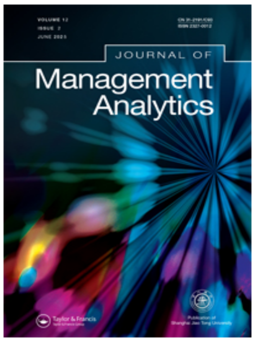

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Post-pandemic sustainable supply chain recovery planning: a case study from an automobile industry

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Along with several sectors, manufacturing industries have been concerned with the devastating impacts of COVID-19 on their supply chains (SCs). Many instantaneous decisions and strategies have been incorporated to mitigate the impacts of COVID-19. However, the significance of these strategies has not been analyzed in the literature considering long-term perspectives and sustainable implications. To fulfil this gap, we develop a sustainable recovery approach with a set of strategies that allow manufacturing SCs sustainable growth in the post-COVID-19 world. To analyze the results, we conduct a case study of automobile SCs of Bangladesh, an emerging economy. It identifies and assesses 16 post-COVID-19 sustainable recovery strategies and evaluates their causal relationships. The findings imply that managers should concentrate on 'Developing a robustness-based risk management system for eliminating SC vulnerabilities' and 'Investing in collaborative strategic planning'. The findings can help SC managers and practitioners to develop sustainable recovery strategies in the post-pandemic era.

Keywords: automobile supply chain; emerging economy; post-COVID-19; sustainable recovery planning

1. Introduction

The COVID-19 pandemic has been a global catastrophe affecting millions of people. It has simultaneously placed the sustainability of supply chains (SCs) into disarray (Singh et al., 2021). Demand and supply mismatches have been observed in the global SC, resulting in chaos and resonance effects. The effect of the pandemic on different industries varies because of the variation in demand and supply patterns (Sharma et al., 2020a). However, the sustainability of all industries has been badly

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impacted during the COVID-19 pandemic due to the disruption in manufacturing and logistics activities (Chamola et al., 2020). As a consequence of the pandemic, after-shock effects have emerged, and the sustainability of SCs is prone to suffer in the medium to long term due to financial constraints, production performance, delivery time, and other issues (Ivanov, 2021; Laing, 2020). In sum, the pandemic revealed the deficiencies and lack of resilience in the current global SC, resulting in a loss of sustainability that will take a long time to recover (Singh et al., 2021).

Manufacturing industries such as textiles, food and beverages, aerospace, and automotive have always been key pillars of economic growth and development in developing countries. The automotive industry is a global one with fierce rivalries on a global scale (Kufelová & Raková, 2020). The expansion of the automotive industry needs to be accelerated because it generates significant economic revenue for a country (Peter et al., 2019). Due to the global SC disruption caused by COVID-19, automobile industries also experienced resource shortages, risks, and restrictions in their manufacturing processes because trade activities had to be suspended to stop the virus from spreading (Anser et al., 2020). For example, demand for automobiles built in Europe is expected to stay 8% below its pre-crisis level in 2021 based on forecasts from the OECD Economic Outlook and an estimated association between car sales and GDP growth. Because of the automotive industry's deep integration into global value chains, COVID-19 has caused severe negative consequences for SC. However, sustained low demand and breakouts may cause subcontractors to terminate operations due to insolvency or bankruptcy. These have so far had a less substantial impact on the processes of crisis transmission than the shock to demand (Klein et al., 2021). As consumers, communities, and local and global governments exert pressure on one another to adopt sustainable strategies, it is necessary to look into how these COVID-19 concerns might be addressed in order to accelerate the recovery of the automobile SC (Yu et al., 2022).

As for the sustainability of the Bangladeshi automobile industry, which has grown significantly over the last two decades with 100% foreign direct investment (Miraz et al., 2016), the COVID-19 pandemic has been a big misfortune. Before the pandemic hit the business market in Bangladesh, the automobile industry had expanded at an annual growth rate of 15–20%, and the auto parts market had a growth rate of 12% (Suman et al., 2020). The manufacture of two-wheelers also saw massive growth during this period, shifting the trend of foreign importation to the local manufacture of parts (Absar et al., 2021). However, the Bangladesh Road Transport Authority (BRTA) reported a 21% decrease in registered passenger vehicles in 2020 amidst the pandemic (Zafri et al., 2021). The economic sustainability of this industry has also been severely suffering due to a drop in gross domestic product (GDP) growth (Raj & Kumar, 2021). Moreover, the chip shortage trend also started in this sector in the second half of 2020, and many automakers were forced to shut down some production lines due to this issue (Wu et al., 2021). Experts predict that if sustainable recovery strategies are not implemented, the automobile SC might struggle to recover its operational and financial sustainability in the post-pandemic environment (Nayak et al., 2021).

As SCs in emerging economies are undergoing a metamorphosis after the COVID-19 pandemic, technology and social innovations can play a crucial role in recovering their sustainability (Sarkis, 2021). Moreover, sustainability can be accelerated throughout the period of operational and economic recovery after the effects of

COVID-19. Many policymakers and practitioners worldwide support the simultaneous adoption of certain strategies to advance sustainable recovery in the post-COVID-19 era (Hepburn et al., 2020). Automobile SCs in emerging economies also need an immediate focus on developing post-COVID-19 recovery strategies that can help them restore the sustainability and dynamics of the business environment and quickly mitigate the disruption caused by the pandemic. There have been studies in recent literature on mitigating SC disruptions in emerging economies during and in the post-pandemic environment in the clothing, pharmaceutical, and other industries (Chowdhury et al., 2021; Taqi et al., 2020). Considering the automobile industry, countries like China have gotten more attention than others as it produces most automotive and automotive parts in the world (Ivanov & Dolgui, 2020). However, considering their complexity and growth potential, particular focus has not been given to automobile SCs in emerging economies like Bangladesh. Given that post-COVID-19, social and economic growth will significantly affect subsequent sustainable development, which can revive and assist the nation's economy in advancing to a better and more sustainable manner (Agrawal et al., 2021). Hence, investigating sustainable recovery strategies in the post-COVID-19 world has theoretical and practical implications for realizing an integrated and collaborative automobile SC.

Therefore, this study focuses on identifying the most critical post-COVID-19 sustainable recovery strategies in the automobile industry of Bangladesh and evaluated the interrelationships between those strategies by addressing the following three research questions (RQs).

RQ1: What are the major sustainable recovery strategies for establishing a resilient automobile SC in the post-COVID-19 world in emerging economies?

RQ2: How are various sustainable recovery strategies interrelated with each other?

The following research objectives (ROs) are set to answer the above RQs.

RO1: To identify sustainable recovery strategies to establish a resilient automobile SC that helps practitioners in the automobile SC in Bangladesh and other emerging economies overcome the adverse consequences of the COVID-19 pandemic.

RO2: To analyze cause-and-effect relationships and determine the priorities of the recovery challenges that are interrelated with each other.

To accomplish the above-mentioned ROs, this research deploys a structured multi-criteria decision-making (MCDM) approach with the decision-making trial and evaluation laboratory (DEMATEL) to address the complexities of automobile SCs in emerging economies.

The DEMATEL method has been widely applied in various areas, including airline safety e-learning, decision-making, knowledge management operations, business policy selection systems, agriculture, technology innovation, marketing, and consumer behaviour (Jeng & Tzeng, 2012). Effective decision-making is becoming more desirable as the environment becomes more complex. Decision-makers must always evaluate a dynamic and perplexing situation, determine the cause of a problem, choose an acceptable solution, and implement an effective action plan (Abughazalah et al., 2023). The foremost attribute of the DEMATEL method is constructing interrelations among criteria (Gumaei et al., 2020).

Aside from the MCDM models, other tools such as data envelopment analysis (DEA), the preference ranking organization method for enrichment evaluations

(PROMETHEE), and the technique for order preference by similarity to ideal solution (TOPSIS) could be used as an alternative approach for service quality evaluation (Hsu et al., 2018). The DEMATEL method is critical in tackling complex decision-making challenges because it provides a structured way to analyse interdependencies, prioritize criteria, and facilitate decision-making (Alshahrani et al., 2024). The grey DEMATEL method has been used in this research to analyze and evaluate post-COVID-19 recovery strategies and to determine the key factors and their classifications. So far, only a few studies have focused on sustainable recovery strategies of automobile industries and revealed the internal connection between sustainable recovery strategies and their economic benefits.

The Bangladeshi automobile SC is chosen due to its prospect and potential to grow into a new giant in the automobile sector through subsequent foreign investments, collaboration with partner nations, and legislative assistance from the local government (Zafri et al., 2021). The findings of this study prioritize sustainable recovery strategies in order to determine the priority of one strategy over another. As a developing country, it would be very challenging to mitigate the impact of the pandemic in the post-pandemic era with limited resources and scarcity. Thus, this ranking will ease the decision-making process of SC practitioners and help them decide which sustainable recovery strategies to consider first under diverse circumstances.

The rest of the paper is structured as follows: Section 2 presents a brief literature review and discusses the research gaps. Section 3 describes the study's methodological approach. Section 4 provides the case study description. The results and discussions are presented in Section 5. Section 6 explains the research implications. Finally, Section 7 concludes the study.

2. Literature review

SC disruptions can be caused by events external to the SC, such as natural disasters, and are beyond the firm's control. Due to the recent COVID-19 pandemic, most organizations outsource many manufacturing and SC activities, which has resulted in a high reliance on suppliers worldwide. This has increased the system's complexity, making it particularly sensitive and vulnerable to SC disruptions. Like all other SCs, COVID-19 impacts on the automobile SC have been disastrous. Existing literature has already alluded to the severe consequences of COVID-19 in automobile SCs. However, sufficient discussion should be made about the SC to clarify the recovery strategy development in emerging economies post COVID-19.

2.1. *Automobile SCs and sustainable post-pandemic recovery strategies*

The COVID-19 pandemic's effects on the automotive industry can be seen in supply restrictions and a drop in consumer demand. Additionally, the pandemic has caused significant financial losses in SC (Meyer et al., 2021). The dependence of the automobile industry on China as a worldwide SC partner has had a considerable influence (Belhadia et al., 2020). Additionally, any disruption in China or India affects firms elsewhere. The majority of manufacturers and suppliers have already informed their global automobile manufacturer businesses of delivery delays because of plant closures, border closures, and other restrictions. These interruptions affected the entire automobile supply chain, impacting both supply and demand. Due to the COVID-19 pandemic, which is the cause of the temporary shutdown of most manufacturing plants in other nations, automobile manufacturing businesses are consequently suffering more inconveniences. A company is unable to continue its business operations due to the loss of earnings and production. Furthermore, the modernity of the situation makes it difficult to access historical data, which contributes to the uncertainty surrounding the total effects on businesses. In order to have sustainable operations, organizations must rethink their current methods in order to develop new skills and put into place fresh circular solutions that meet the issues of economic, environmental, and social elements (Sarker et al., 2021; Williams et al., 2017). Researchers presented different methodical examinations of how disruption impacted the national economies and GDP growth, which could help create and carry out efficient post-pandemic plans, such as an emergency relief plan and a comprehensive socioeconomic plan to deal with COVID-19 related disturbances (Shahed et al., 2021).

While several major outbreaks in the past, the intensity of the current COVID-19 pandemic is significantly higher than in previous events. As a result, a lack of preparedness to deal with such an outbreak has been reported (Sharma et al., 2021). To make national economic development smoother and faster, this research supports that governments worldwide should offer short-term loans, set favourable economic policies, and have robust national macroeconomic regulations for the companies in their countries (Zhang, 2023). Maruti Suzuki India Limited (MSIL), in automobile manufacturing industries, did a single case analysis to figure out how the epidemic (COVID-19) has affected their supply chain management and how they have adapted their business strategy to deal with it (Pharswan et al., 2023).

The authors reported the competencies required to improve the automotive supply chain routine operations to address the parts supply crisis from multitier suppliers in the post-COVID-19 environment (Santharm & Ramanathan, 2022). This paper has identified nine prominent business sectors on which the effect of the outbreak has been analyzed, and an attempt has been made to provide measures for mitigating these perils through the application of circular economy business models (Agarwal et al., 2022).

All countries enforced a strict nationwide lockdown to control the outbreak (Nayak et al., 2021). The rigorous lockdown worldwide has severely disrupted this sector's production sustainability. As people had to stay at home during the lockdown, the use of automobiles decreased globally (Chamola et al., 2020). Even though production resumed in some countries in March 2020, factories across the globe have recorded several problems, i.e. raw material and workforce shortages (Belhadia et al., 2020). Thus, the COVID-19 pandemic demonstrated the necessity to broaden global supply strategies by highlighting how vulnerable the sustainability of the automotive SC is (Ishida, 2020; Rahman et al., 2022).

The effects of the COVID-19 pandemic on automobile SCs and mitigating measures are covered in the existing literature. The service and manufacturing SC resilience in the automotive industry during the COVID-19 pandemic was examined by Belhadi et al. (2021). Their research showed that utilizing Industry 4.0 cutting-edge technologies and developing localized supply sources were the most effective means of lowering COVID-19-related risks in the automobile industry. Concerning automobile SCs in emerging economies, continual coordination and communication with relevant personnel and inventory management are critical to success during this challenging time. Internet of Things (IoT) can assist businesses in navigating the ongoing crisis and help them emerge stronger once activities resume normal and restore sustainability. Another result was to play a vital part in overcoming the issues caused by COVID-19 by delivering real-time information through big data analysis on diverse supply chain activities. Additionally, collaboration amongst supply chain stakeholders is required to meet the pandemic's problems and quicken the use of digital technology. Making a recovery plan for a resilient post-pandemic supply chain will be aided by this study. The issues faced by automotive SCs were discussed by Nayak et al. (2021), who also provided crucial information for formulating strategic solutions. Also, With the use of the COVID-19 pandemic's lessons, Yan et al. (2020) conducted an empirical study to examine SC views in the automotive and other SCs. Moosavi and Hosseini (2021) investigated a measurement technique to assess the effectiveness of resistance tactics in a multi-stage SC. Following the simulation, they suggested resilience solutions, such as prepositioning additional inventory to examine demand fulfilment and enable a greater service level. Measuring SC resiliency to develop a response plan during a pandemic or high-magnitude disruption is also important (Ahmed et al., 2023).

Moreover, during the COVID-19 pandemic, localized sourcing became more important than global SC sourcing for automobile SCs, as dependence on global sourcing led to the long-term discontinuation of sustainable operations (Ishida, 2020). The supply chain's globalization was viewed as a drawback during the pandemic. On the other hand, a looser collaboration can withstand a pandemic if the supply chain is localized. According to the Capgemini Research Institute (2020), 65% of businesses are currently investing predominantly in regionalizing and localizing their supplier and manufacturing bases to decrease risk and also to be close to their consumers. Agile and sustainable procurement through the digitization of supplier networks can also benefit the automobile SC in emerging economies by allowing better collaboration, more transparency, and speeding up the process (Raji et al., 2021).

To stay afloat in the post-pandemic environment and minimize SC disruptions, automobile SCs in emerging economies should focus on sustainable collaborative strategic planning, including small- and large-sized industries. Additionally, greater collaboration between governments and companies will be required in the post-pandemic world to ensure sustainability in global supply networks (Ahmed et al., 2022; Liu et al., 2020). Moreover, policy formulation that considers both automation and health protocols is critical for the enduring sustainability of supply chains (Karmaker et al., 2021). A significant complementary interaction between coordination and cooperation is found in the automotive component industry, thus affecting SC adaptability and a firm's sustainability (Feizabadi & Alibakhshi, 2021). Manufacturers are forced to increase production to keep up with the rising demand because of shortages of raw materials and shipping delays. To investigate how the government's sales exemption measure assists the automobile recovery business, this article advises conducting an evaluation and empirical analysis (Wong, 2022).

Gallardo et al. (2020) asserted that organizations must adopt advanced health and safety cultures and practices to create a sustainable work environment. Hence, in the complex work environment of automobile SCs in emerging economies, updated health and safety standards will ensure the sustainability of human resources. Tamers et al. (2020) proposed an integrated strategy to address worker safety and well-being issues. They emphasized how the workplace can contribute to worker outcomes and how it can be modified to enhance workforce outcomes. Additionally, a well-established framework is required to increase sustainable supply chain survivability and to prevail in the post-pandemic business world (Sharma et al., 2020b). Moreover, adopting the new normal after COVID-19 requires the organization's workers to facilitate digital training regarding digitization, health, and safety.

Reserve capacity can lessen the adverse effects of supply chain disruptions and can be adapted to automobile SCs in emerging economies to recover sustainability (Lücker et al., 2019). Furthermore, using intelligent decision-making systems such as artificial intelligence (AI) and big data in automobile manufacturing can help automakers downsize manufacturing costs and provide a safer and more efficient production floor. Abdulmajeed et al. (2020) proposed an online forecasting method that employs data streaming to adjust the parameters of an ensemble model. To resist the COVID-19 pandemic disruption, Agrawal et al. (2020) suggested that manufacturers use a digital twin of a supply network to predict supplier and customer behaviour in advance. Bag et al. (2021) investigated the critical resources necessary for the adoption of Industry 4.0 (I4.0) technologies and their impact on sustainable production and circular economy (CE) capabilities, particularly in the context of developing countries like South Africa. They identified thirty-five key resources essential for I4.0 adoption, which were categorized through exploratory factor analysis into several groups, including production systems, human resources, project management, management leadership, green logistics, green design, information technology, big data analytics, and collaborative relationships. Yadav et al. (2020) explored the key challenges of I4.0 and CE-based solutions to improve sustainable supply chain management adoption.

Relevant solutions that are also applicable to the dynamic system of automobile SCs have been found in the most recent literature on sustainable recovery strategies during and after the COVID-19 pandemic in numerous SCs. Due to a number of circumstances, including transportation and labour limitations, workforce availability issues, demand variations, an increase in sick leave, and new health and safety standards, the pandemic caused severe disruptions. This reflects the need to re-design resilient supply chain management by providing recovery plans considering different measures at different stages. Eldem et al. (2022) and Moktadir et al. (2023) designed frameworks to ensure resilience by considering internal, external, and technological challenges during the pandemic. El Baz and Ruel (2021) recommended integrating a vulnerability mitigation strategy into SC development and a risk management procedure at every company level to ensure resiliency during a disruption.

Table 1 presents the most recent literature closely related to the current study. Four aspects (automobile SC, recovery strategies, post-pandemic era, and emerging economies) have been considered. It is evident that this study differentiates itself from other literature by addressing all four aspects.

2.2. *Grey DEMATEL in SC decision-making*

The DEMATEL approach or its extensions are employed to tackle real-world problems (Si et al., 2018). The DEMATEL technique is used to make better decisions after considering causal and effect group factors (Moktadir et al., 2020). The Delphi method is used to develop a multidisciplinary and multinational consensus during COVID-19. According to Garg (2021), the DEMATEL technique identifies

Table 1. List of relevant research on automobile SCs and sustainable recovery strategies in the post-COVID-19 era.

References	Method	Automobile SC	Recovery strategies	Post-pandemic era	Emerging economy
Belhadi et al. (2021)	Time-to-Recovery (TTR) and Financial Impact (FI) analysis	√	√	√	
Butt (2021b)	Cross-Sectional Study	√	√	√	
Ojha et al. (2021)	DEMATEL	√		√	
Nandi et al. (2021)	Circular Economy Performance Measurement Model (CEPMM)			√	√
Pereira et al. (2021)	Empirical Approach			√	√
Raj et al. (2022)	Grey-DEMATEL		√	√	
Paul et al. (2021)	Grey-DEMATEL		√	√	
Chen et al. (2021)	Mixed Integer Linear Programming (MILP)		√	√	
Mańkowska et al. (2021)	Inductive Reasoning Approach		√	√	
Frederico (2021)	Empirical Approach		√	√	
Moosavi and Hosseini (2021)	Discrete-Event Simulation		√	√	
Butt (2021a)	Empirical Analysis		√	√	
Rahman et al. (2021)	Agent-Based Modeling		√	√	
Yu et al. (2022)	Empirical Analysis	√			√
Kamble et al. (2021)	PROMETHEE -II	√			√
Agrawal et al. (2021)	Fuzzy-TOPSIS	√			√
Lee et al. (2021)	Empirical Approach	√			√
Kayikci et al. (2021)	Fuzzy -DEMATEL	√			√
Adhi Santharm and Ramanathan (2021)	Empirical Approach	√			√
Aguilar Esteva et al. (2021)	Circular Economy Framework	√			√
Caballero-Morales (2021)	Multidisciplinary Approach		√		√
Manupati et al. (2022)	Genetic Algorithm-Based Approach		√		√
Current Study	Grey-DEMATEL	√	√	√	√

the elements that influence the adoption of a sustainable SC in the automobile industry. Tian et al. (2019) integrated grey and DEMATEL to estimate the weights of every criterion. Parkouhi et al. (2019) considered two dimensions: resilience enhancer and resilience reduction, to identify and segment suppliers for further evaluation. The grey DEMATEL technique was applied to each criterion to decide the importance of these two dimensions.

This study aims to explore the effect of lean practices in the automotive industry. Using the grey DEMATEL technique helps decision-makers devise the appropriate strategy to identify major practices that influence the lean supply chain (Kumar Singh & Modgil, 2023).

A grey DEMATEL method is employed to analyze the importance and interrelationships of the identified supply chain recovery in the Bangladeshi ready-made garment industry (Kumar et al., 2021). This paper follows a Grey Decision-Making Trial and Evaluation Laboratory (Grey-DEMATEL) approach to examine how supply chain challenges are related to each other during the COVID-19 pandemic in an emerging economy. The grey-DEMATEL process ranks the challenges and segregates them into cause-and-effect categories (Raj et al., 2022). The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method is also applied to understand the causal relationship (Chatterjee et al., 2022). In the highly uncertain post-epidemic era, this study uses DEMATEL to construct the causal relationships among key factors that attract foreign investment (Huang et al., 2021).

The grey DEMATEL method has been used in this study to analyze and evaluate post-COVID-19 recovery strategies and to unveil the causal relationships between them. The integration of the grey theory with the DEMATEL model is an improved approach that can incorporate uncertainty and ambiguity of the problem, depending on subjective judgments. The findings can help develop strategic policies to overcome the challenges for recovery in the post-COVID-19 era.

This technique aims to analyze and uncover the causal links between strategies and prioritize these strategies based on their influence degree (Özdemir & Tüysüz, 2015). Besides, the DEMATEL method evaluates both the causal relationships between factors and the strength of the relationships between those factors (Khan et al., 2020). Moreover, this method uses matrix calculations and graph theory to solve complex relationships and create a network relation map between criteria (Özdemir & Tüysüz, 2015).

2.3. *Research gaps*

Automobile SCs encountered numerous challenges in operating effectively, similar to every other area of SC amidst the COVID-19 pandemic. In the post-COVID-19 era, companies should focus on implementing new strategies to improve the sustainability of their operations. From the literature studied, it is understandable that significant attempts were made to predict the pandemic's effects and investigate SC disruptive behaviours during the pandemic. However, the focus on developing sustainable post-COVID-19 recovery strategies has been less. This gap has motivated this study, considering the automobile SC in an emerging economy.

This study contributes to sustainable SC recovery strategy-related literature by identifying and analyzing the strategies of automobile SCs in the post-COVID-19 world for better resilience and sustainability. Furthermore, this study incorporates the grey DEMATEL method to determine the automobile SC's most influential post-COVID-19 recovery strategy. It also unveils the causal relationships among them. Furthermore, the outcome of this research work will enlighten SC practitioners and provide them with a thorough insight to develop meaningful actions accordingly.

3. Research methodology

The research is carried out in three stages. Initially, a comprehensive literature review identified 148 papers. However, 43 relevant projects, documents, and articles were ultimately assessed following adherence to the study procedure and a thorough full-text screening to meet the research questions. Next, 32 experts from Bangladeshi automobile companies participated in a questionnaire survey, which is presented in Table A1 of Appendix A. Their participation helped eliminate and add recovery strategies to those found in the literature by employing the snowballing method. The second stage involved collecting experts' opinions from seven professionals on the interrelationship among strategies on a linguistic scale. The qualifications for professionals included at least a bachelor's degree in business studies, industrial engineering, or mechanical engineering, along with at least four years of experience and expertise in automotive supply chain planning, operations, procurement, or sourcing. A summary profile of the professionals who contributed to the study is provided in Table A2 of Appendix A. Finally, the collected data were used to formulate matrices and analyze the strategies using the Grey DEMATEL model. Figure 1 depicts the research framework.

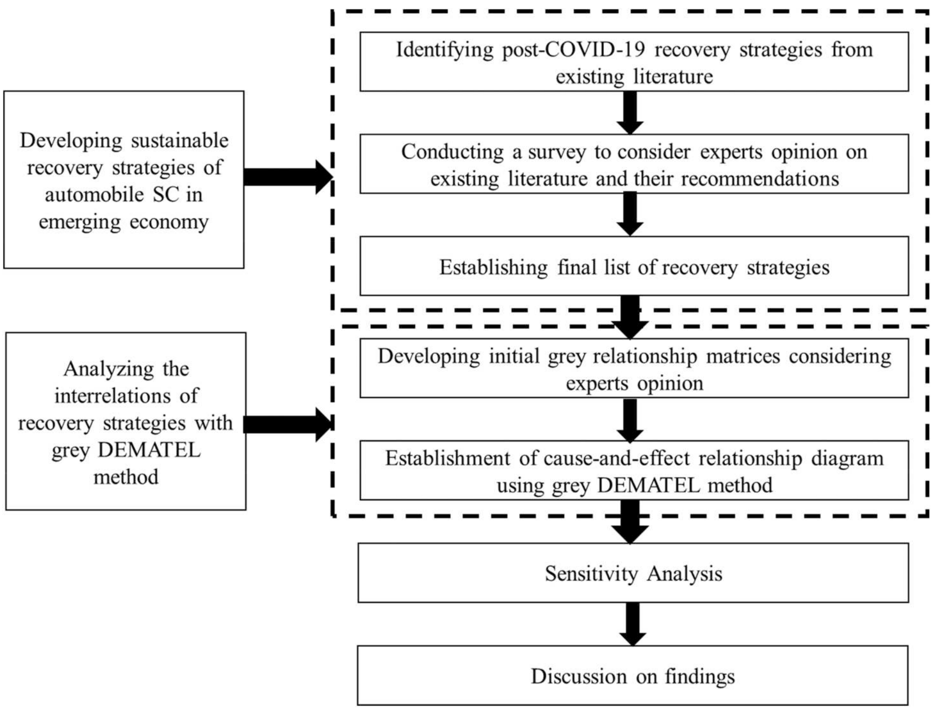

Figure 1. Research framework.

3.1. *Using grey DEMATEL to develop causal relationships among the strategies*

The steps in establishing the grey DEMATEL model are as follows.

Step 1: Constructing the initial matrices

The recovery strategies are identified through a rigorous literature review. Also, experts' opinions from the industry are considered when establishing initial matrices.

Table 2. Linguistic scale using grey numbers.

Linguistic Variables	Grey numbers
No effect	[0.0, 0.2]
Very low effect	[0.2, 0.4]
Low effect	[0.4, 0.6]
High effect	[0.6, 0.8]
Very high effect	[0.8, 1.0]

A total number of "n" recovery strategies is identified, and "K" number of experts is selected to identify the strategies in pairs to construct the initial direct relationship matrix using a grey linguistic scale of five levels, as shown in Table 2.

Step 2: Constructing initial grey relation matrices

The initial direct relationship matrix constructed in step 1 is then used to obtain a grey initial direct relationship matrix from the translation of the linguistic scales to grey numbers. If recovery strategy "i" has "very low effect" over the recovery strategy "j" assigned by expert "m", then the grey number will be [0.2, 0.4]. The following is the notation for grey numbers, which includes both upper and lower values.

$$\otimes G_{ij}^{p} = (\underline{\otimes}\, G_{ij}^{p},\ \ \overline{\otimes} G_{ij}^{p}). \tag{1}$$

In this Equation (1), $1 \leq p \leq P$, $1 \leq i \leq n$, $1 \leq j \leq n$ and $\underline{\otimes}\, G_{ij}^{p}$ and $\overline{\otimes}\, G_{ij}^{p}$ denote the grey number's lower and upper limit values, respectively, from expert"p". Thus, grey number values for the "P" expert will be as follows:

$$[\otimes\, G_{ij}^{1}],\ [\otimes\ \ G_{ij}^{2}],\ \ldots\ ,[\otimes\ \ G_{ij}^{K}].$$

The grey relationship matrix developed by each expert and their credentials are presented in Tables A3-A9 of Appendix A.

Step 3: Computing average grey relational matrix (AGRM)

"P" grey relation matrices shown are averaged to obtain AGRM $[\otimes\, \tilde{G}_{ij}\,]$ in Equation (2).

$$\otimes\, \tilde{G}_{ij} = \left(\frac{\sum_p \underline{\otimes} G_{ij}^{p}}{P}, \frac{\sum_p \overline{\otimes} G_{ij}^{p}}{P} \right). \tag{2}$$

The obtained AGRM can be found in Table A10 of Appendix A.

Step 4: Determining the crisp relation matrix (CRM)

Using Equations (3)–(8), crisp values from the grey numbers are obtained, which is illustrated in

a. Transforming crisp numbers from grey numbers $\otimes \tilde{G}_{ij} = \left(\frac{\sum_p \underline{\otimes} E_{ij}^p}{P}, \frac{\sum_p \overline{\otimes} E_{ij}^p}{P} \right)$

$$\underline{\otimes} G_{ij} = (\underline{\otimes} \tilde{G}_{ij} - \ min\ \underline{\otimes} G_{ij}) \ / \Delta_{min}^{max}, \tag{3}$$

$$\overline{\otimes} G_{ij} = (\overline{\otimes}\ \tilde{G}_{ij} - \ min\ \overline{\otimes}\ \tilde{G}_{ij}) \ / \Delta_{min}^{max}, \tag{4}$$

where

$$\Delta_{\min}^{\max} = \max \overline{\otimes} G_{ij} - \min \overline{\otimes} G_{ij}. \tag{5}$$

b. Calculating the total normalized crisp value

$$F_{ij} = \left(\frac{(\underline{\otimes} G_{ij}(1 - \underline{\otimes} G_{ij})) + (\overline{\otimes} G_{ij} \times \overline{\otimes} G_{ij})}{(1 - \underline{\otimes} G_{ij} + \ \overline{\otimes} G_{ij})} \right), \tag{6}$$

c. Calculating the final crisp value

$$F_{ij}^* = \ (min\ \underline{\otimes} \tilde{G}_{ij} + (G_{ij} \times \ \Delta_{min}^{max})), \tag{7}$$

and

$$F = [F_{ij}^*], \tag{8}$$

where F is the matrix of the initial relation of crisp values. The crisp relation matrix is shown in Table A11 of Appendix A.

Step 5: Constructing normalized crisp direct relation matrix (H)

The matrix of normalized crisp direct relation matrix, H, in Equation (10) is calculated from the computation F and multiplication of the average relation matrix F with K in Equation (9).

$$K = \frac{1}{max_{1 \le i \le n} \ \sum_{j=1}^{n} F_{ij}^*}, \tag{9}$$

and

$$H = F \times K. \tag{10}$$

Normalized crisp direct relation matrix has been constructed and shown in Table A12 of Appendix A.

Step 6: Formulating total relationship matrix (TRM)

$$Q = H \times (I \ - \ H)^{-1}. \tag{11}$$

In Equation (11), I represents the identity matrix and Q is the TRM.

Step 7: Assessing the cause–effect relationship and developing a digraph

The following three steps are used to construct a digraph and cause–effect diagram.

Step 7a**:** The sum of row (r_i) and column (c_j) for each row i and column j of in matrix P is calculated using Equations (12)–(15).

$$r_i = \sum_{j=1}^{n} P_{ij}, \forall i, \tag{12}$$

$$c_j = \sum_{i=1}^{n} P_{ij}, \forall j. \tag{13}$$

Step 7b**:** Equations (14) and (15) are used to evaluate the overall prominence and the net effect, respectively.

$$W_i = [r_i + c_j], \forall i = j. \tag{14}$$

$$Y_i = [r_i - c_j], \forall i = j. \tag{15}$$

W_i indicates the overall prominence of recovery strategy i, and Y_i indicates the net effect of recovery strategy "i". The recovery strategy "i" is designated a net cause for other recovery strategies when the value of Y_i is positive. Furthermore, recovery strategy "i" is considered as net effect by other recovery strategies if the value of Y_i is negative. TRM is presented in Table A13 of Appendix A.

Step 7c**:** Calculating the threshold and drawing the digraph

A threshold value (θ) is adopted to simplify the digraph, which considers the most significant correlations among variables. To get the threshold value, mean and standard deviation of all matrix Q are calculated and only values with one standard deviation above the mean are included. A digraph using the dataset of $((r_i + c_j), (r_i - c_j)), \forall i = j$ depicts the causal relationship.

4. A case study from automobile SC

A case study is performed to examine the outcomes and conclusions. The study's context is deemed to be the automotive manufacturing industry. It is viewed as a standard bearer, a useful indicator of the current riches of the global economy, and it positively affects the expansion of the economy (Kamble et al., 2020). For instance, the UK's automotive sector employs more than 823,000 people and earns over £82 billion in sales yearly, contributing a sizable £18.6 billion to the nation's GDP (Belhadi et al., 2021). As a South Asian developing country, Bangladesh has enormous potential to elevate its economic growth by effectively driving the operations of the automotive industry. With a large population and lower labour costs, Bangladesh is one of the most attractive markets for the automobile industry (Veloso & Kumar, 2002). Due to COVID-19, a significant retrogression has been marked in its processes, which makes it obvious to investigate sustainable recovery strategies while considering actual information from the ongoing situation (Chowdhury et al., 2020; Paul et al., 2023). Therefore, sustainable recovery strategies for automotive SCs were accumulated in this study, considering relevant literature and expert's opinion. Eleven recovery strategies were initially identified by studying and reviewing the relevant literature. Recent studies on automobile SCs, the impacts of the COVID-19 pandemic, and strategies to follow in the post-pandemic world were examined the most while selecting the recovery strategies.

Next, as per the questionnaire survey presented in Table A1 of Appendix A, the recovery strategies were finalised. The majority of the experts agreed on the importance of recovery strategies and additionally recommended "Implementing automated inventory management capabilities using IoT", "Implementing advanced forecasting and analytics solutions", "Managing disruption risk in SCs using reserve capacity under uncertain demand", "Developing intelligent decision-making system to use data for useful information", and "Facilitating training programs for workers on digitization, health and safety", to consider. Table 3 shows all the recovery strategies selected and recommended by the experts.

5. Results and discussions

The results obtained from the grey DEMATEL technique and some observations are presented in this section. The recovery strategies' relevance value $W_i = [r_i + c_j]$ can be used to determine their relative rank. According to the research, the recovery strategies are ranked in the following order.

S1>S5>S8>S12>S9>S16>S4>S3>S7>S10>S15>S6>S2>S14>S13>S11

The ranking indicates that 'Developing robustness-based risk management process for eliminating SC vulnerabilities' is the most prominent strategy (S1) in the post-COVID-19 world. With the increased vulnerabilities in the COVID-19 pandemic situation, the management of automobile firms should immediately form risk management processes that can handle any disruption with sufficient robustness and restore the sustainability of critical operations in automobile production (Ahmed & Huma, 2018). Furthermore, the robustness of the risk management process should include other actionable measures to combat vulnerabilities beyond the COVID-19 pandemic. Developing robust risk management in the firm will not only handle the disruptions in different stages of SC, but also boost the overall capability of the SC to develop other major strategies at the strategic and tactical levels. The beneficial indirect benefits of such practices suggest that businesses faced with the unprecedented risks of COVID-19 were driven to "improvise" new measures of risk assessment and processing, notwithstanding the insignificant direct impact of SC risk assessment and mitigation on SC robustness. In the end, integrating these techniques helped to provide a favourable influence of SC risk management on SC robustness (El Baz & Ruel, 2021).

The next most prominent sustainable strategy, 'Investing in collaborative strategic planning to reduce disruptions in SC (S5)', indicates the need to build strong SC strategic plans through collaboration among different stages to ensure the transparency and risk-sharing capability of SC (Awan et al., 2021). The most effective disruption mitigation strategies included establishing SC agility, adopting strategic policies, sourcing and flexible capacity, building trust, collaboration and coordination, and introducing financial incentives (Moosavi et al., 2022). 'Collaborating with government in policy development of automation and health protocols for long-term sustainability (S8)' is a key sustainable strategy for automobile firms in emerging

Table 3. List of post-COVID-19 sustainable recovery strategies in the automobile SC in an emerging economy.

Code	Strategy	Brief Description of the Strategy	References
S1	Developing robustness-based risk management system for eliminating SC vulnerabilities	To build an SCRM system with action plans that are responsive to the sudden fluctuation of the business environment and that can effectively handle any disruption and uncertainty with agile actions.	El Baz and Ruel (2021)
S2	Implementing automated inventory management capabilities using Internet of Things (IoT)	To leverage IoT in building a smart inventory management system for automobile inventory capable of handling order variability through real-time visibility and transparency.	Expert opinion
S3	Diversifying localized supplier network for enhancing procurement capability	To establish a pool of localized suppliers of auto components and raw materials and enhance the strength of these local ventures through sustainable investment.	Nandi et al. (2021)
S4	Integrating agile procurement system by digitizing supplier network	To digitalize sourcing, procurement, and other related activities in the automotive industry to connect all supply chain stages seamlessly.	Almeida et al. (2020)
S5	Investing in collaborative strategic planning to reduce disruptions in SC	To invest in developing a dynamic and opportunistic collaborative strategic planning system for shared disruption mitigation in both small and large industries.	Ivanov and Dolgui (2021)
S6	Incorporating updated occupational health and safety standards in firms	To adopt advanced health and safety cultures and practices with respect to COVID-19 health protocols in order to create a sustainable work environment.	Taleizadeh et al. (2021); Tamers et al. (2020)
S7	Prioritizing sustainability to withstand environmental and regulatory disruptions across SC	To develop a framework focusing on sustainable value chains that promote green supply chain concepts by ensuring economic and environmental growth during SC disruptions.	Bui et al. (2021)
S8	Collaborating with government in policy development of automation and health protocols for long-term sustainability	To work with the government to formulate policies that consider investment in automation and specialized health protocols for the automobile industry.	Karmaker et al. (2021)

(Continued)

Table 3. Continued.

Code	Strategy	Brief Description of the Strategy	References
S9	Increasing vertical collaboration for increasing SC performance under disruption	To ensure the highest level of collaboration among upstream and downstream stages in improving planning and coordination and reducing overall SC costs during SC interruptions.	Lotfi and Larmour (2021)
S10	Implementing advanced forecasting and analytics solutions	To incorporate advanced analytics and blockchain technologies in predicting uncertain demand, consumer behaviour trends, etc., with integrated and timely response capability.	Expert opinion
S11	Managing disruption risk in SCs using reserve capacity under uncertain demand	To properly plan and utilize safety inventory and related reserve capacity of the facilities to lessen the adverse effects of supply chain disruptions for adequate resiliency.	Expert opinion
S12	Developing intelligent decision-making system to use data for useful information	To best use intelligent decision-making systems such as artificial intelligence (AI) and big data for robust SC performance.	Expert opinion
S13	Developing flexible outbound logistics for secured order fulfilment	To build a flexible logistics system with flexible transportation networks, routings, fleet capacity, and provision for relocating manufacturing and storage facilities during disruptions.	Butt (2021a)
S14	Reinforcing worker safety regulations to ensure better workplace security	To strictly implement the proper health safety practices among all employees within a supply chain.	Margherita and Heikkilä (2021)
S15	Facilitating training programmes for workers on digitization, health and safety	To arrange adequate digital health training programmes for employees to ensure a safer work environment and enhanced employee performance by reducing sickness absences at the workplace.	Expert opinion
S16	Developing holistic crisis management plans for all SC stakeholders	To establish a holistic SC crisis management body consisting of all stages of supply chains for shared risk mitigation and maximizing overall supply chain surplus under unforeseen circumstances.	Safa et al. (2021)

economies to seek immediate support from the legislative bodies. This strategy will enable automobile SCs to get financial aid from governmental bodies to improve the technological infrastructure of the industry. Additionally, policies related to health protocols will ensure that work safety measures are not violated in the post-COVID-19 environment. ‘Developing intelligent decision-making system to use data for useful information (S12)' is a crucial strategy for automobile SCs in the post-COVID-19 world. The strategy suggests that automobile firms in emerging economies should capitalize on the increased utility of data and develop decision-making systems to foresee future market trends and disruptions (Katsaliaki et al., 2021). This will make automobile SCs sustainable to various changes and disruptions in the post-COVID-19 era.

'Increasing vertical collaboration for increasing SC performance under disruption (S9)', and 'Developing holistic crisis management plans for all SC stakeholders (S16)' can be twined to increase shared risks among the stakeholders of automobile SCs as well as integrated sustainable performances under uncertainty in post-COVID-19. Vertical SC collaboration greatly increases SC resilience by enhancing product quality, supplier communication, and demand risk reduction (Shashi et al., 2020). A holistic crisis management process will allow automobile firms to develop actions for their customers and key stakeholders to support and maintain relationships during a disrupted economic environment (Lozada-Contreras et al., 2021).

The next five recovery strategies are 'Integrating agile procurement system by digitizing supplier network (S4)', 'Diversifying localized supplier network for enhancing procurement capability (S3)', 'Prioritizing sustainability to withstand environmental and regulatory disruptions across SC (S7)', 'Implementing advanced forecasting and analytics solutions (S10)', and 'Facilitating training programs for workers on digitization, health and safety (S15)'. These strategies can significantly help automobile SCs in emerging economies formulate an integrated SC with sufficient technology enablers to predict disruptions, deploy efficient resource and waste management, and improve worker skills and safety (Galanakis et al., 2021; Vanapalli et al., 2021). The strategies will accelerate the sustainability of automobile SCs in emerging economies by adopting circular economy practices, even in a disrupted business environment.

The remaining strategies are 'Incorporating updated occupational health and safety standard in firms (S6)', 'Implementing automated inventory management capabilities using Internet of Things (IoT) (S2)', 'Reinforcing worker safety regulations to ensure better workplace security (S14)', 'Developing flexible outbound logistics for secured order fulfillment (S13)', and 'Managing disruption risk in SCs using reserve capacity under uncertain demand (S11)'. As the COVID-19 pandemic has dramatically affected the whole SC management differently from previous pandemics, these strategies can also be adopted to mitigate the complications of long-term SC disruption in the post-COVID-19 world. The ranking of the strategies and their net cause–effect relationships are presented in Table 4.

In comparison to the studies focused on sustainable operations of automobile SC during COVID-19, our study has proposed new strategies to consider for accelerating the post-COVID-19 recovery. Eldem et al. (2022) have recommended more attention to analyzing and monitoring information and data internally and externally, flexibility in operational processes, and focusing on external operations to accelerate SC recovery. Without considering the COVID-19 perspective, Gopal and Thakkar (2016) analyzed the key success factors (CSFs) underlying the adoption of sustainable SC practices in the automotive industry. They have considered 'understanding organizational complexities' as the most critical factor in forcing sustainable practices throughout Automobile SC. Masoumi et al. (2019) presented a process-oriented literature review on automobile SC. They discussed the importance of inputs/

Table 4. The ranking and net cause-effect for sustainable recovery strategies.

Strategies	r_i	c_j	$W_i = [r_i + c_j]$	Ranking Order	$Y_i = [r_i - c_j]$	Cause/Effect
S1	1.739	0.806	2.544	1	0.933	Cause
S2	0.460	0.773	1.233	13	−0.313	Effect
S3	0.499	1.095	1.594	8	−0.597	Effect
S4	0.615	1.011	1.626	7	−0.396	Effect
S5	1.350	0.865	2.215	2	0.485	Cause
S6	0.505	0.823	1.329	12	−0.318	Effect
S7	0.691	0.851	1.542	9	−0.161	Effect
S8	1.056	0.770	1.826	3	0.286	Cause
S9	0.903	0.835	1.738	5	0.067	Cause
S10	0.728	0.774	1.501	10	−0.046	Effect
S11	0.313	0.342	0.654	16	−0.029	Effect
S12	0.794	0.964	1.757	4	−0.170	Effect
S13	0.394	0.500	0.894	15	−0.106	Effect
S14	0.480	0.549	1.029	14	−0.069	Effect
S15	0.819	0.539	1.358	11	0.280	Cause
S16	0.922	0.769	1.691	6	0.153	Cause

stakeholder requirements, legislation and standards, resources/mechanisms, and outputs/performance for sustainable SC in the Automotive Industry. The effects of the COVID-19 pandemic on automobile SC were investigated by Ghadir et al. (2022). They came to the conclusion that some of the challenges during the COVID-19 outbreak were supply market shortages, losing key suppliers, transportation uncertainty, inconsistent delivery, etc. Sudan and Taggar (2022) examined how the COVID-19 pandemic caused disruptions to the Indian automotive industry's supply chain. In order to lessen SC disruption in the automobile industry, they stressed government laws and proactive and reactive risk mitigation measures taken by the enterprises. It is also important to emphasize taking strong action to address the present SC challenges in the automotive industry to strengthen SC systems' resilience and protect them from economic downturns.

Our study is distinct from the studies that were discussed earlier as it reveals that developing robustness-based risk management system for eliminating SC vulnerabilities, investing in collaborative strategic planning to reduce disruptions in SC, and collaborating with the government in policy development of automation and health protocols for long-term sustainability are the most pertinent strategies in recovering sustainable supply chain to support the automotive industry (emerging economy). Nevertheless, there has been a lack of research examining the causal relationship between the prioritization of sustainable automobile supply chain recovery factors and the impact on the national and global economy in the context of emerging economies following the COVID-19 pandemic. Although some recent studies (Belhadi et al., 2021; Butt, 2021b) highlighted some of the important aspects of the automobile industry during a pandemic, our study differs in the problem approach by focusing on the causal relationship of the strategies, which gives a comprehensive view on the root causes of different disruption. Furthermore, few studies (Raj et al., 2022; Chen et al., 2021; Mańkowska et al., 2021; Frederico, 2021; Moosavi & Hosseini, 2021; Butt, 2021a; Rahman et al., 2021) developed different approaches using decision making, simulation and mathematical modelling to understand the effect of a pandemic and strategies to mitigate them, however, none of them tried to develop an automobile SC centric formulation. Finally, some recent studies (Yu et al., 2022; Kamble et al., 2021; Agrawal, Wankhede, et al., 2021; Lee et al., 2021; Kayikci et al., 2021; Adhi Santharm & Ramanathan, 2021; Aguilar Esteva et al., 2021;) tried to look into the intricate aspects of automobile SCs, but the effects of a pandemic on the SC was not highlighted.

5.1. *Cause group recovery strategies*

The six causal-oriented strategies have the following order of importance.

S1>S5>S8>S9>S16>S15

The study shows some cause group recovery strategies according to rank order. The highest cause group recovery strategy is ‘Developing robustness-based risk management process for eliminating SC vulnerabilities (S1)’. Based on the experts’ views, the previous section also shows that S1 is similarly the most vital recovery challenge for automobile SCs. Experts examine how these advanced technologies can manage and predict disruptions and develop a resilient and robust SC.

The next biggest causal recovery strategies include ‘Investing in collaborative strategic planning to reduce disruptions in SC (S5)’ and ‘Collaborating with government in policy development of automation and health protocols for long-term sustainability (S8)’. Investing appropriately in strategic planning and engaging with the government on policy development are needed to make an SC more resilient in the post-COVID-19 world.

The strategies ‘Increasing vertical collaboration for increasing SC performance under disruption (S9)’, ‘Developing holistic crisis management plans for all SC stakeholders (S16)’, and ‘Facilitating training programs for workers on digitization, health and safety (S15)’, are ranked 4th, 5th, and 6th, respectively. These strategies can be causal, and they also have an enormous impact on effect group strategies (refer to Figure 2). Implementing a vertical collaboration plan in the post-COVID-19 world will increase SC effectiveness and efficiency by limiting disruption.

Overall, automobile SCs in emerging economies should emphasize implementing significant causal recovery strategies to mitigate the SC disruption. However, while all strategies may be implemented, prioritizing them allows businesses to focus their limited resources on the most important ones first. In the post-COVID-19 world, with reduced material and cash flow, it is challenging for automobile SCs to survive in the business market. Considering this, industries need to prioritize sustainable strategies to manage the impacts on SCs in post-COVID-19.

5.2. *Effect group recovery strategies*

The effect group for recovery strategies is in the following order:

S12>S4>S3>S7>S10>S6>S2>S14>S13>S11

A common recovery strategy for most cause group is ‘Developing intelligent decision-making system to use data for useful information (S12)’, meaning that additional causal group strategies can influence it. Attaining effective strategy deployment is possible if decision-makers successfully tackle the key causal group recovery

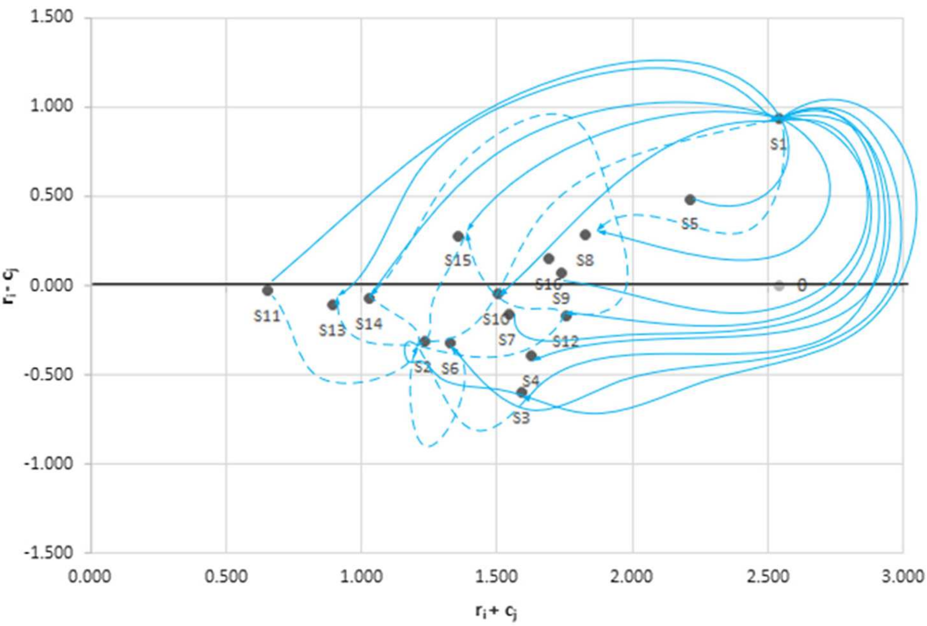

Figure 2. Cause and effect diagram with relations.

strategies. However, given many relevant causal factors, it can be a particularly challenging problem to deal with, and may persist even after solving the most influential difficulties. As a result, management will almost certainly experience a delay in making various decisions due to the uncertainty associated with handling several other strategies.

‘Integrating agile procurement system by digitizing supplier network (S4)’, **‘**Diversifying localized supplier network for enhancing procurement capability (S3)’ and ‘Prioritizing sustainability to withstand environmental and regulatory disruptions across SC (S7)’ are three recovery strategies that are less influenced by the causal group. ‘Reinforcing worker safety regulations to ensure better workplace security(S14)’, ‘Reinforcing worker safety regulations to ensure better workplace security (S13)’ and ‘Managing disruption risk in SCs using reserve capacity under uncertain demand (S11)’ are heavily influenced by the cause group. Expert’s feedback indicates that digitizing supplier networks and diversifying localized supplier networks need to be strongly established. If major causation strategies such as S1 and S5 are overcome, S4 and S3 will be developed.

5.3. *Sensitivity analysis*

A sensitivity analysis was performed to confirm the study’s reliable performance. Through this approach, each expert received the highest weighting possible while the other experts received equal weighting. The rating of the results is then checked for errors. Examining the variance in the output is critical to determine if the cause-and-effect link between recovery strategies will be impacted. In this study, each expert is given the highest weightage of 0.4, while the others are given the same value of 0.1, as shown in Table 5.

Table 5. Weight assigned to each expert.

	E1	E2	E3	E4	E5	E6	E7
Situation 1	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Situation 2	0.1	0.4	0.1	0.1	0.1	0.1	0.1
Situation 3	0.1	0.1	0.4	0.1	0.1	0.1	0.1
Situation 4	0.1	0.1	0.1	0.4	0.1	0.1	0.1
Situation 5	0.1	0.1	0.1	0.1	0.4	0.1	0.1
Situation 6	0.1	0.1	0.1	0.1	0.1	0.4	0.1
Situation 7	0.1	0.1	0.1	0.1	0.1	0.1	0.4

Table 6 shows the sensitivity analysis results, which demonstrate a slight variance. Apart from that, the recovery challenges' cause–effect group and rankings are the same as the original results. This conclusion implies that expert ratings are relatively consistent, meaning that the research findings and analysis are relatively robust.

6. Research implications

This section discusses the ramifications of the research findings and the way these findings will help overcome the problems of automobile SCs in emerging economies caused by the COVID-19 pandemic. The implications have been explained from theoretical and practical perspectives to critically analyze recovery strategies. The feasibility of this study in proficiently implementing the outcome in a constructive scenario to reinstate balance among SC contributors and practitioners is also discussed.

Bangladesh, a growing South Asian economy, is no exception and has been severely impacted by the COVID-19 outbreak. The pandemic put automobile companies in Bangladesh in crisis and disrupted the sustainable flow of SC both domestically and globally. The in-depth analysis of this study identifies sustainable recovery strategies to assist practitioners in the automobile SC in Bangladesh as well as other emerging economies in conquering the adverse consequences of the COVID-19 pandemic. Further, assessing these sustainable recovery strategies will help interpreters realize the significance of these strategies post-COVID-19. The correlation between them concludes the influence of one to another and helps differentiate the dominating one. Also, prioritizing these sustainable recovery strategies would help determine the hierarchy of strategies that can lessen the turbulences of SC in the aftermath of the COVID-19 pandemic, which requires immediate attention, considering inadequate resources. By further evaluating and exploring these sustainable strategies, numerous aspects of SC will emerge to address the consequences of the post-pandemic world in the automobile industry and other business and operational domains.

As one of the competitive markets, automobile SCs confronted much more uncertainty, hindrances, and severe impacts amidst the COVID-19 pandemic. As this

Table 6. Cause-effect relationships among strategies obtained from sensitivity analysis.

Strategies	Cause/Effect	Situation 1		Situation 2		Situation 3		Situation 4		Situation 5		Situation 6		Situation 7	
		C/E	$r_i - c_j$	C/E	$r_i - c_j$	C/E	$r_i - c_j$	C/E	$r_i - c_j$	C/E	$r_i - c_j$	C/E	$r_i - c_j$	C/E	$r_i - c_j$
S1	Cause	C	0.858	C	0.913	C	0.897	C	0.88	C	0.921	C	0.857	C	0.929
S2	Effect	E	−0.313	E	−0.313	C	0.027	E	−0.279	E	−0.288	E	−0.359	E	−0.345
S3	Effect	E	−0.569	E	−0.508	E	−0.512	E	−0.491	E	−0.489	E	−0.578	E	−0.569
S4	Effect	E	−0.375	E	−0.386	C	0.39	E	−0.384	E	−0.393	C	0.013	E	−0.379
S5	Cause	C	0.505	C	0.489	C	0.48	C	0.455	C	0.494	C	0.469	C	0.483
S6	Effect	E	−0.32	E	−0.296	E	−0.289	E	−0.35	E	−0.329	E	−0.359	E	−0.299
S7	Effect	E	−0.162	E	−0.192	E	−0.177	E	−0.167	E	−0.172	C	0.144	E	−0.135
S8	Cause	C	0.247	C	0.233	C	0.259	C	0.288	C	0.265	C	0.29	C	0.263
S9	Cause	C	0.066	C	0.057	C	0.059	C	0.068	C	0.062	C	0.068	C	0.059
S10	Effect	C	0.039	C	0.047	E	−0.003	C	0.045	C	0.047	C	0.039	C	0.045
S11	Effect	E	−0.032	E	−0.027	E	−0.032	C	0.023	E	−0.026	E	−0.024	E	−0.029
S12	Effect	E	−0.019	E	−0.023	E	−0.014	C	0.004	E	−0.013	E	−0.014	E	−0.012
S13	Effect	E	−0.12	E	−0.113	E	−0.102	E	−0.103	E	−0.117	E	−0.1	E	−0.107
S14	Effect	E	−0.068	E	−0.066	E	−0.068	E	−0.069	E	−0.07	C	0.005	E	−0.072
S15	Cause	C	0.239	C	0.286	C	0.241	C	0.289	E	−0.04	C	0.237	C	0.264
S16	Cause	C	0.126	C	0.122	C	0.11	C	0.181	C	0.137	C	0.125	C	0.126

industry comprises a vast domain, it encounters supreme turbulences in operating SC drivers amidst the COVID-19 pandemic and will endure more to overcome its consequences. Therefore, SC professionals and practitioners need to develop effective strategic planning and decisions to return the SC to its former state, considering the impact of the disruption.

This study can enormously contribute to the decision-making process of automobile SC practitioners, managers, and policy-makers worldwide in the post-COVID-19 era. Understanding the sustainable recovery challenges discussed in this study can assist policy-makers and practitioners in decision-making in finances and investments, as they have to function with limited capital and resources. Furthermore, the findings of this study determine the causal relationships between the recovery strategies, thereby providing the practitioners with a comprehensive decision-making framework. It helps them categorize and rank these strategies based on their cause-and-effect relationship and depicts the supremacy of one strategy over the other, considering the net negative and positive impacts.

This paper analyzes sustainable supply chain recovery strategies in the post-pandemic context, specifically within the automobile industry. It highlights the need for SC managers to adopt actionable and practical measures to enhance resilience and sustainability amid changing global landscapes. One key strategy is supplier diversification, where manufacturers extend their supplier networks to mitigate risks associated with reliance on single-source suppliers, such as sourcing lithium for batteries from multiple countries. However, challenges such as quality control and increased logistics costs may arise. Another critical avenue is the implementation of circular economy practices. For instance, manufacturers can facilitate vehicle take-back programmes, which enable the recycling of components like metals and plastics. While these strategies can reduce waste, engaging customers in such initiatives and managing the logistical complexities of material recovery can pose significant obstacles. The paper also emphasizes the role of digitalization and technology adoption in fostering supply chain transparency and efficiency. The integration of IoT technologies enables real-time inventory tracking and predictive maintenance. Nevertheless, the initial investment and potential cybersecurity risks are challenges that organizations must navigate.

Moreover, transitioning to sustainable packaging solutions is vital for reducing environmental impact. While efforts can be made to use biodegradable materials, this transition may incur additional costs and necessitate redesigning existing processes. Collaboration is identified as essential for effective SC management. Engaging in collaborative planning with stakeholders can optimize routes and minimize emissions, albeit requiring trust-building and data-sharing among partners.

Finally, this study advocates for scenario planning to enhance preparedness for various supply chain disruptions. Although challenging due to the unpredictability of disruptions, developing robust contingency plans can be invaluable for resilience. Additionally, pursuing sustainability certifications like ISO 14001 can solidify a company's commitment to environmental management, though the certification process demands significant resources and ongoing compliance efforts. This study underscores the importance of practical implementation strategies for SC managers in the automobile industry to navigate post-pandemic challenges and successfully leverage opportunities for sustainable recovery.

As the findings of this study present the relative importance of recovery, it is evident that one strategy may require more attention than others for the successful implementation of the findings in some instances. In this case, differentiating the categories will help practitioners deal first with the most significant ones. Generally, the cause group needs more attention than the effect group as the effects are caused by it. Therefore, practitioners of the automobile SC need first to consider the cause strategies to eliminate the effects. This study concludes with separate rankings for the cause-and-effect groups, revealing their individual importance. For instance, 'Developing robustness-based risk management process for eliminating SC vulnerabilities (S1)' and 'Investing in collaborative strategic planning to reduce disruptions in SC (S5)' are more important than 'Facilitating training programs for workers on digitization, health, and safety (S15)' because of their high prominence and effect values. Similarly, 'Developing intelligent decision-making system to use data for useful information (S12)' and 'Integrating agile procurement system by digitizing supplier network (S4)' need to be considered first among the other effect group recovery strategies because of their values. Considering their importance based on the ranking, managers and policymakers can give preference to these sustainable recovery strategies in the post-COVID-19 context.

According to the findings, 'Developing robustness-based risk management process for eliminating SC vulnerabilities (S1)' is the most important recovery strategy. Automobile SC practitioners need to develop a risk management framework to assess the robustness of the SC to identify and eliminate any disruptions that may arise in the post-pandemic era. This can help managers and practitioners to take preventive action to minimize SC turbulences in the automobile industry. Furthermore, the results suggest 'Investing in collaborative strategic planning to reduce disruptions in SC (S5)' as the next prominent sustainable strategy to focus on. Collaboration among the practitioners will help the automobile SC recover its sustainability by ensuring transparency. As the third most important recovery strategy, SC practitioners need to focus on 'Collaborating with the government in policy development of automation and health protocols for long-term sustainability (S8)'. This can help SC practitioners to emphasize governmental stimuli to overcome the defeats and highlight demanded health protocols to ensure effective operations post-Covid-19. Likewise, the remaining recovery strategies are important based on the developed ranking and need very specific execution planning under certain circumstances. On the contrary, 'Reinforcing worker safety regulations to ensure better workplace security (S14)', 'Developing flexible outbound logistics for secured order fulfillment (S13)', and 'Managing disruption risk in SCs using reserve capacity under uncertain demand (S11)' are the least critical recovery strategies, according to the established ranking. Managers and practitioners do not need to consider any detailed action plans for these strategies, as they fall under the effect group. Focusing on the higher-ranked recovery strategies will consequently assist in establishing them as well.

The global automotive market will be greatly impacted by the development and business practices of the emerging economies automotive sector, which is predicted to become the most worthwhile market in the world. To strengthen worldwide automotive supply networks after the pandemic, this study emphasizes the necessity of recovery strategies for developing countries' automobile supply chains. The research findings may impact how the world economy recovers after the pandemic, particularly in terms of international trade, demand stimulation, investments in emerging technologies, and so on.

The COVID-19 pandemic has significantly reshaped supply chain structures and practices within the automobile industry, prompting a fundamental reevaluation of established methodologies. Pre-pandemic supply chains were predominantly characterized by Just-In-Time (JIT) production, global sourcing, linear operational models, and limited digital integration. While efficient under normal conditions, these frameworks were severely tested during the pandemic, leading to widespread disruptions, material shortages, and operational halts.

The immediate impacts of the pandemic highlighted the vulnerabilities inherent in traditional supply chain approaches. Disruptions to production, logistical challenges, and fluctuations in consumer demand necessitated a shift towards more resilient supply chain strategies. This period catalyzed a transformation marked by an increased focus on local sourcing, enhanced collaboration among stakeholders, and the acceleration of digital transformation initiatives. Organizations began integrating advanced technologies such as artificial intelligence, IoT, and big data analytics to improve visibility and adaptability.

In response to the lessons learned during the crisis, post-pandemic supply chain practices emphasize resilience, sustainability, and comprehensive risk management. Companies are prioritizing holistic crisis management frameworks, maintaining strategic redundancies, and adopting circular economy principles to align their economic and environmental objectives. Enhanced collaboration with suppliers and stakeholders has become crucial for fostering trust and ensuring agile responses to future disruptions. This comparative analysis of pre- and post-pandemic supply chain practices underscores a significant paradigm shift in the automobile industry, driven by the need for adaptability and sustainability in an increasingly volatile global landscape. As organizations continue to navigate the post-pandemic environment, these transformations will play a critical role in defining the future of supply chain management. The recovery strategies outlined in this research study align directly with several Sustainable Development Goals (SDGs). For example, SDG-9 (Industry, Innovation, and Infrastructure) can be addressed through initiatives such as 'Developing a robustness-based risk management system to eliminate SC vulnerabilities' (S1), 'Investing in collaborative strategic planning to reduce disruptions in SC' (S5), and 'Collaborating with the government in policy development for automation and health protocols for long-term sustainability' (S8). Furthermore, the adoption of these recovery strategies also aids in achieving SDG-8 (Decent Work and Economic Growth), SDG-12 (Responsible Consumption and Production), and SDG-17 (Partnerships for the Goals) by investing in collaborative strategic planning (S5), prioritizing sustainability to withstand environmental and regulatory disruptions across the supply chain (S7), and by developing flexible outbound logistics for secured order fulfilment (S13).

Finally, by evaluating the findings of the study, management and concerned personnel can promptly recognize the most legitimate sustainable recovery strategy they need to incorporate in their industry. Policymakers can also enlighten themselves by studying the inner workings of the proposed sustainable recovery approach and practicing it in different real-life scenarios.

Moreover, the identified recovery strategies in this study can be applied to other industries experiencing supply chain disruptions due to unforeseen occurrences like the COVID-19 pandemic. For example, the automotive supply chain heavily depends on electronics industries, which are often reliant on complex global supply chains (Manley et al., 2022). To mitigate risks such as component shortages or logistical disruptions, these industries could adopt a robustness-based risk management system to enhance resilience (Holgado & Niess, 2023). Similarly, the pharmaceutical industry, which depends mostly on uninterrupted supply chains for raw materials and finished products (Wahab et al., 2023), would benefit from intelligent decision-making systems and vertical collaboration to enhance transparency and responsiveness (Javed et al., 2024; Shashi, 2023). Furthermore, the food production industry could emphasize local supplier diversification and agile procurement systems to maintain supply continuity and meet environmental regulatory requirements (Michel-Villarreal et al., 2021; Sharma et al., 2023).

However, universal implementation of these strategies may encounter limitations. Resource constraints, particularly in smaller firms, could hinder investments in advanced risk management and digitalization (Bella et al., 2024). Moreover, some industries may lack the infrastructure or technological expertise to support advanced analytics or IoT-based inventory management, slowing adoption and effectiveness (Nozari et al., 2022). Additionally, fostering government collaboration and ensuring policy alignment can be time-intensive and dependent on political commitment and economic priorities, which may delay the implementation process. Despite these challenges, elements of these strategies can be tailored to strengthen resilience and promote sustainable recovery across various industries.

7. Conclusions

The COVID-19 pandemic has severely disrupted the world economy and has had long-lasting negative effects on every element of SC, including logistics, transport, and distribution. The pandemic has had a major negative impact on the long-term viability of the SC auto industry. Most emerging markets and developing economies have survived better than expected during the COVID-19 outbreak but still confront formidable long-term economic concerns. This necessitates the immediate identification and assessment of sustainable recovery strategies in the post-COVID-19 world to ensure a rapid recovery from SC disruptions, particularly in a country transitioning to an emerging economy within a decade. This paper identifies 16 post-COVID-19 recovery strategies for the automobile SC of Bangladesh and evaluated their interrelationships in order to make SCs more resilient in the post-COVID-19 era. This study uses the grey-DEMATEL technique to teach SC stakeholders and practitioners how to use the most effective recovery measures depending on their rank in order to save the automotive SC from the COVID-19 pandemic's devastation. The results' robustness is then assessed using a sensitivity analysis.

This investigative study into the causal relationship among the 16 recovery strategies classifies six strategies (S1, S5, S8, S9, S16, and S15, in order of their importance) as the 'cause' groups and the other ten strategies (S12, S4, S3, S7, S10, S6, S2, S14, S13, and S11, in order of their importance) as the 'effect' groups. The findings of this study suggest that automobile firms should focus primarily on developing a robustness-based SCRM framework to mitigate the vulnerabilities caused by the pandemic. Another important sustainable recovery strategy would be to invest in strategic planning in collaboration with all the supply chain stages. Another vital collaboration between two parties – industry and the government – is required to develop health protocols and facilitate automation to achieve long-term sustainability and recovery. This study also reveals that taking advantage of the recent development in artificial intelligence is another meaningful recovery strategy. The experts suggest developing intelligent systems capable of decision-making under unprecedented circumstances. Other significant strategies include increasing vertical collaboration, developing holistic crisis management plans, integrating agile procurement systems, diversifying local suppliers, developing flexible outbound logistics, and implementing advanced data analytics.

The study, being exploratory in nature, has some limitations. These limitations can further be explored and improved in future works. A more meticulous dynamic study of the strategies might consider the most recent strategies, as the pandemic progresses with many changes. Additionally, the work can be extended by formulating strategic measures to eradicate the problems discussed. Another limitation of the study is the data collected from the industry of one country. Future research may include experts from multiple countries as well as multiple domains comprising different business dynamics to address the complexity. Furthermore, this study extensively concentrates on the automobile industry in the emerging economy. Further research might be conducted to incorporate different strategies in the diverse industrial sectors, such as plastic, chemical, electronics, maritime, and food, in developing countries. In the future, contemporary techniques such as Bayesian best-worst method, modified total interpretive structural modelling, and fuzzy Matrice d'Impacts Croisés Multiplication Appliquée à un Classement can be employed to comprehensively analyze the connections between different components and classify them according to their impact and dependence. Moreover, machine learning and deep learning can be employed to deal with a greater number of variables using extensive datasets, hence ensuring the resilience of the model.

Statement of contributions

Sharmine Akther Liza: Conceptualization; Formal Analysis; Methodology; Writing – Original Draft Preparation. **Naimur Rahman Chowdhury:** Conceptualization; Formal Analysis; Methodology; Writing – Original Draft Preparation. **Rafia Munjerin:** Conceptualization; Formal Analysis; Methodology; Writing – Original Draft Preparation. **Shah Murtoza Morshed:** Formal Analysis; Writing – Original Draft Preparation. **Sanjoy Kumar Paul:** Conceptualization; Methodology; Supervision; Writing – Review & Editing. **Doulotuzzaman Xames:** Writing – Original Draft Preparation; Formal Analysis. **Rafat Rahman:** Formal Analysis; Methodology; Visualization; Formal Analysis.

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Appendix A

Question 1. Please mention your designation and experience in your organization.

Question 2. Please select the mentioned sustainable recovery strategies as per their importance in automotive SC in the post-COVID-19 world in the following table. Please mention if you recommend any additional recovery strategies.

Table A1. List of sustainable recovery strategies for expert opinion.

Name of the sustainable recovery strategies	Yes/No
Developing robustness-based risk management system for eliminating SC vulnerabilities	
Diversifying localized supplier network for enhancing procurement capability	
Integrating agile procurement system by digitizing supplier network	
Investing in collaborative strategic planning to reduce disruptions in SC	
Incorporating updated occupational health and safety standards in firms	
Prioritizing sustainability to withstand environmental and regulatory disruptions across SC	
Collaborating with government in policy development considering health protocols and automation for long-term sustainability	
Increasing vertical collaboration for increasing SC performance under disruption	
Developing flexible outbound logistics for secured order fulfilment	
Reinforcing worker safety regulations to ensure better workplace security	
Developing holistic crisis management plans for all SC stakeholders	
Additional recovery strategy name:	

Table A2. Credentials of experts.

Expert Name	Designation	Experience (Years)
Expert 1	General Manager, Research and Development	13
Expert 2	Manager, Supply Chain	12
Expert 3	Regional Manager, Sourcing & Procurement	12
Expert 4	Associate Manager, Logistics	09
Expert 5	Manager, Supply Chain	07
Expert 6	Senior Assistant Manager, Operations	10
Expert 7	Senior Executive, Operations	04

Table A3. Grey relationship matrix for assessing SC recovery strategies from expert 1.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.4	0.8	0.4	0.6	0.6	0.6	0.4	0.0	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	0.6	1.0	0.6	0.8	0.8	0.8	0.6	0.2	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.2	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.4	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A4. Grey relationship matrix for assessing SC recovery strategies from expert 2.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.4	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.6	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.2	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0

(*Continued*)

Table A4. Continued.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A5. Grey relationship matrix for assessing SC recovery strategies from expert 3.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.4	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.6	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.4	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.2	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4

(*Continued*)

Table A5. Continued.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A6. Grey relationship matrix for assessing SC recovery strategies from expert 4.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.4	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.6	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.2	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A7. Grey relationship matrix for assessing SC recovery strategies from expert 5.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.2	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.4	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.6	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.0	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.2	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A8. Grey relationship matrix for assessing SC recovery strategies from expert 6.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0

(*Continued*)

Table A8. Continued.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.6	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.0	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.2	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A9. Grey relationship matrix for assessing SC recovery strategies from expert 7.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.2	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.4	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4

(*Continued*)

Table A9. Continued.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S11	0.2	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.0	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.2	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A10. Average relationship matrix for assessing SC recovery strategies.

Strategies	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.0	0.2	0.8	0.6	0.8	0.6	0.4	0.8	0.8	0.4	0.6	0.6	0.6	0.4	0.4	0.8
	0.0	0.4	1.0	0.8	1.0	0.8	0.6	1.0	1.0	0.6	0.8	0.8	0.8	0.6	0.6	1.0
S2	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.8	0.0	0.0	0.0	0.0
	0.2	0.0	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.2	1.0	0.2	0.2	0.2	0.2
S3	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.0	0.4	0.8	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.4
S4	0.2	0.4	0.8	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.6	1.0	0.0	0.2	0.2	0.2	0.2	0.6	0.6	0.2	0.8	0.2	0.2	0.2	0.2
S5	0.6	0.2	0.6	0.2	0.0	0.4	0.8	0.8	0.6	0.2	0.2	0.4	0.4	0.0	0.2	0.8
	0.8	0.4	0.8	0.4	0.0	0.6	1.0	1.0	0.8	0.4	0.4	0.6	0.6	0.2	0.4	1.0
S6	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.0
	0.4	0.2	0.2	0.2	0.2	0.0	0.8	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.8	0.2
S7	0.2	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.4	0.0	0.4	0.2	0.0	0.6	0.4	0.2
	0.4	0.2	0.2	0.2	0.4	0.8	0.0	0.2	0.6	0.2	0.6	0.4	0.2	0.8	0.6	0.4
S8	0.0	0.6	0.2	0.4	0.6	0.6	0.2	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.6	0.2
	0.2	0.8	0.4	0.6	0.8	0.8	0.4	0.0	0.2	0.8	0.2	0.8	0.2	0.8	0.8	0.4
S9	0.6	0.0	0.6	0.8	0.2	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
	0.8	0.2	0.8	1.0	0.4	0.2	0.2	0.8	0.0	0.2	0.2	0.2	0.8	0.2	0.2	0.8
S10	0.2	0.6	0.6	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.0	0.2	1.0	0.2	0.2	0.2	0.4
S11	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.4
S12	0.2	0.6	0.4	0.8	0.6	0.0	0.2	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.8	0.6	1.0	0.8	0.2	0.4	0.4	0.2	0.8	0.2	0.0	0.2	0.2	0.2	0.2
S13	0.2	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.2	0.2	0.0	0.2	0.2	0.4
S14	0.2	0.0	0.0	0.0	0.0	0.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.4	0.2	0.2	0.2	0.2	1.0	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.0	0.2	0.4
S15	0.2	0.6	0.6	0.6	0.0	0.4	0.2	0.2	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
	0.4	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.2	0.8	0.2	0.8	0.2	0.2	0.0	0.2
S16	0.4	0.2	0.6	0.0	0.6	0.6	0.6	0.2	0.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	0.6	0.4	0.8	0.2	0.8	0.8	0.8	0.4	0.8	0.2	0.2	0.2	0.6	0.2	0.2	0.0

Table A11. Crisp relation matrix.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0	0.35	0.97	0.73	0.97	0.73	0.5	0.97	0.97	0.65	0.95	0.73	0.95	0.5	0.65	0.97
S2	0.05	0	0.03	0.73	0.03	0.03	0.03	0.03	0.03	0.95	0.05	0.97	0.05	0.03	0.05	0.03
S3	0.35	0.05	0	0.27	0.73	0.03	0.03	0.03	0.73	0.05	0.05	0.03	0.05	0.03	0.05	0.27
S4	0.35	0.65	0.97	0	0.03	0.03	0.03	0.03	0.5	0.65	0.05	0.73	0.05	0.03	0.05	0.03
S5	0.95	0.35	0.73	0.27	0	0.5	0.97	0.97	0.73	0.35	0.35	0.5	0.65	0.03	0.35	0.97
S6	0.35	0.05	0.03	0.03	0.03	0	0.73	0.03	0.03	0.05	0.05	0.03	0.05	0.97	0.95	0.03
S7	0.35	0.05	0.03	0.03	0.27	0.73	0	0.03	0.5	0.05	0.65	0.27	0.05	0.73	0.65	0.27
S8	0.05	0.95	0.27	0.5	0.73	0.73	0.27	0	0.03	0.95	0.05	0.73	0.05	0.73	0.95	0.27
S9	0.95	0.05	0.73	0.97	0.27	0.03	0.03	0.73	0	0.05	0.05	0.03	0.95	0.03	0.05	0.73
S10	0.35	0.95	0.73	0.73	0.03	0.03	0.03	0.5	0.03	0	0.05	0.97	0.05	0.03	0.05	0.27
S11	0.35	0.05	0.03	0.03	0.27	0.03	0.5	0.03	0.03	0.05	0	0.03	0.05	0.03	0.05	0.27
S12	0.35	0.95	0.5	0.97	0.73	0.03	0.27	0.27	0.03	0.95	0.05	0	0.05	0.03	0.05	0.03
S13	0.35	0.05	0.03	0.03	0.27	0.03	0.5	0.03	0.5	0.05	0.05	0.03	0	0.03	0.05	0.27
S14	0.35	0.05	0.03	0.03	0.03	0.97	0.5	0.5	0.03	0.05	0.05	0.03	0.05	0	0.05	0.27
S15	0.35	0.95	0.73	0.73	0.03	0.5	0.27	0.27	0.03	0.95	0.05	0.73	0.05	0.03	0	0.03
S16	0.65	0.35	0.73	0.03	0.73	0.73	0.73	0.27	0.73	0.05	0.05	0.03	0.65	0.03	0.05	0

Table A12. Normalized crisp relation matrix.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0	0.28	0.97	0.73	0.97	0.73	0.5	0.97	0.97	0.52	0.76	0.73	0.76	0.5	0.52	0.97
S2	0.04	0	0.03	0.73	0.03	0.03	0.03	0.03	0.03	0.76	0.04	0.97	0.04	0.03	0.04	0.03
S3	0.28	0.04	0	0.27	0.73	0.03	0.03	0.03	0.73	0.04	0.04	0.03	0.04	0.03	0.04	0.27
S4	0.28	0.52	0.97	0	0.03	0.03	0.03	0.03	0.5	0.52	0.04	0.73	0.04	0.03	0.04	0.03
S5	0.76	0.28	0.73	0.27	0	0.5	0.97	0.97	0.73	0.28	0.28	0.5	0.52	0.03	0.28	0.97
S6	0.28	0.04	0.03	0.03	0.03	0	0.73	0.03	0.03	0.04	0.04	0.03	0.04	0.97	0.76	0.03
S7	0.28	0.04	0.03	0.03	0.27	0.73	0	0.03	0.5	0.04	0.52	0.27	0.04	0.73	0.52	0.27
S8	0.04	0.76	0.27	0.5	0.73	0.73	0.27	0	0.03	0.76	0.04	0.73	0.04	0.73	0.76	0.27
S9	0.76	0.04	0.73	0.97	0.27	0.03	0.03	0.73	0	0.04	0.04	0.03	0.76	0.03	0.04	0.73
S10	0.28	0.76	0.73	0.73	0.03	0.03	0.03	0.5	0.03	0	0.04	0.97	0.04	0.03	0.04	0.27
S11	0.28	0.04	0.03	0.03	0.27	0.03	0.5	0.03	0.03	0.04	0	0.03	0.04	0.03	0.04	0.27
S12	0.28	0.76	0.5	0.97	0.73	0.03	0.27	0.27	0.03	0.76	0.04	0	0.04	0.03	0.04	0.03
S13	0.28	0.04	0.03	0.03	0.27	0.03	0.5	0.03	0.5	0.04	0.04	0.03	0	0.03	0.04	0.27
S14	0.28	0.04	0.03	0.03	0.03	0.97	0.5	0.5	0.03	0.04	0.04	0.03	0.04	0	0.04	0.27
S15	0.28	0.76	0.73	0.73	0.03	0.5	0.27	0.27	0.03	0.76	0.04	0.73	0.04	0.03	0	0.03
S16	0.52	0.28	0.73	0.03	0.73	0.73	0.73	0.27	0.73	0.04	0.04	0.03	0.52	0.03	0.04	0

Table A13. Total relation matrix.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
S1	0.054	0.073	0.155	0.126	0.143	0.116	0.1	0.134	0.14	0.092	0.087	0.12	0.101	0.078	0.08	0.136
S2	0.016	0.021	0.027	0.089	0.017	0.01	0.012	0.015	0.014	0.086	0.007	0.108	0.009	0.008	0.009	0.012
S3	0.045	0.016	0.026	0.044	0.083	0.018	0.021	0.024	0.086	0.016	0.011	0.019	0.02	0.011	0.013	0.045
S4	0.043	0.066	0.113	0.031	0.026	0.014	0.015	0.021	0.064	0.066	0.01	0.089	0.015	0.01	0.011	0.02
S5	0.108	0.062	0.119	0.073	0.05	0.089	0.128	0.123	0.111	0.061	0.044	0.089	0.075	0.036	0.056	0.126
S6	0.039	0.017	0.02	0.019	0.015	0.024	0.082	0.018	0.016	0.017	0.012	0.02	0.01	0.1	0.08	0.016
S7	0.047	0.02	0.029	0.026	0.043	0.09	0.026	0.024	0.062	0.02	0.055	0.043	0.017	0.082	0.062	0.044
S8	0.034	0.103	0.066	0.086	0.092	0.096	0.056	0.029	0.029	0.102	0.014	0.108	0.018	0.086	0.088	0.048
S9	0.094	0.029	0.107	0.116	0.06	0.031	0.031	0.091	0.038	0.029	0.016	0.035	0.088	0.02	0.022	0.094
S10	0.043	0.094	0.097	0.099	0.031	0.019	0.019	0.062	0.025	0.029	0.011	0.117	0.014	0.014	0.015	0.04
S11	0.035	0.011	0.016	0.013	0.035	0.016	0.057	0.013	0.016	0.011	0.007	0.013	0.011	0.011	0.012	0.035
S12	0.048	0.094	0.082	0.119	0.088	0.022	0.044	0.047	0.03	0.095	0.014	0.038	0.017	0.015	0.017	0.026
S13	0.039	0.012	0.021	0.018	0.038	0.017	0.058	0.017	0.06	0.012	0.011	0.015	0.011	0.012	0.013	0.039
S14	0.038	0.015	0.018	0.016	0.018	0.106	0.063	0.056	0.016	0.015	0.011	0.018	0.011	0.02	0.021	0.036
S15	0.045	0.096	0.099	0.101	0.028	0.061	0.042	0.043	0.026	0.097	0.012	0.101	0.014	0.018	0.014	0.02
S16	0.077	0.044	0.1	0.034	0.096	0.094	0.097	0.053	0.1	0.024	0.018	0.03	0.068	0.027	0.026	0.032