



FUTURE OF SUPPLY CHAIN MANAGEMENT IN A POST-PANDEMIC WORLD

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Abstract

The COVID-19 pandemic during 2020–2021 severely disrupted global supply chains, creating unprecedented challenges for organizations as they struggled to respond to sudden fluctuations in demand for critical products and services. This study investigates the roles of supply chain coordination (SCCO), supply chain resilience (SCRE), and supply chain robustness (SCRB) in improving supply chain performance (SCFP), while considering the contributions of supply chain flexibility (SCFL) and the integration of Internet of Things (IoT) and Big Data Analytics (BDA). The research examines how SCFL strengthens coordination, resilience, and robustness, ultimately leading to enhanced supply chain performance. A cross-sectional survey was conducted, yielding 217 valid responses from supply chain professionals, and the data were analyzed using AMOS 20. The results reveal that SCCO, SCRE, and SCRB mediate the relationship between SCFL and IoT-BDA integration. However, the relationships among SCCO, SCRB, and SCRE were not found to be statistically significant. Overall, the findings demonstrate that supply chain flexibility is a strong predictor of improved coordination, resilience, and robustness, thereby contributing significantly to better supply chain performance, particularly in the post-pandemic business environment.

Key terms: Flexibility-IoT-BDA ,Performance -Resilience -Robustness -Supply chain management (SCM)

1.Introduction

Over the past three decades, supply chains have become increasingly complex due to the growing adoption of outsourcing and the involvement of multiple organizations in managing material, information, and financial flows. Rapid changes in customer demands and continuous technological advancements have further increased the need for flexible and efficient supply chain management practices. The COVID-19 pandemic caused unprecedented disruptions to both manufacturing and service industries, exposing vulnerabilities in global supply networks and creating severe economic challenges. Many sectors experienced significant declines in operations, production, and revenue as a result of lockdowns, restricted trade, and changing market conditions. Despite these setbacks, several industries demonstrated resilience by gradually recovering as restrictions eased and demand improved. These developments highlight the



importance of building adaptable, resilient, and well-coordinated supply chains to withstand future disruptions and ensure sustainable business performance. Bibliometric analysis

2.Review of Literature:

Literature during the pandemic and post-pandemic periods examined novel decision-making settings entailed in supply chains and manufacturing systems through the COVID-19 pandemic followed by other major crises. The contexts and scopes of these settings differ across industries and services but share a set of common attributes, such as a crisis-like environment, deep uncertainty about short-term and long-term futures, and adaptability as a ‘new normal’ instead of stability and long-term planning.

The COVID-19 pandemic has unveiled the lack of resilience in supply chain and manufacturing systems. The importance of not only efficient and resilient but also *viable* value creation systems capable of production continuity and ensuring the fundamental needs of society in the presence of long-term crises is an imperative adaptation (Graves, Tomlin, and Willems [Citation2022](#); Ivanov [Citation2022a](#); Sodhi, Tang, and Willenson [Citation2023](#)).

New research areas such as supply chain viability and adaptation-based supply chain resilience have appeared (Ivanov [Citation2023a](#), [Citation2023b](#); Ivanov et al. [Citation2023](#); Ivanov and Keskin [Citation2023](#); Sawik [Citation2023](#)). The main conclusion of these studies is that proactively applying resilience analytics to model supply chain and manufacturing system reactions to disruptions and associated recovery policies will increase the probability of society survival through major disruptions such as the COVID-19 pandemic.

3.New areas in supply chain resilience during and after the pandemic

In this section, we Analyse in detail new areas of supply chain resilience research which appeared during and after the pandemic and are considered to be future research agenda.

3.1. COVID-19 pandemic

Supply chain management during the COVID-19 pandemic was characterised by surges in demand and supply, capacity disruptions, and governmental control measures (Li et al. [Citation2023c](#); Paul et al. [Citation2022](#)). The pandemic literature can be classified into three areas:

- The prediction of pandemic impacts (Ivanov [Citation2020](#))
- Adaptation strategies, e.g. production capacity scalability (Li et al. [Citation2023b](#)), production-ordering policy adaptation (Rozhkov et al. [Citation2022](#)), supply substitution through ad hoc emergent capacity conversion (Kosasih and Brintrup [Citation2022](#); Sodhi, Tang, and Willenson [Citation2023](#)), commercial capacity conversion to healthcare production (Dolgui et al. [Citation2024](#)), public–



private collaboration (Shen and Sun [Citation2023](#)), and severe demand surges (Paul et al. [Citation2022](#))

- Exiting the pandemic (Ivanov [Citation2021d](#))

During the COVID-19 pandemic, increased attention to epidemiological models has been observed. This aspect is new and has been addressed, e.g. in the study of Brusset, Jebali, and La Torre ([Citation2023b](#)), who developed a combination of epidemiological and supply reconfiguration models. One specific research area which is indirectly related to resilience and appeared through the pandemic years is vaccine supply chains, along with their design and timely deployment (Ivanov and Keskin [Citation2023](#)).

3.2. Viability

A viable supply chain and its associated frameworks are proposed by Ivanov and Dolgui ([Citation2020](#)) and Ivanov ([Citation2022b](#)), comprising both the supply chain and the ISN levels. An ISN is an ‘entirety of interconnected supply chains which, in their integrity, secure the provision of society and markets with goods and services’ (Ivanov and Dolgui [Citation2020](#)). As shown by Ivanov et al. ([Citation2023](#)), an ‘ISN is different from traditional supply chains of a company since it contains supply chains of different industry sectors that intersect, sharing common nodes and links. Firms in the ISN may play different roles. For example, a firm can be a producer of displays in an electronic supply chain and a supplier of displays in a healthcare supply chain’. Ruel et al. ([Citation2021](#)) develop a measurement scale for supply chain viability and note that ‘supply chain viability can be viewed from an overarching adaptation perspective that extends the supply chain resilience notion of a closed-system, “bounce-back” view, with a viable, open supply chain system perspective incorporating “bounce-forward-and-adapt” options’.

3.3. Cross-industry ripple effects

The COVID-19 example clearly showed that supply chains are tightly coupled with one another, sharing common suppliers, warehouses, and manufacturers. This provides a very specific context of the *ripple effect* in global supply chains. When firms in one supply chain had to stop production worldwide because of missing supply, quarantine measures, and market disruptions, these disruptions cascaded to other supply chains (Dolgui, Ivanov, and Sokolov [Citation2018](#); Ivanov [Citation2020](#); Li et al. [Citation2021](#)). In this setting, a combination of macroeconomics and supply chain level studies becomes a crucial future research avenue.

3.4. Intertwined supply networks and network-of-networks

The ISN was introduced by Ivanov and Dolgui ([Citation2020](#)) in their position paper on supply chain management under pandemic conditions. ISNs form complex digital ecosystems. Related concepts are the digital supply chain, which represents a combination of the physical supply chain (Ivanov, Dolgui, and Sokolov [Citation2022](#); MacCarthy and Ivanov [Citation2022a](#); MacCarthy and Ivanov [Citation2022b](#)), a cyber-physical system, and a digital supply chain twin (Ivanov and



Dolgui (Citation2021). Ivanov (Citation2023b) examined adaptation strategies of intertwining and substitution through resource sharing among manufacturers and the use of collective emergency sourcing. Ivanov (Citation2023b) and Echefaj et al. (Citation2024) simulated the ripple effect in ISNs. Feizabadi, Gligor, and Choi (Citation2023) examined the ISN through a biology-based jury-rigging search behaviour and managing the interdependencies across the supply chains as adaptive mechanisms drawing on complex adaptive systems and Ashby's law of requisite variety. They also developed a model for cross-industry supply chain coordination using the example of healthcare and commercial supply chain intertwining in the wake of the COVID-19 pandemic for capacity conversion to produce healthcare products using commercial supply chains.

3.5. Efficient resilience

Before the pandemic, resilience was mostly considered as something waiting for an emergency case and not participating in everyday operations and value creation. As noted by Ivanov and Dolgui (Citation2022a), 'relative stability in demand and supply in some supply chains over decades led to the formation of a crisis-free management mentality, belief in having risks and uncertainty under control, long-term planning, rigid and lean network structures, and planning paradigms – it was all turned upside down during the COVID-19 pandemic. The pandemic challenged supply chain management by introducing a novel and distinct context of order and chaos, controllable and uncontrollable, rigid and fluid, fixed and adaptable, and certain and uncertain'.

Digital technology and visibility

Digital technologies have experienced tremendous development during the pandemic in all areas of life and so in supply chains, aiming at improving visibility, real-time decision-making support, and human-AI collaboration (Dubey et al. Citation2021a; Ivanov, Dolgui, and Sokolov Citation2022; Lv et al. Citation2022; MacCarthy, Ahmed, and Demirel Citation2022; Ruel et al. Citation2021; Xue and Li Citation2023; Zhang, MacCarthy, and Ivanov Citation2022). The development of AI has been a general trend for the last years, but it was also instigated by the pandemic (e.g. a digital world caused by travel contact restrictions).

New modelling context: deep uncertainty and focus on recovery

Supply chain resilience theory has been developed in the first two decades of the twenty-first century in the era characterized by a relative stability of demand and supply. The focus of supply chain resilience was therefore directed on some short-term, instantaneous disruptions (e.g. natural catastrophes, strikes, or man-made disruptions) (Blackhurst et al. Citation2005; Chopra and Sodhi Citation2014; Fiksel et al. Citation2015; Hägele, Grosse, and Ivanov Citation2023). The objective of resilience modelling and optimisation in this stability-based view was to predict possible disruption scenarios and propose strategies for resilient supply chain design as a protection response and recovery as a reactive response (Aldrighetti, Battini, and Ivanov Citation2023; Lückner, Seifert, and Biçer Citation2019). This research has a set of common elements such as the availability of past data to forecast future disruptions and their probabilities,

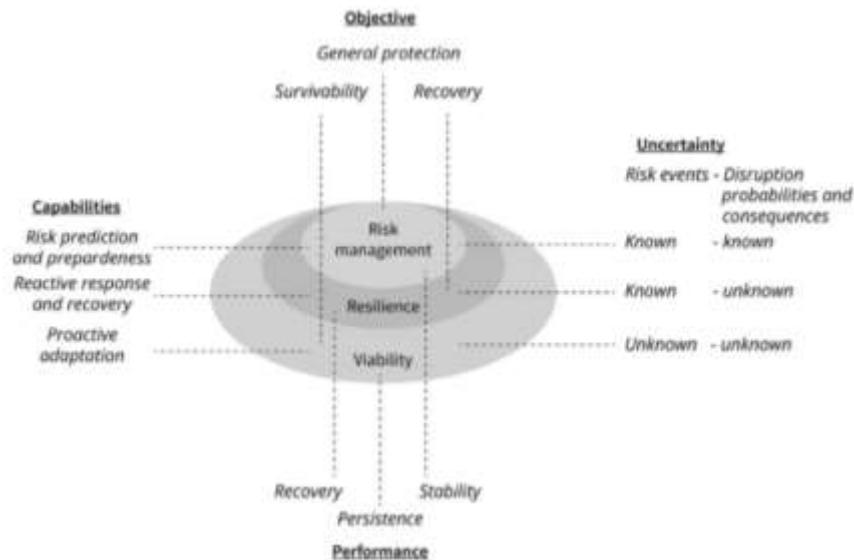


the beginning of recovery after a disruption using some predefined contingency plans, and the ultimate objective to return to some original, pre-disruption operational plans and performance.

Theoretical and managerial implications of new developments in supply chain resilience research

In this section, we engage in the analysis of theoretical and managerial implications of new developments in supply chain resilience research. The analysis shows that pre-pandemic and pandemic/post-pandemic research on supply chain resilience have jointly evolved into a comprehensive framework

Generalized framework of supply chain resilience research



Creating relevant knowledge for these future challenges now is imperative and of vital importance. Under such settings, there is an obvious call to the research community for developing modelling and optimisation techniques that account for such settings and guiding firms in building adaptable, reconfigurable, resilient, and viable supply chains. These and other related questions entail a number of interesting and novel contexts for supply chain management and engineering research, such as the following:

- Modelling and optimizing supply chain and manufacturing systems under deep uncertainty;
- The multi-objective optimisation of strategic network design, with a consideration of efficiency, adaptability, resilience, sustainability, and viability;
- Contingency planning for and the reactive deployment of capacity intertwining of healthcare and commercial supply chains for coping with disasters;
- Investments in resilience in the settings of deep uncertainty;



- The dynamic modelling and optimisation of supply chain and manufacturing systems at the tactical and operative control levels; and
- The design and management of supply chains and manufacturing systems based on inherent adaptability and the ability to change as ‘normal’ and not as a reaction to exceptional events.

Findings

Our major findings are as follows. Along with an exponential growth of literature on supply chain resilience in and after 2020, we observed a major shift from preparedness and disruption predictions in the pre-pandemic literature towards recovery and proactive adaptation in pandemic and post-pandemic research. While pre-pandemic resilience research mainly presumed the continuous availability of recovering and bouncing back to the ‘old normal’, resilience research during and after the pandemic has developed novel perspectives of adaptation and viability (Ivanov Citation2023c). Through and after the pandemic, resilience understanding has evolved from recovery policies used in emergency situations only to a major supply chain management capability based on building resilience-centric, structurally adaptable, and flexibly reconfigurable networks.

When focusing in particular on production research, the results of our study indicate several major areas for future analysis. Through the pandemic, a novel context of production re-purposing has appeared which provides a number of opportunities to develop novel and substantial contributions. Production planning with the consideration of an infected and recovered workforce has been identified as a new and visible research area. The production of vaccines is another interesting topic which includes distinct features of an extremely short ramp-up time and the integration of product design, production–distribution planning, and supply chain design.

Conclusion:

From the supply chain resilience modelling and optimisation perspective, we observed that pre-pandemic research mostly dealt with the settings of *known–known*/random uncertainty (i.e. known disruption events and known impact) and partially *known–unknown*/epistemic uncertainty (i.e. known disruption events and unknown impact). During the pandemic, the focus thus shifted to adaptation instead of predictions and to the acceptance of disruptions as a part of ‘new normal’ business-as-usual operations instead of considering resilience as some external emergency capability outside of everyday operations. In other words, supply chain resilience modelling and optimisation were confronted with a novel setting of *unknown–unknown*/deep uncertainty (i.e. unknown disruption events and unknown impact). This novel context of supply chain resilience has induced several novel characteristics in supply chain resilience modelling and optimisation, such as the following:

- Long-lasting crises with hardly predictable scaling and uncertainty about both the short-term and long-term future in the supply chain and its environment, i.e. deep uncertainty (unknown–unknown)



- Simultaneous disruptions in supply, demand, and logistics
- Recovery performed in the presence of a disruption and its hardly predictable scaling (i.e. coupling of supply chain and disruption dynamics)
- Simultaneous and/or sequential openings and closures of suppliers, facilities, and markets
- Response and recovery strategies taking potential crisis recurrence and setbacks into consideration
- Cascading effects of disruptions through the supply chain networks (i.e. the ripple effect) and cross-industry ripple effects

Through the COVID-19 pandemic, supply chain adaptability and viability have been driven towards the forefront of research and practical analysis, entailing numerous novel decision-making settings which go beyond the state of the art on supply chain resilience and the management of short-term disruptions. To this end, there is an acute need to develop a new body of research, i.e. resilience analytics that could support decision making related to long-term supply chain and manufacturing system crises with deep and inherent uncertainty about current and future developments.

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