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Mitigate risks in perishable food supply chains: Learning from COVID-19

Anish Kumar [a], Sachin Kumar Mangla [b,c], Pradeep Kumar [a], Malin Song [d,*]

[a] Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, India
[b] Jindal Global Business School, O P Jindal University, Haryana 131001, India
[c] Plymouth Business School (PBS), University of Plymouth, Plymouth PL4 8AA, United Kingdom
[d] Collaborative Innovation, Center for Ecological Economics and Management, Anhui University of Finance and Economics, China

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ABSTRACT

Food Supply Chains (FSCs) are among the essential services in a pandemic. Perishable food supply chains (PFSC) perform under higher risks as they struggle against greater wastage and product life cycle issues along with the logistics, operational, financial, and health risks during the COVID-19 pandemic. While facing these contingencies, it is essential to formulate strategies in real-time. In this paper, we identify and analyze risk mitigation strategies for PFSC during the current pandemic. We have initially discussed the uncertainties and risks related to pandemic situations and subsequently identified risk mitigation strategies to manage PFSC in such situations. We prioritized the identified strategies using the fuzzy-best worst methodology (F-BWM). The BWM is a highly effective decision-making method with higher consistency. The fuzzy extension to the best worst method (BWM) helps in incorporating vagueness and fuzziness in the decision. As a result, F-BWM is an excellent approach to analyze risk mitigation strategies as the business contingencies in PFSC during this pandemic are unique, with the industry having only a few clear ideas about how best to mitigate them. Among the risk mitigation strategies, "collaborative management," "proactive business continuity planning," and "financial sustainability" are the top risk mitigating strategies. Other identified strategies are also extremely useful for varied environmental contingencies. Thus, this research has been underpinned by the contingency theory and discusses all mitigation strategies concerning the socioeconomic contingencies originating from COVID-19. This research is a novel effort in identifying and analyzing the risk mitigation strategies for enhancing the socioeconomic-ecological performance of PFSCs in meeting the sustainable development goal of healthy and safe food for everyone.

1. Introduction

The year 2020 brought with it a global crisis. Global economies faced a "black swan situation," a pandemic. Nobody can predict such a crisis's scale and timing; neither can we specify the best response strategy for such an event (Ker and Cardwell, 2020). The economies running on just-in-time supply chains were brought to a halt by lockdowns and numerous trade barriers. However, as food items are an essential commodity and a basic human survival requirement, the food supply chains (FSCs) need to stay functioning even through the crisis. This pandemic has severely hit FSCs due to risks ranging from humanitarian issues to an uncertain business environment, with its socioeconomic impact felt across the globe. Food security, in particular, has been the most critical risk in this pandemic. The pandemic has impacted all four pillars of food security- availability, accessibility, utilization, and stability (Laborde et al., 2020). According to the World Food Programme's executive director, this pandemic could easily convert into a hunger pandemic resulting in starvation, food catastrophes, and famines of biblical proportions (Harvey, 2020). Although, thanks to a swift global response, no significant food shortage has been reported yet. Global food security is challenged due to disrupted production, processing, and marketing upstream of the FSC, disrupting economic and physical access to food downstream of the FSC. The fluctuating and unfulfilled demand for food items led to panic buying, price fluctuations, supply disruptions, etc. The nutritional requirements of millions of people who depend upon government programs have been under threat during this pandemic. Perishable food supply chains (PFSC) are the worst hit among FSCs. Perishable products such as fruits and vegetables, if they are not harvested, procured, processed and marketed promptly, could lead to disastrous amounts of wastages, farmers in financial crisis, societal

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* Corresponding author.
E-mail address: songmartin@163.com (M. Song).

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distress and economic losses throughout the marketplace. Along with the health risk associated with the supply chain transactions, the current pandemic's socioeconomic risks call for immediate action and the formulation of mitigation strategies.

The FSCs in developed countries are resilient as they are more organized and automated, while in developing countries, they are labor-intensive and unorganized. The effects have been much more devastating for developing economies, where due to restrictions, many developing countries find themselves on the brink of hunger and malnutrition (Dahir, 2020). Previous researchers have also shown that economic growth in lower-middle-income countries is most significantly impacted by disasters, either catastrophic or non-catastrophic (Onuma et al., 2020). Thus, we take a developing economy perspective, studying the PFSC in India in this paper. A complete lockdown was declared in India on 25 March 2020; this was further extended then later relaxed throughout different phases (Kumar and Managi, 2020). This resulted in disruptions across all sections of society and the general economy. Disruptions were seen in the supply and demand across the FSCs with the changing scenarios of rising infections in India (Singh et al., 2020). The situation in PFSC is critical in India, where a significant population depends on agriculture for employment. Perishable products such as milk, fruits, and vegetables are a source of sustainable income for many. Due to the disruptions, the farmers in PFSC are paying more for the labor and transport, yet being underpaid for their produce. Further, the demand side of PFSC in India has also witnessed severe disruptions due to the closure of markets, interrupted logistics, and sudden lockdowns. The organizations in FSCs in India bear the burden of providing for the food requirements of the massive population of India. Thus, it is vital to strategize to mitigate the socioeconomic risks originating from the pandemic from the perspective of a developing economy such as India.

Organizations working in PFSC in India are under tremendous stress owing to the risks in operations arising in a pandemic - shortages of labor, cash, raw material, etc. Many of the risks faced are typical of disasters, such as demand and supply uncertainties, inadequate logistics, and lack of information credibility (L'Hermitte et al., 2016). Some characteristics, such as suspension of major economic activities and shutting off of markets and significant demand sources at the national and global level, are specific economic challenges posed by this pandemic. Although organizations cannot predict such events, they should still proactively plan for mitigating risks and uncertainties in their value chains. Such disruptions require proactive as well as reactive planning for mitigation and preparation (Yao et al., 2018). While significant loss and damage in PFSC have already taken place, the pandemic does not seem to be over yet. The best option for planners and managers is to deal with it in real-time (Ker, 2020). They should build contingency plans for their operations and should include different stakeholders in such planning. They should be aware of the contingencies as well as new opportunities in the market and business environments.

While it is necessary to study the gaps and identify the risks arising out of them, the need-of-the-hour is to formulate risk mitigation strategies, which is the paper's primary contribution. A few studies have previously focused on risks in FSC (Diabat et al., 2012; Nakandala et al., 2017); risk mitigation has been mostly untouched in the PFSC domain. Even among those previous studies on risks in FSC/PFSC, none has ever specifically considered a pandemic disruption of the scale of COVID-19. Thus, the present study examines the problem of risk mitigation strategies in PFSC during the COVID-19 pandemic in the Indian context. We have consulted previous literature and experts working in the PFSC sector in India for this study. We discussed with them the risks they were facing during the COVID-19 pandemic and the strategies they were following to mitigate these risks. The identified strategies are analyzed and prioritized using the fuzzy-best worst method (F-BWM). A few papers have analyzed FSC/PFSC related problems using the best-worst method (BWM) (Kumar et al., 2020; Rezaei et al., 2019). However, the previous applications of BWM have not explored the context of prioritizing risk mitigation; this is, therefore, another major contribution of this study.

The paper is theoretically grounded using contingency theory (CT). CT identifies no "one size fits all" model for appropriateness and efficiency of risk mitigation strategies (Talluri et al., 2013). An organization's performance in mitigating risks depends upon how well its strategic behavior matches the environmental contingencies (Wong et al., 2011). While a priority among risk mitigation strategies is generated through the F-BWM multi-criteria decision making (MCDM) technique, various inter and intra-organizational factors play a key role in selecting the optimal strategy. Decision making for risk mitigation strategies should depend upon the risk context in the organizational environment (Chang et al., 2015; Grötsch et al., 2013). Building upon the notion of CT, we first identify various contingencies originating due to the pandemic and later relate these contingencies with the mitigation strategies. Using the CT perspective, the appropriateness of different mitigation strategies is suggested.

Based on this view, the following are the research objectives for this study:

i Identify risk mitigation strategies in PFSC;
ii Analyze and prioritize the risk mitigation strategies;
iii Suggest managerial implications for relating the appropriateness of the risk mitigation strategies with the contingencies.

Section 2 presents the theoretical background of this study. Section 3 presents the research methodology adopted for this study. We use F-BWM to analyze the risk mitigation strategies. The data collection and the results of the analysis are presented in Section 4. Section 5 presents a discussion of the results of the analysis and the managerial implications by relating the mitigation strategies with the contingencies during COVID-19. Finally, Section 6 completes the study with a conclusion and limitations.

2. Theoretical background

Researchers have previously identified that discontinuity scenarios such as pandemics will play a pivotal role in the future of global supply chains (SC) and logistics (Von der Gracht and Darkow, 2013). FSCs are significant for global food security and health; however, a pandemic can have a devastating impact on them. We review the relevant literature to identify the socioeconomic impacts of a pandemic on PFSC and identify the contingent scenarios to frame possible risk mitigation strategies.

2.1. Impacts (socioeconomic) of a pandemic on PFSC

The studies on the impact of COVID-19 in the Canadian agriculture sector were published recently (Ker and Cardwell, 2020). However, they explicitly consider Canadian agriculture and the effects of COVID-19 on it. Health, transportation, trade, and financial stability are the most important factors for food availability and continuity of FSCs (Deaton and Deaton, 2020). Hailu (2020), studying the effects of supply and demand shocks, identifies the impact of policies to contain the epidemiological effect of the pandemic spread on the food processing industry. Recent articles mostly recognize the SC of staples such as grains, oilseeds, and pulses, to be stable, at least in the short term (Brewin, 2020). However, that is not the case with perishables such as fruits, vegetables, meat, and even milk. Immediate losses in PFSCs are visible due to lack of procurement as well as distribution channels, inability to shift distribution from restaurants and bars to retailers (Richards and Rickard, 2020), the shutdown of processing plants, the disruption to exports and imports, plus labor shortages (Weersink et al., 2020). The socioeconomic impacts of such risks are falling producer incomes, increasing supply chain costs, shortages, and wastages. With disrupted logistics due to a ban on exports, large amounts of perishable products are waiting for marketing; companies require more storage. The crisis has led to severe constraints on storage space capacity (McEwan et al., 2020). The articles produced in this special issue are focused on Canada, a developed country. However, the concerns from the perspective of developing economies may be very different.

The possibility of transmission of the infection through the FSC cannot be overlooked (Rizou et al., 2020). Thus, vital supplies, such as personal protective equipment (PPE), hygiene-related products, and sanitizers, are also critical to allow operations to continue (Rowan and Laffey, 2020); these also have been severely constrained during the current situation. Practicing social distancing and working with greater virtual and fewer physical interactions are essential requirements of the measures in place to contain the COVID-19 virus. However, operations in FSCs require a lot of physical contact and human interaction for various activities (Jawed et al., 2020). Poor implementation of safety measures and hygiene standards in local markets is a significant health risk in PFSC.

A range of factors, such as labor shortage, closure of businesses, price fluctuations, supply and demand fluctuation, are simultaneously affecting PFSC (Cranfield, 2020; McEwan et al., 2020). Price fluctuations in FSCs have the potential to cause a food crisis, as was seen at a global level in 2008 (Moseley, 2011). Procurement failure, the weak market price, reduced labor and farm harvesting machinery availability, and disruption to feed and farm inputs are some of the risks at the farm level. This pandemic has also highlighted how laborers are among the most vulnerable groups facing the pandemic. The panic exodus of labor resulted in sudden and severely hampered operations in PFSCs in India (Vyas and Singh, 2020). Other workforce-related disruptions in a pandemic are the constrained movement, absenteeism, and unavailability. A pandemic response's robustness is strictly dependent upon the operational continuity of critical infrastructure (National Infrastructure Simulation and Analysis Center, 2007). The sudden closure of local markets where farmers could sell their produce directly has sent significant supply shocks down the PFSC. Business continuity faces a shortage of essentials to keep plants running, such as packaging material and fuel. Further, there are health and safety concerns and regulatory issues such as the hard handedness of local authorities, with police shutting down warehouses and facilities.

Demand management also becomes significant in crises. First, the massive economic shock due to COVID-19 has caused a significant drop in household income and consumption (Martin et al., 2020). Further, consumers may also resort to hoarding and panic buying in anticipation of shortages and stock-outs of essentials (Weersink et al., 2020). The demand side also shows uncertainty with a shift in consumer behavior affecting restaurants, the retail sector, and increased online channels (Goddard, 2020). The stigma of going out also impacts demand. Governments also enforce legal policies and promote people's behavioral self-restraint from going out (Kurita and Managi, 2020). Faced with a psychological fear of infection and the stigma of going out (Katafuchi et al., 2020), consumers are shifting more towards online buying. Distribution planning and resource allocation in a pandemic face demand uncertainties and sudden cancellations of previous orders (Schätter et al., 2015). Transportation bottlenecks often lead to increased inventory at the producer end and product shortages at the retailer end (National Infrastructure Simulation and Analysis Center, 2007). There were bottlenecks in last-mile delivery in the early stages. Many areas were suddenly brought under lockdown, leading to many delivery failures, causing unsatisfied orders, wasted vehicle trips, and wasted products. Further demand risk is aggravated by misinformation, causing a sudden drop in the purchase of specific products such as meat and poultry owing to misinformation and fear of infection (Ghosal, 2020).

The dynamic and exogenous nature of the pandemic disruption makes it tough to frame an effective risk mitigation policy. However, managers should keep various contingencies under consideration while formulating these policies. In line with CT, we further look for FSC literature on risk mitigation and SC resilience strategies that could be useful in mitigating the above-discussed contingencies.

2.2. Strategies for risk mitigation in PFSC during a pandemic

In a pandemic, business continuity planning (BCP) forms a vital part of the SC chain risk management and mitigation plan (Schätter et al., 2019). Organizations in PFSC need to maintain operations continuity even during the SC vulnerabilities and shortages caused by a crisis (Tosh et al., 2014). BCP involves identifying critical partners, processes, generating plans for disruption scenarios, selecting alternatives to replace the disrupted nodes, and generating plans to tackle the expected contingencies (Abercrombie, 2007). Manning and Soon (2016) suggest that BCP should specifically consider the contingencies and degree of turbulence in the environment in which it will operate. It is challenging but necessary to ensure that PFSCs are resilient with minimum disruption (Huff et al., 2015). However, research in business continuity and supply chain resilience is not given due consideration. The present pandemic has brought these two concepts to the center stage (Pournader et al., 2020).

Human resource (HR) and staff-related challenges are critical for an effective pandemic response (Avisoet al., 2018; Chaturvedi et al., 2014). Hecht et al. (2019) identify emergency response planning, with a dedicated staff at its center, as a critical factor for organizational resilience in an FSC. Allotting dedicated staff and forming a dedicated response team is the first step in crisis management. Such a response team should be centrally coordinated and cross-functional. It should manage risk mitigation and maintain continuity of supply chains (Chowdhary and Quaddus, 2016).

Further, PFSCs involve a lot of person to person and person to product interactions; the staff must be well trained on new procedures, hygiene, social distancing, and safety guidelines. An organizational emergency response's effectiveness depends on how well the team is trained and how protocols are communicated to them (Hecht et al., 2019). Staff skills and knowledge retention are vital to adapt to changing roles and positions in a disruptive scenario (Stone and Rahimifard, 2018). Thus, training and proper communication with staff and employees are critical for the effective use and implementation of available resources (Chowdhary and Quaddus, 2016; Stone and Rahimifard, 2018).

Quick adaptability of shifting from one SC model to another, such as flexibility of moving from centralized collection centers for agri-produce procurement to moving procurement closer to the farmers, can significantly reduce mobility requirements and pandemic related risks (Cullen, 2020). Ishfaq (2012) and Tang (2006) identified SC flexibility as an essential antecedent to resilience. Rajesh (2017) recognized the capability to modify SC design and capacity enhancement as strong drivers of SC resilience. Initially, disruptions in FSC come in terms of demand fluctuations; further down the timeline, material shortages and supply disruptions are seen. However, flexibility realized through surplus inventories and capacity margins can significantly dampen these effects (National Infrastructure Simulation and Analysis Center, 2007). Flexible SC design using multi-modal transportation with multiple suppliers for critical supplies fare better in a crisis. Tukamuhabwa et al. (2015) suggest flexibility in the supply base, transportation, workforce arrangement, and order fulfillment to enhance SC's resilience in a crisis. Redundancy of supplies, resources, infrastructure, suppliers, and service providers are key factors for the emergency response of a resilient FSC (Hecht et al., 2019). Vlajic et al. (2012) suggest the use of multipurpose resources and temporary workers to enhance the flexibility of FSC during a crisis. While flexibility often reduces the efficiency of an SC, redundant and alternate resources improve the feasibility of an organization's survivability strategy.

SC collaboration is an essential antecedent framing SC resilience constructs (Scholten and Schilder, 2015). It is realized through information sharing and regular communication, risk and resource sharing, joint solution-seeking, and knowledge creation while responding to disruption. Stone and Rahimifard (2018) identify cohesion, co-learning, and collaboration as important capabilities for agri-food SC resilience.

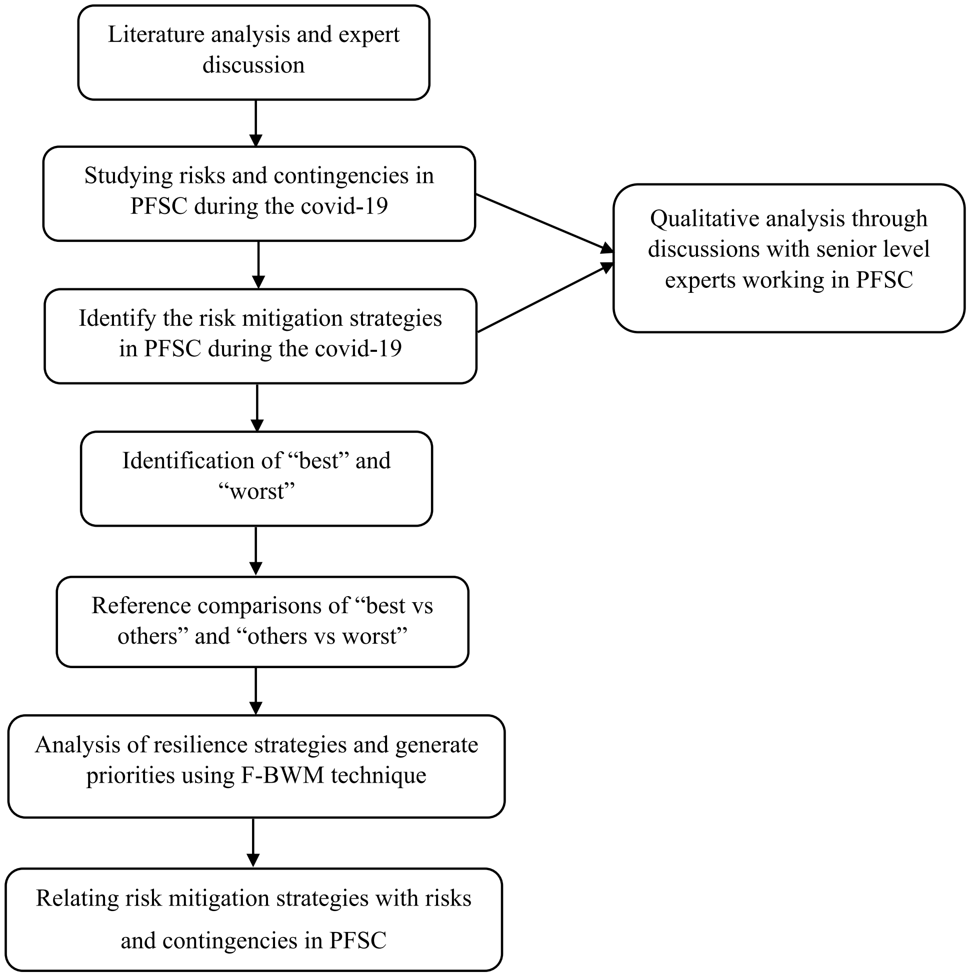

Fig. 1. Research framework.

Such collaboration enables the effective usage of resources to mitigate multiple risks during a crisis. Information and knowledge management are critical for agri-food SC's resilience (Zhao et al., 2018). While managing a crisis, asymmetry in information could be a significant source of risk in an SC (Pournader et al., 2020); information management is a primary antecedent to SC resilience (Ponomarov, 2012). Upside and downwards information flow help manage internal processes such as inventory and stock-out conditions in the FSC and handle external situations such as lockdowns and policy measures from the Government. Managing information flow is necessary to minimize vulnerabilities (Tukamuhabwa et al., 2015). Accurate information on food logistics and the SC situation, assuming retailers' capacity to provide for future demand, can ease consumer concerns (Hailu, 2020). Transparency, accuracy, and speed of information are critical to support decision-making in a crisis (Vlajic et al., 2012). In a crisis, where the cost of a safety lapse is high, buyers prefer sourcing from suppliers with high standards of transparency and traceability (Sun and Wang, 2019). While previously, consumers were only interested in product-specific traceability information, now there is also the demand for information related to the people involved in its logistics. In such an environment, firms that excel in data and technology management in their SCs are better placed. It enhances connectivity, visibility, and collaboration to better respond to disruption (Tukamuhabwa et al., 2015). Another perspective of technology management is the digital transformation of FSCs. Government policies related to banking, trade, marketing, and other administrative interventions are crucial in managing FSC during such a crisis (Yazdani et al., 2019). Such policies must ensure the protection of agriculture and dairy farmers by providing financial support and continued access to markets and on-field procurement (Khan et al., 2020). Financial sustainability is essential for every stakeholder of the FSC, such as farmers, who can only produce when they have access to finance (Cullen, 2020). Financial stability is a key supportive capability for all other resilience capabilities as well (Stone and Rahimifard, 2018). Hailu (2020) identified that at least 25% of Canada's food processing firms are unable to meet short-term financial obligations. Many governments have already announced financial support for firms as well as farmers. However, it is essential to provide immediate targeted relief to farmers and firms in PFSC.

Based on a review of relevant literature and extensive discussions with experts, we have identified the following risk mitigation strategies; these will be analyzed later.

In this study, we take a CT approach to discuss the above-identified risk mitigation strategies' appropriateness with the risks during COVID-19. The mitigation strategies' success depends on the contextual factors of a firm's operations (Fiedler, 1964). The contextual factors could be environmental uncertainties as well as situational uncertainties (Lusiantoro et al., 2018). Before selecting a mitigation strategy, it is necessary to understand the risks and uncertainties and individualize its best response (Trkman and McCormack, 2009). Various studies on risk management in SC have used the CT approach (Ali et al., 2018; Chang et al., 2015; Grötsch et al., 2013). Thus, we base our discussion of risk mitigation strategies on CT to identify their appropriateness concerning various contingencies.

3. Research methodology

The crisis caused by the COVID-19 pandemic is still developing, with new risks in PFSC emerging. To identify the risk mitigation strategies, we use two parallel strategies of referring to the literature review along with discussions with senior-level managers of organizations working in the PFSC industry. Basing our study on a CT view, experts were asked about the risks they were facing in PFSC during the COVID-19 pandemic and which strategies they suggest for mitigating those risks. The identified risk mitigation strategies were validated, and "best" and "worst" strategies were identified through a pilot survey. Using the "best" and "worst" strategies, we conducted reference comparisons for F-BWM. The steps for F-BWM are given in sub-Section 3.1. F-BWM gives us the priorities among the risk mitigation strategies. The results of F-BWM were further analyzed with respect to the contingencies in PFSC. A schematic of the research framework is shown in Fig. 1.

3.1. Fuzzy-best worst method

The Best-Worst Method (BWM) is a multi-criteria decision making (MCDM) method based on pairwise comparisons of all other factors with the "best" and the "worst" factor, introduced by (Rezaei, 2015). Previous studies have shown this method to give better results in terms of consistency, conformity, and total deviation of results as compared to other methodologies (Orji et al., 2019). The method also performs better in terms of the number of comparisons required as compared to other MCDM methods such as Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) (Gupta and Barua, 2016).

A fuzzy extension of decision-making methodologies is extremely useful in problems consisting of vagueness and fuzziness in decision making, as is the current problem. A fuzzy extension of the BWM, earlier proposed by Guo and Zhao (2017), is apt for such a decision-making problem. The triangular fuzzy number (TFN) is used here; it is widely used in literature due to its conceptual simplicity and ease of computation (Kannan et al., 2014).

A TFN, $\overline{A}$ on the set R, with its membership function $\mu_{\overline{A}}(x) : R \rightarrow [0,1]$, is defined by a triplet (l,m,u), with its membership functions defined as follows (Mangla et al., 2015)-

$$\mu_{\overline{A}}(x) = \left\{ \begin{array}{l} \frac{x-l}{m-l},\ x\epsilon[l,m] \\ \frac{x-u}{m-u},\ x\epsilon[m,u] \\ 0,\ Otherwise \end{array} \right\}$$

Assuming two TFN, $A = (l_1, m_1, u_1)$, and $B = (l_2, m_2, u_2)$, the operational laws of TFN are as follows (Wang et al., 2018)-

$$A(+)B = (l_1,\ m_1, u_1) + (l_2,\ m_2, u_2) = (l_1 + l_2,\ m_1 + m_2,\ u_1 + u_2)$$

$$A(-)B = (l_1,\ m_1, u_1) - (l_2,\ m_2, u_2) = (l_1 - u_2,\ m_1 - m_2,\ u_1 - l_2)$$

$$A(\times)B\ = (l_1,\ m_1, u_1) \times (l_2,\ m_2, u_2) = (l_1 l_2,\ m_1 m_2,\ u_1 u_2)$$

$$A(/)B = (l_1,\ m_1, u_1)/(l_2,\ m_2, u_2) = (l_1 l_2,\ m_1 m_2,\ u_1 u_2)$$

$$A^{-1} = \left(\frac{1}{l_1}, \frac{1}{m_1}, \frac{1}{u_1}\right)$$

The Graded-Mean-Integration representation is (GMIR); $G(\overline{A}_j)$ is used to rank the TFN and de-fuzzify the solutions.

$$G\left(\overline{A}_j\right) = \frac{l_j + 4m_j + u_j}{6}$$

The steps for F-BWM are as follows:

Step 1 Identification and finalizing risk mitigation strategies.

The risk mitigation strategies were identified based on a literature

Table 1.
Risk mitigation strategies in PFSC.

Mitigation Strategy	Brief Explanation	References
Training and Communication **(S1)**	Top management should continuously communicate with their employees to motivate and guide them through situations and solve problems in real-time. Regular training and communication of protocols enable the operational response to a disruption.	(Hecht et al., 2019; Ivanov, 2020)
Proactive Business Continuity Planning **(S2)**	Identify critical business operations, suppliers, vendors, personnel as well as backup personnel associated with them. Formulate and implement organizational hygiene and operational guidelines for the pandemic.	(Manning and Soon, 2016; Sahebjamnia et al., 2015; Schätter et al., 2019)
Collaborative Management **(S3)**	New collaborations could help organizations arrange necessary supplies, solve logistics issues, find new business opportunities, transfer extra labor from a partner organization to operations with a labor shortage. Organizations should communicate and collaborate with local authorities	(Chowdhary and Quaddus, 2016; Scholten and Schilder, 2015; Stone and Rahimifard, 2018)
Central Response Team **(S4)**	A central response team with top management involvement reduces decision making lag. It adds responsiveness with a top-down implementation and synchronization of resilient strategies needed.	(Chowdhary and Quaddus, 2016; Hecht et al., 2019; Manning and Soon, 2016)
Enhance Transparency **(S5)**	Transparency regarding the organizational sanitation and safety standards and those of the suppliers could help raise employee and customer confidence and organizational responsiveness towards disruptions. Further, knowledge of procurement location, if it lies in a COVID hotspot, protects suppliers' health status, reducing operational risks.	(Muzvondiwa, 2017)
Digital and Technology Management **(S6)**	The use of technology for real-time vehicle monitoring, real-time employee temperature monitoring, image/voice capture software, automatic packaging could significantly monitor and reduce health risks. Rising online sales would require swift and smooth digital transformation with steps such as alignment of organizational resources, updating inventories online, online issuing city passes, etc.	(Ivanov, 2020; Ivanov and Dolgui, 2020)
Information Management **(S7)**	Firms should deploy early warning systems for capturing regulatory changes, quick responses to	(Chaturvedi et al., 2014; Stone and Rahimifard, 2018; Vlajic et al., 2012; Zhao et al., 2018)

(*continued on next page*)

Table 1. (*continued*)

Mitigation Strategy	Brief Explanation	References
	new COVID hotspots, and reallocate resources accordingly. Any strategic organizational change is communicated to lower-level management and employees in good time.	
Flexible business model **(S8)**	The firm moves from a centralized to a decentralized procurement system, explore new markets, new customers, and a product portfolio. It should keep redundant resources with a broader supply base for swift repurposing of resources in case of disruption.	(Ishfaq, 2012; Jiang et al., 2009; Tang, 2006; Tukamuhabwa et al., 2015)
Financial sustainability **(S9)**	Mitigating COVID risks incorporates new expenses such as providing insurance cover to employees, extra sanitation expenditure, PPEs, salaries for absent employees as well as overtime for present employees. Firms should ensure cash liquidity and credit availability. They should avoid adding fixed expenses and limit extra costs.	(Cullen, 2020; Hailu, 2020; Stone and Rahimifard, 2018)

Table 2.
Linguistic terms for fuzzy-reference comparisons.

Linguistic Term	Membership Function
Equally Important (EI)	(1, 1, 1)
Weakly More Important (WI)	(0.667, 1, 1.5)
Strongly More Important (SI)	(1.5, 2, 2.5)
Very Strongly More Important (VSI)	(2.5, 3, 3.5)
Absolutely More Important (AI)	(3.5, 4, 4.5)

review and expert discussions. The set of identified strategies, shown in Table 1, is coded as $S = (S_1, S_2, ...S_n)$

Step 2 Selecting the "best" and "worst" strategies.

Step 2 is crucial in the methodology as the reference comparisons are conducted for the "best vs. others" and "others vs. best" strategies. Using an initial pilot survey, we identify "Collaborative Management" as the best strategy with "Training and Communication" as the worst risk mitigation strategy; they are coded as-

S_B = "Collaborative Management"

S_W = "Training and Communication."

Step 3 Conduct fuzzy reference comparisons of "best vs. others" and "others vs. worst" strategies.

The experts participating in the study were mailed a copy of the second part of the survey, containing questions for reference comparisons using the linguistic terms given in Table 2.

The expert inputs are coded as follows;

$\overline{C_B^k} = (\overline{c_{B1}^k}, \overline{c_{B2}^k}, ...\overline{c_{Bj}^k}, ..., \overline{c_{Bn}^k})$, reference comparison of "best" strategy with "others" by expert k.

$\overline{C_W^k} = (\overline{c_{1W}^k}, \overline{c_{2W}^k}, ...\overline{c_{jW}^k}, ..., \overline{c_{nW}^k})$, reference comparison of "all others" with "worst strategy by expert k.

The inputs for any reference comparison from a total K number of experts is aggregated to a fuzzy reference comparison input for F-BWM as follows;

$\bar{c} = (l, m, u) = (\min l^k, \text{ GM } m^k, \max u^k)$, where min stands for minimum lower bound, GM for geometric mean, and max for maximum among the upper bounds of all fuzzy inputs by experts for a particular reference comparison value.

Step 4 Generating fuzzy-optimal weights ($\overline{W_1}$, $\overline{W_2}$, ...$\overline{W_n}$)

The reference comparisons will be perfectly consistent if all comparisons are such that $\frac{\overline{W_B}}{\overline{W_j} = \overline{c_{Bj}}}$ and $\frac{\overline{W_j}}{\overline{W_B} =} \overline{c_{jW}}$. However, this may not always be the case, and we have to minimize the difference between $(\frac{\overline{W_B}}{\overline{W_j}}$ and $\overline{c_{Bj}})$, as well as $(\frac{\overline{W_j}}{\overline{W_B}}$ and $\overline{c_{jW}})$. For this, the constrained programming problem is given by Guo and Zhao (2017). The fuzzy formulation of the constrained programming problem for the BWM to generate the fuzzy-optimal weights ($\overline{W_1}$, $\overline{W_2}$, ...$\overline{W_n}$), numbered as "Problem 1", is given below;

$$\min \xi \qquad \text{(Problem 1)}$$

Such that

$$\left|\frac{(l_B,\ m_B,\ u_B)}{(l_j,\ m_j,\ u_j)} - (l_{Bj},\ m_{Bj},\ u_{Bj})\right| \le (k^*,\ k^*,\ k^*)$$

$$\left|\frac{(l_j,\ m_j,\ u_j)}{(l_W,\ m_W,\ u_W)} - (l_{jW},\ m_{jW},\ u_{jW})\right| \le (k^*,\ k^*,\ k^*)$$

$$\sum_{j=1}^{n} G(W_j) = 1$$

$$l_j \ge 0;$$

$$l_j \le m_j \le u_j$$

$$j = 1,\ 2,\ ....,\ n$$

Where, $\overline{W_B} = (l_B,\ m_B,\ u_B)$, $\overline{W_W} = (l_W,\ m_W,\ u_W)$, are the fuzzy weights of the best and worst factors.

$\overline{c_{Bj}} = (l_{Bj},\ m_{Bj},\ u_{Bj})$, are the aggregated "best" vs "others" reference comparisons.

$\overline{c_{jW}} = (l_{jW},\ m_{jW},\ u_{jW})$, are the aggregated "others" vs. "worst" reference comparisons.

$\bar{\xi} = (l^{\xi},\ m^{\xi},\ u^{\xi})$, is the minimized objective function, we suppose $\bar{\xi} = (l^{\xi},\ m^{\xi},\ u^{\xi}) = (k^*,\ k^*,\ k^*)$, such that, $k^* \le l^{\xi}$.

As the above equation set with fuzzy numbers cannot be solved in a solver directly, the above fuzzy non-linear constrained programming problem is transformed to the following non-linear constrained problem with non-fuzzy numbers obtained using the operational laws of the TFN, numbered as "Problem 2", is given below;

$$\min k^* \qquad \text{(Problem 2)}$$

Such that

$$|l_B - (l_{Bj}u_j)| \le (k^* u_j)$$

$$|m_B - (m_{Bj}m_j)| \le (k^* m_j)$$

$$|u_B - (u_{Bj}l_j)| \le (k^* l_j)$$

$$|l_j - (l_{jW}u_W)| \le (k^* u_w)$$

$$|m_j - (m_{jW}m_W)| \le (k^* m_W)$$

$$|u_j - (u_{jW}l_W)| \le (k^* l_W)$$

$$\sum_{j=1}^{n} G(W_j) = 1$$

$$l_j \ge 0;$$

Table 3.
Consistency index for F-BWM.

Linguistic terms	EI	WSI	SI	VSI	AI
$\tilde{c}_{BW}$	(1,1,1)	(0.667, 1, 1.5)	(1.5, 2, 2.5)	(2.5, 3, 3.5)	(3.5,4, 4.5)
CI	3	3.80	5.29	6.69	8.04

Table 4.
Identifying "best" and "worst" risk mitigation strategies.

Risk Mitigation Strategy	Importance Score
Training and Communication **(S1)**	2.23
Proactive Business Continuity Planning **(S2)**	3.27
Collaborative Management **(S3)**	3.32
Central Response Team **(S4)**	2.68
Enhance Transparency **(S5)**	2.82
Digital and Technology Management **(S6)**	2.64
Information Management **(S7)**	2.82
Flexible business model **(S8)**	3.18
Financial sustainability **(S9)**	3.13

$$l_j \leq m_j \leq u_j$$

$$j = 1,\ 2,\ \ldots\ldots.,\ n$$

This transformed problem, given in "Problem 2″, is coded in LINGO 18.0 and solved to determine the fuzzy weights $\overline{W_1}$, $\overline{W_2}, \ldots\ldots.\overline{W_n}$.

Step 5 Determine the consistency ratio for all the reference comparisons conducted.

The reference comparisons for the BWM will be consistent when for all the reference comparisons, $\overline{c_{Bj}} \times \overline{c_{jW}} = \overline{c_{BW}}$. However, it is not possible for expert inputs to be perfectly consistent; thus, we end up with the inequality "Eq. (1)″.

$$\overline{c_{Bj}} \times \overline{c_{jW}} \neq \overline{c_{BW}} \tag{1}$$

To assess the consistency of reference comparisons, we use the consistency ratio (CR), which is the ratio of the inconsistency in the pairwise comparisons to the consistency index (CI). CI is the maximum possible inconsistency for any possible reference comparison input.

$$CR = \frac{\xi^*}{CI}$$

Where, "ξ^*" is the inconsistency of the pairwise comparisons obtained as the value of the "problem 2″ objective function.

The inequality in "Eq. (1)″ is converted to equality as follows to establish "Eq. (2)″.

$$\overline{c_{Bj}} - \xi) \times (\overline{c_{jW}} - \xi) = (\overline{c_{BW}} + \xi) \tag{2}$$

The inconsistency in Eq. (2) due to inequality will be maximised when $\overline{c_{Bj}} = \overline{c_{jW}} = \overline{c_{BW}}$ and when the value of $\overline{c_{BW}}$ is maximum. Thus, we have

$$\overline{c_{BW}} - \xi) \times (\overline{c_{BW}} - \xi) = (\overline{c_{BW}} + \xi) \tag{3}$$

The maximum possible value of $\overline{c_{BW}}$ will be the upper boundary value, "u_{BW}" of the fuzzy number $\overline{c_{BW}}$. Thus, "Eq. (3)″ is transformed into

$$u_{BW} - \xi) \times (u_{BW} - \xi) = (u_{BW} + \xi) \tag{4}$$

On solving Eq. (4), the value obtained for ξ is the CI. In our paper, the value of the maximum fuzzy number is (3.5, 4, 4.5); thus, u_{BW}= 4.5. The CI for different values of u_{BW} are given in Table 3, after Guo and Zhao (2017); we select the CI for u_{BW} =4.5, for which CI= 8.04.

Step 6 De-fuzzifying the solution.

Once we have solved "problem 2″ for $\overline{W_1}$, $\overline{W_2}, \ldots\ldots.\overline{W_n}$, the fuzzy weights are de-fuzzified using GMIR, to get W_1, W_2, ……, W_n (Table 4).

Table 5.
Details of experts participating in the study.

S. No	Position	Experience	Expertise criteria for inclusion in the study	Product
1	President	18 years	He has a huge experience as a consultant in Agri-FSC, is pursuing a Ph.D. in Agri-FSC	Fruits and vegetables, organic products
2	Regional Head	8 years	Working at a senior level in 3PL services, with operations in many states of India during COVID-19	Fruits, vegetables, and retail products
3	Inventory Supervisor	4 year	Working in a B2B company of fruits and vegetables, with operations in many states of India during COVID-19	Fruits and vegetables
4	Director	25 years	Huge experience in Agri-FSC and as an auditor of food safety	All food products
5	Director	25 years	Huge field experience as a director of a Farm Producer Organization (FPO)	Fruits and vegetables
6	Manager	6 Years	Working at a managerial level in a multi-national restaurant chain, operational field experience during CIVID-19	Perishable, packaged food products
7	Assistant Manager	3 years	Working at a managerial level, with experience of cold chain logistics, operational during COVID-19	Perishable food products

4. An application

4.1. Data collection

Experts from three organizations working in the PFSC domain were contacted through phone calls and video conferencing for an initial discussion. They explained the problems they were facing while functioning in this pandemic and how they are tackling these problems. Among the three organizations, the first one had business in dairy products; the second was in the business to business (B2B) domain of fruits and vegetables; the third one provided third-party logistics (3PL) services to organizations in fruits and vegetables. After multiple rounds of interviews, each of which lasted for 30–45 min, and a literature review, we finalized a list of 9 broad risk mitigation strategies. We added the risk mitigation strategies to a questionnaire and sent it to more than 100 participants, from which 25 participants made completed returns; 3 were rejected for response bias. The questions asked are shown in Section-i, Appendix A. The purpose of this was to pilot test and validates the list of risk mitigation strategies and identify the "best" and "worst" strategy for further F-BWM analysis. The arithmetic mean of the responses was calculated, identifying "Collaborative Management" as the best strategy and "Training and Communication" as the worst strategy; the overall scores for all strategies are as follows:

Building upon the initial discussions, literature support, and the initial questionnaire survey, nine risk mitigation strategies were finalized for analysis using F-BWM methodology. The questionnaire for reference comparisons of "best vs. others" and "others vs. best" was sent to experts; 9 of the respondents agreed to participate. They were phone called and briefed about the purpose and methodology. For clarity about methodology, they were sent the questionnaire through email. A total of 7 replies were accepted, with 2 rejected for response bias. The questions asked are shown in Section ii., Appendix A. The details of 7 experts participating in the F-BWM are given in Table 5 as follows:

The decision methods based on pairwise comparisons, such as AHP,

Table 6.
Aggregate reference comparison values.

"Best vs. Others"				"Others vs. Worst"			
Strategies	l_{Bi}	m_{Bi}	u_{Bi}	**Strategies**	l_{iW}	m_{iW}	u_{iW}
S1 (W)	3.5	4	4.5	**S1 (W)**	1	1	1
S2	0.667	1.641	2.5	**S2**	2.5	3.257	4.5
S3 (B)	1	1	1	**S3 (B)**	3.5	4	4.5
S4	0.667	2.284	3.5	**S4**	1.5	2.438	4.5
S5	0.667	1.919	4.5	**S5**	1.5	2.246	4.5
S6	1.5	2.901	4.5	**S6**	1.5	2.784	4.5
S7	2.5	3.394	4.5	**S7**	0.667	2.420	3.5
S8	0.667	2.737	4.5	**S8**	0.667	2.155	4.5
S9	0.667	1.738	4.5	**S9**	1.5	3.203	4.5

Table 7.
Priority ranking for risk mitigation strategies in PFSC during COVID-19.

Risk Mitigation Strategy in PFSC during COVID-19 Pandemic	l_j	m_j	u_j	Crisp Weight	Priority Ranking
Training and Communication **(S1)**	0.044	0.049	0.054	0.049	IX
Proactive Business Continuity Planning **(S2)**	0.108	0.125	0.168	0.130	II
Collaborative Management **(S3)**	0.227	0.228	0.228	0.228	I
Central Response Team **(S4)**	0.081	0.085	0.168	0.098	V
Enhance Transparency **(S5)**	0.060	0.088	0.168	0.097	VI
Digital and Technology Management **(S6)**	0.060	0.102	0.168	0.106	IV
Information Management **(S7)**	0.060	0.084	0.124	0.087	VII
Flexible Business Model **(S8)**	0.060	0.072	0.168	0.086	VIII
Financial Sustainability **(S9)**	0.060	0.123	0.168	0.12	III

ANP, and BWM, are widely used methodologies. Many studies consider 5 to 10 experts appropriate to provide accurate results (Kusi-Sarpong et al., 2019; Luthra et al., 2016). Seven expert inputs were considered sufficient to go forward with the analysis.

The linguistic comparison ratings by all the seven experts for "best vs. others" and "others vs. best" are as shown in Table-i. And Table-ii., Appendix-B. The aggregate values obtained using the approach given in Step 3 of the research methodology is used to formulate the aggregate reference comparisons, as shown in Table 6, with S_1, "Training and Communication," the "worst" strategy, and S_3, "Collaborative Management" as the "best" strategy.

These values are analyzed using the code for Prob 3., developed in LINGO 18.0. The results from the analysis are discussed in the next subsection.

4.2. Findings

The analysis results carried out using F-BWM to establish the priorities of risk mitigation strategies in PFSC during the COVID-19 are as given in Table 6. As the initial results are in the form of fuzzy membership functions, they are de-fuzzified to get crisp priority weights to be able to make sense of the results. The initial fuzzy results and the crisp weights obtained using GMIR are given in Table 7.

A prioritization ranking of these risk mitigation strategies helps managers function in times of such crisis. We can infer from these results that "Collaborative Management - 0.228″, "Proactive Business Continuity Planning – 0.130″, "Financial sustainability - 0.120″, and "Digital and Technology Management - 0.106″ are the top strategies that managers should focus upon to manage PFSC in a such a crisis. These top strategies are followed by "Central Response Team - 0.098″, "Enhance Transparency - 0.097″, "Information Management - 0.87″, and "Flexible Business Model - 0.86″, "Training and Communication - 0.049″ has the lowest priority. The consistency ratio for the reference comparisons to generate these priorities is found to be

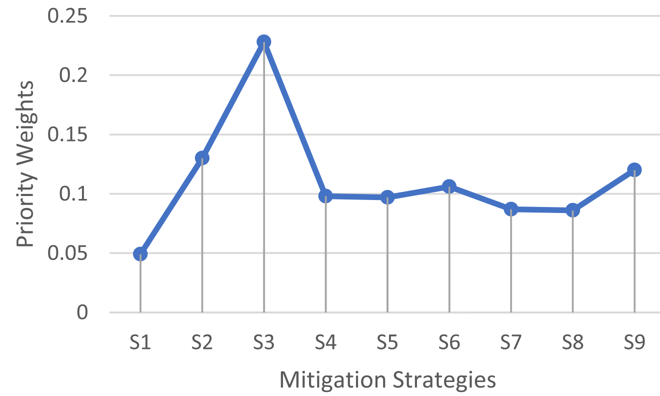

Fig. 2. Priority weights for mitigation strategies.

$$CR = \frac{k}{CI} = \frac{0.688}{8.04} = 0.085,$$

which is less than the CR value of 0.1, specified as satisfactory in Mahdiyar et al. (2020). This is also much less than the threshold values specified in Liang et al. (2020). Thus, the results are satisfactorily consistent to go forward with the discussion. A graphical representation of these results is given in Fig. 2.

The rankings can identify the extent of these strategies' importance from a manager's perspective. These can also assist the planners and practitioners to better manage the risks in PFSCs. Their significance may depend upon the contingencies in a PFSC. Thereby, the following section discusses the mitigation strategies based on the contingencies during the COVID-19.

5. Discussion

The results show "Collaborative Management" "Proactive Business Continuity Planning" and "Financial Sustainability" to be the best three strategies followed by "Digital and Technological Transformation," "Central Response Team," "Enhance Transparency," "Information Management," "Flexible Business Model" and "Training and Communication." We further discuss their priority and relative significance of each risk mitigation strategy to different contingencies originating in the PFSC due to the COVID-19 pandemic.

Experts identified "Collaborative Management" as essential to mitigate risks related to market uncertainties and a sudden shortage of resources. They suggested that "*effective collaboration helps in maximum utilization of common resources for multiple business partners*." At the start of lockdowns in India, many companies functioning in PFSC had their in-transit trucks and vehicles stuck at state borders for many days, meaning that many organizations' logistics operations came to a sudden halt. One expert reported that "*at the start of the lockdown, they had 20–25% of their total stocks in-transit, which was stopped suddenly*." In such a scenario, acquiring redundant resources from partner organizations, rapid communication of delivery delays, and supply and demand status help manage the crisis better. Firms should include their partners in scenario planning, identify critical nodes of risks in their SCs, figure out where the disruptions are for different suppliers, and strategize to mitigate those risks. Also, firms should identify their essential supplies and bring on-board their suppliers to stocking these essentials and de-stocking non-essential supplies. Further, they must realize that they cannot rely entirely on their existing partners and expand their business network and service partners by entering into new collaborative relations. In times of such crises, "*organizations should focus on entering in collaborative partnerships with companies having complementary strengths and resources,* *and expecting an increase in demand.*" The collaboration of ITC and Domino's to provide food essentials to consumers using Domino's last-mile delivery capabilities is one such example (Ambwani, 2020).

An active collaborative SC helps in business continuity in times of such crisis; this leads us to our second most prioritized risk mitigation strategy of "Proactive Business Continuity Planning" given a priority weight of "0.130″. A BCP includes planning for continuing operations with staff shortages, formalizing health and hygiene standards across the FSC, selecting backup employees for critical processes, and providing online application of passes for smooth movement of its employees, suppliers, and drivers through city and state borders. One expert revealed that "*even the pre-existing hygiene standards are not properly implemented in PFSC, especially in the unorganized sectors*." For health risk, social distancing is an effective mitigation strategy during COVID (Yoo and Managi, 2020). BCP should include regular monitoring and recording of the employees' health status and generating compliance reports for government agencies. Experts suggested "*proactive steps to impart confidence among the employees, such as insurance and extra pay benefits for drivers and distributors."* Further, organizations should communicate with alternative suppliers of essential supplies. On the demand side, they should explore alternative markets if a sudden closure. Further, one expert suggested, "*Firms should formalize the BCP through policy documents. They should regularly update all the employees by putting signboards in the company, early morning briefings, weekly company newsletter, and video messages*." Another expert suggested, "*They should ready a list of all the permissions that the organization will require to continue business in a crisis, and identify where to get them. So that there is a minimum lag in recovery post disruption*".

"*In a crisis, cash is the king,*" said one expert. "Financial Sustainability" is identified as the next, third crucial risk mitigation strategy, with a weight of "0.120″. PFSCs in India, especially those of fruits, vegetables, and milk, mostly run on low margins. Hence, with fluctuating demand and increased operating costs, organizations find it tough to stay afloat financially. Experts suggest "*organizations should save costs through lean operations. Those in the processed food sector should restrict merchandised stock-keeping-units (SKUs), focus on prioritized categories, on larger package sizes, and source locally"*. They should try to reduce fixed costs and keep them variable as much as possible. They should avoid investing in fixed assets and should preferably take facilities and resources on lease. Companies should coordinate with their financial and funding partners to ensure sufficient cash. Taking the example of Domino's, which declared a cash-on-hand of $300 million to stay afloat amidst any uncertainties arising out of COVID-19 (Ann Arbor, 2020).

"Digital and Technology Transformation" is a significant risk mitigation strategy, ranked fourth with a "0.106″ weight. Technology helps improve the efficiency and transparency of transactions (Song and Guan, 2015). The current pandemic has shown that an organization has to be able to transform and manage digital and technological transformation efficiently and swiftly. Various technology-based interventions could be useful in this crisis. Some examples are facial identification apps to check if employees are wearing masks, real-time monitoring of employees' health status, contact tracing apps, digital on-boarding, training, etc. Further, with a sudden increase in online-channel demand, and a decrease in physical outlet demand, online channels should integrate their data with physical inventory data. The store-level inventories should be visible in online databases. The use of digital technologies could provide a better quality of decision making when faced with severe crisis and disruption in SC (Ivanov and Dolgui, 2020).

Such strategic interventions to manage a crisis require higher-level managers' involvement. The steps for BCP require a greater commitment from department heads and mid-level management. Organizations should form a "central response team" to effectively manage risks arising out of COVID-19 and to frame policies to mitigate those risks. It enables efficient response to any internal or external contingency such as labor issues or regulatory changes. Further, a central response team could better coordinate other risk mitigation strategies for maximum effectiveness. Therefore, forming a "Central Response Team" is another effective risk mitigation strategy, ranked fifth with a "0.098″ weight.

Next, "Enhance Transparency" is the sixth most significant risk mitigation strategy with a weight of "0.097″. SC transparency provides end-to-end visibility to stakeholders to detect and react to any disruption upstream and downstream of the SC (Scholten and Schilder, 2015). Organizations with better transparency and traceability know their product locations. They are better positioned to mitigate logistical disruptions. It also enhances customer and stakeholders' confidence when organizations are transparent about their supplier policies, locations, and health and hygiene standards. In the current pandemic, while there is a higher demand for at-home services/home deliveries, customers are increasingly conscious of the health risk. They are demanding information about the health status of the people involved in handling and delivering the product. The burden of information lies with the focal company, which has to procure it from its upstream suppliers and manage it for its delivery staff. Transparency is essential for an organization from a social perspective. Protocol conformity of operations must be in place while managing such a crisis. Transparency is hence necessary to mitigate the risks related to health as well as the decrease in customer confidence.

"Information Management" is the seventh crucial risk mitigation strategy with a weight of "0.087″. In a crisis, organizations that act early to mitigate a risk acquire a better strategic position. However, during the COVID-19 pandemic, information about the Government's regulatory actions and changes, new areas coming under containment zones, local relaxations in lockdowns, etc., is critical. Experts readily stated that "*they could not deliver a product due to sudden closure of a market or that area coming under containment zone*." In such a condition, due to the perishable nature of food products, wasted vehicle trips essentially mean wasted products. Thus, information flow from stakeholders downstream of the PFSC is critical to avoid losses. Further, one expert suggested "*frequent monitoring of government regulations and connecting with the local administration to align company operations with them*." Government should provide information from a single-window source with enough clarity to avoid confusion in the industry. District wise helplines should be set up for farmers to provide the information required to resolve their transportation, storage, and market-related issues (Vyas and Singh, 2020). Essential information related to lockdown relaxation, farm produce procurement, labor movement, opening and closure of city and state borders, the minimum support price of products, etc., should be provided. A lot of confusion has existed during lockdown related to local markets' opening, with little clarity on their functioning. Large amounts of farm produce were sold at low prices, causing significant loss to farmers. Experts suggested, "*organizations should work more closely with farmers and provide helpline numbers for farmers, to help them by providing critical information*."

"Flexible Business Model" is the eighth crucial risk mitigation strategy with a "0.086″ weight. During the current pandemic, some business models have operated under more intense stress compared to others. For example, those working on "business-to-customer" were better placed in the same market than those on "business-to-business." Previous literature also supports a flexible supply base and flexible transportation to enable an organization to swiftly change modes of transport and shift production among suppliers to manage SC disruptions (Tang, 2006). Experts suggested, "*firms should work with partners with flexible capacity, should rework their unit economics, and should bundle and consolidate delivery operations*." New business models such as multi-modal transportation, a hyper-local business model, and omnichannel SC provide greater SC resilience through disruptions (Ishfaq, 2012). Also, farmers who are heavily dependent upon the local aggregation markets can achieve flexibility in the procurement of their produce through the farmgate collection, thus reducing wastage, farmer distress, and health risks. "Flexible Business Model" could be a key strategy to manage disruptions in crucial infrastructure and to deal with logistics-related risks

Table 8.
Relating mitigation strategies with contingencies.

S. NO.	Risk mitigation strategy	Mitigated contingency
1.	Collaborative Management	Market uncertainty related to suppliers and stakeholders, sudden order cancellations, resource shortage, disruption of essential supplies. Supplier and logistical non-performance.
2.	Proactive Business Continuity Planning	HR issues such as sickness, employee shortage, absenteeism, and health risks in the organization. Plan for the non-performance of critical SC nodes.
3.	Financial Sustainability	Financial vulnerabilities arising out of uncertainties in the business environment such as falling sales and investments, plus disruptions from the bankruptcy of partners.
4.	Digital and Technology Management	Demand variabilities and sudden spikes due to switching of demand from physical to online channels. Operational challenges requiring digital collaboration, traceability, and data management
5.	Central Response Team	It directly strategizes for labor, HR challenges, and regulatory uncertainties. It also enables coordinating organizational strategies for different contingencies.
6.	Enhance Transparency	It manages falling consumer confidence and panic, also minimizes reaction time to any contingency.
7.	Information Management	It mitigates regulatory uncertainty and a lack of policy clarity. It eases panic and distress among farmers. It reduces shocks from the sudden closure of food outlets, markets, border restrictions, etc.
8.	Flexible Business Model	It manages the failure of crucial infrastructure, closure of markets, logistical challenges. Better management of procurement challenges from smallholding farmers.
9.	Training and Communication	HR challenges due to labor shortage, staff limitations, and absenteeism. Health risk arising from operational protocols

in PFSC during the COVID-19 pandemic.

“Training and Communication” is identified as the last, ninth-ranked risk mitigation strategy in PFSC during the COVID-19 pandemic, with a “0.049″ weight. Although ranked low, it is still an essential strategy for risk mitigation in PFSC; risks related to the staff and labor shortages have to be faced. During such a crisis, regular communication from upper management to those working on the ground is essential to motivate, support, and advise staff facing unexpected situations. Also, organizations facing sudden shortages of labourers and drivers have to hire new employees in the short term. These new employees have to be trained and inducted into the organization in a short period. Regular communication, motivation, and training could be crucial for staff members to stay efficient and resilient in their operations.

5.1. Implications for practitioners considering a socioeconomic lens

The results of this study can implicitly aid managers and decision-makers in PFSC to successfully mitigate the risks during the COVID-19 pandemic as well as in any future disruptions. Managers should focus on the top-ranked strategies in their initial work and later include the lower-ranked strategies. Top management should allocate sufficient human as well as capital resources to ensure that all risk mitigation strategies are effectively applied. Different targeted approaches should depend upon social and economic contingencies. From a social perspective, health risks to employees, farmer distress, and falling customer confidence are major issues. Financial and market uncertainties, demand variabilities, resource shortages, and logistical challenges are the key contingencies from the economic perspective. From a social standpoint, information management, enabling transparency, proactive BCP, training, and communication are key mitigation strategies that could help in the wider societal, health and employee-related contingencies. Collaborative management and financial sustainability using digital and technology management could be critical in managing contingencies from an economic perspective. Drawing from the theoretical base of CT, we have discussed the appropriateness of identified risk mitigation strategies for different socioeconomic contingencies. Table 8 presents suggestions for managers to relate the identified mitigation strategies to different uncertainties and contingencies earlier discussed in Section 2.1.

Managers and planners should carefully consider the contingencies and uncertainties in their organizational environment. They should select their mitigation strategies as per these contingencies. The identified mitigation strategies relative to the contingencies could help them choose the correct strategy to follow; the given priority could help them determine which strategy to focus on more.

6. Conclusion

The PFSC in an emerging economy like India, has several inherent risks and challenges to be managed. These risks are further aggravated during the COVID-19 pandemic. The first contribution of this study is the identification of key risk mitigation strategies in PFSC during COVID-19. This research discusses the various contingencies in the PFSC during a pandemic scenario. It identifies and analyzes risk mitigation strategies through a literature review and consultations with experts. Giving a preference order for risk mitigation strategies is the second significant contribution of this study. The F-BWM provides priority weights of risk mitigation strategies using linguistic terms-based reference comparisons of “best vs. others” and “others vs. worst” strategies. F-BWM is a recently developed decision tool; its application has not been explored in the domain of PFSC. Thus, the use of F-BWM to analyze risk mitigation strategies in PFSC during the COVID-19 pandemic is another major contribution of this study from a methodological perspective. Expert opinions are vital here as the situation is still evolving; there are no previous studies specific to risk mitigation strategies in PFSC in a pandemic scenario. Hence, CT, in conjunction with experts’ inputs, provides the necessary theoretical grounds for this research. Taking a CT perspective of the risk mitigation strategies, we have extensively discussed these strategies in relation to the uncertainties and contingencies originating in PFSC due to COVID-19.

There are some limitations in this study, which also provide an opportunity for future research. The study is based on experts’ opinions. Experts’ views are generally localized and based upon their organizational experience. Thus, they may not necessarily represent the broader pan-industry perspective. This research has been conducted in the context of a developing country - India; therefore, there is scope to compare these results with other developed as well as developing countries. Additionally, there is a great need for studies in PFSC with developing economic perspectives. There is also the scope from a research methodology perspective, as the methodology adopted could be extended through its hybrid versions with other decision-making tools and empirical research.

Author credit statement

Anish Kumar- Writing - Original Draft, Investigation, Formal analysis.

Sachin Kumar Mangla- Writing - Review & Editing, Conceptualization, Methodology, Supervision.

Pradeep Kumar- Conceptualization, Validation, Resources, Supervision.

Maling Song- Writing - Review & Editing, Conceptualization.

Appendix A

Section-i

Name-
Position-
Experience-
Organizational Business Activities-

- The following survey is divided in two parts, where Part-A explains the context of the survey, Part-B requires your inputs.
- You may feel free to refer and add any inputs to the explanations at the end of Part-A.
- Your inputs in Part-B are essential and of great importance to us, kindly fill them to the best of your knowledge.
- This survey is only for academic and publication purpose, your details will not be revealed by us anywhere.

Part A

Global Economies are currently facing a "black swan situation," a pandemic of the scale that nobody expected to happen, and was prepared for. Due to this, Food Supply Chains have been the hit very hard, with looming crisis of hunger, malnutrition, and wastages across the globe. Perishable products such as fruits, vegetables, milk products, and meat have limited shelf life and high environmental sensitivity. Their supply chains have various risks that become more critical during a pandemic.

To mitigate such risks, based on the panel discussions conducted thus far, we have shortlisted a few supply chain risk mitigation strategies in PFSC about COVID-19-

Part- B

1 What are the most relevant disruptions in Perishable food supply chains (PFSC) due to the COVID-19 pandemic?

S. NO.	Disruptions from "outside" the Supply Chain
1	
2	
3	
4	
5	
6	

S. NO.	Disruptions from "inside" the Supply Chain
1	
2	
3	
4	
5	
6	

1 Which of these disruptions has had the worst effect on operations in agro-food supply chains?

Disruptions	Effects on PFSC

1 What strategies are most effective in mitigating the effects of disruptions in agro-food supply chains?

S. NO.	Strategies for mitigating Disruptions
1	
2	
3	
4	
5	
6	

Based on the following linguistic scales, rate the mitigation strategies previously identified on a scale of 0–4 about how important a particular mitigation strategy is in the present COVID-19 pandemic.

1- Not Important (NI)

2- Somewhat important (SW)
3- Important (I)
4- Very Important (VI)
5- Extremely Important (EI)

S. No.	Mitigation Strategy	Rating
1.	Training and Communication (S1)	
2.	Proactive Business Continuity Planning (S2)	
3.	Collaborative Management (S3)	
4.	Central Response Team (S4)	
5.	Enhance Transparency (S5)	
6.	Digital and Technology Management (S6)	
7.	Information Management (S7)	
8.	Flexible business model (S8)	
9.	Financial sustainability (S9)	

Please feel free to contact and revert back for any discussion, knowledge exchange, or in case of any confusion.

Thank you

Section-ii

Dear Participants, We thank you for your enlightened inputs in our survey based on Risk Mitigation Strategies in Perishable Food Supply Chain Management.

Based on the feedback in the previous survey, the following results of importance-weights were produced-

Training and Communication- 2.23

Proactive Business Continuity Planning - 3.27

Collaborative Management- 3.32

Central Response Team - 2.68

Build Transparency- 2.82

Technology Management- 2.64

Information Management- 2.82

Flexible business model- 3.18

Financial sustainability- 3.13

Q1- How much more important is the best strategy- "Collaborative Management" is compared to all other strategies

0- Just Equally Important (EI), 1- Weakly More Important (WI), 2- Strongly More Important (SI), 3- Very Strongly More Important (VSI), 4- Absolutely More Important (AI)

Best vs. Others	EI	WI	VI	VSI	EI
Proactive Business Continuity Planning					
Central Response Team					
Build Transparency					
Digital and Technology Management					
Information Management					
Flexible business model					
Financial sustainability					

Q2- How much more important are the other strategies as compared to - "Training and Communication"- “worst strategy.

0- Just Equally Important (EI), 1- Weakly More Important (WI), 2- Strongly More Important (SI), 3- Very Strongly More Important (VSI), 4- Absolutely More Important (AI)

All vs. Worst	EI	WI	VI	VSI	EI
Proactive Business Continuity Planning					
Central Response Team					
Build Transparency					
Digital and Technology Management					
Information Management					
Flexible business model					
Financial sustainability					

Thank You Very Much For your participation.

Please feel free to contact me if you feel any difficulty in filling this questionnaire

Appendix B

Table i
- Reference comparison of best-“collaborative management, S_3” vs. others.

Best Vs-	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
Expert1	AI	VI	EI	VSI	AI	AI	AI	VSI	VSI
Expert2	AI	VI	EI	VSI	AI	VSI	AI	AI	WI
Expert3	AI	WI	EI	VSI	VSI	AI	AI	VSI	VI
Expert4	AI	VI	EI	VI	WI	VI	VSI	WI	VI
Expert5	AI	VI	EI	VSI	WI	VI	VSI	AI	WI
Expert6	AI	VI	EI	VI	WI	VSI	VSI	VI	WI
Expert7	AI	EI	EI	WI	VI	VSI	VSI	AI	AI

Table ii
- Reference comparison of others vs. worst- "training and communication, S1".

Others	Expert1	Expert2	Expert3	Expert4	Expert5	Expert6	Expert7
S_1	EI	EI	EI	EI	EI	EI	EI
S_2	VSI	VSI	AI	VSI	AI	VSI	VSI
S_3	AI	AI	AI	AI	AI	AI	AI
S_4	VI	VI	AI	VI	AI	VI	VI
S_5	VI	AI	VSI	VI	WI	VSI	VI
S_6	VSI	VSI	VSI	VI	VSI	VI	AI
S_7	VSI	VSI	VSI	WI	VSI	VI	VSI
S_8	VSI	WI	VSI	VSI	WI	VI	AI
S_9	VSI	AI	VSI	VI	AI	VSI	AI

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