Computers & Industrial Engineering 165 (2022) 107963

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Assessing measures implemented by export-oriented RMG firms in an emerging economy during COVID-19

Ziaul Haque Munim [a,*], Majid Mohammadi [b], Mohammad Hassan Shakil [c,d], Syed Mithun Ali [e]

[a] Faculty of Technology, Natural and Maritime Sciences, University of South-Eastern Norway, Horten, Norway
[b] Faculty of Science, Vrije Universiteit Amsterdam, the Netherlands
[c] School of Business Administration, East Delta University, Chittagong, Bangladesh
[d] Taylor's Business School, Taylor's University, Subang Jaya, Malaysia
[e] Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

ARTICLE INFO

Keywords:
COVID-19
Supply Chain Disruption
Fashion Industry
Best-Worst Method
Risk Management

ABSTRACT

Manufacturing firms that continued production activities during the COVID-19 have been taking necessary measures to cope with the risks imposed by the pandemic. This study assesses the measures implemented by the Ready-Made Garments (RMG) sector in Bangladesh. With the increase in COVID-19 cases in Bangladesh, following government order, along with firms in other manufacturing sectors, the RMG firms had to shut-down their production between March 26 and April 25, 2020. Soon after the factories reopened, they had to take necessary actions to ensure employee safety, supply of raw materials, and purchase orders from buyers. Using a semi-structured interview approach, we identify 16 measures that have been implemented in the RMG sector in Bangladesh for the employees, suppliers and buyers. Then, we assess the degree of implementation of these measures using the Bayesian Best-Worst method. We find that providing healthcare safety, bringing previously outsourced activities in-house, and ensuring smooth delivery of existing orders were the three most implemented measures for employees, suppliers and buyers, respectively. On a higher level, the RMG industry professionals prioritised buyer-related measures the most, followed by employee and supplier-related. The analysed measures provide a blueprint for supply chain risk management during future waves of COVID-19 transmission and for other potential large-scale natural disasters.

1. Introduction

Nowadays global supply chains are spanning over multiple countries across different continents. Managing such supply chains is complex, and disruption in one part of the supply chain often has a significant impact on the overall supply chain. Meanwhile, disruptions are not uncommon in supply chains, and studies on supply chain uncertainty, risk management, resilience, and in general supply chain disruptions (SCDs) have been increasing significantly over the last two decades (Xu, Zhang, Feng, & Yang, 2020). However, majority of the studies deal with typical disruptions such as supplier failure (Ruiz-Torres & Mahmoodi, 2007), transportation disruption (Albertzeth, Pujawan, Hilletofth, & Tjahjono, 2020), demand uncertainty (Gupta & Maranas, 2003), and technological disruption (Ivanov, Dolgui, & Sokolov, 2019). Olivares-Aguila and ElMaraghy (2020) modelled the impact of SCDs on inventory levels, costs, service levels and profit of the supply chain in a multi-tier supply chain setting. Regardless of these efforts, studies focusing on irregular global disruptions such as the 2008 financial crisis or 2020 coronavirus crisis are rare.

Although the nature of the COVID-19 disruption is different from previous global disruptions such as the 9/11 in the United States or the global financial crisis in 2008, learning from those disruptions could be useful for firms in surviving the SCD caused by the COVID-19 pandemic. After 9/11, Kleindorfer and Saad (2005) analysed the global supply chain risks in the context of the chemical industry arising from disruptions caused by activities outside the scope of typical SCDs due to co-ordination issues in supply chains. One of the main mitigation strategy in such disruptions is to fix issues within one's own firm first before expecting or forcing supply chain partners to do so (Kleindorfer & Saad, 2005). As a pre-disruption measure, firms can utilise emerging technologies and increased access to information to optimise safety stocks to reduce stock-outs during SCDs (Di Nardo, Clericuzio, Murino, & Sepe,

* Corresponding author.
E-mail address: ziaul.h.munim@usn.no (Z.H. Munim).

https://doi.org/10.1016/j.cie.2022.107963
Received 20 October 2020; Received in revised form 11 June 2021; Accepted 14 January 2022
Available online 21 January 2022

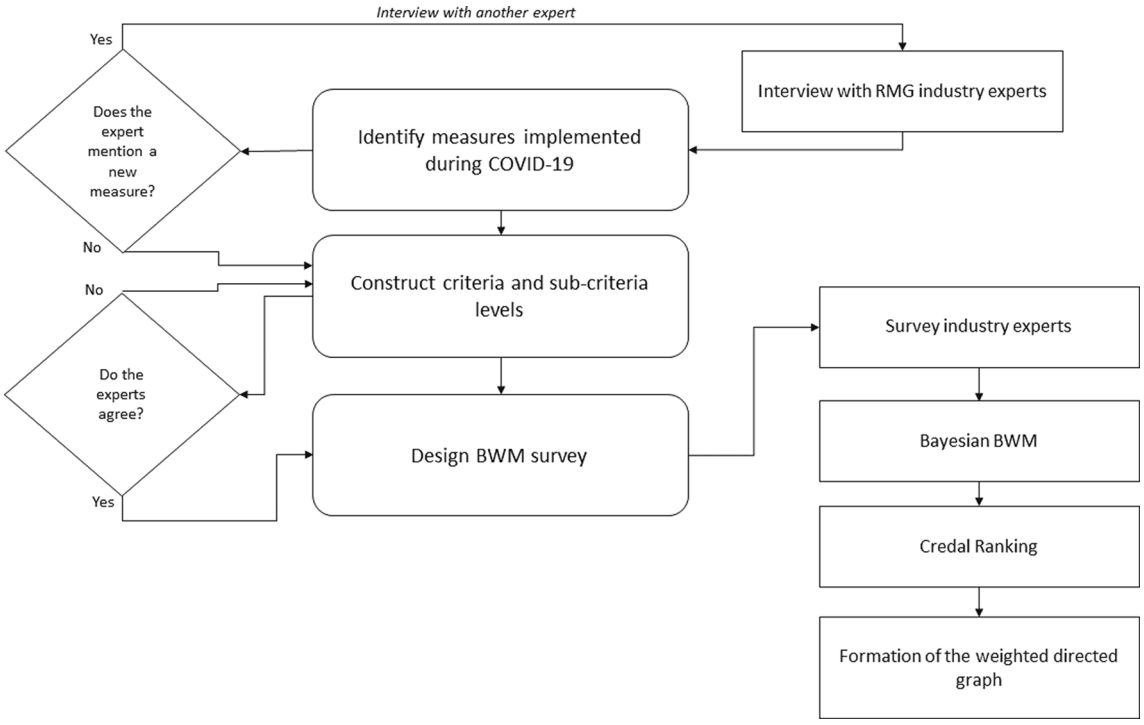

Fig. 1. Workflow of this study.

2020).

Usually, a diversified supply chain reduces risk in such disruptions, particularly when a region or country is mainly exposed to the disruption, such as the United States during 9/11. Even having a diversified portfolio of suppliers across the world may not be a useful risk mitigation strategy when the whole world is affected by the disruption, which is evident from the 2008 financial crisis, although to a lesser magnitude compared to the current COVID-19 pandemic. Blome and Schoenherr (2011) studied risk management strategies of European firms in the context of the global financial crisis in 2008. Blome and Schoenherr (2011) argued that companies improved the comprehensiveness of their supply chain risk management approaches and also started to accept risks more in comparison to risk avoidance. Despite such development of supply chain risk management strategies and the growing number of literature on the topic, the COVID-19 pandemic has shaken the global supply chains.

Since the starting of the SCD due to the COVID-19 in March 2020, studies have examined its impact on global supply chain (Ivanov, 2020) and risk management strategies (Chowdhury, Sarkar, Paul, & Moktadir, 2020; Sharma, Shishodia, Kamble, Gunasekaran, & Belhadi, 2020).In this context, de Sousa Jabbour et al. (2020) stated that different industries face different challenges, and accordingly, strategies taken by industry professionals' varies. To the best of the authors' knowledge, an in-depth investigation of the measures implemented by manufacturing firms, particularly, in the context of an export-oriented industry of a developing country, is not evident. Hence, we investigate measures implemented in the Ready-Made Garments (RMG) industry of Bangladesh using a novel Multi-Criteria Decision-Making (MCDM) framework. We develop the MCDM framework based on four interviews with industry experts. Based on the MCDM framework, we collected data from 11 respondents using a complex web-survey and used the Bayesian Best-Worst Method (BWM) to analyse the survey data.

The next section presents the context of the study, design process of the survey, data collection and methodological detail of the Bayesian BWM. Section 3 presents the results, and Section 4 discusses the theoretical and practical implications of the findings. Finally, Section 5 summarizes the study with limitations and future research direction.

2. Data and methodology

2.1. Context of the study

This study investigates the measures implemented by the RMG firms in Bangladesh. The RMG sector of Bangladesh not only plays a significant role in the country's economy but also a major supplier for the global fashion industry. The RMG sector accounts for 84% of Bangladesh's total export, about USD 34.13 billion for the 2018–19 fiscal year. Besides, followed by China, Bangladesh is the second-largest global RMG supplier[1].

Regardless of its significant contribution to the Bangladesh economy, the RMG sector of Bangladesh has been vulnerable to disruptions. Political unrest, labour union strikes and accidents have been part of the industry since the early 1980s. However, since the collapse of Rana Plaza Complex (that hosted several garment factories) in 2013, global brands and retailers joined effort for workers' health and safety. The Accord on Fire and Building Safety in Bangladesh and the Alliance for Bangladesh Worker Safety was established in 2013 initiated by mainly European and North American retailers, respectively. Since then, the number of incidents has been declined significantly as well as the safety in RMG factories improved. Initially, the Accord-Alliance was established for a five-year term to run inspection, remediation and workplace empowerment programs. In 2018, Accord-Alliance terms came to an end and members of both continued their word through locally-formed organizations. For instance, as of June 1, 2020, the RMG Sustainability Council (RSC) took over the functions of the Accord office in Bangladesh[2].

While the industry has been functioning well in recent years, the COVID-19 pandemic has made it vulnerable again. The Regulation of International Supply Chains (RISC) has already published a report on the early and expected impacts of the COVID-19 pandemic on the

[1] See http://bgmea.com.bd/bgmea/investment-trade/rmg-sector/, accessed on October 14, 2020.

[2] See https://bangladeshaccord.org/, accessed on June 01, 2021.

Table 1
Overview of interview participants.

Informant	Designation	Education	Experience	Employees	Firm Origin
1	Production Planning Executive	Master Degree	05 years	+10,000	South Korean MNC
2	Chairman	Bachelor Degree	10 years	+200	Bangladesh Originated
3	Senior Merchandiser	Bachelor Degree	09 years	+28,000	Bangladesh Originated
4	Managing Director	Master Degree	12 years	+3000	Bangladesh Originated

Table 2
List of identified criteria and sub-criteria.

Criteria	Sub-criteria
Supplier-related measures	C1. Search for alternative local or foreign suppliers
	C2. Increased sourcing from local suppliers
	C3. Bringing activities in-house which were earlier outsourced
	C4. Collaborate with suppliers using digital technology (e.g., cloud manufacturing)
	C5. Minimize transportation of goods
Employee-related measures	E1. Provide healthcare safety (e.g. handwash booth, musk, temperature check and disinfection booth)
	E2. Reduce employee travel
	E3. Supply food (lunch) for employees during working hours
	E4. Reduce working/factory hours
	E5. Maintain employee salaries and benefits as before COVID-19
	E6. Social distancing ensured (plastic between two production lines)
Buyer-related measures	B1. Ensure smooth delivery of existing orders
	B2. Offer discounted price per unit for existing orders to minimize order cancellation (35–50%)
	B3. Offer favourable terms for new orders (e.g., extended payment terms, price discount)
	B4. Negotiate post-pandemic contracts with buyers
	B5. Offering new COVID-19 related products such as PPE

lower capacity than regular times.

2.2. Survey design

This study includes three stages. In the first stage, we interview RMG experts to identify and finalize a list of measures implement during the COVID-19 pandemic. Such an approach has been implemented in previous MCDM studies as well, for example, Pintelon, Di Nardo, Murino, Pileggi, and Vander Poorten (2021) and Ali, Hossen, Mahtab, Kabir, and Paul (2020). The second stage, includes the BWM survey design and data collection from industry experts. In the final stage, we analyse collected survey data using the Bayesian BWM. The three-stage workflow of the study is depicted in Fig. 1.

To identify measures implemented to keep the factories open during COVID-19, we choose four industry experts for interviews based on purposive sampling approach. The interviews were conducted sequentially. Our goal was to identify implemented measures for the suppliers, employees and buyers. After the first interview, we prepared a list of measures under these three criteria. Then, we proceed with the second interview with the aim of validating the already listed measures and identifying additional measures. The same approach was followed for the four interviews. Table 1 presents an overview of the interview participants. The interviews continued between 45 min to 75 min.

After the fourth interview, the authors reached data saturation, that is, no new measures were introduced. Hence, we discussed the full list of 18 measures with the four participants, which was an iterative process and two measures were removed due to low degree of implementation, i.e. introducing in-house accommodation for workers and mobile banking for salary payment. Following the validation of the identified measures by the four interviewees, we proceed with the BWM survey design. In consultation with the interviewees, we group identified measures as sub-criteria under three criteria – supplier-related, employee-related and

Table 3
Background of the survey respondents.

Respondent	Company Age (years)	Company Size	ISO 9000 Certification	Accord-Alliance Member	Experience	Expertise	Education
1	10	Medium	No	No	More than 10 years	Marketing and Sales	Master degree
2	10	Medium	No	No	More than 10 years	Marketing and Sales	Master degree
3	20	Large	Yes	Yes	7 to 10 years	Marketing and Sales	Bachelor degree
4	15	Large	No	No	7 to 10 years	Supply Chain Management	Bachelor degree
5	46	Large	Yes	Yes	1 to 3 years	Marketing and Sales	Master degree
6	21	Large	Yes	Yes	4 to 6 years	Supply Chain Management	Bachelor degree
7	15	Large	Yes	Yes	4 to 6 years	Production and Operations Management	Master degree
8	34	Large	Yes	Yes	1 to 3 years	Production Planning and Coordination	Bachelor degree
9	20	Large	Yes	Yes	4 to 6 years	Production and Operations Management	Master degree
10	18	Medium	Yes	Yes	More than 10 years	Production and Operations Management	Bachelor degree
11	34	Large	Yes	Yes	More than 10 years	Production and Operations Management	Master degree

Small: 1 to 100; Medium: 101 to 1000; Large: More than 1000 employees and workers.

Bangladesh RMG sector. In the report, Leitheiser et al. (2020) discuss some of the major challenges the industry is facing such as cancellation of orders by the large multinational brands leadings to financial distress among suppliers further impeding the life of the workers. The RMG industry in Bangladesh employs more than four million workers, who are in financial, health and safety hazards due to the COVID-19. Hence, this study investigates the measures taken by RMG firms in Bangladesh to sustain the pandemic by keeping their business running even though in a

buyer-related measures. Table 2 presents the criteria and their respective sub-criteria.

2.3. Data collection

Following the development of relevant criteria and sub-criteria, we designed a BWM survey. BWM surveys, and MCDM survey, in general, are different from conventional Likert scale surveys and complex in nature. The survey was distributed digitally to contacts of the authors working in the RMG industry in Bangladesh as well as across social media by means of professional RMG industry related groups in Facebook and LinkedIn. As the country was going through government-imposed lockdowns and physical meetings were discouraged, web-based digital survey was the appropriate medium to collect data. The survey was active for one month from June 1 to June 30, 2020. In total, 26 industry experts responded in the survey. After removing responses from industries other than RMG (03), duplicates (02), logically wrong inputs (05) and straight lining (05), 11 responses were left for analysis. Table 3 presents the background of the respondents who participated in the survey. The majority of the respondents' firms have ISO 9000 certification (08 out of 11), and are members of the Accord Alliance (08 out of 11). This indicates that firms represented by our sample already have quality management systems in place as well as worker health and safety standards. Data of the Best-to-Others and Others-to-Worst vectors are available as online supplementary material.

2.4. Bayesian best-worst method

In order to identify the importance of identified criteria in Table 2, this study takes advantage of a multi-criteria decision-making (MCDM), Bayesian Best-Worst Method (BWM), which is a group-decision making method. In Bayesian BWM, the preferences of multiple experts/decision-makers (DMs) are aggregated within a probabilistic framework, which allows us to draw conclusions on the final aggregated priorities of criteria.

Let $C = \{c_1, \ldots, c_n\}$ be a set of criteria that are evaluated by K experts or DMs. The following steps are required for applying the Bayesian BWM:

Step 1: First, expert k selects the best (c_B^k) and the worst (c_W^k) criteria out of C.

In this step, each of the experts are asked to choose only the best and the worst criteria from the criteria set C. At this stage, the expert does not make any pairwise comparison between the criteria and only selects the best and the worst. The best is the most implemented, while the worst is the least implemented criterion for expert k, and different experts can opt for different criteria as their best and/or worst.

Step 2: Expert k makes the pairwise comparison between the best (c_B^k) and the other criteria in C.

In this step, each of the experts needs to express their preferences of the best criterion over other criteria in C by a number between one and nine. An assignment of *one* means that the criteria being compared are equally implemented, while an assignment of *nine* means that c_B is extremely more implemented. The set of pairwise comparison for expert k in this stage results in a vector, called "Best-to-Others", shown as A_B^k, and is defined as:

$$A_B^k = \left(a_{B1}^k, a_{B2}^k, \ldots, a_{Bn}^k\right), \quad k = 1, 2, \ldots, K, \tag{1}$$

where a_{Bj}^k denotes the preference of the best criterion (c_B^k) over $c_j \in C$ for expert k.

Step 3: Expert k makes the pairwise comparison between the worst criterion (c_W^k) and the other criteria in C.

In this step, each of the experts needs to identify their preferences of the other criteria over the worst criterion, which is selected in Step 1, by a number between one and nine. An assignment of *nine* in this step shows that the corresponding criterion is extremely more implemented than the worst, while an assignment of *one* means that the two criteria are equally implemented. This step results in the "Others-to-Worst" vector, shown as A_W^k for expert k, and is defined as:

$$A_W^k = \left(a_{1W}^k, a_{2W}^k, \ldots, a_{nW}^k\right)^T \tag{2}$$

where a_{jW}^k is the preference of criterion $c_j \in C$ over the worst criterion for decision-maker k (c_W^k).

Step 4: Computing the aggregated weights of all K experts $w^* = (w_1^*, w_2^*, \ldots, w_n^*)$ and the weight for each of the experts $w^k, k = 1, \ldots, K$ by the following probabilistic model of the Bayesian BWM:

$$A_B^k | w^k \sim multinomial(1/w^k), \quad \forall k = 1, \ldots, K, \tag{3}$$

$$A_W^k | w^k \sim multinomial(w^k), \quad \forall k = 1, \ldots, K, \tag{4}$$

$$w^k | w^* \sim Dir(\gamma \times w^*), \quad \forall k = 1, \ldots, K, \tag{5}$$

$$\gamma \sim gamma(0.1, 0.1), \tag{6}$$

$$w^* \sim Dir(1), \tag{7}$$

where *multinomial* is the multinomial distribution, *Dir* is the Dirichlet distribution and $gamma(0.1, 0.1)$ is the gamma distribution with the shape parameters of 0.1. The probabilistic model identified by equations in (7) does not bear a closed-form solution. As a result, a Markov-chain Monte Carlo (MCMC) (Gilks, Richardson, & Spiegelhalter, 1995) sampling is required to estimate the solution. The Bayesian BWM is implemented in JAGS (*J*ust *A*nother *G*ibbs *S*ampler) (Plummer, 2004), and is freely and publicly available[3].

After solving the problem by using the Bayesian BWM, it provides S sample from the posterior distributions of the aggregated weight w^*. According to the aggregated weight, we can draw the importance of each criteria, as well as the extent to which one criterion is preferred over another based on the preferences of all experts/DMs. To compute such an extent, we need to make an inference in a Bayesian sense. The following definitions and computations would provide such a probabilistic sensing based on the aggregated priorities w^*.

Definition 2.1. Credal Ordering (Mohammadi & Rezaei, 2020): For a pair of criteria c_i and c_j, a credal ordering O is defined as

$$O = (c_i, c_j, R, d) \tag{8}$$

where

- R is the relation between the performance metrics c_i and c_j, i.e., $<, >$, or $=$;
- $d \in [0, 1]$ is the confidence degree of the relation.

Definition 2.2. Credal Ranking (Mohammadi & Rezaei, 2020): For a

[3] https://github.com/Majeed7/BayesianBWM

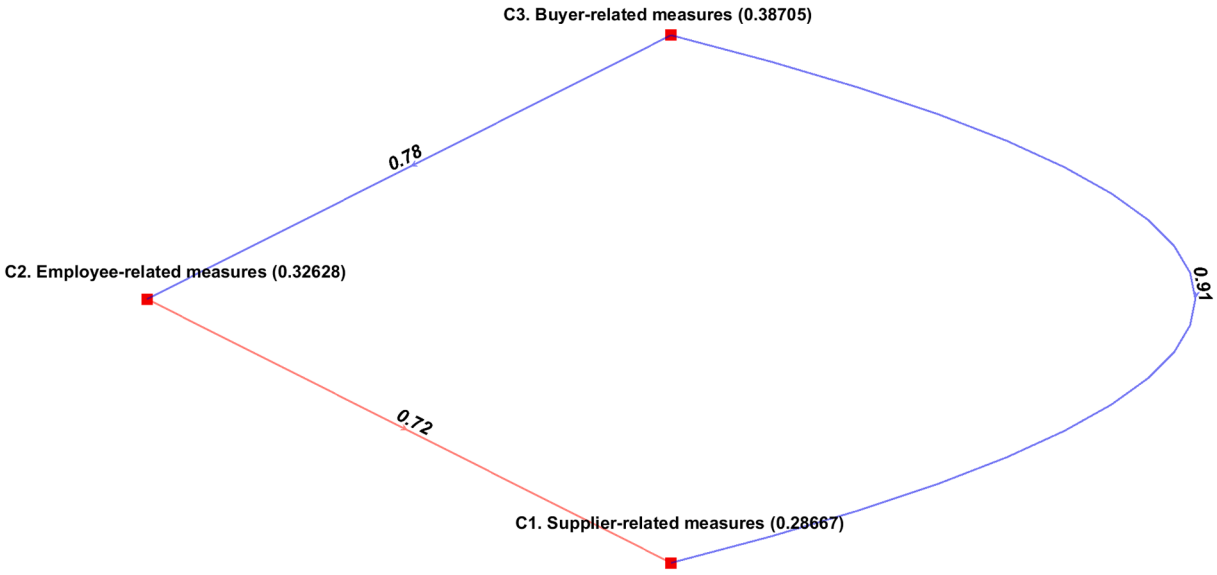

Fig. 2. Ranking of criteria implementation.

set of criteria $C = (c_1, c_2, \ldots, c_n)$, the credal ranking is a set of credal orderings which contains all pairs (c_i, c_j), for all $c_i, c_j \in C$.

We now only need to compute the degree in credal ordering for each pair of criteria c_i and c_j. For doing so, we take advantage of S samples obtained from JAGS, and compute the degree as:

$$P(c_i > c_j) = \frac{1}{S}\sum_{s=1}^{S} I(w_i^{*s} > w_j^{*s}). \tag{9}$$

Given this computation, we can make a probabilistic comparison between criteria. In the following sections, we visualize the credal ranking of a set of criteria by using a weighted directed graph, where all the required information about the probabilistic comparison can be readily realized. For robustness, two of the authors analysed the data separately and both yield the same result.

3. Results

This section presents the ranking of the implemented measures estimated using the Bayesian BWM. For each of the problems, we create a weighted directed graph. The nodes of such a graph represent the criteria as well as their average weight computed as the mean of the w^* distribution, and each edge $A \xrightarrow{d} B$ means that A is more important than B with a confidence degree of d. In other words, each edge in the graph represents a credal ordering, and the whole graph visualizes the credal ranking of a set of criteria.

That being said, we first present the credal ranking of the main criteria as shown in Fig. 2. Among the three criteria levels, buyer-related measures were most implemented (0.38705), followed by employee-related (0.32628) and supplier-related (0.28667). Further, buyer-related measures were more implemented with 0.91 confidence than supplier-related, while with 0.78 confidence than employee-related, and employee-related measures were more implemented than supplier-related with 0.72 confidence. Although it depends on the decision makers perception, for simplicity of the interpretation of the confidence scores, we can use 0.70 threshold to indicate strong confidence. Probability based confidence sores are visible on the edges in the figure.

As buyer-related measures were the most implemented, we first present the local ranking of these measures in Fig. 3. Ensuring smooth delivery of existing orders (0.24543) is the most prioritized measure

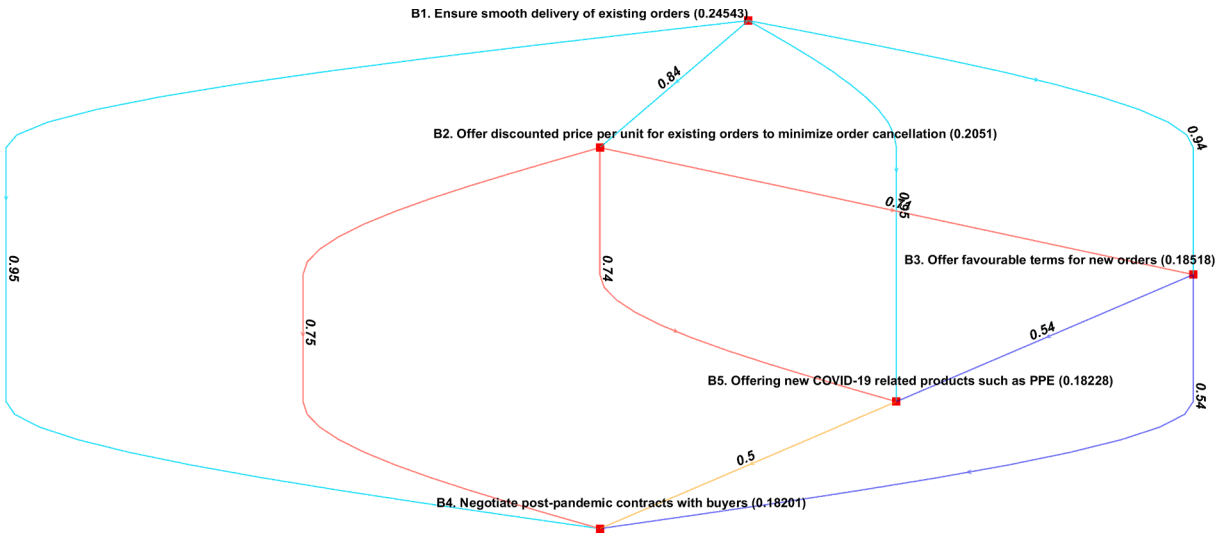

Fig. 3. Ranking of buyer-related implemented measures.

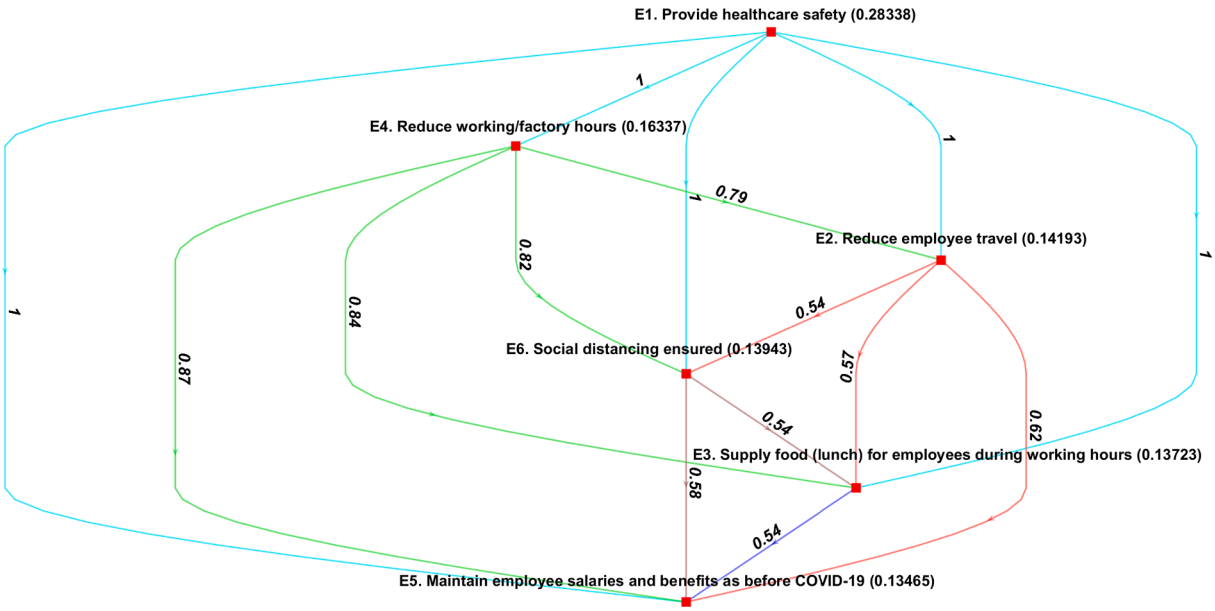

Fig. 4. Ranking of employee-related implemented measures.

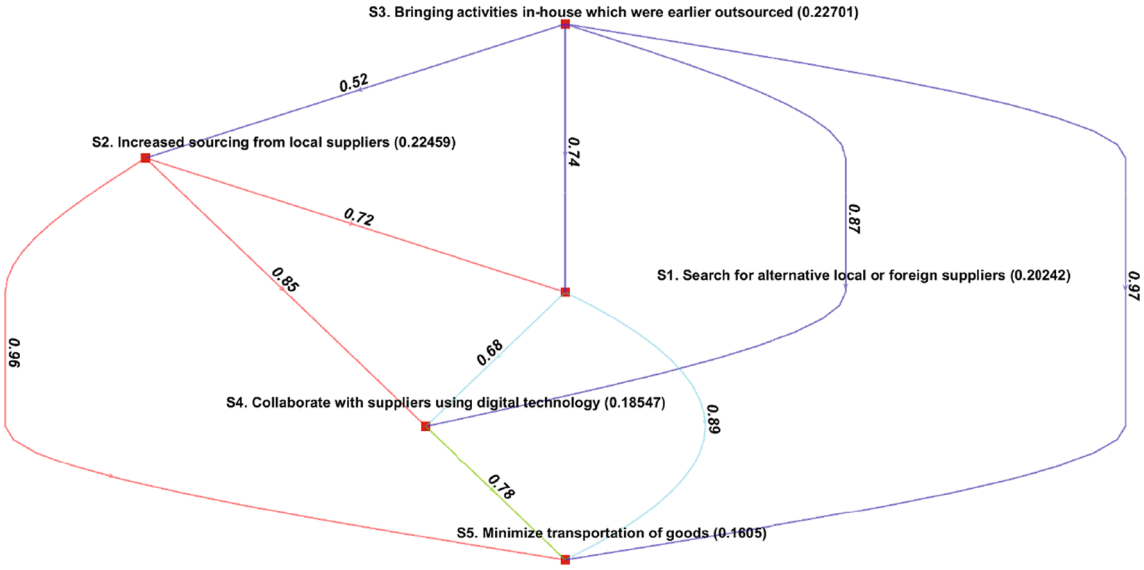

Fig. 5. Ranking of supplier-related implemented measures.

followed by offering discounts to existing orders to minimize order cancellation (0.2051) and offering favourable terms for new orders (0.18518). Considering the threshold of 0.70, ensuring smooth delivery of existing orders were significantly more implemented in comparison to all other buyer-related measures. We can also see the inter-relationship structure among the implemented measures as represented by different colours in Fig. 3.

Local ranking of the employee-related measures are presented in Fig. 4. Out of the six measures under this criteria, the three most implemented measure was providing healthcare safety of the workers and employees (0.28338), reducing working/factory hours (0.16337), and reducing employee travel (0.13943). Further, providing healthcare safety was extremely more implemented than all other measures, as evident from confidence scores ranging between 0.99 to 1.00.

Finally, Fig. 5 presents the local ranking of the supplier-related implemented measures. Bringing activities in-house which was earlier outsourced was implemented the most (0.22701). Moreover, RMG manufacturers increased sourcing from local suppliers (0.22459) and started actively searching for alternative suppliers both in local and foreign markets (.20242). Again, considering 0.70 threshold, bringing activities in-house was significantly more implemented than other supply-related measures except for increased sourcing from local suppliers (0.52).

We report the confidence score matrix for each of the figures in Table 4–7 in the Appendix. Furthermore, by multiplying the criteria level weights with their respective sub-criteria level local weights, we get the global ranking of the 16 implemented measures. Fig. 6 depicts the global rankings. We find that ensuring smooth delivery of existing orders is the most implemented (0.0950), and maintaining employee salaries and benefits as before COVID-19 is the least implemented (0.0440).

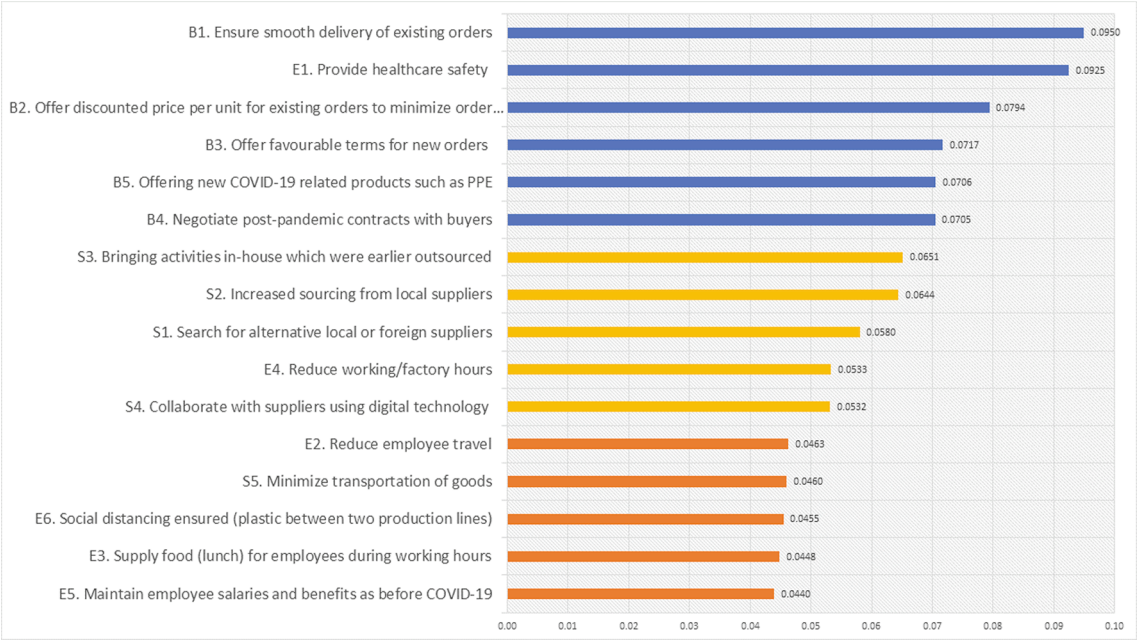

Fig. 6. Global ranking of the implemented measures.

4. Discussion

We discuss the findings reported in Section 3 considering studies published on SCDs and the four interviews conducted for the identification of the implemented measures.

4.1. Setting priorities

Setting clear priorities is one of the most important SCD mitigation strategies (Kleindorfer & Saad, 2005). This study contributes to the SCD literature by providing a validated MCDM framework for determining priorities during SCDs. We found that RMG firms in Bangladesh are focusing more on buyer-related measures than employee and supplier-related ones. As reported in Fig. 6, out of the first six most implemented measures five are buyer-related. Although on the criteria level, employee-related criteria ranked second, on the global ranking of implemented measures, employee related ones rank lowest. The implications of this finding are twofold. First, it shows that to keep the business running firms should prioritise their buyers. On the other hand, RMG firms in Bangladesh are paying too little attention to their employees and workers. For an industry that has long been criticised on this dimension, firms should consider improving this situation even during the pandemic.

4.2. Negotiating contracts

Many orders were cancelled due to COVID-19. By April 2020, orders worth USD 1.8 billion were cancelled, and a further USD 1.4 billion worth of orders to the RMG industry was put on hold (Leitheiser et al., 2020). In case of cancellation of orders, the best approach is to negotiate a new deal. One of the implemented negotiated deals include securing buyers guarantee to cover cost of goods already produced for their orders, mainly by mean of offering discounts from the suppliers' side. Other negotiation deals includes order postponement or slow delivery. It is essential to bear in mind that business can flourish again with the same buyer after the COVID-19. As evident in our findings, even new business opportunities might arise during the COVID-19. Hence, it might be naïve to force legal power too early based on existing contracts. In future sourcing contracts between buyer and supplier should incorporate disruption risk-sharing clauses (Majumdar, Shaw, & Sinha, 2020). For remaining orders, it is necessary to ensure smooth delivery to the buyers. Also, all four interviews stated that they were expecting winter orders from their foreign buyers and were starting to prepare.

4.3. New product development

Some RMG firms have started to manufacture face masks and personal protective equipment (PPE). By the time of interview, Interviewee 2's firm already started production of PPE and cotton-based musk for buyers located in the USA and Canada. According to the interviewee, those buyers put on hold existing orders and gave new purchase orders for PPE and face masks. One of the largest RMG manufactures of Bangladesh, Beximco Textile, has already invested USD 20 million on a PPE and face mask production plant in Detroit, USA[4]. Besides, the disruption in the production process can be useful for deletion of an existing product, and introduce more sustainable version (Zhu, Shah, & Sarkis, 2018). Further, Rapaccini, Saccani, Kowalkowski, Paiola, and Adrodegari (2020) suggest that manufacturing firms should provide services through digitalisation to enhance resilience toward future disruptions. Such initiatives would require innovation in existing business models leading to new product development (de Sousa Jabbour et al., 2020).

4.4. Supplier diversification, but how

The majority of the RMG firms in Bangladesh have been sourcing their materials from China, as reported by all the four interviewees. Companies that already source from multiple suppliers in different countries also realize that they cannot depend on outside suppliers for their core supplies, and thus, are planning to or have already started in-house production of core supplies (de Sousa Jabbour et al., 2020). As stated by Interviewee 1, even though their firm re-opened, supply of incoming materials, majority sourced from China, were cancelled. Hence, they were producing products of which materials they already had in stock. Meanwhile, they were looking for new suppliers (also, stated by all interviewees). Some firms have initiated increasing level of

[4] See https://www.bloombergquint.com/onweb/detroit-to-get-bangladeshi-investment-for-plant-to-make-masks, accessed on October 14, 2020.

safety stock, which is a coping strategy with SCDs as Bueno-Solano and Cedillo-Campos (2014) reported earlier that disruptions due to terrorist attacks can lead to a 600% increase in inventory levels. Riddle et al. (2020) also confirm that SCDs lead to capacity expansion decisions by firms that are not sustainable in the long-run. Hence, we suggest manufacturing firms to stress their supply chain resilience strategies, which are often conflicting with lean supply chain strategies.

4.5. Improvement of workers' health and safety

As reported in Fig. 6, out of the five least implemented measures, four are employee-related measures. The same has been reported by Leitheiser et al. (2020), too. This situation needs attention from the RMG firms, their buyer, policymakers, and government agencies. For the COVID-19 pandemic, manufacturing firms in several emerging markets have received financial support from their governments to support their workers (Karmaker et al., 2020). In collaboration with Bangladesh Garment Manufacturers and Exporters Association (BGMEA), the government of Bangladesh has already initiated financial subsidy plans for the RMG industry. The subsidy plan provides financial support at 2% interest rate to the RMG sector to be paid back in 18 monthly instalments after six months grace period (Interviewee 4 stated during interview). The RMG Sustainability Council (RSC) that took over the functions of Accord has recommended the RMG factories to keep the factory workers as safe as possible[5]. The RSC may negotiate support programs with Western retailers for mitigating the impact of COVID-19 on RMG workers' health and safety. Meanwhile, Majumdar et al. (2020) argue that multinational brands should prefer suppliers that provide better working environment for their workers, including permanent employment contracts. In the same vein, we argue that some of the measures taken for workers' health and safety, e.g. ensuring cleanliness of the factory, regular health monitoring, and arraigning food supplies for the workers, should stay after the COVID-19.

5. Conclusion

COVID-19 has brought many challenges for manufacturing firms. An in-depth study on disruption mitigation strategies adopted by the firms is still unexplored in the literature. Therefore, this study investigates the measures implemented by RMG firms in Bangladesh while continuing production facilities during the pandemic. We investigate implemented measures from the perspectives of suppliers, employees and buyers, as these three stakeholders are the most important for any manufacturing firm. First, we conducted four interviews to form a list of implemented measures. Then, we designed a BWM survey, and distributed it among the RMG industry professionals in Bangladesh.

This study has demonstrated the application of a novel MCDM method. Methodology-wise, we used the Bayesian BWM. For group decision making in the original BWM, we usually analyse preferences of multiple decision makers separately, and then aggregate their priorities using arithmetic mean. As such an approach can be sensitive to outliers, the Bayesian BWM reduces this sensitivity by analysing probabilistic group preferences. We find that buyer-related measures such as ensuring smooth delivery of existing orders, offering discounts to buyers to reduce order cancellation, and revised terms for new orders are most implemented measures in the RMG sector in Bangladesh. As of upstream supply chain, companies are looking into bringing outsourced functions in-house and developing local alternative suppliers. We also found that employee-related measures need further attention. To tackle such disruptions in the future, the RMG firms need to improve their supply chain resilience. Long-term relationship building with buyers, maintaining a diversified portfolio of suppliers including local ones, increased safety stock, organizational and absorptive capability development are essential.

Meanwhile, on a brighter note, the COVID-19 pandemic has forced digitalisation in manufacturing firms. Although located in a developing country, RMG firms have started to look into the application of emerging digital technologies such as cloud manufacturing, blockchain, crowdsourcing and others. Future research should investigate adaption of these technologies in developing countries in the long-run. Also, this pandemic has influenced new product development and internationalisation of some Bangladeshi RMG firms. These topics need further exploration, too.

[5] See https://www.rsc-bd.org/en/resource, accessed on June 01, 2021.

Table 4
Criteria level confidence scores.

Criteria	C1	C2	C3
C1. Supplier-related	0.0000	0.2803	0.0878
C2. Employee-related	0.7197	0.0000	0.2156
C3. Buyer-related	0.9122	0.7844	0.0000

Table 5
Buyer-related measures' confidence scores.

Sub-Criteria	B1	B2	B3	B4	B5
B1. Ensure smooth delivery of existing orders	0.0000	0.8422	0.9427	0.9532	0.9514
B2. Offer discounted price to minimize order cancellation	0.1578	0.0000	0.7106	0.7456	0.7422
B3. Offer favourable terms for new orders	0.0573	0.2894	0.0000	0.5375	0.5361
B4. Negotiate post-pandemic contracts with buyers	0.0468	0.2544	0.4625	0.0000	0.4956
B5. Offering new COVID-19 related products	0.0486	0.2577	0.4639	0.5044	0.0000

Table 6
Employee-related measures' confidence scores.

Sub-Criteria	E1	E2	E3	E4	E5	E6
E1. Provide healthcare safety	0.0000	1.0000	1.0000	0.9997	1.0000	1.0000
E2. Reduce employee travel	0.0000	0.0000	0.5741	0.2062	0.6202	0.5401
E3. Supply food for employees during working hours	0.0000	0.4259	0.0000	0.1565	0.5417	0.4623
E4. Reduce working/factory hours	0.0003	0.7938	0.8435	0.0000	0.8686	0.8224
E5. Maintain employee salaries and benefits as before COVID-19	0.0000	0.3798	0.4583	0.1314	0.0000	0.4185
E6. Social distancing ensured (plastic between two production lines)	0.0000	0.4598	0.5377	0.1776	0.5814	0.0000

CRediT authorship contribution statement

Ziaul Haque Munim: Conceptualization, Data collection, Writing - original draft, Writing - review & editing, Validation. **Majid Mohammadi:** Methodology, Formal Analysis, Software. **Mohammad Hassan Shakil:** Data collection, Writing - review & editing. **Syed Mithun Ali:** Data collection, Writing - review & editing.

Table 7
Supplier-related measures' confidence scores.

Sub-Criteria	S1	S2	S3	S4	S5
S1. Search for alternative local or foreign suppliers	0.0000	0.2836	0.2628	0.6831	0.8939
S2. Increased sourcing from local suppliers	0.7164	0.0000	0.4751	0.8529	0.9648
S3. Bringing activities in-house which were earlier outsourced	0.7372	0.5249	0.0000	0.8660	0.9690
S4. Collaborate with suppliers using digital technology	0.3170	0.1471	0.1340	0.0000	0.7808
S5. Minimize transportation of goods	0.1061	0.0352	0.0310	0.2192	0.0000

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Tables 4–7

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cie.2022.107963.

References

Albertzeth, G., Pujawan, I. N., Hilletofth, P., & Tjahjono, B. (2020). Mitigating transportation disruptions in a supply chain: a cost-effective strategy. *International Journal of Logistics Research and Applications, 23*(2), 139–158.

Ali, S. M., Hossen, M. A., Mahtab, Z., Kabir, G., Paul, S. K., et al. (2020). Barriers to lean six sigma implementation in the supply chain: An ism model. *Computers & Industrial Engineering*, 106843.

Blome, C., & Schoenherr, T. (2011). Supply chain risk management in financial crises–a multiple case-study approach. *International Journal of Production Economics, 134*(1), 43–57.

Bueno-Solano, A., & Cedillo-Campos, M. G. (2014). Dynamic impact on global supply chains performance of disruptions propagation produced by terrorist acts. *Transportation research part E: Logistics and Transportation Review, 61*, 1–12.

Chowdhury, M. T., Sarkar, A., Paul, S. K., & Moktadir, M. A. (2020). A case study on strategies to deal with the impacts of covid-19 pandemic in the food and beverage industry. *Operations Management Research*, 1–13.

de Sousa Jabbour, A.B.L., Jabbour, C.J.C., Hingley, M., Vilalta-Perdomo, E.L., Ramsden, G., and Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (covid-19/sars-cov-2) pandemic: lessons and trends. Modern Supply Chain Research and Applications.

Di Nardo, M., Clericuzio, M., Murino, T., & Sepe, C. (2020). An economic order quantity stochastic dynamic optimization model in a logistic 4.0 environment. *Sustainability, 12(10):4075*.

Gilks, W. R., Richardson, S., & Spiegelhalter, D. (1995). *Markov chain Monte Carlo in practice*. CRC Press.

Gupta, A., & Maranas, C. D. (2003). Managing demand uncertainty in supply chain planning. *Computers & Chemical Engineering, 27*(8–9), 1219–1227.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (covid-19/sars-cov-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*, 101922.

Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research, 57*(3), 829–846.

Karmaker, C. L., Ahmed, T., Ahmed, S., Ali, S. M., Moktadir, M. A., & Kabir, G. (2020). Improving supply chain sustainability in the context of covid-19 pandemic in an emerging economy: Exploring drivers using an integrated model. In *Sustainable Production and Consumption*.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management, 14*(1), 53–68.

Leitheiser, E., Hossain, S.N., Sen, S., Tasnim, G., Moon, J., Knudsen, J.S., and Rahman, S. (2020). Early impacts of coronavirus on bangladesh apparel supply chains.

Majumdar, A., Shaw, M., & Sinha, S. K. (2020). Covid-19 debunks the myth of socially sustainable supply chain: A case of the clothing industry in south asian countries. *Sustainable Production and Consumption, 24*, 150–155.

Mohammadi, M., & Rezaei, J. (2020). Bayesian best-worst method: A probabilistic group decision making model. *Omega, 96*, 102075.

Olivares-Aguila, J., & ElMaraghy, W. (2020). System dynamics modelling for supply chain disruptions. *International Journal of Production Research*, 1–19.

Pintelon, L., Di Nardo, M., Murino, T., Pileggi, G., & Vander Poorten, E. (2021). A new hybrid mcdm approach for rpn evaluation for a medical device prototype. *Quality and Reliability Engineering International*.

Plummer, M. (2004). Jags: Just another gibbs sampler.

Rapaccini, M., Saccani, N., Kowalkowski, C., Paiola, M., & Adrodegari, F. (2020). Navigating disruptive crises through service-led growth: The impact of covid-19 on italian manufacturing firms. *Industrial Marketing Management, 88*, 225–237.

Riddle, M. E., Tatara, E., Olson, C., Smith, B. J., Irion, A. B., Harker, B., Pineault, D., Alonso, E., & Graziano, D. J. (2020). Agent-based modeling of supply disruptions in the global rare earths market. *Resources, Conservation & Recycling, X*, 100042.

Ruiz-Torres, A. J., & Mahmoodi, F. (2007). The optimal number of suppliers considering the costs of individual supplier failures. *Omega, 35*(1), 104–115.

Sharma, R., Shishodia, A., Kamble, S., Gunasekaran, A., & Belhadi, A. (2020). Agriculture supply chain risks and covid-19: mitigation strategies and implications for the practitioners. *International Journal of Logistics Research and Applications*, 1–27.

Xu, S., Zhang, X., Feng, L., & Yang, W. (2020). Disruption risks in supply chain management: a literature review based on bibliometric analysis. *International Journal of Production Research, 58*(11), 3508–3526.

Zhu, Q., Shah, P., & Sarkis, J. (2018). Addition by subtraction: Integrating product deletion with lean and sustainable supply chain management. *International Journal of Production Economics, 205*, 201–214.