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Designing supply chain strategies against epidemic outbreaks such as COVID-19: Review and future research directions

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Abstract

The supply chain is vulnerable to disruptions, which can lead to operational failure. Therefore, it is crucial to investigate and monitor the risks associated with such disruptions. Epidemics, including the profound impact of COVID-19, exemplify disruptive risks that engender complexities throughout the value chain. COVID-19 has caused significant disruptions to the global supply chain due to the preexisting fragile supply chains, resulting in the unavailability of essential raw materials, halts in production, and imbalances between supply and demand. It has forced the supply chain community to rethink their risk mitigation strategies. Despite its significance, there are a few studies on the existing options and strategies to mitigate the risks associated with epidemics such as COVID-19. This special issue explores state-of-the-art knowledge of various risks and their mitigation strategies, presenting optimized models and solutions. This editorial seeks to introduce valuable insights and illuminate promising avenues for future research by reviewing existing studies. The comprehensive understanding derived from this editorial and the accompanying articles of this special issue will benefit both researchers and practitioners, enabling them to navigate the multifaceted landscape of epidemic-induced disruptive risks in the supply chain and adopt suitable mitigation strategies. Furthermore, this special issue lays a solid foundation for implementing advanced methods for managing and mitigating the disruptive risks that epidemics pose to the supply chain.

KEYWORDS
COVID-19, epidemic, supply chain management

1 | INTRODUCTION

The current business model of globalization brings nations closer together but also causes a ripple effect that can destabilize and compromise the entire supply chain (SC). Such impacts can lead to long-term negative consequences for a company's value chain and are typically classified as operational or disruption risks. While both risks cause concerns, the impact of disruption risks tends to be more severe than operational risks. Baz and Ruel (2021) found that disruption risks, which occur less frequently but with a high impact, are more significant than common operational disruptions like demand fluctuations and delivery time mismatches. Epidemic outbreaks are a prime example of the disruptive supply chain risk that creates high uncertainties and ripple effects throughout the value chain. Recent studies (Ivanov, 2020a, 2020b; Scott & Rutner, 2019) have explored the effects of epidemics on supply chains and identified various threats that may challenge the viability of effective supply chains.

The COVID-19 pandemic, originating in Wuhan, China, in December 2019, has had far-reaching and devastating consequences worldwide. This epidemic has presented a unique and unprecedented supply chain risk, rendering various parts of the supply chain ineffective for an uncertain duration.

According to Govindan et al. (2020), COVID-19 has affected 209 countries and caused fatal illness in many individuals. The pandemic's disruptive effects have reverberated throughout upstream and downstream supply chains, affecting nearly 94% of Fortune companies (Fortune, 2020). The disruption of raw material supply has led to the closure of numerous manufacturing plants and created imbalances between supply and demand, further amplifying the strain on the global economy. Such shortages of raw materials and products have been shown to spread quickly and affect overall supply chain performance, supply chain agility, supply chain mapping, supply chain efficiency, and resilience (Bai et al., 2023; Chopra et al., 2021; Kahkonen et al., 2023; Mubarik et al., 2023). The outbreak has also resulted in the loss of nearly 200 million jobs globally, according to the ILO (2020). It has been considered the "deepest global recession in decades" by the World Bank (2020). No sector has been spared from the impact, as supply chains in agriculture (Alabi & Ngwenyama et al., 2023), medical (Ali and Kannan, 2022; Banik et al., 2022; Xu et al., 2023b), food (Ali & Govindan, 2021; Shafiee et al., 2022), infrastructure (Govindan et al., 2021), tourism (Bai & Run, 2022; López-Vizcarra et al., 2023), fashion (Dohale et al., 2022), and manufacturing (Spieske & Birkel, 2021) have all been severely affected, demonstrating the inadequate risk management strategies employed by global companies. Managing such epidemic risk in global supply chains poses operationalization difficulties, as discussed in the existing literature (van Hoek, 2020; Xu et al., 2023a,c).

The SC risks from epidemic outbreaks have unique features that have scarcely been addressed in the literature as follows:

- The infection characteristics of epidemic outbreaks can potentially affect entire cities at once.
- The impact of epidemic outbreaks on the supply chain is immediate and significant as public health challenges arise and key entities like manufacturers, suppliers, distribution centers, and transportation links may become temporarily unavailable.
- Many impacts of epidemic outbreaks, such as delivery delays and material shortages, propagate downstream of the SC, especially in global SCs (Ivanov, 2020a, 2020b).

Consequently, for the SC planning process in the face of epidemic outbreaks, the future decision-making environment is shaped by many types of uncertainty that are most often significant. The COVID-19 outbreak has become one of the most severe disruptions during the last decades, leading to substantial losses in many global SCs (Araz et al., 2020). In some SCs that produce necessities to cater to social welfare under epidemic outbreaks, economic objectives may have to change to social welfare objectives, or economic objectives would need to be optimized subject to constraints such as the stockpile requirement. Furthermore, traditionally, several strategies exist for an SC, a logistical system, or a production system that can be utilized to manage the risks associated with disruptions (Tang, 2006). Considering the significance of addressing the issues of epidemic outbreaks' risks in supply chains, this editorial review investigates the literature on SC strategies against epidemic outbreaks. Specifically, we introduce the papers accepted for publication in this special issue on "Designing supply chain strategies against epidemic outbreaks such as COVID-19."

2 | LITERATURE REVIEW

This section has two subsections. The first subsection highlights the existing literature on supply chain management and COVID-19. This subsection presents the existing knowledge within the considered field and seeks to strengthen further arguments about the existing gap based on observed knowledge through the literature review. The second subsection's objective is to review the articles accepted in this special issue, which provides a quick summary of each article and further identifies potential future research opportunities and questions.

2.1 | State of the review

To gain an understanding of the current state of research on supply chain and COVID-19, we conducted a literature review on SCOPUS using the following search criteria: (TITLE-ABS-KEY "supply chain" OR "supply network") AND TITLE-ABS-KEY ("COVID-19" or "post COVID-19") in May 2023. To ensure appropriate input quality, we included only peer-reviewed journal articles. Specifically, journals under the subject categories "Operations and Technology Management" and "Management Science and Operations Research" in the Association of Business Schools (ABS) Journal Guide were searched (Hiebl, 2021). Our search yielded 279 papers published between 2020 and 2023, and the 908 keywords found from 279 papers were used for cooccurrence analysis. In this cooccurrence analysis, 53 keywords were used that occurred at least four times. Figure 1 shows the results of the VOS Viewer cooccurrence analysis after manually refining the keywords to remove repetitions or similar terms, e.g., disruption and disruptions.

From the information presented in Figure 1, the field of supply chain and COVID-19 focuses on various themes such as resilience, viability, digital technologies, and sustainability.

The COVID-19 pandemic has greatly affected supply chains, causing disruptions in the transportation and manufacturing of goods and services across borders. It has resulted in significant challenges for supply chains of all sizes, with delays and shortages common in various industries. As a result, the topics of resilience and viability have become increasingly important for these supply chains to address.

Supply chain viability refers to the ability of a supply chain to operate efficiently in the face of changes such as economic fluctuations, natural disasters, geopolitical risks, and other disruptive events like COVID-19 (Ivanov & Dolgui, 2020). Despite these challenges, a viable supply chain can

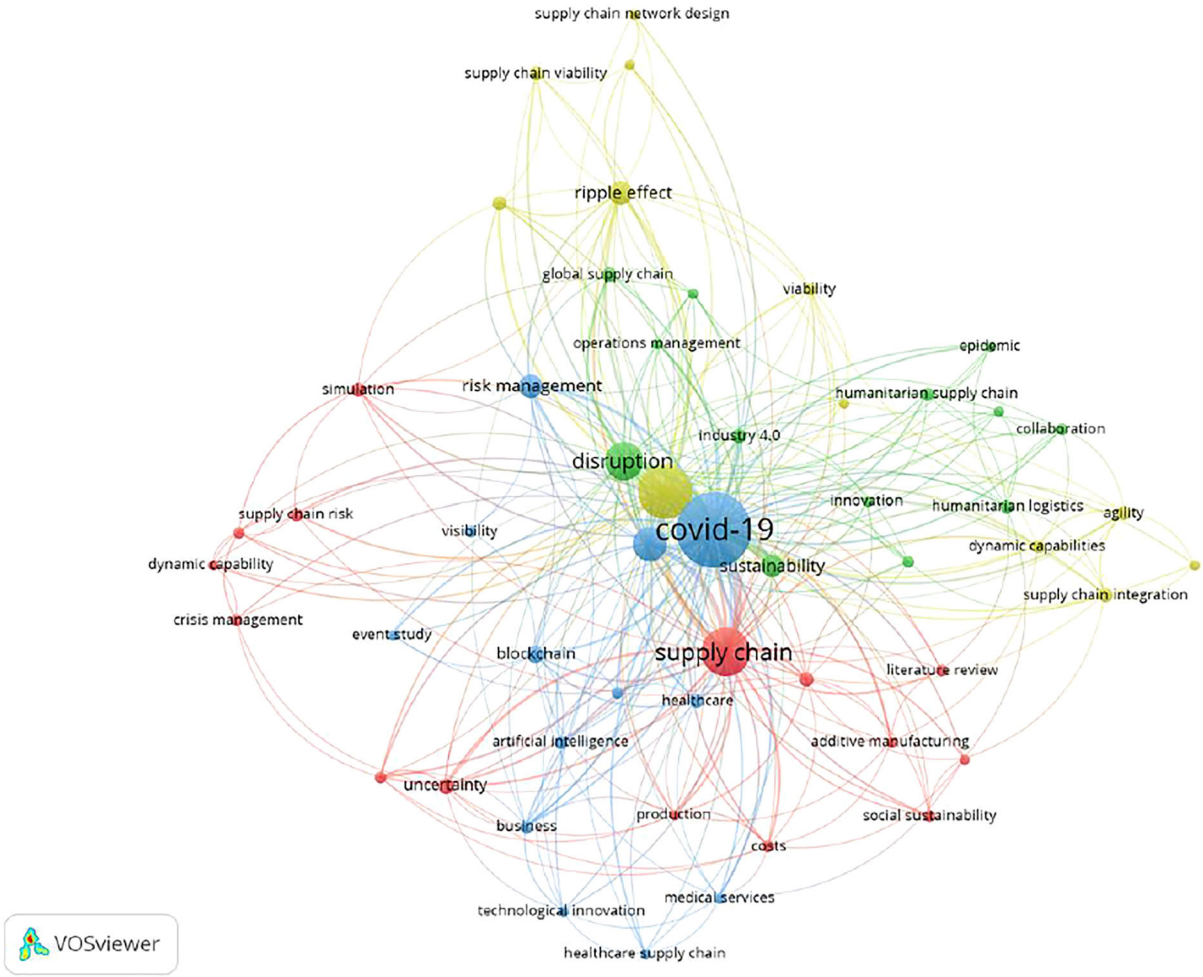

FIGURE 1 Cooccurrence analysis in VOS viewer

maintain its operations and meet customer demands. On the other hand, supply chain resilience is the ability of a supply chain to recover and continue functioning after disruptions or occurrences of unexpected events (Hosseini et al., 2019). While supply chain resilience has received considerable attention in the literature, viability has not been considered much. Ivanov and Dolgui emphasize integrating resilience and viability concepts within the supply chain domain. In their study, Sun et al. (2023) investigated the impact of pandemic-relieving product adaptation (PRPA) strategy on financial performance for pandemic relief by integrating social responsibility initiatives with resilient strategies. In addition, Craighead et al. (2020) introduced the "transiliency" concept, which allows businesses to restore and change processes simultaneously to face the challenges caused by the pandemic and be ready for the next one.

The utilization of Industry 4.0 and digital technologies can significantly contribute to the resilience and sustainability of supply chains. These advancements can effectively manage the ripple effects caused by crises, empowering companies to recover quickly. Indeed, businesses that excel in digital manufacturing networks have a distinct advantage during times of crisis and play a critical role in coordinating recovery efforts (Ivanov, 2020a, 2020b; Ivanov & Dolgui, 2020).

The COVID-19 crisis has emphasized the significance of sustainability in supply chains. As businesses aim to develop more resilient supply chains, they need to consider their operations' environmental and social consequences. That involves reducing carbon emissions, promoting ethical labor practices, and implementing circular economy principles to decrease waste and improve resource efficiency. Silva et al. (2022) confirmed that the link between sustainability and resilience is crucial in ensuring effective crisis management. In addition, the research conducted by Majumdar et al. (2021) substantiated the correlation between environmental sustainability and supply chain resilience in mitigating various risks. Furthermore, Sarkis (2020) and Sarkis et al. (2020) emphasized that a circular economy can play a vital role in ensuring the long-term survival of supply chains in a post-COVID-19 era.

The points mentioned above are depicted and supported by Figure 1. It is evident that the most studied topics are sustainability, Industry 4.0, and disruption. Below is a summary of the primary subjects identified through cooccurrence analysis.

First, the red cluster focuses on supply chain risk, uncertainty, and crisis management. For example, Flynn et al. (2020) reflected on the lessons learned from COVID-19 that can be applied in the future, and El Baz and Ruel (2021)

examined how supply chain risk management can help reduce the adverse effects of disruptions caused by the COVID-19 pandemic to enhance resilience and robustness. In addition, Yang et al. (2021) analyzed the association between supply chain risk management and resilience, Dohmen et al. (2022) explored the impact of risks mitigation techniques on service performance during the COVID-19 pandemic, and Gomez-Mejia et al. (2021) explored decision-making uncertainties under the COVID-19 pandemic.

The second cluster (green) focuses on sustainability and Industry 4.0 concepts. A few studies have examined the association between resilience and sustainability (Bechtsis et al., 2021; Karmaker et al., 2023) and how digital technologies can reduce the impact of supply chain disruptions due to the COVID-19 pandemic (Bechtsis, 2021; Hopkins, 2021; Karmaker et al., 2023).

The third cluster (blue) focuses on pandemics and specifically on the healthcare industry. Many studies have explored different issues in healthcare supply chains during or after a pandemic, such as resilience (Bag et al., 2021; Spiekse et al., 2022), network optimization (Nagurney, 2021), green supply chain management (Kholaif et al., 2023), resource planning (Fattahi et al., 2023), viability (Alizadeh et al., 2022), and supplier selection (Pamucar et al., 2022).

Finally, the fourth cluster (yellow) mainly analyzes resilience, viability, and the ripple effect. Li et al. (2020) and Brusset et al. (2023) analyzed the disruption propagation behaviors concerning the ripple effect. Kumar et al. (2023) explored digitalization and viability to manage the ripple effect. Santiago Scarpin et al. (2022) studied how COVID-19 impacted the ripple and bullwhip effects. Sindhwani et al. (2022) explored the ripple effect mitigation capabilities.

In conclusion, the COVID-19 pandemic has highlighted the need for increased resilience, viability, and collaboration across the supply chain. By adopting new strategies and technologies, businesses can minimize the disruptions caused by pandemics and build more sustainable and resilient supply chains for the future.

2.2 | Papers in this special issue on "Designing supply chain strategies against epidemic outbreaks such as COVID-19"

After a rigorous review, we selected three articles from 60 submissions for publication in this special issue. The articles in the special issue provide new and innovative contributions of high practical relevance that are methodologically rigorous and advance research on designing supply chain strategies in the COVID-19 environment. This section summarizes the key contextual, methodological, and managerial areas covered by the articles in this special issue.

Srinivasan et al. (2023), in their paper "To talk or not?: An analysis of firm-initiated social media communication's impact on firm value preservation during a massive disruption across multiple firms and industries," examined the efficacy of firm-initiated social media communication using Twitter in mitigating the negative impact of disruptions due to the COVID-19 pandemic on shareholder value of firms using signaling theory as a theoretical lens. They used stock market data collected from 467 S&P 500 firms and their Twitter activity (121,998 tweets) to test their six hypotheses by considering frequency, observability, sentiment, and extent of interest of firm social media communication strategies. Regression analysis was used to determine the impact of these strategies on a firm's abnormal stock returns. This work theoretically contributes to the extant literature on the *informational and communication* elements of disruption and also adds to the literature on disruptions-shareholder value by considering large-scale disruptions such as the COVID-19 pandemic, and adds to the growing body of literature on Twitter by considering firm-generated tweets. The findings provide valuable insights for managers looking to communicate relevant information to stakeholders promptly and effectively. Ultimately, the authors recommended that firms increase the frequency of their communication, share a positive outlook, and prioritize the proportion of relevant information to mitigate the adverse effects of disruptions caused by the pandemic on their value (Srinivasan et al., 2023).

Xu et al. (2023d), in their work "Seeking survivals under COVID-19: The WhatsApp platform's shopping service operations," developed an analytical model to investigate how "WhatsApp Shopping Service Operation" (WSO) can be valuable for offline stores under the COVID-19 outbreak. The study was inspired by Timberland's use of WSO in Hong Kong and aimed to uncover its underlying mechanism. The authors considered two important demand factors, namely customers' fear of infection and the proportion of customers willing to use WSO, which are further influenced by the company's pricing and staffing decisions. They concluded that WSO could help alleviate the negative impact of COVID-19, but only within a specific parameter range. In addition, their research explored the overall welfare of workers-consumers-company (WCC) and how government subsidies can effectively respond to COVID-19 (Xu et al., 2023).

In their paper entitled "Using forecasting to evaluate the impact of COVID-19 on passenger air transport demand," Li et al. (2023) studied the impact of the COVID-19 pandemic on passenger air transport by proposing a forecasting approach to separate the supply restriction and demand depression arising from the COVID-19 pandemic, and subsequently evaluated the impact of each force on the passenger air transport demand. Their method includes four steps: passenger segmentation (based on predefined groups), forecasting model selection (SARIMA), scenario simulation (business as usual versus the pandemic scenario), and prediction comparison. To quantify the impact of COVID-19, they employed real-world data from the joint loyalty program of Air France-KLM, the fourth-largest airline in Europe. The data set spanned 1 June 2018 to 31 May 2020. It included 5.8 million passengers (with information on passenger ID and age) and 51 million flights (with information on the flight date, purchasing account, cabin class, origin, and destination of each leg of the flight). They showed that the COVID-19

pandemic caused Air France-KLM to reduce flights by 40.3% and that 57.4% of the total decrease was due to demand depression, while the remaining 42.6% was due to supply restriction. They also showed that the impacts of demand depression and supply restriction were heterogeneous based on passenger segments (nine segments based on age group and purpose of the trip). Finally, they offered two strategies depending on passenger segments: (1) resume flights and (2) restore passenger confidence/increase passenger willingness to fly (Li et al., 2023).

3 | FUTURE RESEARCH DIRECTIONS

This special issue on "Designing supply chain strategies against epidemic outbreaks such as COVID-19" aims to seek and advance existing knowledge on supply chain planning considering epidemic outbreaks' risks, specifically among the readers of *Decision Sciences* (*DS*). The articles accepted in this special issue address the questions and concerns that offer significant opportunities for future research. Here are some of the most important future research questions summarized below to give a little more space. Note that each topic has much greater depth to explore from different perspectives.

3.1 | Detailed design of dispensing strategies immediately after an epidemic outbreak that maintains SC functionality

- Investigate efficient inventory management strategies to help supply chains maintain an adequate stock of essential supplies during and after an epidemic. It involves understanding demand patterns, implementing dynamic inventory control mechanisms, and exploring innovative approaches.
- Explore the benefits and challenges of diversifying supply chain sources and establishing redundancy to minimize dependency on specific regions or suppliers. It includes assessing regional or local sourcing potential, fostering supplier collaboration, and implementing contingency plans to mitigate supply disruptions.
- Develop strategies for agile transportation and logistics operations that can quickly adapt to changing conditions during and after an epidemic. It may involve optimizing routing and scheduling algorithms, exploring alternative transportation modes, and utilizing real-time data and analytics for decision-making.
- Investigate mechanisms and frameworks for enhanced collaboration and information sharing among supply chain stakeholders, including government agencies, healthcare providers, suppliers, and logistics providers. It includes developing platforms and protocols for secure and efficient sharing of critical information, coordinating response efforts, and fostering collaboration to address supply chain disruptions effectively.
- Explore models and algorithms for designing resilient supply chain networks that respond effectively to epidemic outbreaks. It involves determining the optimal locations for facilities, warehouses, and distribution centers, considering factors such as proximity to critical resources, transportation infrastructure, and healthcare facilities. In addition, develop strategies for optimizing network configuration to enhance flexibility and adaptability during an outbreak.
- Future research can compare the effects of risks in developing and developed nations during the COVID-19 outbreak.
- A potentially fruitful direction for future studies is to analyze supply chain behaviors during and after a pandemic from the viability perspective.
- Exploring the potential of reducing disruptions caused by epidemic outbreaks in the design of supply chain networks through utilizing a multistage/scenario-based stochastic programming model could be an intriguing and applicable subject for future investigations.

3.2 | Development of strategies to mitigate the effects of epidemic outbreaks on supply chains

- Extend beyond optimization models and implement more advanced simulation techniques. In the context of pandemics, there is a need to explore queuing theory, scheduling, and forecasting approaches and effectively manage and allocate resources. That implies that decision-makers and policymakers should enhance their supply chains' resilience and response capacity by utilizing optimization techniques and simulations. Simulations can provide a comprehensive understanding of the current state of supply chain responsiveness and resilience and play a crucial role in predicting large-scale disruption scenarios and determining the necessary performance capabilities.
- Develop comprehensive risk assessment frameworks specific to epidemic outbreaks and their impact on supply chains. It includes identifying the key vulnerabilities, evaluating the effectiveness of risk mitigation strategies, and integrating risk management practices into supply chain planning and design.
- Develop improved demand forecasting and planning methodologies under the uncertainties of epidemic outbreaks. Investigate the use of data analytics, machine learning, and statistical models to predict demand patterns, considering factors such as the ripple effect, the bullwhip effect, panic buying, changes in consumer behavior, and shifts in healthcare demands. Develop adaptive planning approaches to ensure the availability of essential goods and services.
- Develop frameworks and metrics for assessing the resilience of supply chains to epidemic outbreaks. Investigate the interdependence between supply chain elements and their impact on overall resilience. Identify strategies for enhancing resilience through redundancy, flexibility, and adaptability in supply chain operations.
- It would be valuable to simulate prepandemic decisions made in anticipation of the crisis to analyze the impact of

early adaptive actions taken by companies throughout the pandemic.
- There is potential for studying inventory and production control policies, as further exploration in these areas can contribute to a better understanding of managing major supply chain disruptions caused by pandemics. In addition, examining the decision-making process concerning reshoring could be an intriguing avenue for research.

3.3 | Healthcare supply chains

- Operational failures in healthcare systems, encompassing issues such as medication and equipment shortages or mismanagement, can potentially disrupt the provision of essential patient services. As a result of various risks originating from various sources, there is a growing emphasis on mitigating risks and building resilient healthcare systems. Although there is an increasing body of research on risk and resilience in the healthcare sector, considerable room remains for further influential investigations. The existing models tend to examine risk and resilience separately or concentrate on specific areas like hospital surgery. As a result, a pressing need exists for quantitative models that can comprehensively analyze both risk and resilience, focusing on the key stakeholders involved in the healthcare supply chain.
- The ongoing pandemic has severely impacted healthcare facilities, including hospitals, nursing homes, and other healthcare establishments, resulting in significant staffing shortages. The nurse shortage is the most critical issue influencing the overall success of the healthcare supply chain, ultimately leading to surgery backlogs and prolonged waiting times for patients seeking essential treatments. The conventional approaches to address staffing shortages revolve primarily around increasing pay rates and improving working environments to enhance the appeal of the nursing profession. However, these methods have proven ineffective in achieving their intended goals, necessitating the exploration of fresh and innovative ideas to complement the nursing workforce and enhance their productivity.
- In future studies, a promising avenue to explore involves adopting a mixed-methods approach that combines qualitative research to investigate different risk factors and resilience strategies and quantitative research to analyze the interconnectedness between risk and resilience in explaining healthcare performance. By employing this comprehensive methodology, researchers can gain a deeper understanding of the multifaceted dynamics at play within healthcare systems, leveraging qualitative insights to explore the nuances of risk factors and resilience strategies. At the same time, the quantitative analysis systematically examines how risk and resilience interact and impact overall healthcare outcomes. This integrated approach allows for a more holistic and robust examination of the complex relationships between risk, resilience, and healthcare performance, contributing to a more nuanced and comprehensive understanding of this critical domain.

3.4 | Integration of data analytics approaches and advanced technologies with OR/MS models

- Given the influence of data analytics on supply chains and the impact of disruption risks on supply chains, it is reasonable to anticipate a connection between data-driven technology and managing supply chain disruption risks. Advanced technologies have the potential to facilitate increasingly self-governing supply chains, allowing control towers to utilize enhanced visibility to handle risks related to demand and supply effectively. The advancement of research can contribute to this by creating frameworks based on OR/MS models for decision-making that assess and consider these technologies. There is a tendency to view these technologies solely as technological advancements, overlooking their broader implications. That suggests there is a chance to consider how technologies can complement one another and assess the potential of existing technologies to address supply chain challenges, not just focusing on newer technologies. Therefore, it is essential for research to aid in creating more refined and comprehensive decision frameworks to navigate this complex landscape.
- Data analytics can serve as a data-driven learning system during the proactive phase, generating appropriate disruption scenarios for designing and planning resilient supply chains.
- Investigate the influence of enhanced visibility achieved through advancements in big data analytics, specifically by enabling more precise assessments of changes in demand, frequency, and duration of disruptions, early identification of potential issues, and detection of supplier disruptions through sensors or similar technologies.
- Examine the possibilities presented by emerging technologies like blockchain, the Internet of Things (IoT), artificial intelligence (AI), and data analytics to enhance supply chain resilience and functionality during and after an epidemic outbreak. Investigate their applicability for real-time tracking and monitoring of supplies, predictive analytics for demand forecasting, and leveraging digital platforms for efficient coordination and decision-making.
- Promote additional research that employs diverse methodologies, particularly qualitative research, to offer complementary scientific evidence and in-depth case studies. This approach will enhance and refine our understanding of the complex and crucial digital transformation issues during the ongoing COVID-19 pandemic.
- Investigate novel digital technologies that potentially enhance the management of ripple effects during epidemic outbreaks.
- Advancing our understanding of how innovative technologies can be effectively utilized to ensure the resilient

operation of supply chains during epidemic outbreaks is a crucial area for future investigation.

4 | CONCLUSION

A comprehensive risk management system is necessary to improve supply chain efficiency and manage uncertainties. Unfortunately, the advent of COVID-19 has disrupted global supply chains, affecting every stage, from sourcing to the end consumer. This editorial compiles articles from the special issue on "Designing supply chain strategies against epidemic outbreaks such as COVID-19" to comprehensively understand the disruptive risks encountered during the COVID-19 era and similar epidemic outbreaks.

The editorial delves into the existing theories by carefully examining the insights presented in this special issue. It emphasizes the criticality of establishing an effective risk management system for future global supply chains, particularly in the context of epidemic outbreaks like COVID-19. Furthermore, the editorial outlines potential research directions that hold promise for the future. These avenues of inquiry aim to facilitate the development of diverse frameworks and strategies that can effectively address the disruptive risks posed by epidemics within the supply chain.

By exploring these future research questions, researchers and practitioners can expand their knowledge and understanding of identifying new risks and their associated management solutions. This collaborative effort serves as a catalyst for the exploration of new frontiers, enabling the supply chain community to better prepare for and navigate the challenges presented by epidemic-induced disruptions.

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