding costs
Route optimisation	Real-time adjustments, multi-stop coordination	Reduces fuel/delivery times, improves punctuality
Inventory management	Predictive restocking, slotting	Optimises stock, reduces errors and costs
Risk identification	Delay prediction, anomaly detection	Enhances resilience, lowers financial risks

This model holistically integrates tech and management for resilient, efficient logistics, prioritises two areas (Davidenko, Ristvej & Strelcova, 2020; Arabelen & Kaya, 2021; Fares, 2025; Unterkalmsteiner, & Gorschek, 2023) – process optimisation (Lean principles, standardised procedures, continuous improvement) and human resource development (training, motivation, teamwork), and outlines integrated guidelines (Singh *et al.*, 2018), addressing risks like supply delays, technical failures, and demand fluctuations through preventive measures such as backups and flexible planning.

Conclusions

The conducted research confirms that forwarding and warehousing services are no longer independent logistics functions but interdependent components of an integrated supply chain system that significantly influences operational efficiency, cost effectiveness, and customer satisfaction. Integration of forwarding and warehousing is critically important for comprehensive logistics efficiency (Struk & Karpil, 2019; Sy, 2025). In the context of globalisation, increasing trade volumes, and technological transformation, the integration of these services becomes a critical prerequisite for maintaining competitiveness and ensuring sustainable

economic development. Technological transformation is a key competitive factor (Kurniadi, 2025; Bahatov, 2022):

- automation reduces operational costs;
- digitisation improves visibility and control;
- artificial intelligence allows proactive risk management;

Strategic approach to warehouse location and layout directly influences (Taletović, 2023):

- transport costs;
- service speed;
- customer satisfaction.

The theoretical analysis demonstrates that forwarding services have evolved from a narrowly defined transport-organising role into a comprehensive supply chain coordination function. Continuous improvement and adaptability to changing market conditions ensure long-term competitive advantage (Arabelen & Kaya, 2021; Zemmouchi-Ghomari, 2025). Modern freight forwarders act as integrators, managing transportation, documentation, customs procedures, warehousing coordination, and information flows. At the same time, warehousing has transformed into a technologically advanced logistics hub responsible not only for storage but also for inventory optimisation, order fulfilment, value-added services, and real-time data generation. The effectiveness of each function is therefore highly dependent on the quality of coordination between them.

The study identifies key factors affecting the performance and integration of forwarding and warehousing services, including information transparency, process synchronisation, resource utilisation, technological maturity, and human resource competence. Inefficient coordination leads to duplicated operations, increased handling costs, longer lead times, and reduced service quality. Conversely, integrated management enables bulk shipment consolidation, faster order fulfilment, reduced logistics costs, improved customer service, and greater flexibility in responding to market changes.

A central contribution of this research is the development of an integrated conceptual model for improving forwarding and warehousing services. The model is based on four core technological pillars: real-time data exchange, automated process management, reduction of human error, and optimised resource utilisation. These pillars are supported by advanced digital solutions such as WMS, ERP/SAP S4HANA, RFID, AGVs, and artificial intelligence applications. AI-driven demand forecasting, route optimisation, inventory management, and risk identification significantly enhance decision-making accuracy, operational resilience, and adaptability under uncertainty. The research also emphasises the importance of integrated risk management. Supply chain disruptions, technological failures, demand fluctuations, price volatility, and regulatory changes pose substantial risks to logistics operations. The proposed model incorporates preventive and corrective measures, including safety stock strategies, alternative routing, backup IT systems, flexible planning, and proactive monitoring, thereby strengthening the robustness of forwarding and warehousing systems.

In addition to technological integration, the study highlights two strategic priorities for long-term improvement: process optimisation and human resource development. The application of Lean logistics principles, standardised procedures, and continuous improvement initiatives enhances operational consistency and efficiency, while targeted employee training, motivation systems, and teamwork development ensure effective use of advanced technologies and support organisational learning.

In conclusion, the integrated model proposed in this study provides a holistic, practitioner-oriented framework for improving forwarding and warehousing services. By aligning technological solutions, operational processes, risk management practices, and human resources, the model contributes to higher service quality, lower logistics costs, increased reliability, and enhanced customer satisfaction. The results offer both theoretical value for logistics and supply chain research and practical guidance for logistics service providers seeking to modernise operations and strengthen their competitive position in dynamic market conditions. Strategic recommendations are focused on adaptation of the model via phased implementation – integrate WMS/ERP with AI for operations, prioritise ABC analysis and AGVs for warehousing, and build cross-functional teams for forwarding. Future research should validate through case studies, focusing on emerging

tech like advanced IoT amid geopolitical risks. This framework not only resolves current inefficiencies but also scales for economic growth in logistics-dependent economies.

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Nikolaj AMBRUSEVIČ is Doctor of social sciences obtained at Vilnius Gediminas Technical University, Associated professor at Vilniaus kolegija/Higher Education Institution. Research interests: brand equity, processes of internationalisation, high technology development, innovations, artificial intelligence, logistics.

ORCID ID: <https://orcid.org/0000-0003-2527-3710>

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