Disaster Medicine and Public Health Preparedness

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Pandemic Triggered Emergency Supply Chain Management Innovations: A Scientometric Analysis Based on Bibliometrics and Dynamic Topic Models

Tian Xie[1,2], Gui-Ye Dai[1], Wei-Fan Chen[2], Chen-Peng Yang[1], Yong-Jian Huang[3] and Yao-Yao Wei[1,2,4]

[1]School of Economics, Management and Law, University of South China, Hunan, PR China; [2]Information Sciences and Technology at The Pennsylvania State University, University Park, PA, USA; [3]School Management, Shanghai University, Shanghai, PR China and [4]School of Education at Central China Normal University, Hubei, PR China

Original Research

Cite this article: Xie T, Dai G-Y, Chen W-F, Yang C-P, Huang Y-J and Wei Y-Y (2025). Pandemic Triggered Emergency Supply Chain Management Innovations: A Scientometric Analysis Based on Bibliometrics and Dynamic Topic Models. *Disaster Medicine and Public Health Preparedness*, **19**, e88, 1–11
https://doi.org/10.1017/dmp.2025.88

Received: 03 November 2024
Revised: 14 February 2025
Accepted: 11 March 2025

Keywords:
pandemic; emergency supply chain; bibliometrics; DTM

Corresponding author:
Yao-Yao Wei;
Email: 24359048@qq.com

Abstract

Objective: The outbreak of major epidemics, such as COVID-19, has had a significant impact on supply chains. This study aimed to explore knowledge innovation in the field of emergency supply chain during pandemics with a systematic quantitative analysis.
Methods: Based on the Web of Science (WOS) Core Collection, proposing a 3-stage systematic analysis framework, and utilizing bibliometrics, Dynamic Topic Models (DTM), and regression analysis to comprehensively examine supply chain innovations triggered by pandemics.
Results: A total of 888 literature were obtained from the WOS database. There was a surge in the number of publications in recent years, indicating a new field of research on Pandemic Triggered Emergency Supply Chain (PTESC) is gradually forming. Through a 3-stage analysis, this study identifies the literature knowledge base and distribution of research hotspots in this field and predicts future research hotspots and trends mainly boil down to 3 aspects: pandemic-triggered emergency supply chain innovations in key industries, management, and technologies.
Conclusions: COVID-19 strengthened academic exchange and cooperation and promoted knowledge output in this field. This study provides an in-depth perspective on emergency supply chain research and helps researchers understand the overall landscape of the field, identifying future research directions.

Major epidemics such as SARS, H1N1, and COVID-19 have significantly increased the demand for vaccines, medicines, protective equipment, and other essential products. Shortages of resources and inadequate coordination have often led to disruptions in the supply chain, causing unprecedented impacts on global social economy. Traditional supply chain systems often struggle to meet this sudden, high volatility, time-sensitive demand. In the context of the COVID-19, we must rapidly optimize the emergency collaborative processes of supply chain systems on demand and efficiently organize and deploy existing supply chain resources and capabilities to make an agile and efficient emergency response. This brings new challenges to the resilience, reliability, flexibility, and adaptability of supply systems, fostering technological and managerial innovations in the field of PTESC.

In the context of the pandemic and supply chain, we have identified relevant scholarly contributions as summarized in Table 1. Scholars have explored supply chains under pandemic conditions from different perspectives. Aday and Aday and Duijzer, van Jaarsveld, and Dekker analyzed the impact of the pandemic on the food and vaccine industries.[1,2] Spieske and Birkel studied supply chain resilience and risk management in the context of epidemics based on a traditional literature review approach.[3,4] Naz et al. investigated the impact of artificial intelligence (AI) on supply chain resilience in the context of the major epidemic.[5,6] Chowdhury et al. used a systematic literature review approach to review existing research on the COVID-19 pandemic in the supply chain discipline and categorized it into 4 main themes: the impacts of the COVID-19 pandemic on the supply chain, strategies to cope with these impacts, the role of technology in the implementation of such resilience strategies, and sustainable practices during a pandemic.[7] Shi, Liu, and Zhang and Cordeiro et al. used structured literature analysis and systematic literature analysis to reveal theories and methods in supply chain management research under the COVID-19 outbreak, identifying resilience strategies and hotspots for SC.[8,9]

Notably, the above studies concentrated on specific aspects or methodologies. For example, Aday and Aday[1] and Duijzer, van Jaarsveld, and Dekker[2] concentrate on the impact of industry supply chains in the context of outbreaks; Spieske and Birkel,[3] Rinaldi et al,[4] Naz et al.,[5] and

Table 1. Relevant scholarly contributions (9 articles)

Author	Article	Data source
Aday S, Aday MS	Impact of COVID–19 on the food supply chain	WOS
Duijzer LE, van Jaarsveld W, Dekker R	Literature review: the vaccine supply chain	WOS
Spieske A, Birkel H	Improving supply chain resilience through industry 4.0: a systematic literature review under the impressions of the COVID–19 pandemic	WOS
Rinaldi M, Murino T, Gebennini E, et al.	A literature review on quantitative models for supply chain risk management: can they be applied to pandemic disruptions?	WOS
Naz F, Kumar A, Majumdar A, et al.	Is artificial intelligence an enabler of supply chain resiliency post COVID–19? An exploratory state-of-the-art review for future research	WOS
Modgil S, Gupta S, Stekelorum R, et al.	AI technologies and their impact on supply chain resilience during COVID–19	WOS
Chowdhury P, Paul SK, Kaisar S, et al.	COVID–19 pandemic related supply chain studies: a systematic review	WOS
Shi X, Liu W, Zhang J	Present and future trends of supply chain management in the presence of COVID–19: a structured literature review	WOS
Cordeiro, MC, Santos L, Angelo ACM, et al.	Research directions for supply chain management in facing pandemics: an assessment based on bibliometric analysis and systematic literature review	WOS

Modgil et al.[6] focus primarily on the risk and resilience of supply chains. The latter 3 studies in Table 1 utilize specific methodologies to study supply chains in the context of the pandemic, such as the systematic literature approach, structural literature approach, and bibliometric. These studies, while insightful, are limited to specific research perspectives, lacking a comprehensive and systematic framework to study the impact of pandemic-triggered emergency supply chain management innovations from a quantitative perspective. Therefore, we propose a 3-stage framework for the PTESC study, which focuses on 3 key main aspects: knowledge base analysis based on co-citation clustering, hotspot analysis using the Dynamic Topic Models (DTM) topic model, and forecasting potential future research directions and trends (Figure 1).

Methods

Research Framework

As depicted in Figure 1, addressing research questions RQ1-RQ4, this study synthesized DTM, bibliometrics, statistical analysis, and regression analysis methods to propose a 3-stage system analysis method for PTESC. The co-citation network analysis stage utilizes co-citation analysis and clustering to uncover the knowledge base. The topic evolution analysis stage tracks the development of topics through text preprocessing and dynamic topic model. The regression analysis stage employs polynomial regression models to analyze variable relationships and predict future research topics.

Data Declaration

Considering comprehensive and accurate information, this study selected the core database of WOS for our search. Focused on the themes of "supply chain" and "pandemic," the search query was "(TI=(suppl* chain*)) AND (TI=(major epidemi*) OR TI=(COVID-19) OR TI=(pandemi*) OR TI=(outbreak*) OR TI=(coronavirus) OR TI=(h1n1) OR TI=(h2n2) OR TI=(h3n2) OR TI=(SARS) OR TI=(personal protective equipment) OR TI=(PPE) OR TI=(N95) OR TI=(protect* cloth*) OR TI=(ventilator) OR TI=(mask*) OR TI=(vaccin*))." The search was conducted without time restrictions, and 888 documents could be retrieved. The search results were examined and organized to obtain 730 articles by excluding irrelevant content such as conference and journal calls for papers and 729 articles by excluding literature without abstracts.

Research Methods and Tools

Bibliometrics and CiteSpace

Bibliometric theory reveals the knowledge structure characteristics of literature in a particular field through co-citation analysis and keyword co-occurrence network analysis.[10] As a bibliometric tool that integrates functions of statistics, data mining, and knowledge graph visualization, CiteSpace assists researchers in visually presenting the knowledge structure of a field.[11] Using CiteSpace, this study analyzed co-citation network knowledge base characteristics of literature in the PTESC field.

Dynamic topic model

DTM is a generative model used to analyze the evolution of topics in document collections over time. It can predict the topic and word distributions in the next time slice based on the topic and word distributions in the previous time slice, forming a dynamic topic evolution process.[12] Its principle is shown in Figure 2: First, dividing literature into specific time periods. Second, the text is preprocessed by natural language processing methods. Third, utilizing Blei, Ng, and Jordan's confusion formula in LDA modeling[13] and Röder, Both, and Hinneburg's coherence value (cv) formula for consistency calculation[14] to determine the optimal number of topics. In each stage, a horizontal topic analysis based on the keywords identified by the DTM and calculating topic strengths to find research focuses is performed.

Results

The number of publications for the period March 2020 to October 2024 totaled 730, accounting for 99% of the total research sample. It showed that there had been an explosion of scientific research results during the last 4 years of the COVID-19 pandemic. The global COVID-19 pandemic had greatly triggered knowledge innovation in the novel field of emergency supply chain.

Co-citation Network of Research on PTESC

Based on the Log-Likelihood Ratio (LLR) algorithm, the literature co-citation network (Figure 3-①) is clustered, and the labels are

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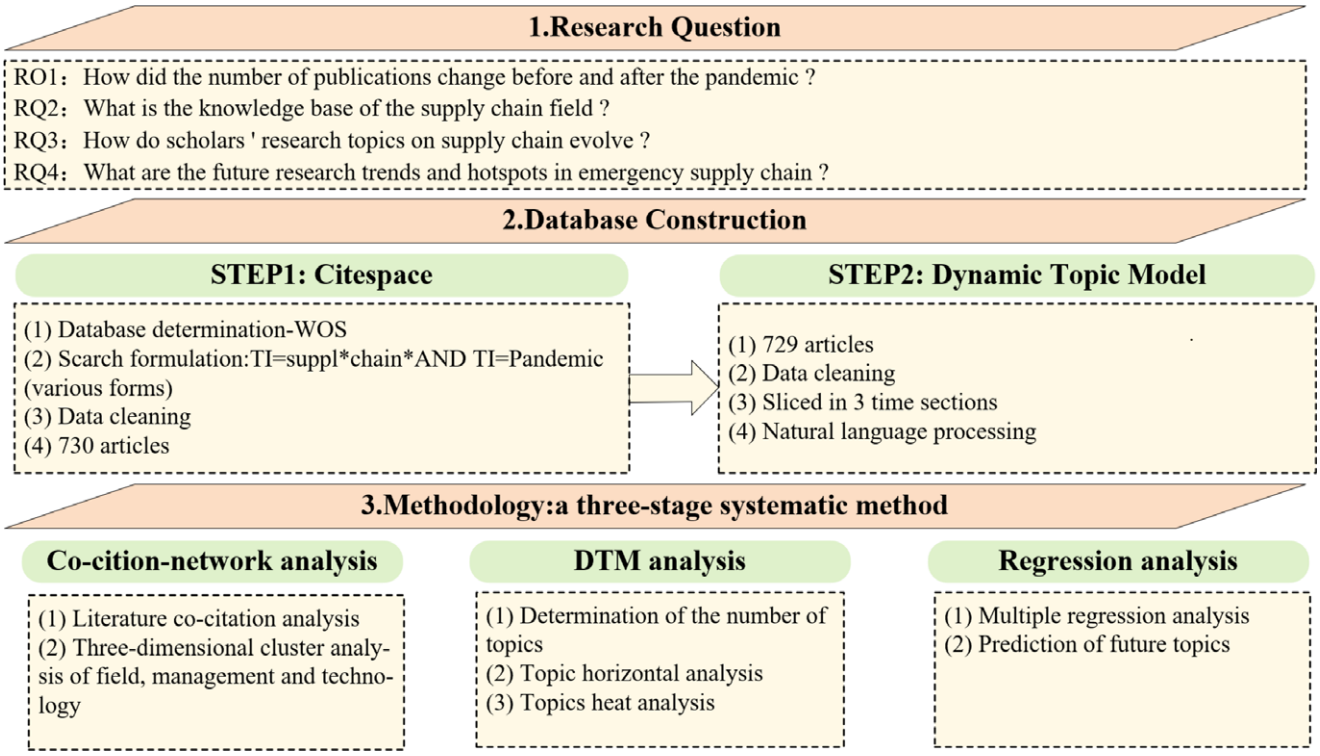

Figure 1. Research framework.

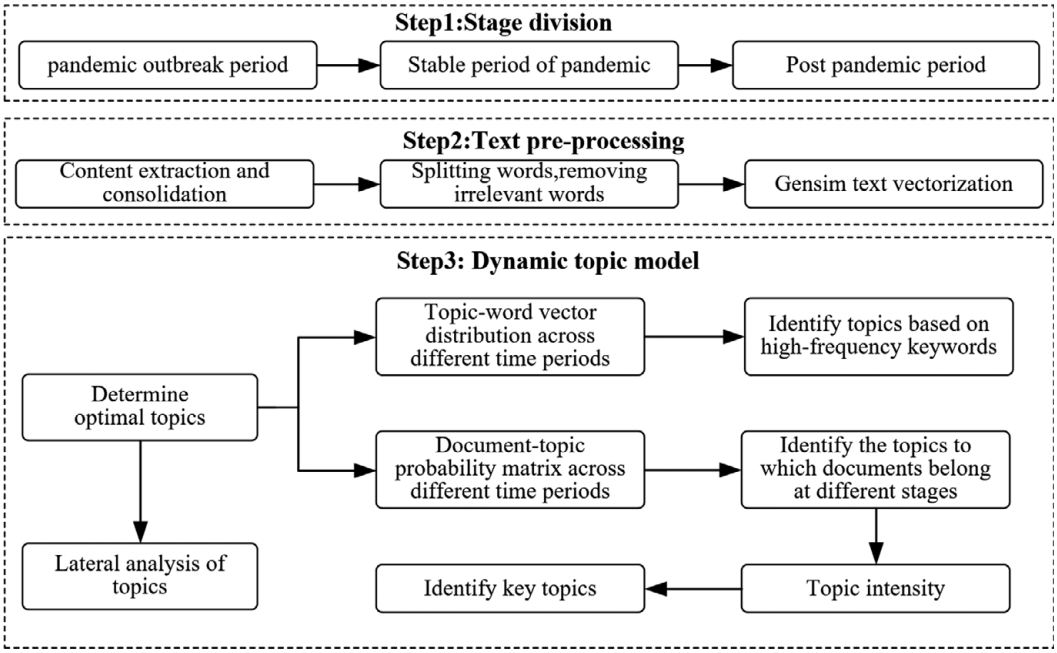

Figure 2. DTM flowchart.

modified based on the coordinate values of the top 5 terms in the labels to plot Figure 3-②. This paper analyzes the knowledge foundation of this field from the following 3 aspects:

Research on the impact of the epidemic on the supply chain

The key high co-cited document nodes in clusters #3, #6, and #8 include: Jill E. Hobbs examined the impact of COVID-19 on food supply chains and supply chain resilience and assessed potential supply-side disruptions in food supply chains, among other issues.[15] A study by Alam et al. identified the challenges facing the COVID-19 vaccine supply chain, and the causal interactions and interrelationships between these challenges.[16] Branch-Elliman et al. identified 4 pillars for preventing infectious diseases: (1) elimination of potential exposure; (2) implementation of

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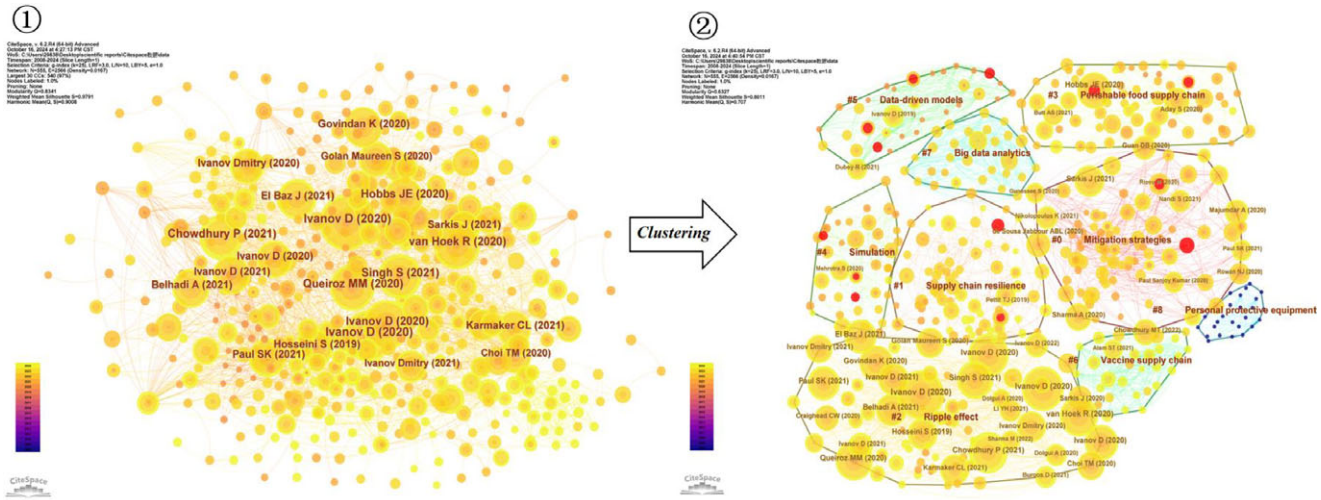

Figure 3. Literature co-citation network and clustering map.

administrative controls; (3) facilitation of engineering and environmental controls; and (4) protection of the health care workers and patients using hand hygiene and personal protective equipment.[17] These studies discussed the impact of pandemics on food, vaccine, and personal protective equipment supply chains from various perspectives, triggered the need for innovation in the supply chain of key emergency products during subsequent epidemics, and laid the knowledge foundation for innovation in emergency supply chains in key industries.

Research on supply chain characterizations

Key highly co-cited literature nodes in Clusters #0, #1, and #2 include: Ivanov's assertion that viability was a potential attribute of supply chains, spanning agility, resilience, and sustainability. He proposed a new research direction: resilience-centered viable supply chains.[18] Pettit, Croxton, and Fiksel argued that supply chain resilience was an enhancement to risk management and advocated the use of resilience analysis in management.[19] Sarkis examined the impact of COVID-19 from the perspective of operational and supply chain environmental sustainability.[20] These documents have accumulated a preliminary knowledge base for research on the fundamental characteristics of emergency supply chain scenarios, such as disruption, resilience, sustainability, and viability under subsequent pandemics.

Research on supply chain analysis and optimization techniques

Key highly co-cited literature nodes in Clusters #4, #5, and #7 include: Dubey et al. used a model to demonstrate how blockchain technology affects operational supply chain transparency and how blockchain-based swift-trust can improve collaboration among disaster relief participants and enhance supply chain resilience.[21] Ivanov, Dolgui, and Sokolov looked at the relationship between digitization and supply chain disruption risk from a chain reaction perspective and explored the application of the 4 elements of digitization management (big data analytics, Industry 4.0, additive manufacturing, and advanced tracking and tracing technologies) to supply chain management.[22] The literature proposed various technologies to enhance the nature of the supply chain through modeling, quantitative analysis, and other methods, fostering technological innovations in PTESC.

Hotspots Analysis of Research on PTESC

Determination of the number of topics

This study calculated the perplexity and coherence of topics across 3 periods: the outbreak period (2008-2021), the stable period (2022), and the post-pandemic period (2023-2024).[23] To avoid over-fitting, this study selected the values (12, 13) at the obvious turning points from Figure 4-① as the candidate number of topics. Combining with Figure 4-②, the number of topics was determined to be 12.

DTM clustering analysis

The clustered topics 0-11, respectively, include supply chain risk, protective supply chain, supply chain resilience, supply chain digitization, supply chain viability, vaccine supply chain, supply chain strategy, big data and AI, pharmaceutical supply chain, food supply chain, supply chain sustainability, and blockchain technology (Appendix Table A1). Based on the topic names, high-frequency keywords, and primary literature, the 12 topics can be categorized into 3 main aspects of research hotspots in the PTESC field.

(1) Industry innovations in PTESC. Topics 1, 5, 8, and 9 correspond to industry-specific innovations in PTESC. During the early and mid-pandemic periods, emergency supplies such as protective equipment, vaccines, medicines, and food were in short supply, necessitating urgent upgrades to the production processes, technologies of these products, and the flexibility of the industry's supply chain. The clustering results are consistent with the actual demand of this period.

For the protective supply chain, the number of N95 filtering facepiece respirator models as an indicator of supply chain stability technologies.[24] And such as vaporized hydrogen peroxide, active chlorine+ technology, and new reusable half-face respirators have optimized the personal protective equipment (PPE) supply chain's processes to meet the surging product demand during the pandemic.[25-27] Sigala IF et al. analyzed the different types of disruptions occurring in the personal protective equipment supply chain through system dynamics modeling.[28] For the pharmaceutical supply chain, the research mainly focused on quality management, cross-border cooperation, and price regulation of vaccines and other medicines.[29] Hu et al. first established a vaccine supply chain management system combining blockchain, Internet of Things (IoT), and machine learning for improving vaccine demand

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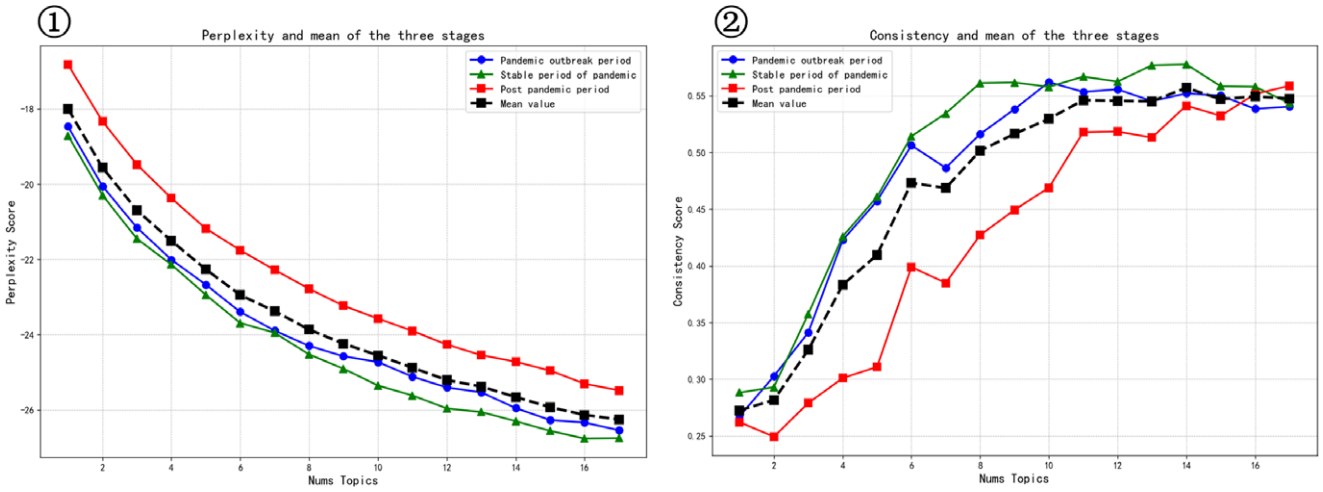

Figure 4. Topics perplexity and consistency.

forecasting accuracy and vaccine quality.[30] For the food supply chain, scholars studies have focused on food transportation safety, price, and inventory capacity.[31]

(2) Management innovation in PTESC. Topics 0, 2, 4, 6, and 10 correspond to management innovations in PTESC. Major epidemics such as COVID-19 have led to production disruptions and logistics obstructions. Strengthening risk management, improving the resilience, viability, and sustainability of supply chains, and innovating in supply chain management will help build a more flexible and resilient supply chain system.

Xu et al. proposed the "GREAT-3Rs" (responsiveness, resilience, and restoration) framework and described the issues and key elements of global supply chain management at different stages of a pandemic.[32] Nasir et al. developed a new decision aid methodology combining Pareto analysis, gray theory, and fully explanatory structural modeling, showing that the creation of SC digital twins and the transformation of SC into SC networks will help to cope with the "new normal."[33] Rajak et al. identified important factors to improve the viability of sustainable supply chains (SSCs) during the pandemic using stepwise weighted assessment ratio analysis, indicating that supply chain network feasibility is the main criterion for improving the viability of SSCs during and after the pandemic.[34] Kovács and Falagara Sigala suggested that lessons should be learned from humanitarian supply chains to standardize product and process management.[35]

(3) Technological innovation in PTESC. Topics 3, 7, and 11 correspond to technological innovations in PTESC. Epidemics such as COVID-19 have made it difficult for the traditional supply chain model to adapt, and how emerging technologies such as blockchain, big data, and AI can be applied to vaccine, food, and agricultural supply chains has become a research hotspot.

Bhaskar et al. proposed a new governance system and used advanced analytics and blockchain to analyze critical inventories to improve production efficiency and strengthen the coordination, integration, and management of global supply chains.[36] Nandi et al. argued that combining blockchain with circular economy theories contributes to the traceability and responsiveness of digital supply chains.[37] Dubey found that digital technology, moderated by crisis leadership, significantly improved the information visibility and collaboration of emergency supply chain responders.[38] Choi developed an analytical model to explore how logistics and technology can work together to transform "static service operations" into "near service" mobile service operations.[39]

DTM topic evolution path analysis on PTESC

All 3 time-phase studies involved supply chain industries, management, and technology, though with varying degrees of emphasis. This study used Python to calculate the intensity of topics and created a heat map to reflect research focuses in different stages, as shown in Figure 5.

(1) Pre-epidemic and outbreak periods. From Figure 5, supply chain risk, protective supply chain, food supply chain, and blockchain technology are the research focuses at this stage, with their topic heats as high as 0.149, 0.130, 0.129, and 0.113, respectively. In the early stages of the major epidemic, especially when the mode of transmission of the virus was not understood, it was widely believed that reducing contact with the virus was the key to preventing infection. Therefore, protective products and food received more attention than pharmaceuticals. Meanwhile, the epidemic might lead to blockades, restrictions on movement, and other measures, while food was a basic need for survival. The epidemic has impacted the supply chain, and people's most immediate response was how to manage the risk. However, less attention is paid to supply chain characteristics and technology.

(2) Stabilization of the epidemic. In terms of evolutionary trends, there has been a decrease in the focus on industry-specific supply chains and an increase in the focus on common supply chain management and technology. The prominence of the topics of industry-specific supply chains such as protective products, food, and pharmaceuticals decreased by 25.87%, 51.23%, and 33.65%, respectively, while the prominence of supply chain resilience, supply chain strategy, and supply chain sustainability increased by 104.44%, 57.29%, and 54.50%, respectively. The prominence of supply chain digitization and blockchain increased by 28.68% and 8.07%, respectively, indicating that blockchain technology can effectively solve problems in the supply chain, such as predicting risks, responding to disruptions, and real-time tracking. Researchers hoped to use digital technology to help supply chains cope with the epidemic crisis, improve operational efficiency, and reduce risks.

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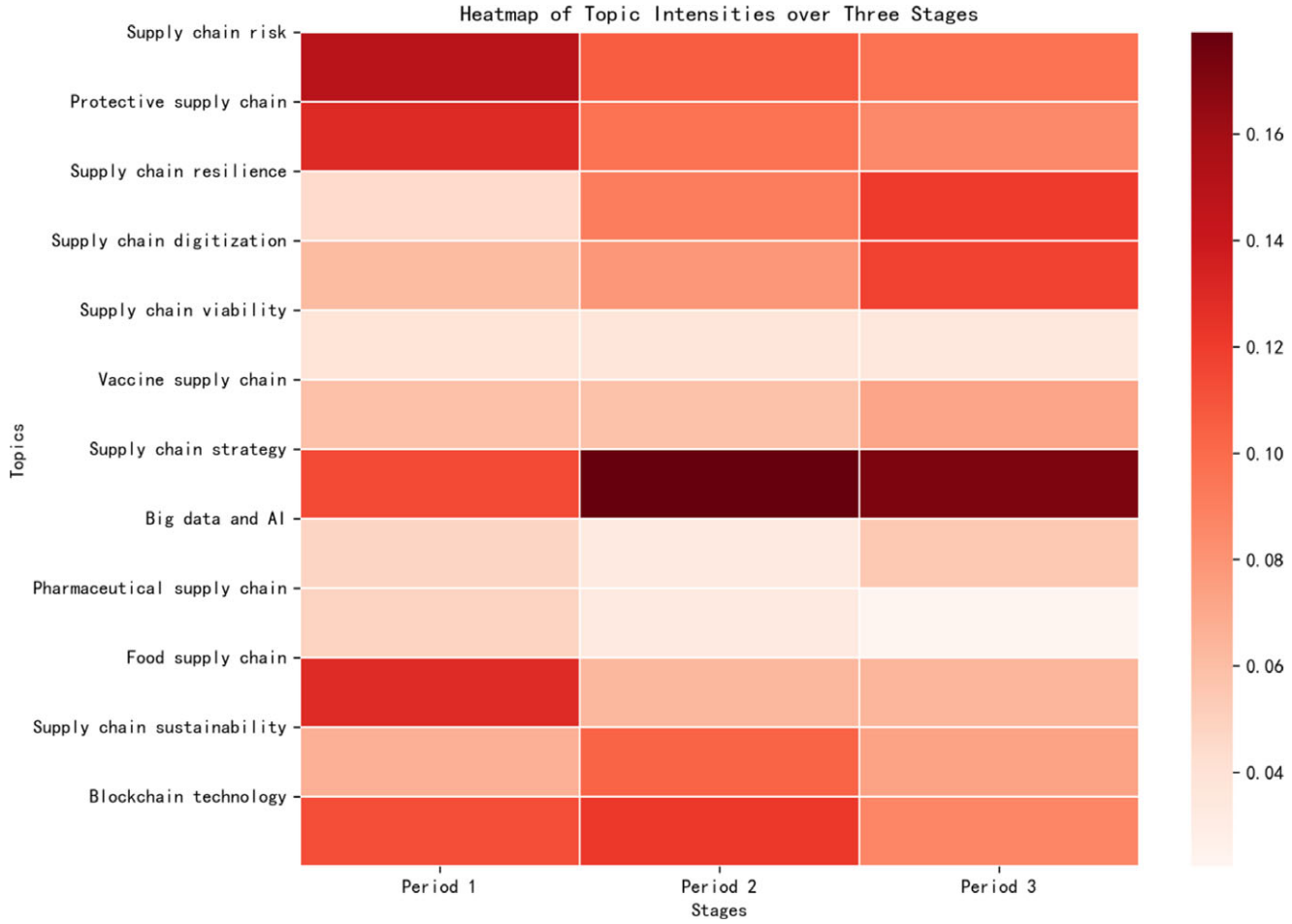

Figure 5. Topics heat map.

(3) Post-epidemic era. During this period, big data and AI heat has increased by 63.08%, indicating that researchers are beginning to utilize technologies such as AI to advance the intelligent transformation of the supply chain. In the supply chain industry, the hotness of protective goods and pharmaceuticals decreased by 5.70% and 30.86%, respectively, while the hotness of supply chain resilience increased by 33.34%. Researchers are shifting their focus to the nature of the supply chain and are looking to improve supply chain resilience and survivability by applying emerging technologies, thereby better formulating strategies and conducting supply chain management.

Analysis of the Emerging Trends in PTESC

This study conducted regression analysis on the time-topic intensity probability distribution of each topic (Figure 6), identifying 3 main trend lines: falling, leveling, and rising. The topic evolution processes can be classified into the following 4 patterns: "U-shaped," "Inverted U-shaped," "Vibrant," and "Declining."

According to the regression results in Figure 6 and the latest literature in the field of PTESC, it is found that the future trend and evolution direction of this field still focuses on the 3 aspects: industry innovation, management innovation, and technological innovation in PTESC.

Industry innovation trends in PTESC: From Figure 6-①, the food supply chain continues to receive attention, and from Figure 6-②, the vaccine supply chain is on the rise. For these industries, issues related to the resilience, recovery, precision optimization, digitization, and sustainability of supply chains will become hotspots in the future. For food supply chains, digital technologies of blockchain, smart contract, and machine learning are used to strengthen the traceability supervision and risk assessment of the entire processes of production, logistics, and inventory. This can improve the emergency response capacity of the agricultural supply chain and its resilience to the COVID-19 crisis.[40-42] For vaccine supply chains, future research directions will include demand forecasting models considering vaccine timeliness and vaccination coverage, multi-criteria decision-making techniques considering safety stock and flexible production scheduling, and vaccine delivery time windows and distribution routes to achieve accurate optimization of the vaccine emergency supply chain.[43,44]

Management innovation trends in PTESC: From Figure 6-⑤⑥⑧, all these topics are on the rise and will remain hot topics in the future. Future research should consider supply chain mitigation strategies such as food security assessments, government incentives and policies, health care systems, energy, and the circular economy in conjunction with technologies such as AI.[45] Digital technology can greatly enhance supply chain resilience,[46] so combining "algorithmic

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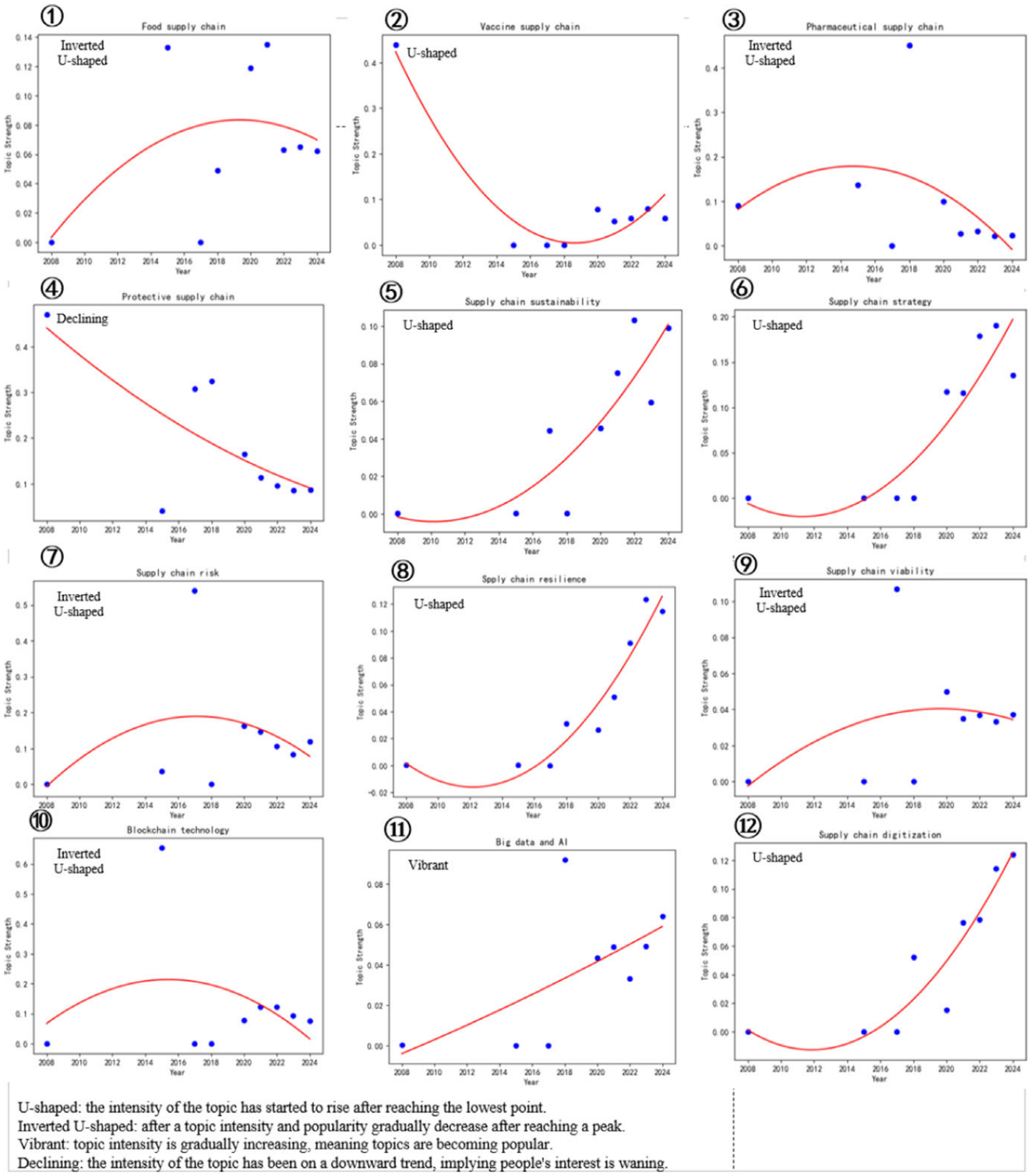

Figure 6. Topics regression diagram.

aversion" and human over-weighting of real-time alarm signals to build cross-border, feasibly interwoven, reconfigurable, green, cloud supply chain networks and manufacturing systems, designing intelligent digital twins, can achieve highly adaptive resilience that accepts oscillations and performance deviations.[47,48] This involves shifting from cost optimization to resilience optimization, combining emergency supply chain viability with macroeconomics to enhance the sustainability of supply chains. Thus realizing the shift from reactive response to pandemic to proactive adaptation.[23,49]

Technological innovation trends in PTESC: From Figure 6-① and Figure 6-⑪, both topics are showing an upward trend and will become hotspots of research in the era of supply chain intelligence.

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The convergence of AI and blockchain with emerging paradigms such as federated learning, digital twins, autonomous IoT, 6G telecommunications, quantum computing, and the metaverse could become a promising area for the future. Use reinforcement learning and deep learning to strengthen supply chain intelligent decision-making, enhance disaster risk prediction capabilities, and reduce operating costs.[50] In the future, there is a need to enhance the security and privacy of the meta-universe in the emergency supply chain. Adopting edge-edge, edge-cloud, and edge-end design, utilizing fog computing and green edge cloud computing, and developing a new metaverse architecture design will help realize a green supply chain network.[51] In short, we should make innovations and work for SC resilience in crisis times with a particular focus on data analytics, AI, and machine learning,[52] and consider combining Industry 5.0 with the supply chain to establish a supply chain ecosystem and achieve digitization, intelligence, interconnection, and a high degree of self-adaptation throughout the entire supply chain process.

Conclusions

Discussion

Significance of the proposed 3-phase framework

Unlike traditional bibliometrics and qualitative research methods, this paper synthesized quantitative research methods such as bibliometrics, DTM, and regression analysis and innovatively proposed a 3-stage analysis method. The framework forms a complete and systematic chain of analysis from knowledge base, research hotspots to future trends through co-citation analysis, DTM, and regression analysis, which helps to comprehensively reveal the internal rules and external manifestations of the PTESC field. Each stage of the framework employs a scientific research methodology, which not only enhances the scientific and objective nature of the study but also increases the reliability and validity of the results. The framework provides a replicable and extensible paradigm for researchers and offers theoretical support for policy-makers and practitioners. For example, by analyzing research hotspots and future trends, policy-

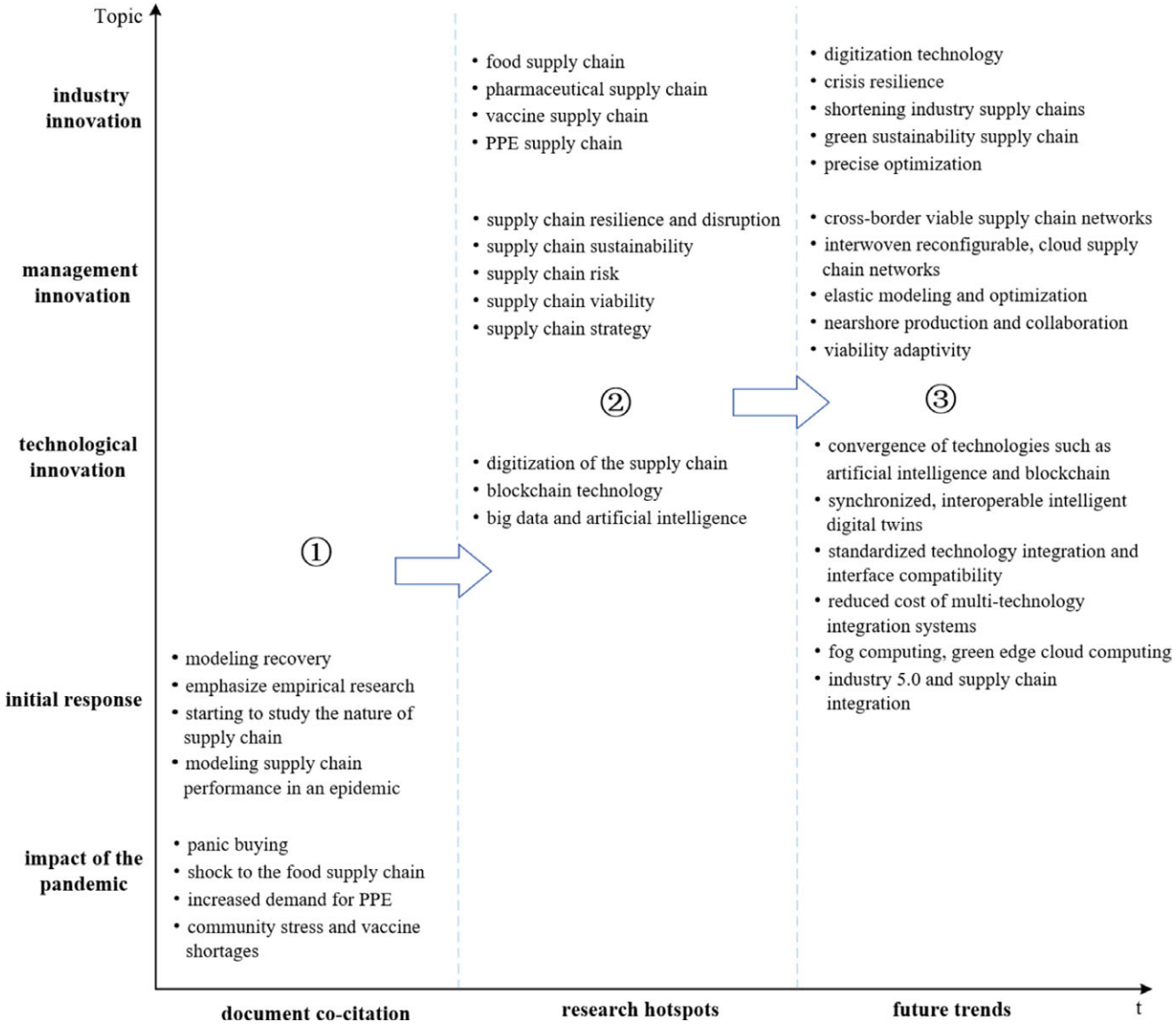

Figure 7. The evolution process of the topics.

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makers can develop more forward-looking policies, and practitioners can optimize supply chain management strategies. By sharing research methods and results, researchers can better understand each other's research progress and results and promote the common development and progress of the field.

Significance of the insights

This study discovered the emerging research field, PTESC, and systematically analyzed and revealed the knowledge base, research hotspots, and trends of the research results in this field. The analysis of literature co-citation, research hotspots, and future trends revealed the evolution of important research directions in the field, as shown in Figure 7.

From the analysis of the document clusters (Figure 7-①), the surge in demand for emergency supplies and supply chain disruptions caused by the pandemic laid the foundation for current emergency supply chain innovation. The original response of the supply chain to the pandemic provided the research direction for this field (Figure 7-①), which in turn gave rise to subsequent research hotspots in the era of pandemics such as supply chain industry, management, and technology (see Figure 7-②). Researchers need to focus on the survival mechanism of supply chains in pandemics and track government policy directions in emergencies such as epidemics to provide targeted recommendations. Policy-makers should set up special funds, provide tax incentives and financial subsidies to encourage green procurement and circular economy, and realize the resilience and sustainability management of enterprise supply chains. Supply chain experts should help enterprises formulate contingency plans, improve mitigation strategies, establish emergency material stockpiles, strengthen collaboration and information sharing, and promote energy conservation and emission reduction to minimize environmental impacts. Future research innovations in this field will focus on 3 important directions: green and sustainable supply chain industry innovation; efficient and flexible supply chain management innovation; and advanced and intelligent supply chain technology innovation (Figure 7-③). In the post-pandemic era, the development and application of technologies such as edge computing, fog computing, and green edge cloud computing will help decision-makers to improve the intelligence and digitalization of logistics and warehousing systems and optimize supply chain processes. The Innovation Platform and Technical Standards Committee will promote enterprise technology innovation and the integration of Industry 5.0 with the supply chain. Strict data protection policies and standards, encryption technology, authentication, and access control will ensure supply chain network data security and privacy in the meta-domain. Reinforcement and deep learning are important techniques for experts to develop intelligent decision-making systems to assess and optimize emergency supply chain resilience, inventory management, and demand forecasting. The latest advances and use cases of blockchain, big data, and artificial intelligence provide effective technological support to ensure transparency and traceability, reduce costs, and improve efficiency in emergency supply chains during major epidemics.

Limitations and Future Works

Limitations of this paper include the limited extent of the data. Due to the constraints of the knowledge graph software, only the core data in the authoritative database WOS is used, while other Chinese and French databases are not considered, which will be one of the focuses of our next work. In future research, we will focus on the impact of other disasters (e.g., earthquakes) on different sectors of the supply chain and the enhancement of supply chain resilience and survivability under different contingencies. Technologies such as cloud computing and IoT can also be further integrated into supply chain management, with in-depth consideration given to building a robust global supply chain system. We hope that future scholars can use this research methodology as a reference to conduct more detailed analysis on topics of interest.

Data availability statement. All data were obtained from the Web of Science database. All the figures represented in this manuscript have been produced by the author(s).

Acknowledgments. We thank all the staff who participated in this research.

Author contribution. Tian Xie—Conceptualization, Original draft; Supervision and review; Gui-Ye Dai—Data curation, Formal analysis, Original draft; Wei-Fan Chen—Conceptualization, Original draft, Supervision, and review; Chen-Peng Yang—Technical Support; Yong-Jian Huang—Technical Support; Yao-Yao Wei—Conceptualization, Original draft, Technical Support.

Funding statement. This study was supported by the Key Project on Teaching Reform Research in Ordinary Higher Education Institutions in Hunan Province of China (HNJG20230582); National Natural Science Foundation of China (71974090); Key Scientific Research Project of Education Department (20A443); Social Science Key Breeding Project of USC (2018XZX16); Philosophy and Social Science Foundation Youth Project of Hunan Province of China (19YBQ093); State Scholarship Fund From CSC (202108430098); State Scholarship Fund from CSC (202208430061).

Competing interests. The authors declare no conflict of interest for this study.

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https://doi.org/10.1017/dmp.2025.88 Published online by Cambridge University Press

Appendix

Table A1. List of subject words

Topic 0	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
supply	supply	supply	supply	supply	vaccine
chain	chain	chain	model	health	supply
COVID–19	global	COVID–19	chain	chain	chain
pandemic	COVID–19	research	COVID–19	COVID–19	COVID–19
risk	health care	study	proposed	capacity	vaccines
disruptions	pandemic	data	network	essential	vaccination
demand	research	sustainable	optimization	challenges	production
network	study	management	case	medicines	service
chains	public	resilience	study	system	model
production	mask	effect	robust	care	quality
Topic 6	Topic 7	Topic 8	Topic 9	Topic 10	Topic 11
supply	supply	supply	food	supply	supply
chain	COVID–19	COVID–19	supply	chain	chain
resilience	chain	chain	COVID–19	COVID–19	COVID–19
study	impact	pharmaceutical	chain	management	study
COVID–19	pandemic	countries	pandemic	pandemic	firms
research	study	recovery	study	sustainability	impact
sc	government	production	chains	study	pandemic
pandemic	diagnostic	China	agri-food	social	global
findings	stock	items	impact	environmental	challenges
strategies	price	coronavirus	consumer	literature	blockchain

https://doi.org/10.1017/dmp.2025.88 Published online by Cambridge University Press