UDC 004.8:658.7:330.131.7
JEL Classification C61, C45, L91, D81

Sevastyanov Rodion

SMART SYNERGY IN LOGISTICS: ADAPTIVE MODELS AND ARTIFICIAL INTELLIGENCE INTEGRATION FOR ECONOMICALLY SOUND DECISION MAKING

National University “Zaporizhzhia Polytechnic”, Zaporizhzhia, Ukraine

This article explores key transformations in modern logistics driven by the need for increased resilience (ResiLog), resource flexibility (FlexHub), and environmental responsibility (GreenChain) in the face of protracted shocks and high uncertainty. Particular attention is paid to the Ukrainian context, where full-scale war has led to the destruction of transport infrastructure, the blockade of traditional export routes, the mass relocation of production facilities, and chronic instability in delivery times and routes. In such conditions, traditional linear management models (ERP, classic SCM systems) are insufficient to ensure the continuity of supplies of critical resources and create a persistent “logistical gap” between the needs of the economy and the capabilities of existing supply chains. The concept of Smart-Synergy is analyzed – an integrated approach to building adaptive logistics ecosystems that combines sustainable logistics (ResiLog), flexible infrastructure solutions based on the “logistics as a service” model (FlexHub), environmentally oriented innovations (GreenChain, ReLoop Logistics), as well as the use of artificial intelligence (SmartFlow), big data (DataChain), and resource sharing models (CrowdRoute). The study shows how these components can be adapted to the conditions of Ukraine’s wartime and post-war economy to overcome the logistics gap, reduce the vulnerability of supply chains to military and political risks, and support post-war reconstruction. The paper outlines the economic effects of implementing adaptive logistics models (reducing CAPEX through FlexHub, optimizing OPEX and reducing losses from disruptions, monetization of “dead” assets through CrowdRoute, reduction of carbon footprint thanks to GreenChain and ReLoop Logistics) and analyzes their potential for increasing the investment attractiveness of Ukrainian enterprises, particularly in the context of access to “green” financial instruments and international recovery programs.

Keywords: logistics, artificial intelligence, decision making, smart-synergy, investment attractiveness.

DOI: 10.32434/2415-3974-2025-22-2-232-243

Problem statement

The modern global economic environment is characterized by high volatility, uncertainty, and crises (wars, pandemics, climate change). Traditional linear and rigidly planned logistics systems (ERP, SCM) have proven to be insufficiently effective for rapid adaptation. From an economic point of view, the logistics gap manifests itself as a systematic lag of existing supply chains behind the actual dynamics of market demand and risks. This generates structural losses: lost revenue due to supply disruptions, excess inventory, penalties for late delivery, as well as image losses, which in today’s economy quickly translate into a decline in market share. The crises of recent years have shown that traditional logistics systems, focused on stability and cost optimization under "normal" conditions, are unprepared for non-standard, high-frequency shocks. For businesses, this means higher cost of capital, as investors factor uncertainty of supply and dependence on vulnerable routes into the risk premium. The lack of ResiLog resilience and FlexHub flexibility effectively translates into higher operating costs and lower margins.

In addition, stricter regulatory requirements in the field of ecology and ESG are stimulating a transition to models where environmental performance is not just an element of social responsibility, but a factor in market competitiveness. Companies that do not integrate green metrics into their logistics risk facing restrictions on access to certain markets, financial instruments, and partnerships.

The logistics gap that new models are closing is the lack of:

– Resilience (ResiLog): The inability of most systems to automatically rearrange routes and suppliers during unpredictable external threats;

– Resource flexibility (FlexHub): An excess of idle warehouse space and equipment, while companies cannot quickly obtain resources "on demand" during peak periods;

– Environmental integration (GreenChain): A focus primarily on speed and cost rather than minimizing carbon footprint and material circularity.

Analysis of the latest research and publications

The relevance of the study is determined by the unprecedented level of logistical shocks that Ukraine faces in the context of full-scale aggression and a prolonged war economy. The destruction of transport infrastructure, the blockade or restriction of traditional maritime export routes, the shift of flows to land corridors through EU countries, mass relocation of production facilities to relatively safe regions, and chronic uncertainty about delivery times and routes create a persistent "logistical gap" between the actual needs of the economy and the capabilities of existing supply chains. In these conditions, classic linear management models, focused on stability and cost minimization in a "normal" environment, prove ineffective and fail to ensure the continuity of supplies of critically important resources, especially for the defense-industrial complex, the agricultural sector, and energy.

The full-scale war against Ukraine has posed unprecedented challenges for national logistics and supply chains. The destruction of transport hubs, the blockade of traditional export routes, the mass relocation of production facilities, and chronic instability in delivery times and directions have led to the formation of a persistent "logistics gap" between the needs of the economy and the capabilities of the existing infrastructure.

In such conditions, local optimisation of individual sections of the logistics chain no longer provides the necessary level of stability. Integrated, adaptive models are needed that are capable of quickly restructuring supply networks, flexibly managing resources, and leveraging the advantages of digitalisation, artificial intelligence, and the green transition. One such concept is Smart-Synergy, which offers a comprehensive framework for combining resilient logistics, flexible infrastructure, circular solutions, and digital platforms.

Contemporary scientific literature clearly shows a transition from linear, rigidly determined supply chains to adaptive, digitally controlled systems, which directly correlates with the Smart-Synergy concept. Systematic reviews of the application of artificial intelligence (AI) in supply chain management show that AI solutions are shifting the focus from classic "demand-driven planning" to continuous self-adjustment of networks, taking into account risks, sustainability, and environmental constraints [1; 2; 4].

Bibliometric works and reviews focused on sustainable and "green" supply chains show that AI is becoming the core of the integration of economic efficiency and resource circularity. A comprehensive analytical review of AI applications in sustainable supply chains records explosive growth in the number of publications, highlights research clusters related to transportation optimization, inventory planning, and circular economy support, and highlights the role of AI tools in reducing carbon footprints and increasing network transparency [5].

For the ResiLog block, systematic reviews at the intersection of AI and supply chain resilience are particularly relevant, where taxonomies of resilience phases (readiness, response, recovery, adaptation) are proposed and compared with specific AI techniques – from Bayesian networks and multi-agent systems to deep learning methods [1; 2; 3]. Additional empirical and review studies show that AI-driven innovations significantly enhance the ability of networks to absorb shocks, reduce recovery time after crises, and increase service stability through predictive analytics, inventory optimization, and scenario planning support [7].

Several key areas directly relevant to the Smart-Synergy concept in logistics and the development of the ResiLog and FlexHub models can be traced in recent studies. Systematic reviews show that supply chain resilience is interpreted as the ability of a network to anticipate, absorb, and recover from disruptions while maintaining an acceptable level of service and economic efficiency [13; 14]. Particular attention is paid to the consequences of the COVID-19 pandemic and the Russian-Ukrainian war for global flows of goods, energy, and food. Geopolitical risks are systemic in nature and affect the configuration of supply chains, inventory structure, and diversification strategies [15].

For Ukraine and the Eastern European region, additional context is provided by studies analyzing the specifics of supply chain resilience in wartime, particularly in terms of infrastructure restoration, transport flow redistribution, and the role of digital platforms in coordinating participants.

Generative AI is a separate area of focus. Recent work shows its potential for building digital twins of supply chains, automated scenario modeling, and supporting human-machine collaborative decision-making [6]. A research agenda is proposed for using GenAI to identify network vulnerabilities, synthesize response and adaptation policies, and evaluate trade-offs between cost, time, and resilience [3; 6].

Classic reviews of AI applications in SCM emphasize that the most mature practical cases relate specifically to logistics tasks—demand forecasting, dynamic routing, warehouse planning, and transportation management [4]. This creates a methodological foundation for the implementation of integrated Smart-Synergy models, where machine learning algorithms ensure continuous adaptation of the network to changes in the external environment (ResiLog), and digital platforms allow for rapid reconfiguration of resources (FlexHub).

The FlexHub component logically builds on research devoted to platforms for sharing logistics resources. Works on on-demand warehousing platforms describe them as B2B marketplaces that connect owners of excess space with companies experiencing peak demand for storage, and show the evolution of these platforms towards “on-demand 4PL,” where the platform operator takes on some of the functions of a supply chain integrator [8]. On the other hand, optimization problems in on-demand warehousing formalize algorithmic approaches to matching supply and demand for warehouse capacity and provide the basis for automated “warehouse-as-a-service” solutions [9].

Together, these areas form the scientific basis of the Smart-Synergy concept: a combination of AI-driven resilience (ResiLog), integrated digital platforms for resource sharing (FlexHub), and a focus on sustainability and circularity in supply chains (GreenChain) [1–9]. This confirms the relevance of the transition from traditional ERP/SCM systems to adaptive, intelligently managed logistics ecosystems.

Systematic reviews of artificial intelligence in supply chain management show a shift from point applications (demand forecasting, routing) to complex intelligent supply chains, where AI supports planning, procurement, production, delivery, returns, and enable functions [10; 11; 12]. The role of machine learning, predictive analytics, digital twins, and generative AI in improving resilience, optimizing inventory, managing risk, and reducing carbon footprint is emphasized.

A separate area of research has emerged in the literature dedicated to Warehouse-as-a-Service (WaaS) and logistics-as-a-service, where warehouse infrastructure is viewed as a flexible resource available “on demand” through digital platforms [15]. WaaS allows you to rent capacity and operational services on a pay-per-use or subscription basis, which reduces capital expenditures, accelerates geographic expansion, and increases adaptability to demand fluctuations. At the same time, approaches to green and sustainable warehousing are developing, where energy efficiency, material, and carbon footprint requirements are integrated into warehouse design and operations [16].

These developments directly correlate with the FlexHub concept as a network of flexible warehouses and micro-logistics hubs integrated through a single digital platform and the Smart-Synergy model.

Research in the field of green logistics and the circular economy shows that logistics infrastructure and operations are becoming a key “bridge” between resources, products, and consumers, ensuring the closure of material flows. Systematic reviews highlight the growing role of green supply chain management, sustainable procurement, green distribution, eco-friendly packaging, and energy-efficient warehousing [17].

More recent work shows that the greatest effect is achieved when green practices are integrated with digital solutions—tracking platforms, carbon emissions analytics, blockchain and IoT technologies for transparency and reverse flow management [18, 19]. In this context, the Smart-Synergy concept, focused on combining resilience, flexibility, and environmental friendliness, fits logically into the current scientific discourse and can be seen as a practical embodiment of the trend toward “digital-green” logistics.

The purpose of the article

The purpose of this article is to theoretically substantiate and adapt the Smart-Synergy concept (ResiLog, FlexHub, GreenChain, ReLoop Logistics, SmartFlow, DataChain, CrowdRoute) to the conditions of Ukraine’s wartime and post-war economy, as well as to demonstrate its potential for overcoming the “logistics gap,” increasing the sustainability and efficiency of supply chains, and supporting post-war reconstruction and integration into EU markets.

Presentation of the main material

The logistical gap in Ukraine in the context of full-scale war is multi-layered and encompasses infrastructure, routes, resources, and information. At the infrastructure level, it manifests itself in the large-scale destruction of transport hubs, damage to bridges, railway stations, and logistics centers, as well as in the blockade or significant restriction of seaports and chronic congestion at border crossings. At the route level, the logistical gap is caused by a radical change in the geography of transport flows: there is a forced transition from sea to land corridors, and the use of alternative ports and transshipment hubs in neighboring countries is intensifying, accompanied by increased transport costs and logistical risks.

At the resource level, there is a shortage of certain types of vehicles, a lack of warehouse space in relatively safe regions, an outflow of qualified personnel, and limited access to financial capital, which makes it difficult for logistics companies to adapt to the new conditions. The information level of the logistics gap is characterized by fragmented data among market participants, low transparency regarding available capacity, existing restrictions, actual delays, and possible alternative routes. Under such conditions, traditional ERP solutions and classic supply chain management (SCM) systems, which are focused on linear and relatively stable processes, do not provide the necessary speed, adaptability, and flexibility of response. This, in turn, deepens the structural gap between the growing demand for logistics services and the actual capabilities of the national logistics system.

For Ukraine, which is simultaneously waging war and preparing for large-scale post-war reconstruction and integration into EU markets, adaptive, resilient, and digitally managed logistics models are of key importance. The Smart-Synergy concept (ResiLog, FlexHub, GreenChain, ReLoop Logistics, SmartFlow, DataChain, CrowdRoute) offers tools for quickly rebuilding supply chains, transitioning from capital-intensive logistics to "logistics as a service" models, and simultaneously taking into account environmental constraints and ESG requirements relevant to access to international financial resources and recovery programs. In this context, Smart-Synergy is not only a technological innovation but also a new economic framework for increasing the sustainability and competitiveness of the Ukrainian economy.

The problem with modeling scenarios for the development of resilient logistics corridors in Ukraine lies in the combination of military destruction of infrastructure, chronic uncertainty of routes, and the need to simultaneously integrate into the EU transport system. Due to the shift of flows from sea to land corridors, congestion at border crossings, and different regulatory regimes within the EU, it is difficult to formalize stable scenarios for the capacity and reliability of corridors. Models must take into account a multi-level "logistical gap" – infrastructure, route, resource, and information – which cannot be described by classic linear ERP/SCM approaches and requires adaptive ResiLog/FlexHub architectures. An additional complexity is the need to simultaneously reconcile economic efficiency, Green Deal requirements, and GreenChain ESG metrics with the realities of a war economy, where rapid and guaranteed access to critical resources remains a priority. Scenario modeling must integrate large arrays of heterogeneous data in the DataChain format – from infrastructure status and risk dynamics to customs restrictions and TEN-T standards — which increases the requirements for data quality and platform interoperability. In a highly volatile external environment, the key challenge is to build digital twins of logistics corridors capable of using SmartFlow and AI algorithms to reproduce multiple scenarios for recovery, redirection of flows, and phased integration into European value chains. Therefore, the scientific problem lies not only in parameterizing such scenarios, but also in creating a Smart-Synergy methodology that will allow assessing the trade-offs between sustainability, cost, delivery time, and environmental compliance at the level of Ukraine's network of resilient logistics corridors in the EU transport system.

In wartime conditions, Ukraine's logistics gap is complex and manifests itself on several levels:

– infrastructure level. Partial or complete destruction of transport hubs (bridges, railway junctions, logistics centers), blockade or restriction of seaport operations, and congestion at border crossing points create bottlenecks that cannot be quickly eliminated using traditional planning tools;

– route level. Radical changes in route geography (the transition from sea to land corridors, the use of alternative ports and transshipment hubs in neighboring countries) increase time and financial costs, as well as the variability of logistical risks;

– resource level. The shortage of certain types of vehicles, lack of qualified personnel, labor outflow, and limited access to warehouse space in "new" safe locations create a gap between the demand for logistics services and the actual available capacity;

– information level. Fragmented data among participants in logistics chains, insufficient transparency regarding actual capacities, delays, restrictions, and alternative routes exacerbate information asymmetry and complicate operational decision-making.

It is at the intersection of these levels that Smart-Synergy can be viewed as a logistical "superstructure" that integrates ResiLog (resilient replanning), FlexHub (on-demand resource reorientation), and DataChain/

SmartFlow (digital transparency and AI-driven forecasting) to reduce the logistics gap. From a business economics perspective, SmartFlow optimizes the cost structure. Automated analytics reduce planning, dispatching, and monitoring costs by replacing manual labor with high-performance digital algorithms. At the same time, the return on investment of transport and warehouse assets increases due to better utilization and reduced idle runs. The integration of data from the IoT and external sources creates the conditions for dynamic pricing of logistics services: rates can vary depending on demand, network congestion, time of day, or environmental priorities. This allows operators not only to optimize revenues, but also to manage user behavior, encouraging, for example, more rational use of infrastructure. In addition, SmartFlow reduces financial risks through improved cash flow: reducing delivery delays means faster turnover of goods, reducing the need for short-term financing and interest expenses associated with inventory financing. Smart-Synergy can be viewed as the economics of network interaction in logistics. DataChain forms an infrastructure to reduce information asymmetry between market participants: manufacturers, distributors, 3PL operators, retailers, and end consumers. This leads to lower transaction costs, faster agreement on terms of cooperation, and the development of more flexible contract models. SmartFlow, using machine learning methods, allows you to move from reactive to proactive management: to predict peaks in demand, risks of congestion, seasonal fluctuations, and fuel price fluctuations. Economically, this reduces the cost of "excess" insurance (excess inventory, duplicate routes) and increases planning accuracy. Resource sharing (CrowdRoute, FlexHub) transforms "dead" assets (empty spaces in transport, underloaded warehouses, private cars) into a source of added value, creating secondary markets for logistics services. Thus, Smart-Synergy is not only a technological but also an economic model of resource redistribution that reduces barriers to entry for small and medium-sized businesses.

ResiLog can be interpreted as economic "insurance" for supply chains. Unlike traditional insurance, which compensates for losses after the fact, resilient logistics aims to prevent and minimize losses by creating mechanisms for quickly reconfiguring routes, suppliers, and transportation schemes. Economically, this translates into reduced unproductive downtime, lost revenue, and emergency costs (emergency delivery, penalties). FlexHub, in turn, is the implementation of the concept of "flexible capital utilization" in logistics. Instead of long-term "freezing" of investments in warehouses and equipment, companies are moving to a "pay-per-use" model, where costs are closer to variable and better match actual demand. This reduces the financial burden (depreciation, maintenance, property taxes) and allows capital to be reallocated to more productive areas (innovation, R&D, marketing).

Together, ResiLog and FlexHub form an adaptive logistics architecture where risks and costs are not only reduced but also become more predictable and manageable, which is important for long-term financial planning. Resilient logistics (ResiLog) is a concept that assumes the ability of the supply chain not only to withstand external shocks (crises, natural disasters, conflicts), but also to quickly restore functionality by automatically changing routes, suppliers, and modes of transport. ResiLog ensures continuity of supply. In the case of Ukraine, ResiLog should be interpreted as the ability of the logistics system not only to maintain a basic level of functioning during military shocks, but also to provide priority access to resources for critical sectors (defense, energy, food security, medicine). This involves building a multi-level network of alternative routes (rail corridors with different capacities, multimodal "rail-road-port" schemes, backup hubs in western and central regions) that can be automatically activated via SmartFlow in case of blockage of the main channels.

In the Ukrainian context, FlexHub should be viewed as a network of flexible logistics centers operating on a "warehouse as a service" model that can be quickly scaled up in regions where displaced businesses and humanitarian flows are concentrated. These can be either specialized industrial parks or temporary modular warehouses integrated into a single DataChain digital platform. For businesses, this means minimizing the need for long-term investments in their own logistics infrastructure and the ability to reorient freed-up capital toward technological upgrades and export expansion.

The Flexible Hub is the physical embodiment of this resilience. FlexHub is an innovative warehouse that operates on a "logistics as a service" model. This allows companies to rent warehouse space, personnel, and equipment not for years, but for hours or days ("on demand"), optimizing capital expenditures and minimizing downtime. FlexHub increases operational flexibility.

Smart-Synergy is defined as an integrative strategy that maximizes logistics efficiency through the synergistic combination of three key elements:

– digitalization (DataChain): a shared data exchange platform between all participants in the supply chain, ensuring transparency;

– Artificial Intelligence (SmartFlow): algorithms that analyze DataChain for automatic decision-making (forecasting, rerouting);

– shared use (CrowdRoute, FlexHub): involving external, underutilized, or private resources to perform tasks.

This synergy allows the system not only to respond to changes, but also to anticipate them and adapt preventively.

SmartFlow (smart logistics flow) is a software and hardware complex that uses AI for dynamic management of material and information flows. Unlike static ERP systems, SmartFlow integrates data from IoT devices, social networks (for demand forecasting), and external factors (weather, traffic jams).

CrowdRoute is a model that solves the "last mile" problem (Smart Last-Mile), which is the most expensive stage in the logistics chain. CrowdRoute uses crowdsourcing – involving ordinary citizens who are already traveling to deliver small parcels "along the way." From an economic perspective, CrowdRoute is a tool for democratizing the logistics services market. For small and medium-sized businesses, the model allows them to avoid the fixed costs associated with maintaining their own transport and move to a more flexible cost structure – paying only for deliveries actually made. This lowers the barrier to entry into the e-commerce and urban delivery market. For individuals, participation in CrowdRoute creates new sources of income without the need for significant investment: existing transport or routes that were planned independently of logistics tasks are used. At the macro level, this contributes to employment growth, the development of micro-entrepreneurship, and the formation of a "platform economy."

From an urban economic perspective, CrowdRoute can help reduce traffic congestion and environmental costs if incentives are properly configured: the more parcels are picked up along the way, the less need there is for additional commercial flights. This leads to a reduction in urban infrastructure costs (road wear, traffic jams, air pollution) and an improvement in the quality of life for residents.

Table 1 provides a comparative analysis of traditional and adaptive logistics models.

Table 1

Comparison of traditional and adaptive logistics models

Parameter	Traditional logistics (One Warehouse Model)	Adaptive logistics (FlexHub & ResiLog)
Flow management	Rigid planning, manual correction	SmartFlow dynamic management (AI, Big Data)
Storage space	Fixed, high capital costs	On-demand rental (FlexHub), minimizing downtime
Response to the crisis	Prolonged, high probability of failures (ResiLog is missing)	Instant adaptation, change of suppliers/routes
Last mile delivery	High cost, inefficiency of small batches	Crowdsourcing (CrowdRoute), Smart Last-Mile

Source: compiled by author

The table shows that the main problem with traditional logistics using a "single warehouse" model is rigid flow planning and manual correction, which makes the system inert and poorly suited to Smart Synergy approaches. Fixed warehouse space with high capital costs blocks flexible resource allocation, complicates scaling, and reduces the economic feasibility of decisions in a dynamic demand environment. The lack of adaptive ResiLog mechanisms means that the response to a crisis is slow, with a high probability of failures, which undermines the stability of supply chains and makes classic business cases economically risky. In the adaptive logistics model, on the contrary, the problem is formulated as a task of transitioning to dynamic SmartFlow management based on AI and Big Data, where the key challenge is the integration of heterogeneous data to support economically sound decisions in real time. The FlexHub concept of renting warehouse space "on demand" reduces downtime and capital expenditures, but requires new models for assessing TCO, risks, and demand scenarios to prove the economic benefits of such flexibility to investors and operators. Instant adaptation of suppliers and routes in the ResiLog architecture requires algorithms that simultaneously take into account cost, time, reliability, and risks, turning planning into a multi-criteria Smart Synergy task rather than simple tariff or distance optimization. Crowdsourcing technologies for the "last mile" (CrowdRoute, Smart Last-Mile) open up the potential for significant savings and service improvements, but create new challenges of standardization, quality control, and integration into a single AI-oriented platform capable of generating transparent and informed management decisions.

GreenChain can be seen as a tool for monetizing environmental performance. With ESG reporting requirements getting stricter, companies that show transparent and trackable emissions reductions get a competitive edge: access to green credit lines, sustainable development investment funds, and preferences in public procurement and public-private partnerships. Automated measurement of the carbon footprint at the level of individual routes and operations allows for the formation of economically sound decarbonization scenarios: for example, comparing the costs of transitioning to a more environmentally friendly mode of transport with the expected reduction in fines, carbon taxes, or carbon offset costs. The use of blockchain in DataChain strengthens trust between market participants and regulators, as environmental indicators become immutable, transparent data. This reduces the risks of greenwashing and increases brand value for consumers, who are increasingly choosing products with a proven green footprint.

GreenChain is a conceptual framework that puts environmental friendliness on par with speed and cost. The GreenChain system:

– performs carbon analytics: Automatically calculates the carbon footprint of each stage of the logistics chain;

– ensures transparency: Uses blockchain (as part of DataChain) for immutable recording of suppliers' environmental performance.

– optimized routes: SmartFlow selects not only the fastest but also the most environmentally friendly route, giving preference to multimodal transport and less harmful fuels.

The key challenge for GreenChain is the Eco-Speed Dilemma – the need to balance delivery speed and environmental friendliness. This is solved by implementing the ReLoop Logistics model.

From the perspective of circular economy theory, ReLoop Logistics transforms packaging and auxiliary materials from the "cost" category to the "long-term assets" category. The transition to reusable solutions with digital lifecycle tracking significantly reduces the cost of purchasing new materials, their disposal, and waste logistics.

The Eco-Speed Dilemma in this model is solved by integrating speed and environmental friendliness into a single optimization function. For example, the system can agree to a slight increase in delivery time in exchange for a significant reduction in carbon footprint, which is offset economically by lower environmental fees and increased customer loyalty. Some of these effects can be capitalized through green certificates or participation in carbon markets.

Involving CrowdRoute and Smart Last-Mile in reverse packaging collection reduces the average cost of a single logistics cycle, as delivery and return costs are combined into a single operation. This creates conditions for scaling circular models without a significant increase in tariffs for the end consumer.

ReLoop Logistics focuses on creating closed loops for packaging and transport materials (containers, pallets, specialized reusable packaging). Instead of using disposable packaging, ReLoop:

– accounts for materials: All cyclical units are tracked in DataChain;

– integrates returns: CrowdRoute or Smart Last-Mile couriers are engaged to collect packaging, combining delivery and collection in a single trip.

This approach not only reduces waste but also lowers the need for new packaging production, minimizing the overall carbon footprint of the supply chain. The impact of key green innovations on ESG indicators is shown in Table 2.

Table 2

Impact of key green innovations on ESG indicators

Innovative concept	Main environmental impact (Environmental)	Main social impact (Social)
Green Chain	Reduction of CO? emissions through route optimization	Enhanced reputation, transparency for consumers
ReLoop Logística	Minimization of waste and use of natural resources	Reduced costs for the end consumer
CrowdRoute	Reduction in the number of empty commercial trips	Creating new opportunities for micro-earnings

Source: compiled by author

The economic effects of implementing Smart-Synergy in Ukrainian supply chains should be assessed according to three groups of indicators:

a) capital intensity of logistics (CAPEX). The transition from the "infrastructure ownership" model to FlexHub reduces the need for investment in warehouses, transport, and auxiliary equipment, replacing them with on-demand service payments. This is especially critical for SMEs and businesses that have moved to new regions and cannot afford long-term investments in real estate;

b) operating expenses and disruption losses (OPEX + disruption losses). Using SmartFlow and DataChain for dynamic routing, risk forecasting, and early detection of bottlenecks reduces costs associated with excess inventory, late delivery penalties, emergency transportation, and production downtime losses;

c) cost of capital and access to financing. The integration of GreenChain and ReLoop Logistics creates a better ESG profile for the company, which in global practice is associated with lower borrowing costs and better access to green financial instruments, international grants, and reconstruction programs. For Ukrainian businesses, this could become one of the key channels for financing logistics modernization. Table 3 shows the components of Smart-Synergy and key KPIs.

Table 3

Smart-Synergy components and key KPIs

Component	Role in Smart-Synergy	Typical KPIs	Example for the Ukrainian context
ResiLog	Resilience, route restructuring	Recovery time after failure, % of orders fulfilled during the crisis	Reducing corridor downtime after shelling
FlexHub	Flexible “warehouse as a service” infrastructure	Warehouse utilization rate, share of variable costs	Use of temporary hubs in western regions
GreenChain	Carbon and environmental control	CO_2/tonne-km, share of green routes	Choosing multimodal routes to EU ports
ReLoop Logistics	Closed-loop packaging	Proportion of reusable packaging, number of usage cycles	Return of containers/pallets via last-mile
SmartFlow	AI-driven flow management	Accuracy of demand forecasting, response time	Forecast of route changes due to blockades
DataChain	Transparent data exchange	Completeness/relevance of data, number of integrated participants	A single platform for agricultural exporters
CrowdRoute	Crowdsourcing for the “last mile” and reverse logistics	Average delivery cost, flight occupancy rate	Connecting local drivers to the platform

Source: compiled by author

The Smart Synergy model in logistics is viewed as a system of interacting modules (ResiLog, FlexHub, GreenChain, ReLoop Logistics, SmartFlow, DataChain, CrowdRoute), each of which optimizes its own subtask. Key performance indicators have been defined for each module, allowing the concept to be operationalized and the impact of decisions on sustainability, environmental friendliness, infrastructure flexibility, data quality, and the cost of logistics services to be quantified. The integration of adaptive models and artificial intelligence enables demand and risk forecasting, dynamic route replanning, optimization of warehouse, transport, and reusable container utilization, as well as intelligent matching of market participants in crowdsourcing services. A distinctive feature of this approach is its adaptation to the Ukrainian context, where logistics solutions must take into account military risks, infrastructure relocation, orientation towards European corridors, and increased data transparency requirements. Together, this forms a comprehensive architecture for supporting economically sound decision-making in logistics, where AI modules are directly linked to measurable economic results through a KPI system.

Table 4 shows the effects of implementing Smart-Synergy.

Table 4

Economic effects of implementing Smart-Synergy

Indicator	Traditional logistics model	Smart-Synergy Model (ResiLog + FlexHub + GreenChain)	Expected effect
CAPEX for warehouses and transport	High, significant share in assets	Low (pay-per-use model)	Capital release, ROA improvement
OPEX on “safety” stocks	High	Reduced thanks to SmartFlow (better forecast)	Less frozen working capital
Disruption losses	Frequent and significant	Reduced by ResiLog	Stabilization of cash flow
Cost of capital (borrowing rate)	Higher	Lower due to better ESG profile (GreenChain, ReLoop)	Cheaper financing
Revenue from asset monetization	Limited	Additional via CrowdRoute/FlexHub	New sources of revenue

Table 4 shows that the transition from traditional logistics to the Smart-Synergy model reduces CAPEX through a pay-per-use approach and increases ROA through asset dematerialization and flexible AI-driven infrastructure utilization. The integration of SmartFlow and ResiLog modules reduces OPEX for safety stocks and expected losses from disruptions, as demand is predicted more accurately, dynamic replenishment is applied, and scenario-based resilience models are implemented. This directly stabilizes cash flow and reduces the volatility of financial results, which is important for investors and lenders. The ESG components GreenChain and ReLoop improve the company's green profile, opening up access to cheaper financing and reducing the cost of capital. The FlexHub/CrowdRoute platform modules transform logistics from a cost center into a source of new revenue, allowing you to monetize excess capacity and form a networked, AI-supported logistics ecosystem.

Conclusions

The conditions of full-scale war in Ukraine have led to the formation of a complex logistical gap that cannot be overcome by local optimizations within traditional ERP/SCM systems. Against this backdrop, the Smart-Synergy concept is seen as an integrated framework for building adaptive logistics ecosystems, combining supply chain resilience (ResiLog), flexible infrastructure based on the "logistics as a service" model (FlexHub), environmentally oriented solutions (GreenChain, ReLoop Logistics), AI-driven flow management (SmartFlow), digital transparency and data interoperability (DataChain), and crowdsourced resource utilization models (CrowdRoute). Together, these elements aim to bridge the gap between the actual needs of the economy and the capabilities of the existing logistics infrastructure in the context of Ukraine's wartime and post-war economy.

ResiLog and FlexHub form an adaptive logistics architecture in which risks and costs are not only reduced but also become more predictable and manageable. The transition from an infrastructure ownership model to a "warehouse as a service" and "capacity on demand" approach reduces the capital intensity of logistics, reduces the need for investment in warehouses and transportation, increases flexibility in responding to shocks, and allows freed-up capital to be directed toward innovation, R&D, and export expansion. At the same time, ResiLog provides the ability to quickly re-plan routes and suppliers, reduce downtime, reduce direct and indirect losses from disruptions, and stabilize cash flows for businesses, which is critically important in conditions of high military and political uncertainty.

GreenChain and ReLoop Logistics are shifting the environmental dimension of logistics from declarative social responsibility to economic decisions. The integration of carbon analytics, transparent environmental performance accounting, and circular packaging models makes it possible to simultaneously reduce emissions, minimize waste, lower material procurement and disposal costs, and develop sustainable green business cases. The Eco-Speed Dilemma is solved by optimizing not only time and cost, but also carbon footprint, which creates the conditions for improving companies' ESG profiles, accessing green financial instruments, participating in reconstruction programs, and increasing the investment attractiveness of Ukrainian logistics and industry in general.

SmartFlow and DataChain enable the transition to proactive, data-driven supply chain management. The combination of predictive analytics, digital twins, IoT data, and scenario modeling allows you to predict logistics shocks, identify bottlenecks faster, and optimize inventory, routes, and capacity utilization. From an enterprise economics perspective, this means reducing "excess insurance" costs in the form of excess inventory and duplicate routes, reducing transaction costs, increasing transparency between market participants, and creating new, more flexible contract models. DataChain, as the digital backbone of Smart-Synergy, reduces information asymmetry and creates a basis for real-time network coordination of logistics solutions.

CrowdRoute and FlexHub complement this architecture by democratizing access to logistics infrastructure and monetizing excess resources. Crowdsourced models for last-mile and reverse logistics bring private and small carriers into the market, turn "dead" assets into a source of income, and expand opportunities for SMEs that cannot maintain their own fleet or warehouse infrastructure. At the city level, this reduces the number of empty runs, transport loads, and environmental costs, while at the national level, it contributes to the formation of new logistics service markets and the development of the platform economy.

The article clarifies the meaning and interrelationships of key concepts in adaptive logistics – ResiLog, FlexHub, GreenChain, ReLoop Logistics, SmartFlow, DataChain, CrowdRoute – in the context of military challenges and post-war reconstruction in Ukraine, and describes the structure and dynamics of "logistical shocks" associated with infrastructure destruction, port blockades, changes in the configuration of export-import corridors, relocation of enterprises, and increased demand volatility. It is shown that this "logistical gap" has infrastructural, route, resource, and informational dimensions and cannot be described and overcome by classical linear ERP/SCM approaches.

The impact of artificial intelligence and digital platforms on improving supply continuity, reducing response times to logistical shocks, and reducing costs associated with excess inventory and route duplication has been analyzed. The main economic effects of implementing Smart-Synergy have been identified: reduction of CAPEX through the transition to FlexHub models, optimization of OPEX, minimization of direct and indirect losses from disruptions, monetization of excess assets through platform solutions, reduction of carbon footprint, and improvement of access to financing. Smart-Synergy is seen as a driver of increased creditworthiness and investment attractiveness of Ukrainian companies, particularly in terms of credit ratings, green instruments, and international reconstruction support programs.

Special attention is paid to proposals for public policy and the regulatory environment aimed at supporting the development of Smart-Synergy adaptive logistics ecosystems. This involves the development of digital infrastructure and uniform data standards, the creation of incentives for green logistics investments, support for resource-sharing platforms, and the formation of a network of resilient logistics corridors integrated with the EU transport system. In this context, the implementation of Smart-Synergy is seen as part of a national logistics recovery strategy, rather than a collection of isolated corporate cases.

At the enterprise level, a phased approach to implementing Smart-Synergy has been proposed: deployment of DataChain as a basic digital platform for data exchange with suppliers and logistics partners; gradual transition to FlexHub models with the release of capital from tangible assets and its reorientation towards innovative areas; pilot implementation of CrowdRoute and ReLoop Logistics in segments with a high frequency of small deliveries and significant volumes of single-use packaging; integration of GreenChain with an internal KPI system that directly links environmental performance to financial results. Investments in DataChain and SmartFlow should be considered strategic, long-term investments, with the formation of business cases that evaluate not only direct cost reductions, but also risk reduction and increased predictability of business processes.

In summary, Smart-Synergy represents a new paradigm of economic efficiency in logistics, where sustainability, flexibility, and environmental friendliness do not compete with each other but reinforce each other. The transition from a linear, fragmented, and resource-intensive model to a networked, adaptive, and environmentally balanced logistics model reduces overall logistics costs, increases the financial stability of enterprises, and increases their long-term market value. For Ukraine, this means the opportunity to simultaneously strengthen military resilience, accelerate post-war reconstruction, and lay the foundations for long-term sustainable development in close integration with European value chains.

REFERENCES

1. Kassa, A., Kitaw, D., Stache, U., Beshah, B., & Degefu, G. (2023). Artificial intelligence techniques for enhancing supply chain resilience: A systematic literature review, holistic framework, and future research. *Computers & Industrial Engineering, 186*, 109714. DOI: https://doi.org/10.1016/j.cie.2023.109714.

2. Zamani, E. D., Smyth, C., Gupta, S., & Dennehy, D. (2023). Artificial intelligence and big data analytics for supply chain resilience: A systematic literature review. *Annals of Operations Research, 327*(2), 605–632. DOI: https://doi.org/10.1007/s10479-022-04983-y.

3. Zaoui, S., Foguem, C., Tchuente, D., & Kamsu-Foguem, B. (2025). The application of artificial intelligence technologies in the resilience and the viability of supply chains: A systematic literature review. *Production Planning & Control.* DOI: https://doi.org/10.1080/09537287.2025.2563616.

4. Pournader, M., Ghaderi, H., Hassanzadegan, A., & Fahimnia, B. (2021). Artificial intelligence applications in supply chain management. *International Journal of Production Economics, 241*, 108250. https://doi.org/10.1016/j.ijpe.2021.108250

5. Abyaneh, A. G., Ghanbari, H., Mohammadi, E., Amirsahami, A., & Khakbazan, M. (2025). An analytical review of artificial intelligence applications in sustainable supply chains. *Supply Chain Analytics, 12*, 100173. DOI: https://doi.org/10.1016/j.sca.2025.100173.

6. Boone, T., Fahimnia, B., Ganeshan, R., Herold, D. M., & Sanders, N. R. (2025). Generative AI: Opportunities, challenges, and research directions for supply chain resilience. *Transportation Research Part E: Logistics and Transportation Review, 199*, 104135. DOI: https://doi.org/10.1016/j.tre.2025.104135.

7. Peprah, J. A., Amoah, J., Kwarteng, K., Jibril, A. B., & Sharif, T. (2025). Artificial intelligence and additive manufacturing for resilient supply chain in Africa: A systematic literature review. *Future Business Journal, 11*, 54. DOI: https://doi.org/10.1186/s43093-025-00477-y.

8. Elia, V., Gnoni, M. G., & Tornese, F. (2024). On-demand warehousing platforms: Evolution and trend analysis of an industrial sharing economy model. *Logistics, 8*(4), 93. DOI: https://doi.org/10.3390/logistics8040093.

9. Ceschia, S., Gansterer, M., Mancini, S., & Meneghetti, A. (2023). The on-demand warehousing problem. *International Journal of Production Research, 61*(10), 3152–3170. DOI: https://doi.org/10.1080/00207543.2022.2078249.

10. Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research, 122*, 502–517. DOI: https://doi.org/10.1016/j.jbusres.2020.09.009.

11. Culot, G. (2024). Artificial intelligence in supply chain management. *Computers in Industry, 154*, 104132. DOI: https://doi.org/10.1016/j.compind.2024.104132.

12. Teixeira, A. R., Ferreira, J. V., & Ramos, A. L. (2025). Intelligent supply chain management: A systematic literature review on artificial intelligence contributions. *Information, 16*(5), 399. DOI: https://doi.org/10.3390/info16050399.

13. Guo, Y., Liu, F., Song, J.-S., & Wang, S. (2024). Supply chain resilience: A review from the inventory management perspective. *Fundamental Research, 5*(2). DOI: https://doi.org/10.1016/j.fmre.2024.08.002.

14. Hosseini Shekarabi, S. A., Kiani Mavi, R., & Romero Macau, F. (2025). Supply chain resilience: A critical review of risk mitigation, robust optimisation, and technological solutions and future research directions. *Global Journal of Flexible Systems Management.* DOI: https://doi.org/10.1007/s40171-025-00458-8.

15. Taofeek, A. (2025). Warehouse-as-a-Service (WaaS): A new paradigm for supply chain agility and cost optimization. *ResearchGate* (preprint). Retrieved from https://www.researchgate.net/publication/390215939_Warehouse-as-a-Service_WaaS_A_New_Paradigm_for_Supply_Chain_Agility_and_Cost_Optimization.

16. Hariyani, D., Hariyani, P., Mishra, S., & Sharma, M. K. (2024). A literature review on green supply chain management for sustainable sourcing and distribution. *Waste Management Bulletin, 2*(4), 231–248. DOI: https://doi.org/10.1016/j.wmb.2024.11.009.

17. Seroka-Stolka, O., & Ociepa-Kubicka, A. (2019). Green logistics and circular economy. *Transportation Research Procedia, 39*, 471–479. DOI: https://doi.org/10.1016/j.trpro.2019.06.049.

18. Nautwima, J. P., & Asa, A. R. (2025). Reimagining logistics for sustainability: Green logistics practices, circular economy integration, and digital enablers in sustainable supply chain management. *International Journal of Management Science and Business Administration, 11*(5), 7–21. DOI: https://doi.org/10.18775/ijmsba.1849-5664-5419.2014.115.1001.

19. Bednarski, L. (2025). Geopolitical disruptions in global supply chains: A state-of-the-art literature review. *Production Planning & Control, 36*(4), 536–562. DOI: https://doi.org/10.1080/09537287.2023.2286283.

Received 05.09.2025.
Revised 15.09.2025.
Accepted 20.11.2025.
Published 25.12.2025.

SMART-SYNERGY У ЛОГІСТИЦІ: АДАПТИВНІ МОДЕЛІ ТА ІНТЕГРАЦІЯ ШТУЧНОГО ІНТЕЛЕКТУ ДЛЯ ПРИЙНЯТТЯ ЕКОНОМІЧНО ОБҐРУНТОВАНИХ РІШЕНЬ

Севастьянов Родіон

У статті досліджено ключові трансформації в сучасній логістиці, викликані необхідністю підвищення стійкості (ResiLog), гнучкості ресурсів (FlexHub) та екологічної відповідальності (GreenChain) в умовах затяжних шоків і високої невизначеності. Особливу увагу приділено українському контексту, де повномасштабна війна зумовила руйнування транспортної інфраструктури, блокаду традиційних експортних маршрутів, масове переміщення виробничих потужностей і хронічну нестабільність термінів та маршрутів постачань. У таких умовах традиційні лінійні моделі управління (ERP, класичні SCM-системи) виявляються недостатніми для забезпечення безперервності постачань критично важливих ресурсів і формують стійкий «логістичний пробіл» між потребами економіки та можливостями існуючих ланцюгів постачань. Проаналізовано концепцію Smart-Synergy – інтегрованого підходу до побудови адаптивних логістичних екосистем, який поєднує стійку логістику (ResiLog), гнучкі інфраструктурні рішення за моделлю «логістика як сервіс» (FlexHub), екологічно орієнтовані інновації (GreenChain, ReLoop Logistics), а також використання штучного інтелекту (SmartFlow), великих даних (DataChain) і моделей спільного використання ресурсів (CrowdRoute). Дослідження показує, як ці компоненти можуть бути адаптовані до умов воєнної та повоєнної економіки України для подолання логістичного пробілу, зниження вразливості ланцюгів постачань до військово-політичних ризиків і підтримки повоєнної відбудови. У роботі окреслено економічні ефекти впровадження адаптивних логістичних моделей (скорочення CAPEX за рахунок FlexHub, оптимізація OPEX і зменшення збитків від збоїв, монетизація «мертвих» активів через CrowdRoute, зниження вуглецевого сліду завдяки GreenChain та ReLoop Logistics) та проаналізовано їх потенціал для підвищення інвестиційної привабливості українських підприємств, зокрема в контексті доступу до «зелених» фінансових інструментів та міжнародних програм відновлення.

Ключові слова: логістика, штучний інтелект, прийняття рішень, smart-synergy, інвестиційна привабливість.

SMART SYNERGY IN LOGISTICS: ADAPTIVE MODELS AND ARTIFICIAL INTELLIGENCE INTEGRATION FOR ECONOMICALLY SOUND DECISION MAKING

Sevastyanov Rodion

National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine

e-mail: rvs_zp@ukr.net

Sevastyanov Rodion ORCID: **https://orcid.org/0000-0001-9088-4433**

This article explores key transformations in modern logistics driven by the need for increased resilience (ResiLog), resource flexibility (FlexHub), and environmental responsibility (GreenChain) in the face of protracted shocks and high uncertainty. Particular attention is paid to the Ukrainian context, where full-scale war has led to the destruction of transport infrastructure, the blockade of traditional export routes, the mass relocation of production facilities, and chronic instability in delivery times and routes. In such conditions, traditional linear management models (ERP, classic SCM systems) are insufficient to ensure the continuity of *supplies of critical resources and create a persistent "logistical gap" between the needs of the economy and the capabilities of existing supply chains. The concept of Smart-Synergy is analyzed – an integrated approach to building adaptive logistics ecosystems that combines sustainable logistics (ResiLog), flexible infrastructure solutions based on the "logistics as a service" model (FlexHub), environmentally oriented innovations (GreenChain, ReLoop Logistics), as well as the use of artificial intelligence (SmartFlow), big data (DataChain), and resource sharing models (CrowdRoute). The study shows how these components can be adapted to the conditions of Ukraine's wartime and post-war economy to overcome the logistics gap, reduce the vulnerability of supply chains to military and political risks, and support post-war reconstruction. The paper outlines the economic effects of implementing adaptive logistics models (reducing CAPEX through FlexHub, optimizing OPEX and reducing losses from disruptions, monetization of "dead" assets through CrowdRoute, reduction of carbon footprint thanks to GreenChain and ReLoop Logistics) and analyzes their potential for increasing the investment attractiveness of Ukrainian enterprises, particularly in the context of access to "green" financial instruments and international recovery programs.*

Keywords: logistics, artificial intelligence, decision making, smart-synergy, investment attractiveness.

REFERENCES

1. Kassa, A., Kitaw, D., Stache, U., Beshah, B., & Degefu, G. (2023). Artificial intelligence techniques for enhancing supply chain resilience: A systematic literature review, holistic framework, and future research. *Computers & Industrial Engineering, 186*, 109714. DOI: https://doi.org/10.1016/j.cie.2023.109714.

2. Zamani, E. D., Smyth, C., Gupta, S., & Dennehy, D. (2023). Artificial intelligence and big data analytics for supply chain resilience: A systematic literature review. *Annals of Operations Research, 327*(2), 605–632. DOI: https://doi.org/10.1007/s10479-022-04983-y.

3. Zaoui, S., Foguem, C., Tchuente, D., & Kamsu-Foguem, B. (2025). The application of artificial intelligence technologies in the resilience and the viability of supply chains: A systematic literature review. *Production Planning & Control.* DOI: https://doi.org/10.1080/09537287.2025.2563616.

4. Pournader, M., Ghaderi, H., Hassanzadegan, A., & Fahimnia, B. (2021). Artificial intelligence applications in supply chain management. *International Journal of Production Economics, 241*, 108250. https://doi.org/10.1016/j.ijpe.2021.108250

5. Abyaneh, A. G., Ghanbari, H., Mohammadi, E., Amirsahami, A., & Khakbazan, M. (2025). An analytical review of artificial intelligence applications in sustainable supply chains. *Supply Chain Analytics, 12*, 100173. DOI: https://doi.org/10.1016/j.sca.2025.100173.

6. Boone, T., Fahimnia, B., Ganeshan, R., Herold, D. M., & Sanders, N. R. (2025). Generative AI: Opportunities, challenges, and research directions for supply chain resilience. *Transportation Research Part E: Logistics and Transportation Review, 199*, 104135. DOI: https://doi.org/10.1016/j.tre.2025.104135.

7. Peprah, J. A., Amoah, J., Kwarteng, K., Jibril, A. B., & Sharif, T. (2025). Artificial intelligence and additive manufacturing for resilient supply chain in Africa: A systematic literature review. *Future Business Journal, 11*, 54. DOI: https://doi.org/10.1186/s43093-025-00477-y.

8. Elia, V., Gnoni, M. G., & Tornese, F. (2024). On-demand warehousing platforms: Evolution and trend analysis of an industrial sharing economy model. *Logistics, 8*(4), 93. DOI: https://doi.org/10.3390/logistics8040093.

9. Ceschia, S., Gansterer, M., Mancini, S., & Meneghetti, A. (2023). The on-demand warehousing problem. *International Journal of Production Research, 61*(10), 3152–3170. DOI: https://doi.org/10.1080/00207543.2022.2078249.

10. Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research, 122*, 502–517. DOI: https://doi.org/10.1016/j.jbusres.2020.09.009.

11. Culot, G. (2024). Artificial intelligence in supply chain management. *Computers in Industry, 154*, 104132. DOI: https://doi.org/10.1016/j.compind.2024.104132.

12. Teixeira, A. R., Ferreira, J. V., & Ramos, A. L. (2025). Intelligent supply chain management: A systematic literature review on artificial intelligence contributions. *Information, 16*(5), 399. DOI: https://doi.org/10.3390/info16050399.

13. Guo, Y., Liu, F., Song, J.-S., & Wang, S. (2024). Supply chain resilience: A review from the inventory management perspective. *Fundamental Research, 5*(2). DOI: https://doi.org/10.1016/j.fmre.2024.08.002.

14. Hosseini Shekarabi, S. A., Kiani Mavi, R., & Romero Macau, F. (2025). Supply chain resilience: A critical review of risk mitigation, robust optimisation, and technological solutions and future research directions. *Global Journal of Flexible Systems Management.* DOI: https://doi.org/10.1007/s40171-025-00458-8.

15. Taofeek, A. (2025). Warehouse-as-a-Service (WaaS): A new paradigm for supply chain agility and cost optimization. *ResearchGate* (preprint). Retrieved from https://www.researchgate.net/publication/390215939_Warehouse-as-a-Service_WaaS_A_New_Paradigm_for_Supply_Chain_Agility_and_Cost_Optimization.

16. Hariyani, D., Hariyani, P., Mishra, S., & Sharma, M. K. (2024). A literature review on green supply chain management for sustainable sourcing and distribution. *Waste Management Bulletin, 2*(4), 231–248. DOI: https://doi.org/10.1016/j.wmb.2024.11.009.

17. Seroka-Stolka, O., & Ociepa-Kubicka, A. (2019). Green logistics and circular economy. *Transportation Research Procedia, 39*, 471–479. DOI: https://doi.org/10.1016/j.trpro.2019.06.049.

18. Nautwima, J. P., & Asa, A. R. (2025). Reimagining logistics for sustainability: Green logistics practices, circular economy integration, and digital enablers in sustainable supply chain management. *International Journal of Management Science and Business Administration, 11*(5), 7–21. DOI: https://doi.org/10.18775/ijmsba.1849-5664-5419.2014.115.1001.

19. Bednarski, L. (2025). Geopolitical disruptions in global supply chains: A state-of-the-art literature review. *Production Planning & Control, 36*(4), 536–562. DOI: https://doi.org/10.1080/09537287.2023.2286283.