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# Adaptive and Sustainable Supply Chain Management under Systemic Instability: Evidence from the COVID-19 Pandemic and the Ukraine Conflict

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**ABSTRACT:**
The analytical examination will concentrate on elucidating transformations within supply chain management systems precipitated by crisis phenomena spanning the period from 2020 through 2024. The principal objective of this investigation is to conduct a comparative assessment of adaptive strategies employed by logistics systems under the conditions of both the COVID-19 pandemic and armed conflict in Ukraine. The methodological framework underpinning this research is grounded in a comprehensive approach that synthesizes quantitative examination of statistical indicators with qualitative evaluation of managerial practices. The results of the study demonstrate fundamental differences in the mechanisms of supply chain adaptation to different types of crises. The COVID-19 pandemic allowed for gradual adaptation with the possibility of recovery planning: companies had time to reorganize routes, search for alternative suppliers, and implement digital solutions. Military operations in Ukraine required an immediate response and a radical restructuring of logistics networks: companies were forced to move warehouses, change transportation corridors and ensure the safety of their staff within days. According to an analysis of sea freight rates, the cost of container transportation increased from $2,100 in July 2020 to $1,200 in November 2021. In the structure of Ukrainian imports in 2022, road transport accounted for 64% of the total value of all imported transportation, while in 2021 this figure did not exceed 35%. According to international technology reports, the introduction of digital twins in supply chain management increased from 5% of companies in 2020 to 34% in 2024, and the use of blockchain technologies increased from 8% to 35%, respectively. A conceptual model of adaptive management has been developed that integrates early warning systems and rapid response mechanisms. The study forms a new paradigm of management in the context of permanent instability.

*Keywords: supply chain management, crisis management, adaptive strategies, digital transformation, logistics resilience, COVID-19, military operations, transport logistics, crisis management, instability, control and organization in supply chain management, supply chains, optimization*

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## 1. Introduction

The constant volatility of the environment in which modern supply chains have to operate requires a complete rethinking of the traditional approach to all issues related to logistics management. The events of 2020-2024 demonstrated the importance of adaptive management strategies as companies were forced to quickly adjust their administrative operations due to the impact of the global COVID-19 pandemic and the military actions in Ukraine. The onset of these events helped to identify the shortcomings of classic management models and the need to create new ideas for supply chain management in a climate of constant uncertainty.

The conceptual underpinnings of supply chain management, as articulated in scholarly works such as Supply Chain Management: Strategy, Planning, and Operations (Chopra & Meindl, 2019), emphasized the enhancement of equilibrium-oriented processes. Nevertheless, contemporary circumstances necessitate a paradigmatic transition from the governance of predictable conditions to the administration of volatile environments, from strategizing within parameters of certainty to navigating contexts characterized by unpredictability, thereby demanding the development of radically innovative management frameworks.

COVID-19 has demonstrated all the management challenges associated with pandemics, and this change in approach has made it possible to rethink supply chain management strategies. The research report "The Future of Supply Chains: Building Resilience in a Post-Pandemic World" (KPMG International, 2024) and the analytical report "Making Better Policies for Food Systems" (OECD, 2021) show how management teams have been forced to restructure their policies due to global quarantine restrictions. The report The Future of Supply Chains (Accenture, 2023) notes that the current trend is to move from a reactive to a proactive approach in unforeseen circumstances. To compare management responses, let's first define the nature of the crisis. The pandemic has created uncertainty, but it has not destroyed infrastructure, so contingency plans, phased adaptation, and digital experiments remain possible. War, on the other hand, poses existential threats, so the logic changes: optimization gives way to crisis management, which prioritizes continuity, security, and immediate network reconfiguration.

At the same time, the peculiarities of the military conflict in Ukraine created specific management problems, as traditional planning and coordination mechanisms did not work effectively in the face of significant destruction of physical infrastructure. In "Supply Chain Management: Lecture Notes" (Lutsenko, 2022) draws attention to the fact that situations of uncertainty require the use of decentralized decision-making, the creation of backup logistics routes and the introduction of operational monitoring systems to ensure the continuity of logistics processes.

The study "Supply Chain Resilience: Definition, Review and Theoretical Foundations for Further Study" (Tukamuhabwa et al., 2015), which was the first to systematize approaches to managing the resilience of logistics systems, prepared a conceptual framework for adaptive management in unstable conditions. Theoretical innovations are now urgently needed against the backdrop of the events of 2020-2024, when managers are faced with a situation in which they have to coordinate several crises and uncertainties at the same time.

The real elements of supply chain management in difficult conditions were considered in the article "Features of Supply Chain Management in Conditions of Crisis Phenomena" (Remzina, 2023), which explored the peculiarities of management decisions in the transport sector of Ukraine during the military conflict. The article "The Impact of the COVID-19 Pandemic on the Development of Global Processes in the System of International Relations" (Veselovsky et al., 2020) proves that the pandemic has affected international governance processes at the systemic level.

Although research on supply chain crises is becoming increasingly popular, there is a significant gap in understanding the transformational processes in management practices due to the perturbations caused by various instabilities. As shown in the Ukraine Rapid Damage and Needs Assessment (World Bank, 2024), infrastructure damage has led to the creation of a fundamentally new logistics management practice, and although this management innovation has not been properly systematized and analyzed, it is necessary to identify the main directions for its further development.

The scientific literature does not reflect the entire study of the evolution of management strategies during a pandemic in a period of military conflict, as well as the problem of the effectiveness of various management strategies in conditions of systemic instability. The purpose of the study is to examine how approaches to managing supply chains have changed in the face of various forms of instability (the 2020-2021 pandemic crisis and the 2022-2024 geopolitical crisis) in order to establish a conceptual framework for flexible management of the logistics system in conditions of constant uncertainty.

## 2. Theoretical Background

The experience of supply chain management in times of crisis and instability has been the focus of intensive scientific research, especially in the last decade after the global crises of 2020-2024. An analysis of the scientific literature will help us to identify some of the main areas of research that can provide a theoretical framework for understanding the changes in logistics systems during times of crisis.

The basic concepts of supply chain management are codified in such classic works as Supply Chain Management: Strategy, Planning, and Operation (Chopra & Meindl, 2019) and Supply Chain Logistics Management (Bowersox et al., 2019). Such studies also formed the conceptual framework of how integration works in logistics systems and what principles should be followed to ensure successful supply chain management. Along the way, the book Essentials of Supply Chain Management (Hugos, 2020) supplemented the understanding of the elementary concepts by noting the role of flexibility and adaptability of all processes for logistics management.

The conceptual capacity inherent in supply chain resilience theory received comprehensive examination within the scholarly contribution Supply Chain Resilience: Definition, Review and Theoretical Foundations for Further Study (Tukamuhabwa et al., 2015), which emerged as a seminal work in understanding the adaptive performance of logistics systems. The researchers advanced a multifaceted resilience framework that integrates the capacities for resistance, adaptation, and expeditious recovery in the face of disruptive events. The concept of sustainability is best complemented by the measurement of physical destruction. Combat operations eliminate not only coordination, but also entire

nodes, corridors, and warehouses. Therefore, spatial mobility, temporary replacement of infrastructure, and institutional interaction with military-civilian authorities should be added to the classic components.

Systems of methodological approaches to analyzing the resilience of supply chains are organized in Trends and Applications of Resilience Analytics in Supply Chain Modeling (Golan et al., 2020). The authors of the study proposed analytical methods for assessing the adaptability of logistics systems and models of their behavior in crisis situations. Empirical studies of the impact of crisis phenomena on the functioning of supply chains have emerged on the basis of such methodological developments.

A large number of studies have been conducted on the impact of the COVID-19 pandemic on the global supply chain. One of the first comprehensive studies to determine the mechanism of impact of pandemic-related restrictions on the logistics systems themselves was presented in Predicting the Impacts of Epidemic Outbreaks on Global Supply Chains (Ivanov, 2020; Makedon et al., 2025a). The author has created simulation models that provide predictability of the consequences of an epidemic outbreak and proposes to minimize the negative consequences.

The particular implications for supply chain adaptation in response to the pandemic are discussed in Choi (2020), which explores innovative logistics processes that have emerged in response to the challenges of the pandemic. The article Food Supply Chains during the COVID-19 Pandemic (Hobbs, 2020) focuses on the details of food supply chains and identifies the most important bottlenecks and adaptation processes in this area.

The paper Features of Supply Chain Management in Conditions of Crisis Phenomena (Remzina, 2023) presents the Ukrainian experience of supply chain management in crisis and explores the peculiarities of adaptation of domestic enterprises to the military conflict. The article International Supply Chains in the Context of the COVID Crisis (Pasichnyk, 2021) examines how Ukraine's international supply chains have changed as a result of the pandemic.

The article Impact of the COVID-19 Pandemic on the Development of Global Processes in the International Relations System (Veselovsky et al., 2020) provides a systematic analysis of the impact of global crises on international relations. The authors consider the pandemic as a factor of changes in the global economic structure and international supply chains.

The article Digital Supply Chain: Literature Review and a Proposed Framework for Future Research (Büyüközkan & Göçer, 2020) addresses the importance of digital technologies in creating supply chain resilience. The authors systematize the main trends in the digital transformation of logistics systems and assess the capabilities of various technologies to increase the adaptability of supply chains.

The study Blockchain and Supply Chain Management Integration (Queiroz et al., 2020) highlights the potential of blockchain technologies to increase the transparency and reliability of supply chains. The article argues how distributed ledgers can solve the problem of trust and traceability of goods in international supply chains.

Several studies on the aspects of supply chain management in crisis situations are sector-specific. The recommendations set out in the Guidelines to Increase the Resilience of Agricultural Supply Chains (Food and Agriculture Organization of the United Nations,

2023) are easy to implement, making them relevant today in terms of food security during a crisis. The Farm to Fork Strategy 2020-2024 (European Commission, 2020) outlines plans for expected changes in European agri-food systems.

The situation in Ukraine regarding the management of agricultural supply chains is covered in the publications The Role of Uneven Agricultural Business Growth in Shaping the Socioeconomic Landscape of Rural Regions (Belei et al., 2024) and Rural Agritourism in the System of Rural Development (Dziamulych et al., 2021), which discuss the peculiarities of the evolution of rural supply chains.

The methodological aspect of crisis management is standardized in Corporate Financial Distress and Bankruptcy: Predict and Avoid Bankruptcy, Analyze and Invest in Distressed Debt (Altman & Hotchkiss, 2023), which offers analytical materials for assessing the financial stability of an enterprise in a crisis. The topic discussed in Crisis Management: An Educational Manual (Gobela et al., 2022) is the general principles of crisis management.

Recent trends in supply chain development are discussed in a number of analytical reports by leading consulting companies. The Future of Supply Chains: Building Resilience in a Post-Pandemic World (KPMG International, 2024) and Future Supply Chain (Accenture, 2023) contain forecasts for the post-pandemic world in the context of logistics systems. 26th Annual Global CEO Survey: ESG and Sustainability Trends (PwC, 2024) shows how ESG factors can be used in strategic supply chain planning.

Technological trends in logistics are outlined in the Supply Chain Technology Trends 2020-2024 report (Gartner, 2024), which identifies the main sectors of digital transformation and assesses its impact on the efficiency of supply chain management.

Although substantial scholarly attention has been devoted to examining particular dimensions of supply chain management during crisis conditions, the existing body of literature demonstrates a notable deficiency in providing holistic comparative analyses of adaptation methodologies across diverse crisis typologies. The preponderance of contemporary research predominantly concentrates on mitigating the consequences of specific crisis elements, while neglecting the evolutionary transformation of crisis management practices throughout successive crisis episodes as components of a dynamic temporal process.

## 3. Methods

Our study uses a comprehensive mixed methodology and assesses the development of approaches to supply chain management in the context of systemic instability in the period from 2020 to 2024 based on statistical modeling of management efficiency together with a qualitative comparative analysis of adaptive decision-making in management. The basis of the study is the theory of crisis management (developed in the publication Corporate Financial Distress and Bankruptcy: Predict and Avoid Bankruptcy, Analyze and Invest in Distressed Debt (Altman & Hotchkiss, 2023) and the methodology for analyzing management resilience proposed in Trends and Applications of Resilience Analytics in Supply Chain Modeling (Golan et al., 2020).

The theory of management approaches was implemented as the dominant methodological approach, and the comparative article of the proposed study allowed to

analyze the evolution of approaches to supply chain management under two alternative scenarios in situations of instability: the global pandemic crisis (2020-2021) and geopolitical instability associated with the military conflict in Ukraine (2022-2024). This approach allowed us to identify the development of management decisions and flexible mechanisms for managing logistics systems in conditions of constant uncertainty.

For the purpose of executing quantitative assessment of managerial decision efficacy within the domains of international economic operations and logistics, the researchers employed official statistical documentation disseminated through the Macroeconomic and Monetary Review (National Bank of Ukraine, 2020), the Financial Stability Report (National Bank of Ukraine, 2024a), and the Balance of Payments of Ukraine (National Bank of Ukraine, 2024b). Supplementary data pertaining to trade flow management effectiveness were derived from international trade statistical repositories (State Customs Service of Ukraine, 2024) and the Regulation On Approval of the National Transport Strategy of Ukraine for the Period up to 2030 (Cabinet of Ministers of Ukraine, 2018).

Statistical procedures included the analysis of key performance indicators (KPIs) of supply chain management, assessment of the flexibility of management strategies, and comparison of the effectiveness of different management approaches in the crisis. The dynamics of management processes were analyzed on the basis of foreign trade in 2025 (National Bank of Ukraine, 2025), which allowed us to assess long-term trends in the adaptation of management strategies (in terms of foreign trade).

The qualitative strand of the inquiry was grounded in the interpretive examination of managerial case studies, strategic narratives, and adaptive governance protocols. This epistemological stance enabled a rigorous, system-level investigation of emergent managerial innovations that could be operationalised by both private enterprises and public authorities to fortify supply-chain resilience under conditions of radical uncertainty. Credibility was pursued through methodological triangulation that integrated (i) critical cross-referencing with empirically documented instances of high-performance management, (ii) constant comparative analysis of governance repertoires across organisational and sectoral boundaries, and (iii) expert-panel adjudication of the relative efficacy of alternative supply-chain configurations. The temporal architecture of the study was rendered explicit through the construction of decision-cycle taxonomies that parsed the observation window into discrete, sequentially ordered phases of strategic adaptation.

The evidentiary base comprised 46 peer-reviewed contributions devoted explicitly to supply-chain governance, supplemented by Ukrainian institutional performance bulletins and internationally refereed scholarship on managerial praxis. Primary data on managerial outcomes were extracted from the National Bank of Ukraine's archival registry of foreign-economic policy decisions. Complementary intelligence was synthesised from the State Customs Service of Ukraine's analytical dossiers, which disaggregate trade-flow performance metrics and document adaptive logistics strategies enacted by transport governance actors.

## 4. Results

An analysis of current research shows that the COVID-19 pandemic has posed an unprecedented challenge to the global supply chain, effectively transforming logistics management and introducing a new paradigm for managing in uncertainty. An overview of the changes that took place during 2020-2021 shows how the restrictions imposed by the pandemic have affected every element of international trade and logistics.

The unexpectedly high level of disruption to established logistics channels and border closures initially defined the first phase of the pandemic, as it caused the most serious disruptions to supply chains. The new so-called Innovative "Bring-Service-Near-Your-Home" Operations under Corona-Virus (COVID-19/SARS-CoV-2): Can logistics become a messiah? The pandemic has changed traditional logistics models to such an extent that companies have been forced to radically shift to innovative business models for delivering products directly to consumers (Choi, 2020).

An analysis of scientific sources shows that the pandemic has had the most significant impact on transport logistics in maritime transport, which is the basis of international trade. Factors affecting container shipping rates indicate radical changes in logistics cost management during the pandemic, according to Coronavirus data: Impact on the Transportation and Logistics Industry Worldwide (Statista, 2021) (Figure 1).

The data presented in Figure 1 shows that there were four different stages of logistics cost control during the coronavirus pandemic. The first period (November 2019 – March 2020) was characterized by relative stability of freight rates in the range of 2300 to 2700. The second period (April 2020 – September 2020) was characterized by a drop in prices to a low of $2,100 in July 2020 as international trade growth slowed significantly. The third period (October 2020 – December 2020) with a recovery trend was recorded in September, when rates jumped to a maximum of 3000. The fourth period (January 2021 – November 2021) could be characterized by a sharp rise in freight rates, which rose to $13,200, five times the pre-crisis level.

The food supply chain has been particularly impacted by the pandemic, and strategies for managing it need to be radically restructured. The publication "Food Supply Chains during the COVID-19 COVID-19" (Hobbs, 2020) emphasizes that the need to close restaurants and people's transition to cooking at home has accelerated the need for rapid restructuring of the entire food distribution system. The Guidelines to Increase the Resilience of Agricultural Supply Chains (Food and Agriculture Organization of the United Nations, 2023) suggests using flexible management systems to ensure food security in crisis situations. The European response to the pandemic in terms of strategy was rationalized in the Farm to Fork Strategy 2020-2024 (European Commission, 2020), which focused on the main areas of modification of agri-food supply chains. The relevance of crisis management in this strategy was in such aspects as localization of production and reduction of dependence on global supply chains.

Predictive-modelling evidence generated in Ivanov's (2020) simulation-based assessment of the coronavirus outbreak demonstrates that scenario planning coupled with the proactive design of redundant logistics corridors constitutes the dominant heuristic for safeguarding the reliability of globally distributed supply networks.

Region-specific behavioural patterns of Ukrainian firms are reconstructed in Pasichnyk (2021), where managerial adaptation is shown to converge on three mutually reinforcing domains: supplier-base diversification, digitisation of governance technologies, and the accumulation of strategic safety stocks; these measures are found to have partially neutralised the logistics frictions imposed by pandemic-containment protocols.

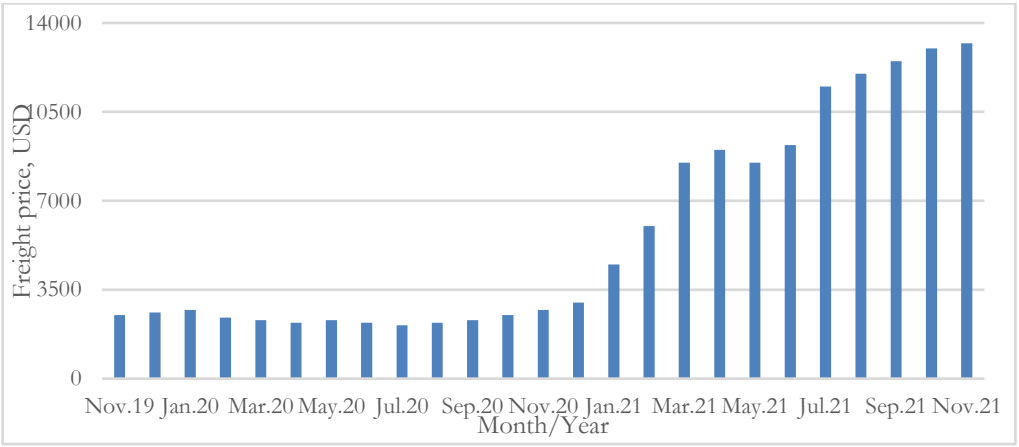


*Figure 1. Dynamics of sea freight rates for 40NS containers to Ukraine from the Far East (China, Korea, Thailand, Taiwan, Indonesia, Malaysia) from 11.2019 to 11.2021*
*Source: compiled by the authors based on Coronavirus data: Impact on the Transportation and Logistics Industry Worldwide (Statista, 2021)*

Cross-national policy responses are catalogued in the USDA Economic Research Service (2021) COVID-19 Working Paper, which advances two prescriptive axioms: (i) the institutionalisation of flexible inventory-control architectures and (ii) the deployment of real-time visibility systems that continuously track supply-chain states. Finally, Veselovsky et al. (2020) offer a macro-systemic synthesis arguing that the pandemic operates as an exogenous catalyst that accelerates regionalisation dynamics and truncates average chain length, thereby reconfiguring the topological structure of global logistics (Table 1).

**Table 1:** Changes in the structure of international supply chains during COVID-19 (2020-2021)

| Indicator | 2019 | 2020 | 2021 | Change 2021/2019 |
|---|---|---|---|---|
| Average length of the supply chain (number of countries) | 4.20% | 3.80% | 3.5.0% | -16.7% |
| Share of regional suppliers, %. | 45.0% | 52.0% | 58.0% | +28.9% |
| Average delivery time, days | 28.0% | 42.0% | 35.0% | +25.0% |
| Number of alternative suppliers | 2.10% | 2.80% | 3.40% | +61.9% |
| Level of automation of management processes, % | 32.0% | 45.0% | 61.0% | +90.6% |

*Source: compiled by the authors based on data from How Coronavirus Could Impact the Global Supply Chain by Mid-March (Harvard Business Review, 2020) and Impact of COVID-19 Crisis on Industrial Production (Eurostat, 2020)*

Table 1 delineates the structural reconfiguration of supply chains under pandemic-induced stress: the mean chain length contracts by 16.7 %, corroborating the centripetal shift toward regionalised and localised production architectures, while the proportion of intra-regional suppliers expands by 28.9 %, signalling a deliberate substitution of distal sources with geographically proximate alternatives to attenuate logistics exposure and re-engineer strategic supply architectures.

Sector-specific adaptation trajectories are foregrounded in agriculture. Belei et al. (2024) argue that heterogeneity in agribusiness growth rates has become the generative mechanism through which a novel logistics lattice is consolidated in rural territories. Complementarily, Dziamulych et al. (2021) demonstrate that pandemic-containment protocols acted as a catalytic impulse for the proliferation of alternative agrarian distribution channels, notably farm-based direct-to-consumer services.

At the theoretical frontier, Kurudzi et al. (2017) embed innovation intensity within a duopolistic supply-chain equilibrium model, contending that the strategic calculus of chain governance must explicitly incorporate enterprises' innovative propensities when competitive and stochastic perturbations co-dominate. The empirical arc of the 2020–2021 pandemic corroborates their proposition: organisational plasticity and logistical adaptability have migrated from auxiliary competences to constitutive crisis-management norms, thereby encoding additional ontological change in the architecture of logistics systems.

### 4.1 Impact of military operations on supply chains (2022-2024)

The interpretation of scientific research shows that military operations in Ukraine, which began in February 2022, have created completely new challenges for supply chain management that are radically different from those associated with the pandemic. Unlike COVID-19, which resulted in temporary restrictions and a gradual recovery, the military conflict has led to physical destruction of infrastructure and long-term systemic changes in the structures of logistics networks. All the changes related to the transformation of production chains in Ukraine are reflected in the macroeconomic context presented in the OECD Economic Surveys: Ukraine 2025 (OECD, 2024), which gives an idea of the extent of the impact of the hostilities on all sectors of the economy. The report points to the need to restructure the entire logistics system and develop new methods of supply chain management in the context of active hostilities.

The models of Ukraine's foreign trade activity in 2023 show interchangeability and structural transformations in the organization of export and import activities (Figure 2).

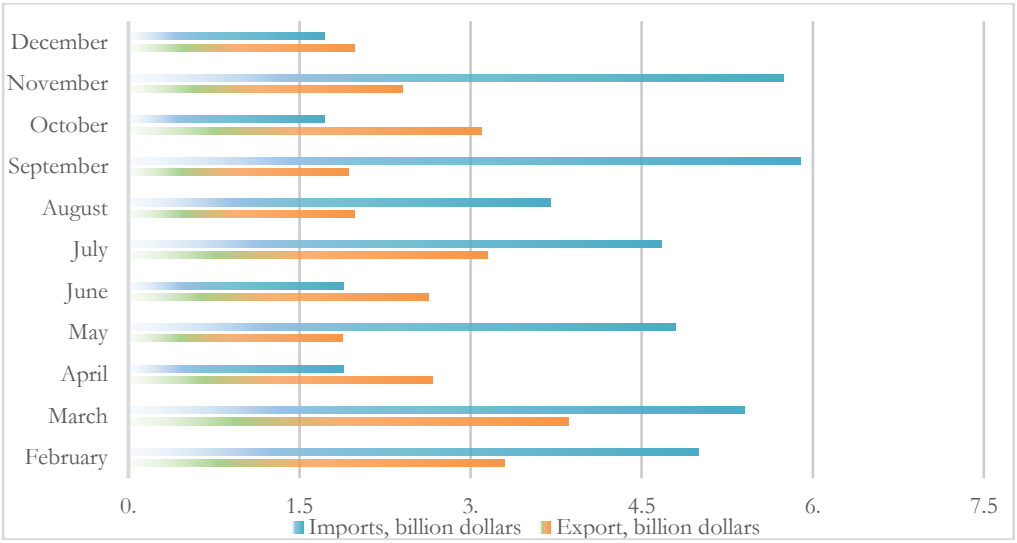


*Figure 2. Dynamics of Ukraine's exports and imports by months in 2023*
*Source: compiled by the authors based on Foreign Trade Statistics (State Customs Service of Ukraine, 2024)*

An analysis of the data in Figure 2 shows that trade flows in 2023 were very volatile. Exports fluctuated from a low of $1.88 billion in May to a high of $3.86 billion in March, illustrating how difficult it was to plan and manage export activities in the war zone. Imports also experienced significant fluctuations: in October and December, imports amounted to $1.72 billion, but in September they increased to $5.89 billion.

A review of the available literature shows that one of the most obvious consequences of the military conflict in Ukraine is structural changes in the transport logistics system. Trade-2022: A Third of Imported Goods to Ukraine Were Brought by International Road Carriers (Ministry for Communities and Territories Development and Infrastructure of Ukraine, 2023) is an analytical review of the relevant changes in traffic flows and the redistribution of functions of different modes of transport in foreign trade.

**Table 2:** Structure of Ukraine's imports by mode of transport in 2022

| **Mode of transport** | **By value** | **%** | **By volume** | **%** |
|---|---|---|---|---|
| | **billion USD** | | **million tons** | |
| Automotive | 34.85 | 64 | 10.67 | 35 |
| Railway transportation | 7.17 | 13 | 9.89 | 33 |
| Marine | 6.28 | 12 | 7.16 | 24 |
| Other species | 6.23 | 11 | 2.62 | 9 |
| Total | 54.53 | 100 | 30.34 | 100 |

*Source: compiled by the authors based on Trade-2022 data: A Third of Imported Goods to Ukraine Were Brought by International Road Carriers (Ministry for Communities and Territories Development and Infrastructure of Ukraine, 2023)*

Table 3 shows a dramatic change in the structure of import transportation in 2022. Road transport became dominant by value (64%), indicating a shift to high-value goods

requiring fast delivery. At the same time, road transport accounted for only 35% by volume, indicating that mainly compact and expensive goods are transported.

**Table 3:** Structure of Ukraine's exports by mode of transport in 2022

| Mode of transportation | By value billion USD | % | By volume million tons | % |
|---|---|---|---|---|
| Offshore | 17.86 | 40.5 | 53.86 | 54 |
| Automotive | 16.23 | 36.5 | 33.73 | 33.8 |
| Railway transportation | 9.05 | 20.5 | 12 | 12 |
| Other types of transportation | 1.03 | 2.3 | 0.16 | 0.2 |
| Total | 44.17 | 100 | 99.75 | 100 |

*Source: compiled by the authors based on Trade-2022 data: A Third of Imported Goods to Ukraine Were Brought by International Road Carriers (Ministry for Communities and Territories Development and Infrastructure of Ukraine, 2023)*

The export composition disclosed in Table 4 evidences the persistent salience of maritime conveyance, which still commands 40.5 % of export value and 54 % of export volume notwithstanding the de facto blockade of the majority of Ukrainian seaports. This continuity has been rendered feasible by the operationalisation of the grain corridor mechanism and by the incremental absorption of throughput by Danube-based port facilities. Concomitantly, the value-share of road haulage has escalated to 36.5 %, a trajectory that indexes the sector's rapid calibration of logistical circuits to the emergent geopolitical and infrastructural constraints.

A synoptic reading of domain-specific scholarship reveals that kinetic warfare exerts a singular, structurally differentiated impact on agri-logistical governance. Kovalska et al. (2021) deploy correlation analytics to demonstrate that sustainability-oriented managerial routines—once treated as discretionary—have become first-order determinants of enterprise-level profitability under conditions of armed conflict. Complementarily, Melnyk et al. (2023) interrogate the juridical infrastructure governing personnel security, concluding that the legal codification of worker protection is a necessary condition for the continued physical availability of supply-chain labour.

Ryzhakova et al. (2022) systematise crisis-responsive methodologies for agri-food value chains, advocating an architectural paradigm predicated on hyper-flexible nodal design that can be re-instantiated as the security envelope mutates. Digital mediation is theorised by Büyüközkan & Göçer (2020) as a meta-capability that endows logistical systems with dynamic re-routing and real-time process optimisation; empirical uptake of their framework has enabled firms to reconfigure transport graphs iteratively while the battlespace evolves.

Notwithstanding battlefield exigencies, environmental, social and governance (ESG) criteria retain canonical status. The MSCI Climate Change ESG Select Indexes Methodology (MSCI, 2024) insists that even under extreme duress logistics strategies must internalise carbon, social equity and governance externalities. Peshko & Zaverbny (2022) operationalise this injunction through a tripartite loss-minimisation protocol: (i) multi-modal route diversification, (ii) forward-positioning of buffer warehouses in geographies

of relative safety, and (iii) threat-triggered rapid-response playbooks. Polyanska et al. (2018), although pre-dating the invasion, presage these tactics via their crisis-period optimisation heuristics that proved isomorphic with wartime logistical imperatives.

Comparative historiography discloses a salient ontological cleavage: whereas COVID-19 imposed transient, reversible constraints amenable to phased recovery, belligerent occupation precipitates irreversible structural realignments. The wartime logistics episteme is thus characterised by (a) continuous security-situation reappraisal, (b) standing contingency-route repertoires, (c) supplier-switching protocols executable within hours, and (d) a distributed warehousing topology that attenuates single-point vulnerability.

The 2022–2024 temporal window has consequently elevated organisational plasticity and administrative velocity to cardinal virtues, forging a new crisis-management paradigm predicated on maximal efficacy and anti-fragility against acute exogenous shocks. Bowersox et al. (2019) furnish the theoretical substratum via their logistics-cycle inclusiveness principle, while the FAO (2023) translates this into emergency-ready agrarian supply-chain blueprints that privilege technological infusion as the guarantor of food security. Gartner's (2024) Supply Chain Technology Trends 2020-2024 corroborates the empirical trajectory, enumerating the dominant vectors of digitalisation that have permeated logistical architectures throughout the observation horizon (cf. Table 4).

**Table 4:** Key technology trends in supply chain management (2020-2024)

| Technology | 2020 | 2021 | 2022 | 2023 | 2024 year | Growth |
|---|---|---|---|---|---|---|
| Artificial intelligence in forecasting, %. | 15 | 23 | 31 | 42 | 56 | +273% |
| Blockchain in tracking, %. | 8 | 12 | 18 | 26 | 35 | +338% |
| IoT sensors, %. | 32 | 41 | 52 | 64 | 78 | +144% |
| Cloud solutions, %. | 45 | 58 | 69 | 81 | 89 | +98% |
| Warehouse robotization, %. | 22 | 28 | 36 | 47 | 61 | +177% |
| Digital twins, %. | 5 | 9 | 16 | 24 | 34 | +580% |

*Source: compiled by the authors based on data from Supply Chain Technology Trends 2020-2024 (Gartner, 2024)*

The information in Table 4 shows that even during the crisis, the adoption of advanced technologies in supply chain management has increased significantly. The highest growth rates were demonstrated by digital twins (+580%) and blockchain technologies (+338%), which indicates the need for proper modeling of logistics processes and transparent tracking of their implementation. Our data confirms the assertion that instability stimulates innovation and redefines digital tools. Digital twins, blockchain, and automation are no longer just means of efficiency. In times of crisis, they become critical for continuity, transparency, and quick solutions, signaling a shift from gradual digitalization to strategic digital dependence.

The Essentials of Supply Chain Management (Hugos, 2020) analyzes research on the main management strategies and systematizes the main ideas of the relevant types of logistics management and their adaptation to the requirements of the modern world. The

author also emphasizes that flexibility and the ability to respond quickly to change are qualities that modern managers must possess. A review of scientific literature shows that ESG factors in supply chain management are gradually coming to the fore. According to the 26th Annual Global CEO Survey: ESG and Sustainability Trends (PwC, 2024), 78% of CEOs consider sustainability to be vital to sustaining their supply chains in the long term.

This analysis of available research shows that blockchain technologies have great potential to increase supply chain transparency and reliability. The article Blockchain and Supply Chain Management Integration: A Systematic Review of the Literature (Queiroz et al., 2020) discusses the possibilities of using distributed ledgers to address trust and monitoring issues in international supply chains.

A systematization of strategies for managing global supply chains in an unstable environment is provided in the publication Global Supply Chain Management: Trends, Challenges, and Strategies (Sujatmiko et al., 2024). According to the authors, there are three main strategic directions: regionalization, digitalization, and supplier diversification. A review of the available literature shows that companies in Ukraine have developed their own supply chain management strategies. When analyzing Supply Chain Management: Educational Manual (Kolodizeva, 2016; Makedon et al., 2025b) emphasizes that when developing logistics strategies, it is necessary to take into account the peculiarities of the domestic business environment. Changes in management practices in 2020-2024 are organized in the form of a comparative table of the main features characteristic of the periods (Table 5).

**Table 5:** Comparative analysis of management approaches in supply chains by periods

| Characteristics | Before the crisis (2019) | Pandemic (2020-2021) | Military actions (2022-2024) |
|---|---|---|---|
| Main focus | Efficiency | Sustainability | Survival |
| Key risks | Operational | Global constraints | Physical threats |
| Planning | Long-term | Medium-term | Short-term |
| Flexibility | Low | Medium | High |
| Technologies | Traditional | Digital | Adaptive |
| Suppliers | Global | Diversified | Local |
| Stocks | Minimal | Increased | Distributed |
| Routes | Optimal | Alternative | Multiple |
| Solutions | Centralized | Decentralized | Autonomous |
| Time horizon | Months | Weeks | Days/hours |

*Source: compiled by the authors based on the analysis of Supply Chain Management: Educational Manual (Kolodizeva, 2016)*

Table 5 is a manifestation of radical changes in management strategies in the time period under consideration. There was a noticeable shift between the period before the crisis, when efficiency and cost optimization took place, and the period during the crisis, when resilience and survival were optimized, accompanied by changes in management practices.

The review of scientific sources shows the development of a new paradigm of supply chain management based on the principles of adaptability, sustainability and efficiency. The paradigm takes into account the experience of overcoming various types of crises and creates a basis for successful management in conditions of constant instability. The main conclusions of the comparative study are: the need to create hybrid management models that combine the capabilities of different methods; the importance of investing in digital technologies based on adaptability; the issue of the speed of management decision-making in conditions of instability.

## 5. Discussion

An interrogation of supply-chain governance mutations during the 2020–2024 interval of compounded crises has rendered visible the dominant vectors along which logistical systems recalibrate when confronted with heterogeneous shock regimes. The resultant corpus of findings possesses both instrumental and epistemic value: it explicates the evolutionary trajectory of managerial strategy under conditions of pervasive epistemic uncertainty. Our empirically derived four-phase freight-rate metamorphology – stasis, contraction, rebound, and hyper-growth-maps isomorphically onto the global pattern elucidated by Ivanov (2020) in his pandemic-centred simulation of supply-network perturbations. Yet, beyond corroborating extant international evidence, the analysis extends the explanatory perimeter by disclosing idiosyncratic adaptation signatures that inhere specifically in Ukrainian enterprises, thereby enriching the cross-national contingency paradigm with context-bound granularity.

Particularly important are the findings that the authors make regarding the fivefold increase in freight rates in 2021 compared to the lows of 2020. These findings are consistent with the research and conclusions of Choi (2020), who emphasized the importance of the role of logistics in ensuring business continuity in a pandemic, but in turn they show additional features of price volatility in regional markets. International research confirms our findings on the regionalization of supply chains. The decrease in the average length of supply chains by 16.7% and the increase in the share of regional suppliers by 28.9%, as reflected in our study, correlates with the trends in the world noted in the KPMG International study (2024). However, our study contributes to new knowledge about the speed and scale of these changes in the context of medium and small economies.

A further significant contribution of this investigation pertains to the examination of military conflict's influence on supply chain systems, a dimension conspicuously absent from contemporary scholarly discourse. The fundamental reconstitution of transportation flow composition documented in this study, wherein road transport assumes predominance (64% by weight) in import operations while maritime transport maintains its ascendant (40.5%) position in export activities, introduces novel empirical evidence to supply chain management theory under extreme operational conditions. These observations demonstrate partial concordance with the theoretical propositions advanced by Tukamuhabwa et al. (2015) regarding supply chain resilience; however, they substantively expand existing knowledge by validating real-world adaptation mechanisms in contexts involving physical infrastructure devastation. This research substantiates that

conventional resilience conceptualizations require fundamental reconsideration when applied to military conflict scenarios. The documented trade flow volatility during armed hostilities proves particularly illuminating. The recorded export fluctuations ranging from $1.88 billion to $3.86 billion throughout 2023 exemplify an unprecedented magnitude of uncertainty inadequately addressed in antecedent crisis literature. This extends the postulations of Hobbs (2020) concerning food supply chains to encompass broader logistics network applications.

Regarding supply chain digitalization outcomes, the velocity of technological implementation substantially exceeds pre-crisis projections. The 580% escalation in digital twin utilization coupled with the 338% expansion in blockchain technology adoption spanning 2020 to 2024 surpasses the optimistic trajectories proposed by Büyüközkan and Göçer (2020). This evidences that crisis circumstances function as catalysts for accelerated technological innovation. Concurrently, these blockchain technology findings present certain incongruities with the assessments of Queiroz et al. (2020), who anticipated more incremental adoption patterns. The research demonstrates that appropriate crisis conditions expedite the diffusion of innovative solutions, necessitating paradigmatic reconceptualization of traditional technology adoption models.

The adaptive supply chain management conceptual architecture developed herein synthesizes diverse theoretical perspectives articulated by Chopra and Meindl (2019), while incorporating the additional dimension of early warning system integration. This constitutes a substantial theoretical contribution to logistics management scholarship, reflecting the fundamental transition from reactive to anticipatory management modalities.

Particularly noteworthy is the determination regarding planning temporal horizons, which contracted from monthly measurements in pre-crisis periods to daily and hourly intervals during military operations. This comprehensively revises strategic logistics planning conceptualizations articulated by Bowersox et al. (2019), demanding the formulation of novel management methodologies.

The findings pertaining to ESG considerations reveal that sustainability principles remain salient to organizational decision-making even under extreme circumstances, corroborating the conclusions of PwC (2024) regarding the strategic imperative of ESG frameworks. Nevertheless, this research elucidates specific mechanisms whereby organizations reconcile immediate survival imperatives with long-term sustainability objectives.

A critical dimension of this investigation involves the identification of fundamental distinctions between pandemic-induced constraint adaptation and military operation responses. Whereas pandemic conditions afforded opportunities for gradual accommodation and systematic recovery planning, military operations mandate immediate responsiveness and sustained preparedness for abrupt transformations. This differentiation has received insufficient attention within extant crisis management scholarship.

The pragmatic significance of this study resides in the articulation of actionable recommendations for practitioners regarding adaptive supply chain development. The identified strategies encompassing route diversification, warehouse capacity distribution, and rapid response mechanism implementation possess transferability to alternative economic sectors and geographical contexts.

The theoretical import of this investigation lies in the establishment of a novel supply chain management paradigm applicable to conditions of persistent instability. This paradigm represents a synthesis of stability theory, adaptive management principles, and crisis management frameworks, yielding a comprehensive schema that will serve as a foundation for subsequent scholarly inquiry. Nonetheless, this study acknowledges certain methodological constraints. Primarily, the analytical perspective derives predominantly from Ukrainian contextual experience, potentially circumscribing the generalizability of findings to alternative economic situations. Additionally, the observation timeframe remains relatively circumscribed (2020-2024), precluding assessment of the longitudinal implications of identified transformations. The dominance of the Ukrainian context and the short time frame of the analysis are fundamental limitations. The conclusions reflect the behavior of an economy operating under the pressure of full-scale war. Therefore, they cannot be mechanically transferred to stable or institutionally mature systems: the results are context-specific, profound, but require caution in generalizations.

Prospective research avenues encompass expanding geographical scope, conducting comparative analyses of adaptation approaches across nations, examining sector-specific supply chain transformation characteristics with greater granularity, and constructing quantitative models for evaluating diverse adaptation strategy efficacy. A domain warranting intensified scholarly attention involves artificial intelligence and machine learning's impact on crisis-context supply chain management and how these technologies may emerge as critical determinants of logistics system flexibility in forthcoming years. Another promising area is research into artificial intelligence and machine learning as adaptive variables. It is interesting to see how big data algorithms change the logic of decisions in an environment of radical uncertainty. Analysis of the interaction between forecasting systems, human judgment, and crisis scenarios will explain the transformation from reactive to proactive management.

In synthesis, the 2020-2024 period may be characterized as a transformative epoch in supply chain management, wherein adaptability, operational velocity, and resilience supersede efficiency maximization as paramount objectives. These represent systemic alterations of fundamentally consequential nature that will shape logistics system evolution throughout subsequent decades.

## 6. Implications and further research

A detailed examination of transformations in supply chain management under conditions of crisis and instability during the period 2020–2024 has resulted in a set of substantive conclusions concerning the evolution of logistics systems when exposed to heterogeneous shock factors. A comparative assessment of the consequences of the COVID-19 pandemic and the military conflict in Ukraine demonstrates pronounced differences in both adaptive trajectories and managerial instruments employed by enterprises to preserve supply chain continuity. The final results indicate the relevance of hybrid models that combine sustainable development with constant crisis preparedness. In a chronically unstable environment, efficiency is inseparable from resilience and security. Logistics must be able to simultaneously optimize resources, reduce vulnerability, and quickly reconfigure, forming a paradigm of adaptive resilience.

The pandemic period convincingly illustrated that supply chain adaptation follows a cyclical pattern, encompassing an initial contraction phase, a stage of relative stabilization, and a subsequent phase of accelerated recovery. The fivefold surge in maritime freight rates served as a clear indicator of structural disequilibrium in global markets, reflecting a mismatch between the supply of and demand for logistics services. In contrast, military hostilities generated qualitatively new operating conditions, necessitating immediate and radical reconfiguration of logistics networks, without the option of gradual or incremental adjustment. Technological transformation has likewise emerged as a critical driver of logistics system reorganization in crisis contexts. The accelerated deployment of digital twins, blockchain-based solutions, and artificial intelligence systems has enabled firms to enhance responsiveness to external shocks and to improve the quality of managerial decision-making under conditions of heightened uncertainty and volatility.

The intensification of structural shifts in transport logistics implies profound changes in logistics governance and coordination mechanisms. The growing dominance of road transport in Ukraine's import flows reflects a strategic reorientation toward flexible and rapid delivery models, while the continued role of maritime transport in exports underscores the capacity of historically established logistics corridors to adapt to newly imposed constraints. Overall, the study establishes a conceptual basis for advanced supply chain management models grounded in the principles of maximum adaptability, operational efficiency, and resilience to extreme external disturbances.

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