Impacts of Resilience Practices on Supply Chain Sustainability

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1 Introduction

Supply chains are continuously exposed to the possibility of disruption as the interconnected nature of their operation creates many vulnerabilities. The interdependence between suppliers, manufacturers, and retailers in the supply chain can lead to various unforeseen situations, subsequently exposing organizations to the risk of disruption. Without an effective strategy, the uncertainty and unpredictable events that could occur might lead to poor supply chain performance and severe loss. Furthermore, major disruptions could cause lasting effects throughout the supply chain. Thus, the importance of supply chain disruption management has been widely emphasized and has become even more crucial in the current global scenario.

The recent virus Covid-19 outbreak has shown how various industries were affected by the major disruption. The impact of the pandemic spans the automotive sector, tourism industry, aviation industry, oil industry, construction industry, telecommunication sector, food industry, and healthcare industry. Supply and sourcing strategies were disrupted because of delayed or stopped manufacturing processes due to the lack of stock, manpower, and travel restrictions. While industries like tourism or aviation suffered from lockdown and travel restrictions, the healthcare supply chain on the other hand was faced with increased demand as the shortage of supply of personal protective equipment and medical equipment affected all around the world.

In India, Singh et al. (2021) reported that the food industry supply chain has been severely affected as the lockdown orders caused the unavailability of the labor force

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and truck operators. Small and medium industries had to suspend manufacturing, while large-scale manufacturing firms had to reduce production capacity to control the outbreak (Udofia et al. 2021). Similarly, in Pakistan, many manufacturing activities were facing substantial delays as their suppliers, which are mainly based in China, are operating at a limited capacity (Butt 2021).

The impact of a pandemic has demonstrated the importance of developing a resilient supply chain for operational continuity. However, alongside the need to develop resiliency in the supply chain, sustainability goals should continue to become the priority for the supply chain. Achieving environmental sustainability in the supply chain would help to reduce costs, improve safety, and protect the environment in addition to increasing customer satisfaction and loyalty. Sustainability measures could range from a small operational improvement, adoption of green technology, or the extent of reconfiguring the whole supply chain, all with the ultimate goal of better environmental performance.

Many researchers have suggested that a supply chain with high resilience would be more sustainable. Mehrjerdi and Shafiee (2021) claim that a supply chain should be resilient enough to maintain its sustainability. However, as the organization takes measures to build resiliency into the supply chain by developing the ability to prepare for, address, and restore operational continuity (Golgeci and Ponomarov 2013), these courses of action could compromise the sustainability aspect of the supply chain. The supply chain practices in managing disruption risks could have a significant impact on the environmental sustainability of the supply chain (Govindan et al. 2014).

Thus, the motivation of this chapter is to address the relationship between strategies employed by a supply chain to build resiliency against disruption and the impact of those practices on the sustainability aspects of the supply chain. Understanding the relationship between resilient practices and sustainability would be important to balance the two supply chain goals.

This chapter could serve as a starting place to gain an understanding of the concept of a resilient and sustainable supply chain, and key strategies to achieve these goals. The chapter is organized as below. In Sect. 2, we present a summary of resilient strategies for dealing with supply chain disruptions. Next, the environmental sustainability aspect of the supply chain is reviewed in Sect. 3. Section 4 discusses the relationship between the resilient practices and sustainability aspect of a supply chain, Sect. 5 presents the literature on the quantitative models that were developed to address the supply chain problem concerning sustainability and resiliency issues. Section 6 presents some observations and insights, while Sect. 7 ends the chapter with the conclusion.

2 Resilient Practices in Supply Chain Disruption Management

Risks in the supply chain can be defined as disruption, uncertainty, disasters, and dangers that are inherent in the supply chain (Ghadge et al. 2013). According to Lynch (2012), any change that occurs in the supply chain can lead to potential risks that interfere with the operation of the entire system. In addition, the source of these failures or disruptions can occur regardless of the scale and is not limited to a function, process, source, or location. Even without a large-scale unprecedented event, disruptions can appear in the daily operation of a supply chain when there are risks of failures in machine operation, slow deliveries, poor planning and scheduling, lack of raw materials, as well as human or employee fault (Kilpatrick 2020). Thus, the concept of a resilient supply chain is based on the rationale that not all risks are avoidable but by building resilience, an organization can address the threat of disruption to their supply chain and ensure continued delivery of products and services to customers (Tukamuhabwa et al. 2017).

Literature offers different classifications of the type of risk. Chopra and Sodhi (2004) categorizes supply chain risk into demand risk, intellectual property risk, risk behavior, and political risk or social. Ghadge et al. (2013), classify the types of risks into six key characteristics: process, organization, location, data, application, as well as technology. Process risk revolves around the sequence of activities in the organization and their end results while organizational risk focuses on human resources concerning their capabilities and roles as well as the relevant team structure and organizational units. Meanwhile, location risk is associated with geographical location and related issues with physical facilities and infrastructure, while data risk focuses on means of addressing the content, structure, and relationships associated with information data. In addition, application risk refers to the capabilities and usability of information systems. Alongside that, technological risk involves the equipment and technology application.

The strive to build resiliency in the supply chain would serve as the long-term strategy for an organization to handle unexpected and continuous disruptions. With this capability, the organization could proactively plan the supply chain to predict unexpected disruptions, respond to disruptions continuously, be able to control structure and function, and be able to maintain robust or better operations to gain advantage in competitiveness (Ponis and Koronis 2012). By being resilient, the supply chain would be able to reduce the impact of vulnerability (due to disruption) through the expansion of required levels of readiness, rapid response, and recovery capabilities (Chowdhury and Quaddus 2015). From a much wider perspective, resilience has been defined as the adaptive capacity where the system is capable to adapt to new conditions and improve other dimensions of performance (Burnard et al. 2018).

Literature has discussed several supply chain capabilities that are strongly linked to resiliency in the supply chain. These include agility, flexibility, responsiveness, adaptability, alignment, robustness, and redundancy (Christopher and Peck 2004; Mensah and Merkuryev 2014; Ponomarov and Holcomb 2009; Sodhi and Tang 2012).

Christopher and Peck (2004) defined several principles for supply chain resilience which include supply chain re-engineering whereby risk reduction is factored in the supply chain design.

According to Shao (2013), responsiveness, competency, flexibility, and speed are characteristics of being agile. Improvement in agility could be achieved by preparing detailed plans and focusing on supply chain policies and initiatives that promote collaboration, integration, and timely information sharing. Through collaboration, faster disruption recovery could be achieved as supply chain parties could coordinate their responses and share resources. Kamalahmadi and Mellat-Parast (2016) suggested that developing contingency plans using flexibility in suppliers' production capacity is an effective strategy for firms to mitigate the severity of disruptions. In addition, the flexibility and reliability of the suppliers and regions play a significant role in determining contingency plans during disruption. Tukamuhabwa et al. (2017), also highlighted the need to increase flexibility and supply chain agility while forming collaborative supply chain relationships. Additionally, the power structure in a supply chain governs the type and configuration of supply chain flexibility (Angkiriwang et al. 2014).

According to Chopra and Sodhi (2014), companies can build resilience by isolating or balancing the supply chain and avoiding too much resource centralization. Mensah and Merkuryev (2014) proposed lean production, the six sigma strategy, and emphasized the strong corporate culture required in a resilient organization. Moreover, Ambulkar et al. (2015) emphasized the need for firms to have a strong awareness of disruption risk and the ability to learn from prior disruptions, the ability to reconfigure resources to manage disruption, and have an infrastructure that is well prepared to handle disruption risks. Dubey et al. (2019) argued that supply chain visibility improves resilience in the supply chain as it facilitates information sharing and data connectivity among supply chain partners as well as building trust when each party shows their commitment to the partnership. Hasani and Khosrojerdi (2016) proposed six resilience strategies including facility dispersion, facility reinforcement, production of semi-manufactured products, multiple sourcing, inventory buffer, and use of a primary and alternative bill of material.

The significance of supplier and inventory management systems has been covered in the literature in relation to supply chain resilience strategies. Kamalahmadi and Parast (2017) evaluated the effectiveness of mitigation strategies using backup providers and emphasized that comprehensive supply risk management strategies should take into account the impact of disruption on interconnected suppliers. Additionally, it is important to use selection criteria that can help reduce disruption and its impact, such as supplier technological capabilities, financial and business stability, as well as process reliability. By creating redundancy through the strategic and selective use of spare capacity and inventory, firms can utilize spare stocks, multiple suppliers, and extra facilities to cope with disruptions (Tukamuhabwa et al. 2015). Moreover, inventory management needs to be aligned for the entire supply chain to minimize the risk of inventory shortage or absence. Furthermore, logistics capabilities need to be enhanced by reducing cycle times and delivery times as well as efficient knowledge management and customer service so that rapid disruption

recovery can occur (Ambulkar et al. 2015). Razavian et al. (2021) also highlighted the use of multiple suppliers, emergency inventory, and protection of suppliers as essential strategies to build resiliency and minimize costs. Udofia et al. (2021) emphasized productivity management to maintain customer satisfaction during disruption.

Following the Covid-19 pandemic, Martins et al. (2021) highlighted three critical elements of resilience: the decision-making process, human resources development and knowledge management, and data security. Additionally, the authors highlighted the importance of digital technology to enhance resilience. The effect of severe disruption would necessitate investment in process digitization and technologies to improve the analysis and decision-making process. Meanwhile, Ivanov and Dolgui (2021) proposed a framework of supply chain disruption management comprising data-driven disruption modeling in the supply chain and uncovering the interrelations of risk data, disruption modeling, and performance assessment. The digital supply chain model would allow end-to-end visibility to improve resilience and allow contingency plan assessment. The authors emphasized the importance of supply chain monitoring and visibility in post-pandemic recoveries.

3 Environmental Sustainability of a Supply Chain

According to the United Nations (UN), environmental sustainability is about acting in a way that ensures future generations have the natural resources available to live an equal, if not better, way of life than current generations. Under UN Sustainable Development Goal 12 (SDG), among the targets are sustainable use of natural resources, efficient management of chemical and all waste, and a reduction in waste generation by the year 2030. In addition, SDG-13 has been developed specifically to address climate change and its effects (*Responsible Consumption and Production | United Nations ILibrary*). In achieving this ideal, both individuals and institutions must play a role in environmental sustainability. Sustainability is important for organizations not only to achieve compliance with regulations and meet stakeholders' requirements, but also to gain business advantages such as improved business image, productivity, and product quality (Youn et al. 2013; Zailani et al. 2015).

In the supply chain context, the aspect of sustainability is seen as a combination of considerations of economic aspects, environmental impact, and social responsibility with an efficient inter-organizational business system. This includes the management of materials, information, capital flows, as well as procurement processes that are effective and able to meet the needs of stakeholders to increase the profitability, competitiveness, and resilience of the organization for the short and long term (Ahi and Searcy 2013). Environmental impact factors in operations should also be addressed for the long term and on an ongoing basis. Environmental problems originating from numerous industries could include acid rain, air, asbestos, metals, toxic substances, and universal waste (Balon 2020). For example, in the automotive industry, pollution results from inefficient use of resources, and the automotive industry are one of the main pollution sources in Asia (Zailani et al. 2015). Waste

materials issue is among the major concern emphasized in the literature including packaging materials waste and scrapped toxic materials (Gupta and Palsule-Desai 2011; Barbosa-Póvoa 2009; Bonney and Jaber 2011). Moreover, traffic congestion has also been highlighted as one of the environmental impacts of supply chain operations (Chin et al. 2015).

Effects of greenhouse gas emissions, especially carbon dioxide emissions from supply chain activities have been heavily mentioned in the literature (Tang and Zhou 2012; Gupta and Palsule-Desai 2011; Eltayeb et al. 2011; Barbosa-Póvoa 2009; Bonney and Jaber 2011). Carbon emissions in the supply chain can be contributed to the procurement process, product manufacturing, distribution and retail, and disposal and recycling. Most of the carbon emissions are accounted for in the transportation and logistics processes of the supply chain (Homayouni et al. 2021). Other mention of environmental concern includes water pollution (Tang and Zhou 2012), soil pollution (Eltayeb et al. 2011), and the production of hazardous material (Gupta and Palsule-Desai 2011) and (Barbosa-Póvoa 2009).

The drive for sustainability would entail the whole parties in the supply chain to be responsible and involved in the initiative. The efforts could be characterized by the approaches taken in managing resource utilization, production processes, and logistics activity that occur daily in supply chain operations in such a way that there will be a minimal harmful impact on the environment. Additionally, the impact on energy consumption is a driver of efforts to increase efficiency in the use of utilities (Tang and Zhou 2012; Chin et al. 2015; Gupta and Palsule-Desai 2011; Eltayeb et al. 2011).

The extent of the implementation of environmental sustainability strategy would differ from one organization to another. A few examples can be offered. Azevedo et al. (2013) presented in their study how one company had changed their plant roof to include transparent roof material so that natural light could be used. The other company in the same study had changed a particular production process to reduce the water and energy consumption at the same time that it reduced the processing time. All the companies employ reverse logistics management, mainly by using returnable/reusable packages and racks, and return of defective items. According to Govindan et al. (2020), sustainability practices either through a green supply chain approach or a sustainable supply chain management can lead to improved operational performance companies through waste reduction, effective use of utilities, employee involvement, as well as community support. Carbon footprint reduction can also be achieved through sustainability program implementation.

4 Relationship Between Resilience Strategies on Supply Chain Sustainability

Environmental practices must be addressed to assure that the management system is sustainable (Carvalho et al. 2011). Sustainable supply chain practices such as green procurement as well as sustainable packaging can have a positive impact on the economic, social, and operational performance of the supply chain (Zailani et al. 2012). According to Azevedo et al. (2013), environmental performance improvement through a green supply chain management approach can reduce the environmental impact of industrial activities without sacrificing quality, cost, reliability, performance, or efficiency of energy use.

There is an argument that sustainability and resilience objectives could be conflicting with each other. Esfahbodi et al. (2016) stated that the adoption of sustainable practices would lead to better environmental performance, but does not necessarily lead to improved cost performance. Similarly, resilient supply chains may not be the lowest cost even though they would possess the capability to cope effectively with disruptions.

In an ideal situation, a supply chain will be resilient and sustainable when it has the required capabilities to respond effectively to disruption while being able to reduce its vulnerabilities (Nayeri et al. 2022). However, according to Mari et al. (2014), it is hard to maintain supply chain network sustainability when the supplier is vulnerable to disruption or when the manufacturer or warehouse is in a risky location.

Fahimnia and Jabbarzadeh (2016) suggested that sustainability practices through the lean and less waste approach could create vulnerability when disruption occurs, as protective redundancy is reduced, thus affecting the disruption management capability. In inventory management, the optimal lot-sizing decision would balance the need for protection against disruption and minimizing carbon emissions. Small and frequent lot-size lead to more carbon emissions due to transportation and increased logistics costs and a greater risk of supply chain disruption, but carbon emissions due to warehouse operations and inventory costs can be saved (Kaur and Singh 2019).

According to Govindan et al. (2014), the use of flexible transportation to mitigate disruption risk will have a significant impact on the environmental sustainability of the supply chain. Furthermore, planning for additional capacity to achieve robustness would require higher supply chain cost (Aldrighetti et al. 2021). Meanwhile, an implementation of a resilient strategy through facility fortification has been reported to increase supply chain resilience and enhances sustainability (Ivanov 2018).

Supplier selection is very important in designing a sustainable supply chain in order to minimize carbon footprint from the purchased materials (Mari et al. 2014). However, sustainable sourcing practices with only a few numbers of suppliers would limit the ability to switch suppliers during disruption.

5 Modeling of Sustainable and Resilient Supply Chain

Even though disruptions could be an everyday occurrence in the supply chain operation, the recent pandemic has amplified the need for effective strategies to mitigate them. As with other optimization models concerning supply chain problems, the modeling approach can be used to assist in the policy and decision-making process. This approach would allow for the exploration of other opportunities and alternative problem solutions. In addition, this also enables a systematic understanding of the whole supply chain system.

The supply chain planning stage is the phase where many significant strategies can be implemented. Thus, the supply chain network design area has been the focus to integrate sustainability into the supply chain model. Similarly, the incorporation of resilient aspects has been approached through supply chain network design (SCND). In the modeling of sustainable and resilient supply chain network design, the goals are set higher wherein the objectives now are to minimize cost and maximize environmental and social performance, while ensuring that the designed supply chain is resilient to supplier disruptions. The expected disruption cost is used to summarize different components that are related to a disruption including damage cost, recovery/restoration cost, trans-shipment cost, procurement cost penalty, backlog cost, delay penalty cost, and transport cost penalty (Aldrighetti et al. 2021).

Shafiee et al. (2021) developed a model integrating leanness, sustainability, and resilience in the supply chain using mathematical modeling. Resilient strategies of multiple sourcing and backup supplier were taken into account in the model. The economic objective function minimizes operational and strategic costs, while the environmental objective function reduces the pollution emitted from installation and transportation.

Salama and McGarvey (2021) proposed a multi-integer linear program model of a resilient supply chain to the pandemic effects. With constraints on workforce limit, operating hours, and shipment size in addition to many limiting factors imposed by the pandemic, different scenarios were studied for the optimal supply chain design and management during the pandemic.

Mehrjerdi and Shafiee (2021) presented a multi-objective mixed-integer programming model for a closed-loop supply chain. In this research, different dimensions of sustainability have been taken into account with consideration for reducing the total cost, energy consumption, pollution, and increasing job opportunities. Information sharing and multiple sourcing strategies have been employed in model development for making the supply chain more resilient.

Mari et al. (2014) proposed a model for a sustainable and resilient supply chain using the weighted goal programming method. The sustainability goal is represented by the carbon footprint of procured materials, and the carbon emission from transportation and manufacturing. The economic goal is to minimize total supply chain network costs. Meanwhile, a resilience metric is used to determine the expected disruption cost or the resilience aspect of the model. The main objective is to ensure that the supply chain network is sustainable, as well as resilient enough to cope with

disruption. The case example shows that when the weightage for the total cost goal is high, the sustainability and resiliency of the supply chain would be reduced.

In the SCND model developed by Jabbarzadeh et al. (2016), the authors consider the risk of disruptions, uncertainties in demand, probability of disruption occurrence, and capacity of facilities in the model. The model's objective is to minimize the total cost of establishing the network while maximizing supply chain resilience. The real-world application involved a case study in which the company planned to build fortified storage units to mitigate fire disasters. The finding from the study shows that facility and initial capital investment are vital in developing a resilient supply chain and reducing strategic supply chain costs.

Fahimnia and Jabbarzadeh (2016) presented a model for a sustainable and resilient supply chain where the aim is for sustainability performance to remain unaffected or only slightly affected by disruptions. The sustainability performance scoring approach is used to quantify the environmental and social performance of the supply chain, focusing on suppliers' sustainability performance. In the case study application, dynamic sustainability trade-off analysis is used to design a supply chain that can provide efficient and effective solutions in normal situations and during disruption. Analysis from the study shows that a small increase in the regular cost of the supply chain can lead to the development of a resiliently sustainable supply chain. In another study by Zahiri et al. (2017), a sustainable-resilient supply chain network design is proposed for the pharmaceutical industry to minimize total network cost and environmental impact and maximize social impact. The social measures in this study include the consideration of job creation and unemployment criteria.

Meanwhile, Ivanov (2018) proposed a scheduling model that considers the coordination of recovery actions in the supply chain. A resilience index was proposed by using the notion of attainable sets which are the range of performance outcomes of the control policies in the presence of disruptions. The model could be used to adjust the supply chain production schedule during severe disruption recovery and assess the resilience status of the supply chain.

Jabbarzadeh et al. (2018) proposed a hybrid approach to design a resilient and sustainable supply chain. In the two-step phase, the sustainability assessment of the suppliers was made followed by the development of a stochastic bi-objective optimization model using sustainability scores as the input parameters. The objectives are to determine the sourcing decisions and resilience strategies such as the need for a backup supplier and extra production capacities. In the case problem of a pipe manufacturing company, environmental measures involved safe treatment and disposal of hazardous materials, waste collection, emission of pollutants, and renewable and non-renewable energy consumption. Additionally, the social criteria focused on human rights, labor working conditions, society contributions, and product responsibility issues, while the economic measures included market shares, profitability, and operating expenses. Findings from the study show that the higher the level of sustainability, the higher the total cost of the chain supply would be. Trade-off analysis was performed to identify opportunities to improve performance such that sustainability remains cost-efficient under various disturbance scenarios.

Later, Pavlov et al. (2019) proposed a network redundancy optimization model using the case example of seaport operations. The authors studied a trade-off between sustainable resource utilization and supply chain resilience in the contingency plan for disruption scenarios that are caused by supply and seaport structural disruptions. The proposed model aims to create resiliency strategies related to the design stage, such as backup suppliers, re-routing in transportation channels, and capacity adjustments. Meanwhile, Hosseini et al. (2019) proposed a stochastic bi-objective mixed-integer programming model to support the decision-making on how and when to use both proactive and reactive strategies in supplier selection and order allocation. The supplier resilience cost is considered to include the mitigation cost to reduce vulnerability and the contingency cost to enhance recoverability. Findings from the study showed that total resilience cost will vary according to different disruption scenarios.

Razavian et al. (2021) developed a model for resilient supply chain model with concurrent consideration for material and financial design. Multiple sourcing, emergency inventory, and additional production capacity were considered and the results show that the strategies could improve the supply chain performance. Meanwhile, the study by Homayouni et al. (2021) proposed a sustainable logistics model that considered assorted vehicle types and gas emissions involved with product transportation. Sustainable logistics planning has the objectives to minimize total cost and maximize the vehicle's transportation performance. The authors categorized carbon emissions sources into operation-related and transportation-related while considering two carbon policies: carbon tax and cap-and-trade. The real-world application of the model involves the design of a supply chain for carbon manufacturers with environmental aspect considerations. This study employed a multi-choice goal programming method to solve the problem and the findings suggested that a cap-and-trade policy is a better carbon policy for reducing pollution.

These studies show the different approaches used in the modeling of sustainable and resilient supply chains. Among the resilience strategies considered include expansion of supplier capacity, use of backup suppliers, and resource investment for faster supplier recovery. Total supply chain cost represents the economic aspect of sustainability while the environmental objective is usually represented by the carbon emissions criteria.

6 Observations and Insights

Following a high-impact disruption event like the Covid-19 pandemic, it is expected that there will be much focus and emphasis on building resiliency in the supply chain to ensure operational continuity during challenging times. Elements of resilience and sustainability like flexibility, agility, robustness, green, and collaboration are not new and have been highlighted extensively in the literature. However, the challenges are to understand the interdependence between these elements when combined together. The actual implementation of resilient strategies has been focused on manufacturing

flexibility and transportation capability. Collaboration in the supply chain is also crucial for a coordinated response when disruption occurs.

The literature on the resilient supply chain has shown that decisions on inventory management, supplier selection, and facility decision are always important to the supply chain. However, the utilization of digital technology has been highlighted as essential to improve both the resilience and sustainability of the supply chain in the current scenario. The application of digital technology is an important strategy to cope with the disruptions caused by the pandemic as it allows the means to cope with the restriction imposed (Shen and Sun 2021). However, the technology risk would need to be fully understood and an action plan would be needed for possible new risks.

Understanding the relationship between resilient practices and sustainability is important. Literature has shown that different resilient strategies would affect the sustainability of the supply chain differently.

The application of the optimization model can be used to find the trade-off between resilience and sustainability. While resilient supply chains would offer better protection against disruptions, they might be costly to implement and maintain. Sustainable practices, on the other hand, can create environmental benefits that offset some of these costs. There would be a challenge for the supply chain manager to accurately evaluate this cost. By understanding how certain changes to a supply chain might impact both resilience and sustainability, it is possible to make informed decisions about which practices to adopt. Furthermore, successful implementation in real practice would depend on the specific supply chain issue and managerial policy.

7 Conclusions

A supply chain should achieve by some means the balance of economic, social, and environmental components of sustainability. In this chapter, we reviewed the resilient practices employed as mitigation strategies against disruption risks in the supply chain. We discussed the environmental sustainability aspect of the supply chain. In addition, the interrelationship between the resiliency element and the sustainability performance of the supply chain is also examined.

The review of the existing quantitative work on sustainable and resilient supply chains shows how the optimization model is used to meet the different objectives including supplier selection and developing a contingency plan and a logistics plan. Some of the studies highlighted that resilience enhancements can be achieved at only a small cost increase.

Different case study results show how the supply chain planning was designed to the specific objectives of the supply chain. Additionally, the real-world application of the model illustrates the improvement in environmental performance and reduction of vulnerabilities in the supply chain.

The research area of the sustainable and resilient supply chain is still expanding. There is still lacking a comprehensive supply chain solutions to improve resilience

and sustainability as supply chain policies and practices should be supported by an effective operational action plan. Further research should consider if a resilient strategy through digital technology application would have an impact on other aspects of sustainability.

Additionally, the decision-making support system using a model-based can be explored from many approaches. The complexities and various supply chain operations offer opportunities for different research perspectives. More research is needed to address and capture the different elements required for a successful sustainable and resilient supply chain implementation.

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