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ORIGINAL RESEARCH

Technology-Driven Responsiveness in Times of COVID-19: A Fuzzy Delphi and Fuzzy AHP-Based Approach

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Abstract
Supply chain responsiveness creates value for firms and their stakeholders and is a key towards generating above-normal profits for firms. Consequently, there has been a surge of research on it, which has expanded due to the pressures to be responsive during the pandemic of COVID19. Responsiveness is an attribute wherein the supply chains are equipped to respond resolutely and within a suitable timeframe to consumer requirements. The trouble to businesses posed by COVID-19 caught several firms off-guard. Further, there is limited research on the augmentation of supply chain responsiveness through new technologies. The present research, therefore, applies a hybrid approach by combining fuzzy Delphi and fuzzy AHP to understand the technology-driven enablers of supply chain responsiveness by employing a case company in food retail. The investigation reveals that supply chain integration technologies, sustainable manufacturing technologies, and smart warehousing are the most important enablers of supply chain responsiveness in the context of food supply chains. The results aid the key enablers that need attention and resources to be directed towards these enablers to eliminate a chance of missing on a successful transition into a more responsive supply chain.

Keywords Technological capability · Responsive supply chains · COVID-19 · Enablers

Introduction

The firms need to adjust and alter their operations speedily to survive and proficiently respond to numerous challenges in the environment (Deshmukh & Haleem, 2020). For example, the COVID-19 outbreak has severely crippled several firms. The lockdown had an aggravating effect on the manufacturing and logistics activities of the firms, which in turn affected the demand and supply of various products (Singh et al., 2021). For example, in the case of food supply chains, the issues that have caught the attention of scholars and policymakers globally include changes in consumption patterns as well as the setup and workforce responsible for maintaining a safe and trustworthy food supply network (Deconinck et al., 2020; Singh et al., 2021). These issues were deemed serious as a pandemic is marked by the restrictions over movement, changes in demand patterns, shut down of food manufacturing units, changes in food trade policies, financial stress, and food safety concerns (Momaya, 2020).

Responsiveness of a firms' supply chain is critical for it to inspect and respond to the changes in customer behavior that can lead to supply chain variability (Yang et al., 2019). A responsive supply chain characterized by shorter lead times, small sizes of the batch, and fewer setup costs. All these factors permit the responsive company to adjust quickly to the changes in demand (Randall et al., 2003). Building responsiveness is seen as an essential approach to revive operations and supply chains in post-COVID-19 times (Frederico, 2021). Moreover, making supply chains responsive is seen as a successful strategy to compete globally (Gunasekaran et al., 2008). The pandemic has led to extraordinary disruptions in the supply chains across several sectors such as healthcare, food, engineering, and automotive, among others. In contrast to other disruptions, the current pandemic has affected all the stages of supply chains, with significant disturbance in manufacturing, logistics, along with substantial shifts in consumption patterns. The aim of developing responsive supply chains

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is to be better prepared for the execution of tasks during unexpected occurrences such as COVID-19.

While responsive supply chains form an integral part of successful manufacturing strategies, how to develop a responsive supply chain has been a pertinent question across the global production environments (Roh et al., 2014). Scholars have argued that firms can transform the traditional supply chains into more responsive ones through strategic actions (Godsell et al., 2006). To this end, the extant literature has argued that technology can pose solutions that can be utilized to enhance the responsiveness of the supply chains. For example, digitalization technologies boost the visibility of the supply chains, which in turn enhances real-time decision-making capability, which further leads to improved responsiveness (Yadav et al., 2020).

The realization of supply chain responsiveness is not reliant upon a few enabling forces but depends upon diverse enablers, frequently spanning firm boundaries. Scholars have argued that the seamless integration and coordination of various operations such as production, distribution, sourcing, and procurement with the help of centralized IT infrastructure can significantly raise overall supply chain responsiveness (Aftab et al., 2018). Therefore, in the paper, we provide a refined understanding of the technology-driven enablers from the perspective of the firms that are in the process of improving the responsiveness of their supply chains. The emergence of responsiveness is influenced by contingent factors faced by the firms that include the ongoing COVID-19 crisis. Therefore, a contingency theory approach has been used as a theoretical lens for the present study. This study identifies critical enablers of responsiveness, which are driven by digitalization. The study underlines the enablers by referring to the literature and supplements them with the assistance of the opinion of experts. These enablers are then analyzed for the case of a firm that is undertaking a transition from conventional to responsive supply chains. Therefore, the present work seeks to answer the following research questions:

- What are the enablers that help the firms in their transition from traditional to responsive supply chains?
- How to establish the priority of these enablers that affect responsiveness?

To address the above research questions, set in the context of an example from the food supply chain, important enablers conveyed in the literature were enlisted through a comprehensive survey of the literature. The fuzzy Delphi technique is utilized to decide the finalization of identified enablers. Fuzzy AHP is used to establish the relative importance of these enablers. The fuzzy logic is applied since AHP is not adequate to manage the uncertainty and vagueness that is present in human judgments (Kumar et al., 2018).

The rest of the study is organized as follows. "Theoretical Background" gives an overview of the theoretical background of the study. The methodology of research is elucidated in "Research Methodology". The case application is discussed in "Case Description". In "Application of the Proposed Methodology to the Case", the proposed methodology is applied to the case. In "Discussion", the discussion of the results obtained from the analysis is presented. In "Conclusions", the study concludes with academic and managerial implications, limitations, as well as future research directions.

Theoretical Background

Contingency Theory Perspective

The operations management (OM) scholars have always emphasized the importance of understanding the relationship between the firm and the environment (Makkonen et al., 2014). The past two decades have witnessed a surge in the application of theories from domains such as strategic management and have immensely benefited the OM scholars. The contingency theorists emphasize that compatibility between the firm and the environment in which it operates is crucial for its performance. Therefore, the firms must adapt their structures by considering the environment to perform better.

Contingency theorists view the organization as an open system where information gets exchanged. The exchange of information happens through a system that comprises inputs, processes, and outputs. The contextual issues faced by the firm are together termed as the input. The responses to these inputs comprise strategies and actions and are termed as processes. The outcomes of the processes are termed output. The contingency theorists posit that the firms strive to find the best solutions to cope with contextual situations by utilizing their processes. As proposed by the contingency theory, when a firm faces contextual issues such as supply chain disruptions, it should devise strategies to cope with the same (McAdam et al., 2019). Proactive management of disruptions in the supply chain due to the pandemic can be managed with the help of technology capabilities specific to the firm's supply chain. The output of such a system can be enhanced decision-making for building a responsive supply chain.

The extant literature suggests that several factors play a crucial role in enhancing a firm's proactiveness towards managing supply chain disruptions (Grötsch et al., 2013). This is in accordance with contingency theory, which suggests that the internal and external situation of a firm decides the optimum course of action. In the present study, the outbreak of the pandemic can be understood as a major contingency, and the level of disruptions faced by the firms are major indicators of the contingent situation (Grötsch et al., 2013). For managing these disruptions, the firms need to build their technological capability proactively.

Technological Capability and Supply Chain Responsiveness

In particular, both researchers and practitioners endorse that greater visibility leads to better responsiveness (Williams et al., 2013). Supply chain integration gives additional access to information as well as processing abilities essential to incorporate responsiveness (Roh et al., 2014). The use of technology improves global supply chain relationships (Sinkovics et al., 2011) as an integrated value chain boosts buyer–supplier collaboration (Gunasekaran et al., 2008). The revolution in the supply chains with the help of digital technologies such as artificial intelligence (AI), big data, among others, are transforming the linear supply chains into integrated structures where information flows in an omnidirectional manner. These technologies can produce massive benefits through cost reduction and making supply chains more responsive to demand. Technology breakthroughs in supply chain strategies such as the ones brought by advanced production technologies and e-procurement increase supply chain responsiveness that helps the supply chains to react quickly against disruptions (Kim et al., 2013). An important component of a responsive supply chain is its capability to sense and respond to eliminate disruptions. Ongoing advances in technology can ease sensing through data collected in real-time (Gunasekaran et al., 2008). Several authors have contended that a data-driven supply chain has a positive effect on supply chain responsiveness (Ishtiaque et al., 2020; Yu et al., 2018). The application of predictive analytics includes identifying safety risks, predicting the sustainability performance of the supply chain, and evaluation of packaging material (Kamble et al., 2020).

Maintaining service levels with appropriate stocking has been widely seen as a strategy for supply chain responsiveness (Piprani et al., 2020). In this regard, several service-level related strategic initiatives can improve responsiveness (see Table 1). For instance, AI has helped food supply chains to reach the market very efficiently through better planning. Large amounts of food can be sorted by size, nutrients, constituents, shape, etc., and sent to customers (Di Vaio et al., 2020). Inventory has a considerable influence on responsiveness. Smart warehousing, order management, and retail management increase the chances of meeting demand by ensuring product availability at the right place and time (Riahi et al., 2021). These systems would be able to track the movement of goods automatically, thus monitoring the inventory in real-time. The service level is maintained by avoiding over or understocking (Riahi et al., 2021). AI also helps to identify factors responsible for failure in a process with its root cause analysis. It can be used to develop a real-time data system for maintaining the stock of products by utilizing a pre-warning approach (Kamble et al., 2020).

In addition, sustainability initiatives such as sustainable manufacturing, packaging, sourcing, and distribution have also been regarded as drivers of responsiveness. These practices reduce the generation of waste and promote effective resource utilization, thereby helping the firm to survive in the long-term survival of the firms (Katiyar et al., 2018). Sustainable practices also enhance the firm's control towards different processes, sustainable practices and are considered a crucial driver of the supply chain responsiveness (Van Der Vorst et al., 2009).

In light of the above several technology-driven enablers of supply chain responsiveness have been found out from the extant literature and been broadly typified under three dimensions, namely visibility, service, and sustainability, as shown in Table 1. The enablers shown in Table 1 will be utilized for achieving the objectives of the present research. The objectives are: (a) To develop an understanding of the enablers that help the firms in their transition from traditional to responsive supply chains? (b) To establish the priority of these enablers that affect responsiveness?

Research Methodology

Fuzzy Delphi Method

The fuzzy Delphi method is a systematic tool for forecasting. The method considers the judgment of the experts as crucial and is more often used in scenarios where a resolution for an issue is unavailable. The method simplifies the decision-making process by eliminating the less important variables (Bouzon et al., 2016). One of the drawbacks of the Delphi method was the collection of data in the form of repeated surveys that were more costly and time-consuming.

To overcome the drawbacks of the Delphi method, the fuzzy-based Delphi method was introduced by Ishikawa et al. (1993). To facilitate group decision-making, various researchers have used the fuzzy Delphi method in combination with fuzzy AHP. Fuzzy Delphi was applied by the panel to assess the consensus level of each enabler. The fuzzy Delphi approach helps to screen out the factors in the preliminary stage on the basis of consensus between experts before ranking is carried out (Gupta et al., 2021). For the study, we have considered fuzzy Delphi to enable group decision-making. It facilitated understanding the

Table 1 Technology led enablers of supply chain responsiveness

Dimension	Enabler	Description	Sample references
Visibility	Supply chain integration technologies	All those classes of technologies that integrate the food supply chain upstream as well as downstream	Li (2012)
	RFID-based location tracking	A no-contact automatic identification communication technology to tag, save and manage information on products using radio frequency signaling and associated tools	Pramatari et al. (2010)
	Big data and cloud-based demand prediction	Management and analysis of data characterized by volume, variety, and velocity	Irani et al. (2018)
	Smart warehousing	A warehouse designed to perform at the highest efficiency	Mahroof (2019)
	Blockchain technology or traceability	A distributed ledger technology (DLT) where alterations are not permitted once data is logged, becoming a trusted source of information, enabling efficiency, transparency, and accountability among participating actors	Stranieri et al. (2021)
	Predictive analytics for resource optimization	AI is derived from data and has the potential to transform industrial productivity	Kamble et al., (2020)
Service	AI for supply network and monitoring	AI is derived from data and has the potential to transform industrial productivity	Di Vaio et al. (2020)
	Smart logistics technologies	Management of physical movement of goods through smart tools and methods	(Rakyta et al. 2016)
	Online transparent presence	Transparency for stakeholders of food supply chains through data and online management of networks	Astill et al. (2019)
	Smart retail technology	Network of smart, intelligent systems engaging in assimilating real-time data to deliver retail services to consumers	Wuenderlich et al. (2015)
	Smart order management technologies	Planning and controlling of orders through smart tools and analytics	Aung and Chang (2014)
	Drone logistics	Intelligent and unmanned technologies to deliver food products	Sah et al. (2020)
Sustainability	Sustainable sourcing and distribution	Sustainability operations such as sustainable sourcing and distribution	Acar et al. (2019)
	Sustainable food packaging	New and improved packaging that increases the shelf-life of food products and decreases the carbon footprint	Mikkonen and Tenkanen (2012)
	Sustainable manufacturing technologies	Technologies that improve sustainability, for example, by minimizing waste, thereby reducing pressures on firms to manage the waste	Dubey et al. (2015)

enablers of supply chain responsiveness. The steps of the fuzzy Delphi method are as follows.

Step 1 The step involved the identification of different enablers of supply chain responsiveness. The enablers identified in the literature survey are given in Table 1.

Step 2 The enablers identified in the earlier step were examined by the industry experts. The judgment of the experts was captured with the help of the linguistic scale given in Table 2.

Let the lth (where $l = 1, 2, 3\ldots m$) enabler evaluation of the kth expert (where $k = 1, 2, 3\ldots n$) is the triangular fuzzy number Y_{kl}:

Table 2 Linguistic scales

Linguistic variables	Fuzzy number
Extremely low	(0, 0, 0.1)
Very low	(0, 0.1, 0.3)
Low	(0.1, 0.3, 0.5)
Medium	(0.3, 0.5, 0.7)
High	(0.5, 0.7, 0.9)
Very high	(0.7, 0.9, 1.0)
Extremely high	(0.9, 1.0, 1.0)

$$Y_{kl} = (\mathrm{M}_{kl}, N_{kl}, O_{kl}). \tag{1}$$

The fuzzy weights of the enabler P_l are computed as follows:

$$P_l = (M_l, N_l, O_l),$$
$$M_l = \min(M_{kl}),$$
$$N_l = \left(\prod_{k=1}^{n} N_{kl}\right)^{1/n}, \quad (2)$$
$$O_l = \max(O_{kl}).$$

Step 3 The importance (S_l) of each enabler is calculated by applying the mean method. The value α (threshold value) is set for selecting the enabler into the list which will be used as an input to fuzzy AHP. If the computed value of importance is lesser than α, that enabler is not selected:

$$S_l = (M_l + N_l + O_l)/3. \quad (3)$$

Fuzzy AHP

AHP was developed as an instrument for multi-criteria decision-making (MCDM) problems. AHP helps in simplifying a complex decision-making problem by disintegrating it into smaller problems (Saaty, 2008). It translates the problem of decision-making into a hierarchy that consists of a goal, criteria, and sub-criteria. AHP method is especially advantageous when different factors have different weights (Yadav et al., 2021). On the other hand, techniques such as ISM and DEMATEL are deemed useful to understand the hierarchical relationships among the factors. In this study, all enablers are being considered to have relative weightage. Due to the many benefits of Fuzzy AHP over other mathematical methods, many researchers have used these methods for handling complex decision-making problems. The AHP considers the judgments of the expert decision-makers. However, it does not resolute the inaccuracy and ambiguity which is associated with human judgments (Chang, 1996). Fuzzy AHP, which is based on the fuzzy set theory. Numerous methods for fuzzifying the AHP process have been documented by scholars in the extant literature. Chang's extent-analysis-based method is one of the widely used approaches among them (Chauhan & Singh, 2020). Chang's extent analysis relies upon the calculation of synthetic extent values of the fuzzy triangular number (FTN) (Chang, 1996). These values were based on pairwise comparisons. An extent analysis for each criterion concerning goal q_i is conducted in this method. The extent-analysis-based tool is used to compute a set for satisfying the goal and this set is known as satisfying extent.

If $V = \{v_1, v_2, ..., v_n\}$ is set for criterion, and $Q = \{q_1, q_2, ..., q_n\}$ is set of goal, to apply Chang's method of extent analysis, an extent analysis is done on each enabler. 'm' values for extent analyses carried out on each enabler are calculated as follows:

$$U_{g_i}^1, U_{g_i}^2, U_{g_i}^3, U_{g_i}^4, \dots U_{g_i}^m, i = 1, 2, 3 \dots n, \quad (4)$$

where $U_{g_i}^j (j = 1, 2, 3 \dots .4)$ are fuzzy triangular numbers (FTNs).

The steps are as follows:

Step 1 The fuzzy Delphi approach is applied to finalize the enablers, which are then evaluated by the experts on a linguistic scale (see Table 3). The linguistic inputs are then converted into FTNs. Buckley's geometric mean method (Buckley, 1985) is applied to calculate the elements of the pairwise comparison matrix, in combination with expert inputs.

Let there be 'n' enablers. The pairwise comparison of ith enabler with jth enabler will lead to the development of the fuzzy matrix $U_{n\times n}$. In the fuzzy square matrix, $\tilde{U}_{ij}$ signifies the relative importance of enabler i with respect to enabler j. In the fuzzy square matrix, $\tilde{U}_{ij} = (1, 1, 1)$ if $i = j$ and $\tilde{U}_{ji}$ is the reciprocal of $\tilde{U}_{ij}$:

Table 3 Membership function of linguistic scale

Intensity of importance	Linguistic	Scale of fuzzy number
9	Perfect	(8, 9, 10)
8	Absolute	(7, 8, 9)
7	Very good	(6, 7, 8)
6	Fairly good	(5, 6, 7)
5	Good	(4, 5, 6)
4	Preferable	(3, 4, 5)
3	Not bad	(2, 3, 4)
2	Weak advantage	(1, 2, 3)
1	Equal	(1, 1, 1)
Reciprocal of above	If activity *i* has one of these numbers assigned when compared with activity *j*, then *j* will have the reciprocal value when compared with *i*	

$$\tilde{U} = \begin{bmatrix} \tilde{U}_{11} & \tilde{U}_{12} \dots & \tilde{U}_{1j\dots} & \tilde{U}_{1n} \\ \tilde{U}_{21} & \tilde{U}_{22} \dots & \tilde{U}_{2j} \dots & \tilde{U}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{U}_{31} & \tilde{U}_{32} \dots & \tilde{U}_{ij} \dots & \tilde{U}_{in} \\ \tilde{U}_{41} & \tilde{U}_{42} \dots & \tilde{U}_{nj} \dots & \tilde{U}_{nn} \end{bmatrix} \tag{5}$$

If the number of experts is K, components of pairwise comparison matrix are computed as follows:

$$\tilde{U}_{ij} = \left(\tilde{U}_{ij}^1 \otimes \tilde{U}_{ij}^2 \otimes \tilde{U}_{ij}^3 \otimes \tilde{U}_{ij}^4 \otimes \tilde{U}_{ij}^5 \otimes \dots \tilde{U}_{ij}^k\right)^{1/K}. \tag{6}$$

Step 2 Estimate the fuzzy synthetic degree with respect to the ith enabler using the following:

$$F_i = \sum_{j=1} U_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} U_{g_i}^j\right]^{-1}. \tag{7}$$

'Fuzzy addition' is carried out on m extent analysis values of a fuzzy square matrix as follows:

$$\sum_{j=1}^{m} U_{g_i}^j = \left(\sum_{j=1}^{m} x_j, \sum_{j=1}^{m} y_j, \sum_{j}^{m} z_j\right), \tag{8}$$

where (x, y, z) is an FTN.

For calculating $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} U_{g_i}^j\right]^{-1}$ fuzzy addition of $U_{g_i}^j$ values is done as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} U_{g_i}^j = \left(\sum_{i=1}^{n} x_i, \sum_{i=1}^{n} y_i, \sum_{j}^{n} z_i\right) \tag{9}$$

The inverse of the above is computed:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} U_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} z_i}, \frac{1}{\sum_{i=1}^{n} y_i}, \frac{1}{\sum_{i=1}^{n} x_i}\right). \tag{10}$$

Step 3 The degree of possibility of the FTNs U_1 and U_2 is calculated by using the following:

$$V(U_2 > U_1) = \sup_{w_2 > w_1}\left[\min\left(\mu_{U_1}(w), \mu_{U_2}(w)\right)\right]. \tag{11}$$

where $U_1 \geq U_2$, i.e., $(x_2, y_2, z_2) \geq (x_1, y_1, z_1)$.

The values on the axis of the membership function of each enabler are $\mu_{U_1}(w)$ and $\mu_{U_2}(w)$.

The condition of $V(U_2 \geq U_1) = 1$ is $y_2 \geq y_1$. If $y_2 \leq y_1$, and $V(U_2 \geq U_1) = hgt\ (U_2 \cap U_1)$. Then:

$$V(U_2 > U_1) = \mu_d = \begin{cases} 1 & if \quad y_2 > y_1 \\ 0 & if \quad x_2 > z_2 \\ \frac{x_1 - z_2}{(y_2 - z_2) - (y_1 - x_1)} & otherwise \end{cases}. \tag{12}$$

Figure 1 demonstrates the intersection of two FTNs. The ordinate of highest between μU_1 and μU_2 is 'I'.

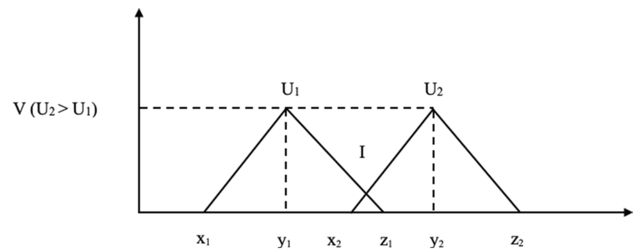

Fig. 1 The interaction between U_1 and U_2 (Chang, 1996)

The degree of possibility for an FTN, greater than k TFNs, U_i ($i = 1, 2, \dots k$) is given as:

$$\begin{aligned} &V(U \geq U_1, U_2, U_3 \dots U_k) \\ &= V\left[(U \geq U_1) \text{ and } (U \geq U_2) \text{ and } (U \geq U_k)\right] \\ &= \min V(U \geq U_i), i = 1, 2, 3 \dots k. \end{aligned} \tag{13}$$

Let $s'(U_i) = \min V(P_i \geq P_k)$ for $k = 1, 2, 3 \dots n$; $k \neq i$. The weights are given as:

$$W' = \left(s'(W_1), s'(W_2), \dots\dots..s'(W_n)\right)^T, \tag{14}$$

where W_i ($i = 1, 2, 3, 4 \dots n$) are n factors whose minimum degree of possibility of a fuzzy number being larger than others is taken into consideration.

Step 4 The weight of each enabler 'W' is calculated by normalization of the above weight vector:

$$W = \left(s(W_1), s(W_2), \dots s(W_n)\right)^T. \tag{15}$$

After calculation of the weight vector, checking the consistency ratio of the matrix obtained by pairwise assessment is important. Hence, for both the 'mean values matrix' and the 'geometric means matrix', the computation of consistency ratios is carried out (Gogus & Boucher, 1998). According to Saaty (2008), a consistency ratio ≤ 0.1 indicates that the matrices are consistent.

Case Description

The company undergoing the transformation to make its supply chain more responsive is a leading food retail chain having its operations spread across India. The company *XYZ* (the name is not revealed for maintaining confidentiality) is "one-stop-shop for fresh shopping, fresh savings and fresh happiness produces." *XYZ* company, found in 2006, has more than 700 stores across more than 90 cities in India selling fresh fruits and vegetables to dairy, cereals to spices, processed food and beverages to home. The company prides itself on an ecosystem that supports small producers to large producers and has been instrumental in modernizing food retail, thereby increasing efficiency in operations and minimizing leakages. Due to increasing global competitiveness and building chorus on the responsiveness of enabled by technologies and their associated benefits thereof, the present company is undergoing the transition from traditional to the responsive supply chain. This coincides with the need for the food supply chains to be responsive in the wake of a pandemic caused by a novel coronavirus (Xu et al., 2020) and augmentation of food supply chains with technologies to increase their responsiveness (Rizou et al., 2020).

The case company is interested in understanding the technology enablers of supply chain responsiveness. The company can focus on the most important factors/enablers and make efforts for their effective implementation. The company also seeks to segregate these enablers by their relative importance to maximize the benefit reaped from them. Data for the investigation of the case company was obtained from the experts' panel. Several rounds of interviews were undertaken to collect the required qualitative and quantitative inputs.

Application of the Proposed Methodology to the Case

A review of the extant literature was helpful for enlisting a number of enablers of supply chain responsiveness that capitalize upon the technical capability of the firms. A fuzzy Delphi approach was applied to incorporate the expert opinions towards the aptness of enablers enlisted from the literature. A decision team of six experts from industrial and academic backgrounds was formed, and a session was conducted. The panel consists of two senior engineering managers from the case company, two senior managers from the firms that were engaged in implementing new technology platforms to enhance the supply chain responsiveness of the case company, and two researchers primarily doing research in such domain. The panel experts had a cumulative work experience of more than 35 years and are highly skilled. The enlisted enablers were assessed for their suitability by the experts. Their inputs were taken with the help of a linguistic scale shown in Table 2. To this end, a questionnaire was developed. A joint meeting was held online to explain the present study to the experts. The questionnaire was sent to the panel experts. Using the fuzzy Delphi approach, eleven out of fourteen enablers were selected. Table 4 highlights the outcome of the application of fuzzy Delphi. As shown in Table 4, a value $r > 0.60$ was considered as a threshold value to decide whether a particular enabler will be considered for fuzzy AHP analysis or not (Kumar et al., 2018). The experts were also requested to suggest any other critical enabler which was missed in the survey of the literature. However, another enabler was not added to the existing list by experts. Hence, after applying the fuzzy Delphi approach, eleven enablers were undertaken for assessment. The selected enablers were taken as an input for fuzzy AHP analysis. For the pairwise comparison of the factors (enablers and dimensions), a second online meeting was held with the panel. Table 4 presents the results of the fuzzy Delphi method. The hierarchy model of selected enablers is depicted in Fig. 2.

The pairwise comparison of each enabler as well as the dimensions was made with the help of an expert panel. The panel of experts remained the same for the fuzzy Delphi and fuzzy AHP approach, in cognizance with the existing studies. Every expert was asked to provide a rating to each enabler on the basis of its relative importance in the pairwise comparison with other enablers. For doing this exercise, the linguistic scale defined in Table 3 was utilized by

Table 4 Results of fuzzy Delphi method

Enabler	M_l	N_l	O_l	S_l	Selected/rejected
Supply chain integration technologies	0.43	0.56	0.82	0.6	Selected
Predictive analytics for resource optimization	0.48	0.65	0.95	0.7	Selected
Smart logistics technologies	0.48	0.65	0.95	0.7	Selected
Smart warehousing	0.48	0.65	0.95	0.7	Selected
RFID-based location tracking	0.45	0.59	0.86	0.63	Selected
Drone logistics	0.25	0.32	0.45	0.34	Not selected
Online transparent presence	0.43	0.56	0.82	0.6	Selected
Sustainable manufacturing technologies	0.43	0.56	0.82	0.6	Selected
Smart retail technology	0.48	0.65	0.95	0.7	Selected
Big data and cloud-based demand prediction	0.46	0.66	0.98	0.76	Selected
AI for supply network and monitoring	0.58	0.81	0.88	0.71	Selected
Sustainable food packaging	0.48	0.65	0.95	0.7	Selected
Blockchain for traceability	0.48	0.65	0.95	0.7	Selected
Smart order management technologies	0.36	0.48	0.7	0.51	Not Selected
Sustainable sourcing and distribution	0.45	0.59	0.86	0.63	Selected

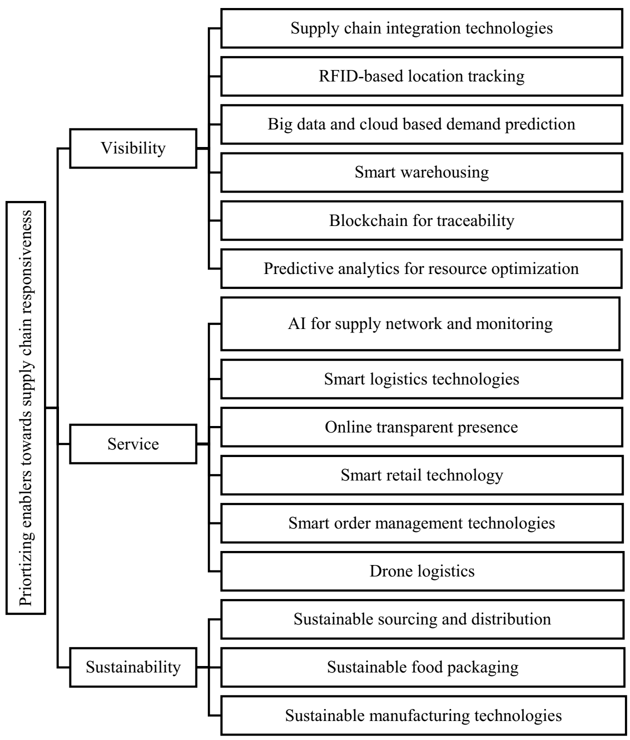

Fig. 2 A hierarchy model of selected enablers

the panel members. Once the rating has been obtained, the corresponding fuzzy number replaced the linguistic scale value (see Table 3). The weights of enablers were computed with the help of the extent analysis method, as explained earlier. Table 5 presents the pairwise comparison matrix for enabler dimensions.

The consistency ratio method was utilized to check the consistency of the matrices. The weights of enabler dimensions are given in Table 6. The pairwise comparisons of enablers are carried out in Tables 7, 8, and 9. The composite weight of each enabler is calculated by multiplying the dimension weight to enabler weight, and the corresponding global ranks are obtained (see Table 10).

Discussion

In this section, we illustrate the research findings of this study to assist the case study in implementing various technologies and tools to enhance the responsiveness of their supply chain.

The supply chain integration technologies (*V*6) enabler obtains the first rank among the enablers. Firms nowadays derive their competitiveness from their supply chains. A well-integrated supply chain enhances the probability of a firm achieving above-normal profits. Supply chain integration technologies can help to integrate the entire supply chain, both upstream and downstream, to increase visibility and transparency, which become of paramount importance in the wake of external shocks (Kumar et al., 2020). These technologies include electronic data exchange, internet, automatic identification, and data capture, open standards, decision-making information systems, and World Wide Web (WWW), which enhances collaboration in supply chain partners (Shamim et al., 2017). Therefore, augmenting supply chain integration technologies to increase the responsiveness of supply chains is of critical value and enhances the competitive advantage and performance of a firm (Singh, 2015).

Sustainable manufacturing technologies (*S*′1) together rank second in the analysis as they drive supply chain responsiveness. The findings resonate with the study conducted by Moktadir et al., (2021) in the leather industry of Bangladesh. The results revealed that sustainable manufacturing practices have the capabilities of reducing waste generation and promote effective utilization of the

Table 5 Pairwise comparison matrix for enabler dimensions

	V			*O*			*S*		
V	1.00	1.00	1.00	1.06	1.55	2.17	0.92	1.43	2.05
O	0.46	0.64	0.94	1.00	1.00	1.00	0.74	1.08	1.64
S	0.49	0.70	1.08	0.61	0.92	1.35	1.00	1.00	1.00

$CR_m = 0.003$, $CR_g = 0.01$

Table 6 Relative weights using fuzzy synthetic extent method

Fuzzy sum of each row			Fuzzy synthetic extent			Degree of possibility			Weights	Normalized weights
2.98	3.98	5.22	0.24	0.43	0.72		1.00	1.00	1.00	0.44
2.20	2.73	3.59	0.18	0.29	0.49	0.65		1.00	0.65	0.29
2.10	2.62	3.44	0.17	0.28	0.47	0.61	0.96		0.61	0.27

Table 7 Pairwise comparison of visibility dimension enablers

	*V*1			*V*2			*V*3			*V*4			*V*5			*V*6			Normalized weights
*V*1	1.00	1.00	1.00	1.06	1.55	2.17	0.31	0.38	0.53	0.64	0.87	1.25	1.15	1.64	2.05	1.06	1.55	2.17	0.18
*V*2	0.46	0.64	0.94	1.00	1.00	1.00	1.32	2.05	2.70	0.92	1.43	2.05	1.06	1.55	2.17	1.52	2.22	2.86	0.24
*V*3	1.89	2.61	3.25	0.37	0.49	0.76	1.00	1.00	1.00	1.32	2.05	2.70	1.32	2.05	2.70	1.32	2.05	2.70	0.27
*V*4	0.80	1.15	1.55	0.49	0.70	1.08	0.37	0.49	0.76	1.00	1.00	1.00	0.84	1.23	1.73	1.00	1.74	2.41	0.16
*V*5	0.49	0.61	0.87	0.46	0.64	0.94	0.37	0.49	0.76	0.64	0.87	1.25	1.00	1.00	1.00	1.00	1.32	1.55	0.10
*V*6	0.46	0.64	0.94	0.35	0.45	0.66	0.37	0.49	0.76	0.42	0.57	1.00	0.64	0.76	1.00	1.00	1.00	1.00	0.06

$CR_m = 0.05$, $CR_g = 0.10$

Table 8 Pairwise comparison of service dimension enablers

	A			*B*			*C*			*D*			Normalized weights
A	1.00	1.00	1.00	1.32	2.05	2.70	0.61	0.92	1.35	0.80	1.15	1.55	0.31
B	0.37	0.49	0.76	1.00	1.00	1.00	0.61	0.92	1.35	0.61	0.92	1.35	0.19
C	0.74	1.08	1.64	0.74	1.08	1.64	1.00	1.00	1.00	0.80	1.15	1.55	0.26
D	0.64	0.87	1.25	0.74	1.08	1.64	0.64	0.87	1.25	1.00	1.00	1.00	0.23

$CR_m = 0.02$, $CR_g = 0.04$

Table 9 Pairwise comparison of technology dimension enablers

	S1			S2			S3			Normalized weights
*S*1	1.00	1.00	1.00	1.52	2.22	2.86	0.92	1.43	2.05	0.58
*S*2	0.35	0.45	0.66	1.00	1.00	1.00	1.00	1.32	1.55	0.23
*S*3	0.49	0.70	1.08	0.58	0.71	1.00	1.00	1.00	1.00	0.19

$CR_m = 0.04$, $CR_g = 0.8$

resources. These practices will also provide them a competitive advantage and will help in the long-term survival of the firms (Katiyar et al., 2018). Apart from providing a competitive advantage, sustainable manufacturing processes can enhance the control of the firm towards different supply chain processes (Kumar & Kumar Singh, 2021). Therefore, sustainable practices are considered a crucial driver of supply chain responsiveness.

The smart warehousing (*V*2) enabler ranks third amongst the list of enablers in the technology enablers of supply chain responsiveness in the food sector. The very distinction between the traditional and smart warehouse is that of efficiency with which the smart warehouse operates, unlike their counterparts which are inefficient due to manual handling of tasks (Kumar et al., 2021a, 2021b). Smart warehouse pride on minimal manual handling and integration of best practices resulting in maximum efficiency (Jabbar et al., 2018). Tasks such as those of pickup, bookkeeping, and delivery should be automated in a warehouse (Liu et al., 2018). A key framework for a smart warehouse is cyber-physical systems consisting of mainly four building blocks- robots, humans, CPS devices, and inventories. Implementing a smart warehouse creates immense efficiencies with such time-efficient communication and human activities recognition (Liu et al., 2018).

The RFID-based location tracking (*V*3) is ranked fourth in the analysis. The RFID is a class of technologies that have shown great promise in bridging the vast information gaps that exist within and beyond the firm and therefore obtains the fourth rank (Angeles, 2007). RFID technologies are touted to be a class of technologies that introduce "process freedoms" with which value can be added along the entire supply chain requiring an effective redesigning of business processes (Zhu et al., 2012). RFID technologies have been instrumental in changing how logistics are managed in supply chains. Traditional technologies such as enterprise resource planning or customer relationship management do increase

Table 10 Final ranking of enablers

Dimension	Relative weight	Enabler	Enabler	Relative weights	Relative rank	Global weights	Global rank
Visibility	0.44	*V*1	Blockchain for traceability	0.209	5	0.092	6
		*V*2	Smart warehousing	0.253	2	0.111	3
		*V*3	RFID-based location tracking	0.22	3	0.097	4
		*V*4	Big data and cloud-based demand prediction	0.218	4	0.096	5
		*V*5	Predictive analytics for resource optimization	0.099	6	0.044	13
		*V*6	Supply chain integration technologies	0.537	1	0.236	1
Service	0.29	*S*1	Smart logistics technologies	0.308	1	0.089	7
		*S*2	Smart retail technology	0.195	4	0.056	11
		*S*3	AI for supply network and monitoring	0.265	2	0.077	8
		*S*4	Online transparent presence	0.232	3	0.067	9
Sustainability	0.27	*S′*1	Sustainable manufacturing technologies	0.579	1	0.156	2
		*S′*2	Sustainable sourcing and distribution	0.231	2	0.062	10
		*S′*3	Sustainable food packaging	0.190	3	0.051	12

the supply chain efficiency, albeit in a limited manner (Singh et al., 2019). This deficiency is mitigated by the use of RFID technologies as the benefits of efficiency and timeliness accrue in the entire supply chain, thereby increasing supply chain visibility, doing away with the human-induced latency. All this increases the supply chain responsiveness (Giannakis et al., 2019).

The results of this research confer the fifth rank to Big data and cloud computing technologies (*V*4) towards increasing the supply chain responsiveness. These technologies have caught the attention of all industries and countries due to the value-additions voluminous data can have on the conduct of the business (Addo-Tenkorang & Helo, 2016). These technologies help firms to do real-time analysis of data augmented by analytics that can be hosted on the cloud and consumer by consumers (Assunção et al., 2015). The findings of the study are in line with the extant literature. For example, authors have argued that the solutions from big data also increase the real-time end-to-end visibility in the supply chain, thereby enhancing its responsiveness (Kumar et al., 2021a, 2021b). Further, the analytics provided by big data drive time compression, which is the essential characteristic of a responsive supply chain to react efficiently in the wake of external environmental shocks (Kache & Seuring, 2017). Therefore, it is essential to the value of big data technologies and analytics in enhancing the supply chain chains and thereby unlocking their true potential.

Predictive analytics for resource optimization (*V*5) of products rank second, last, and last in our analysis. Since the results of the analysis are based on the judgment of the expert panel, certain reasons can lead to this counterintuitive finding. Scholars point towards a much lesser adoption of predictive analytics in the context of Indian food supply chains, as compared to descriptive and prescriptive analytics, the reason being high cost and resistance to change (Kamble et al., 2020). The opinion of experts in the present study can be attributed to similar reasoning, as a result of which predictive analytics is deemed unimportant.

As evident from the analysis, several factors (enablers) play a crucial role in enhancing a firm's proactiveness towards becoming more responsive in the wake of the pandemic. This is in accordance with contingency theory, which suggests that the internal and external situation of a firm decides the optimum course of action (Grötsch et al., 2013). COVID19 is the contingency being faced by the supply chains, and the level of disruptions faced by the firms are major indicators of the contingent situation (Grötsch et al., 2013). In line with the contingency approach, for managing these disruptions, the supply chains need to improve and enhance their technological capability proactively.

Conclusions

The present study provides a structured view of technology-driven enablers from the perspective of the food supply chains that intend to enhance their responsiveness. The ongoing COVID-19 crisis acts as the important contingent factor faced by the organizations and therefore the contingency theory acts as a theoretical lens for the analysis.

Critical enablers of responsiveness, driven by digitalization have been identified with the help of a literature survey and the opinion of experts. The enablers are assessed from the standpoint of a firm that is transitioning towards responsive supply chains. The fuzzy Delphi technique is used to finalize the important enablers. Further, fuzzy AHP establishes their relative importance. The analysis reveals that supply chain integration technologies, sustainable manufacturing technologies, and smart warehousing are the top three enablers of supply chain responsiveness in the food sector. Further, the study provides academic and managerial implications which are discussed below.

Academic Implications

This research work presents a systematic approach to rank, prioritize and choose from a set of technologies to enhance the supply chain responsiveness by taking an example from the food sector, which is an under-researched area in the extant literature. This need is escalated in developing economies to arrest the difficulties caused by inefficiencies in the food supply chain and further intensified by pressures of COVID19. This work identifies key technology enablers through an extensive literature review and through fuzzy Delphi method reduced the number of these enablers, which were then subject to fuzzy AHP process to rank and prioritize these enablers. Finally, we discuss the top four ranked technology enablers—supply chain integration technology, RFID, smart warehousing, and big data and cloud computing as. This work is of particular significance for managers and practitioners to focus on the top-ranked enablers to achieve the much-needed responsiveness in the food supply chain.

Managerial Implications

From the managerial point of view, the research highlights that choosing from a myriad of technology solutions is challenging and sometimes overwhelming. Previous research, which pursues the idea of supply chain responsiveness, identifies different ways and tools to enhance it, yet the literature presents ambiguities with reference to different technologies. This work highlights the various technology-led enablers that can improve the supply chain responsiveness of the food supply chain. A clear and proper understanding of these technology enablers is critical for achieving competitiveness in the supply chain. The study outlines the key enablers that will highlight the strategic field of action for the managers to improve supply chain responsiveness. Responsiveness strategy is an important approach to revive operations and supply chains in post-COVID-19 times. Moreover, business leaders should pay attention to the most important enablers to fare better in the competition globally. This research clearly demonstrates that to achieve responsiveness in the supply chain, managers need to implement supply chain integration technologies, both upstream and downstream, apart from using RFID, smart warehousing, and big data and cloud computing technologies. The process of achieving the supply chain responsiveness is complex, accentuated by the current global pandemic, and hence, with this research, we disentangle the technological opportunities to achieve the same. With supply chain integration and smart warehousing getting enumerated in the top four technologies requires firms to adopt a two-pronged strategy—train and educate the members of your supply chain to achieve supply chain responsiveness through technologies' driven enablers and their intended benefits, and initiate training for employees to change the internal dynamics of the firm as well.

Limitations and Directions for Future Research

This research has certain limitations. The methods used include fuzzy Delphi and Fuzzy AHP to determine the weights of the enablers. This process is cumbersome and involves a high level of human engagement, and therefore, requires extreme care. Future researchers can, therefore, use several other methodological tools such as those of large-scale survey methodology resulting in an extensive data set and fine-grained qualitative case study analysis, among others, to disentangle this complex process further. The findings of this research should be understood with caution as these are country-specific as well. This should pave the way for further research in different countries. This can further aid in our understanding of the supply chain responsiveness through country-specific contextualization and comparisons and underlying idiosyncrasies. The experts' data and findings of the present study are principally based on the food industry. This may limit the generalizability of the results with respect to other industries of varying types, sizes, etc. Therefore, there is scope for further research on the identification of enablers in other supply chains such as healthcare, wellness, etc., which can be assessed. Therefore, empirical examinations can also be carried out, and diverse sample sets could be assessed to identify and evaluate enablers related to responsive supply chains, and the finding may be compared with the present study findings.

Finally, the realized benefits of supply chain responsiveness should be assessed in future research to validate the use of specific technologies and tools.

Key Questions Reflecting Real-Life Applicability

1. What role does the food sector play in the growth of the digital economy? How is the developing country scenario different from that of the developed?

2. Which smart technologies and digitalization principles lead to a trade-off between minimized human contact as well as enhanced responsiveness?
3. In post-COVID-19 pandemic times, which supply chains underwent maximum breakthrough to enhance responsiveness?
4. How do technology-driven enablers differ in developing and developed countries in terms of adoption patterns, and why?

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