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Assessing Supply Chain Innovations for Building Resilient Food Supply Chains: An Emerging Economy Perspective

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Abstract: Food waste reduction and security are the main concerns of agri-food supply chains, as more than thirty-three percent of global food production is wasted or lost due to mismanagement. The ongoing challenges, including resource scarcity, climate change, waste generation, etc., need immediate actions from stakeholders to develop resilient food supply chains. Previous studies explored food supply chains and their challenges, barriers, enablers, etc. Still, there needs to be more literature on the innovations in supply chains that can build resilient food chains to last long and compete in the post-pandemic scenario. Thus, studies are also required to explore supply chain innovations for the food sector. The current research employed a stepwise weight assessment ratio analysis (SWARA) to assess the supply chain innovations that can develop resilient food supply chains. This study is a pioneer in using the SWARA application to evaluate supply chain innovation and identify the most preferred alternatives. The results from the SWARA show that 'Business strategy innovations' are the most significant innovations that can bring resiliency to the food supply chains, followed by 'Technological innovations.' The study provides insights for decision makers to understand the significant supply chain innovations to attain resilience in food chains and help the industry to survive and sustain in the long run.

Keywords: food supply chains; supply chain innovations; digital technologies; resilience; food security

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1. Introduction

The pandemic triggered the discussion on the global vulnerability of food supply chains (FSCs) [1,2]. Global and local supply chains were disrupted and food security challenges emerged. The global lockdown restrictions have diverse impacts on the FSC and thus need innovative practices to keep the pace of supply chains running [3]. To address the challenges now and in the future, a shift toward resilient FSCs is a must [4]. The pandemic has brought an opportunity to rebuild an ecological balance and cultivate an ecosystem for a sustainable and resilient food system for better and healthy human lives. To develop a sustainable system, food supply chain innovation should be the priority [5,6]. Food supply chain innovation signifies the transformation through innovation in processes, technologies, and food networks as the result of food consumption patterns and improvises the stakeholder's value [7,8]. The global and domestic FSC needs to be distinguished, and so do its impacts. In domestic FSCs, it is beneficial to differentiate between SMEs primarily involved in food processing, logistics, food stock trading, and consumer retailing. The other category includes big firms involved in FMCG food retailing business, super-marts, and inter-state logistics businesses [9]. With the change in trends, supply chain innovation is widely practiced by domestic SMEs, and they are growing to become the major actor in supplying food items to consumers in developing countries [10]. In South Asia and Africa, domestic supply chains have an estimated 75% to 91% of overall food consumption, of which the key emanates through SME-subjugated supply chains.

Global FSCs account for 18% to 21% of overall food consumption and exhibit a direct relationship between industrial growth and GDP. However, the pandemic has adversely impacted SMEs due to high labor intensity. The impact of the pandemic on supply chains is rooted in labor-intensive segments [11].

The situation of supply chains in developed nations is more resilient because of their capital-intensive nature. Large companies can mitigate risk and optimize more flexible processes by switching global sourcing [12]. A primary concern is about COVID-19's impact on trade on perishable FSCs. The pandemic has mixed effects on domestic FSCs [13–15].

Moreover, the challenges, including climate change, waste generation, and resource scarcity, are faced by humans that require urgent attention from all stakeholders. Therefore, a need for a new era, wherein the blending of social, environmental, and economic progress determines the sustainable growth of the economy is required [16]. Sharma et al. [17] stated that the digitalization of the industry has the potential to unlock the development of sustainable production, transparency, and resource efficiency. In the era of Industry 4.0, there has been a change in data management, real-time decision making, innovative practices for enhancing the end-of-life, increasing the shelf life of perishable products, etc. [18].

With technological support, organizations may enhance their sustainable production and consumption [19]. Past studies have conducted research in identifying the barrier to resilient FSCs [20–23]. However, how innovative practices, such as digital technology implementation, will affect the resilience of the food supply chain still needs to be explored.

Implementing digital technologies is still in the emerging economies′ beginning era and needs assessment. With the advancement in digital technologies, food waste management can lead to the achievement of sustainable supply chains. Food waste management and circularity may enhance the value chain to reduce GHG emissions [24]. However, the consumption patterns of food products are responsible for various environmental and climate changes, which adversely affect the life pattern of human lives and compromise future generations.

Joshi et al. [25] mentioned that the agri-food supply chain (AFSC) is at risk due to multiple disruptions. Past studies discussed the challenges of deploying circular food supply chains; Kumar et al. [26] discussed circular food supply chains using Industry 4.0 technologies [27,28]. The integration of digital technologies in the food sector has the potential to revolutionize sustainable production and consumption practices [29]. Kamble et al. [30] elaborated on modeling IoT adoption challenges of retail food supplies and food waste management using the digitalization process [31]. Due to the limited literature support [32–34], there needs to be more evidence in the literature that highlights the innovations or innovative practices that have the potential to develop resilient FSCs.

Supply chains need to be evaluated from a different perspective, but more data are required on innovative practices that may build resilient FSCs in developing nations.

Innovation has an essential role in developing sustainable and futuristic food supply chains. Considering the AFSC's intricacy and the perishability of food products, the present study intends to explore the answer to the following research queries:

(1) What are the critical innovative practices that may develop resilient FSCs in emerging economies, such as India?
(2) What are the most effective innovative practices to enhance resilience in FSCs?
(3) How do priority strategies improve innovative practices′ resilience in FSCs?

While past research examines the food and circular supply chains, studies have yet to be conducted on the innovation practices to develop the resilient FSCs. Additionally, there needs to be more studies that offer strategic solutions to enhance resilience in FSCs through innovations. Our study has proposed a framework to identify and assess the innovation practices to develop a resilient FSC in an emerging economy, such as India. This study has employed the SWARA method [35–37].

The proposed framework has been evaluated based on the judgment of decision-makers from the food industry. The critical implications of the study are the pioneering work in exploring ways to bring resilience to FSCs. The study offers the following key contributions:

- Identification of supply chain innovations in FSCs;
- The inter-relationship between supply chain innovations and resilience in FSCs.

The subsequent sections of the paper are placed in the following order. Section 2 discusses the literature review of FSCs. Section 3 explains the research methodology adopted in the study. The results obtained from the research methods are discussed in Section 4. Section 5 gives details on the findings and discusses its implications. Section 6 concludes the study.

2. Literature Review

The section explored the literature on FSCs through a comprehensive review of the previous papers. The initial search results were 191 research documents. As the first step, the process of systematic literature review (SLR), which aims to reduce duplicate records, resulted in 102 unique research articles, which were further reduced to 71 papers after the exclusion of irrelevant articles. Finally, after reading abstract, 49 papers were shortlisted for literature analysis. As the final step of the SLR, data mining was carried out through a critical review of the published articles. The search was related to "food supply chain", "agri-food supply chain", "digitalization", "Industry 4.0", "Innovation,", and "Resilience". The combination of search strings was used for a comprehensive search of relevant articles using the Scopus database. The timeline for the SLR was ten years, between 2020–2022. The data collection was carried out in March–April 2022.

Food Supply Chains and Resilience

During the world Rio summit (1992), world leaders broadly agreed to the continuous deterioration of the ecological environment due to unsystematic patterns. As mentioned in a report by the European Commission, the relevance of sustainable practices is in economic changes and sustainable growth of economic systems [38]. Global food wastage accounts for around one-third of the overall production, which is 1.3 billion tons per annum. As cited in past research, the size of food waste is a matter of great concern for developing economies and developed countries [39]; although, the causes of wastage are diverse [40,41]. Due to structural differences, few forms of food waste are inappropriate for consumption and hence require reprocessing for value recovery [42].

On the other side, environmental threats and hygiene problems are related to food waste management [43]. Additionally, it is challenging to evaluate the cost of wastage at multiple phases of the value chain [44]. The inclusion of advanced technologies has the potential to support agri-food firms in addressing challenges and value creation [45]. Considering the ominous socio-ecological issues in the ecosystem, more than short-term changes or adjustments are needed to foster unsustainability challenges. Instead, a technology-driven systematic approach can address the problem [46]. Thus, there is a need to support the technology with the sustainable consumption patterns of the consumers with a stringent policy framework [47]. The two primary global economic agendas include food loss and waste reduction, as more than thirty-three percent of global food production is either wasted or lost due to the mismanagement of existing food chains [48]. The imperative statistics highlight the need to develop a broader SPC framework for food chains [49]. However, FSCs face several issues due to complex internal and external indicators [50]. Other unique challenges linked to food supply chains broadly include pre-harvesting seasonality, high regularity, perishability, warehousing, in-transit losses and damages, adulteration, recycling, and reuse [51]. These challenges escalate with the change in food consumption patterns [52]. Furthermore, comprehending the essence of food waste and its appropriate management presents another significant obstacle. The COVID-19 outbreaks have made the resilience of the supply chain a primary concern.

There is a need for agility and responsiveness in the supply chains to respond immediately to a variety of disruptions (viz., change in demand, inventory shortages, low inventory turnover, and reduction in productivity) [53]. According to the study conducted by Scholten [54], there are various causes of supply chain disruption (including natural disasters, logistics delays, price variation, cyber-attacks, and product–demand misfits). The author suggested that supply chain resilience can be evaluated across all phases of disruption. Additionally, the arguments opposing the presence of equilibrium gave rise to adaptive resilience. Therefore, resilience is viewed as a situational capability developed through continuous learning and adaptations drawn from disruptions [55]. The previous literature on supply chain resilience has been expanded drastically in the aftermath [56]. However, [57,58] claimed that further research is needed to understand how supply chains build resilience. Therefore, this study extends the literature on supply chain innovations that help develop resilient FSCs in an emerging economy, such as India. Based on the literature review, the experts explore and validate the innovation practices in the supply chains. The classification of the innovations in supply chains for building resilient supply chains is shown in Table 1.

Table 1. Supply chain innovations in building resilient food supply chains.

Criteria	Sub-Criteria	Implied Meaning	References
Social innovations (C_1)	Awareness and technological education ($C_{1\text{-}1}$)	The involvement of the workforce in creating and sustaining value chains has become a prominent feature in food supply chains. The purpose of the transformation is to improve the labor shortfall challenge and also to improve worker safety.	[59–61]
	Safety of labor workforce ($C_{1\text{-}2}$)		
	Workforce replacement flexibility with automated machines ($C_{1\text{-}3}$)		
	Workforce sourcing flexibility ($C_{1\text{-}4}$)		
Business strategy innovations (C_2)	Customer segmentation and marketing flexibility ($C_{2\text{-}1}$)	A strategic framework for multiple alternatives sourcing and supply is required. Additionally, the strategic vision of a collaborative environment is needed.	[62–64]
	Multisource to mitigate supply chain risk($C_{2\text{-}2}$)		
	Inventory and capacity buffers ($C_{2\text{-}3}$)		
	Logistics planning and shipment flexibility ($C_{2\text{-}4}$)		
	Collaboration with the government ($C_{2\text{-}4}$)		
	Multiple supply locations to reduce risk ($C_{2\text{-}5}$)		
	Emergency food hubs ($C_{2\text{-}6}$)		
	Governance ($C_{2\text{-}7}$)		
Technological interventions and innovations (C_3)	Data analytics ($C_{3\text{-}1}$)	Development and usage of digital solutions for emergencies. With advanced technological innovations, customer satisfaction can be enhanced. Additionally, the increasing concern for green and sustainable technology among the stakeholder needs to be implemented for developing resilient agri-food supply chains.	[65–68]
	Digital technologies for improving customer hygiene ($C_{3\text{-}2}$)		
	Usage of E-commerce platforms for contactless delivery ($C_{3\text{-}3}$)		
	Food processing ($C_{3\text{-}4}$)		
	Green technology ($C_{3\text{-}5}$)		
	Traceability ($C_{3\text{-}6}$)		
	Regenerative agriculture infrastructure ($C_{3\text{-}7}$)		
Financial resilience innovations (C_4)	Capacity development SMEs ($C_{4\text{-}1}$)	Support to the domestic, agri-food supply chains, which struggle in the post-pandemic situation. Incentives, such as a tax credit for agri-food firms willing to transform their system in the face of economic vulnerabilities.	[69–72]
	Tax credits for digitally enabled supply chains ($C_{4\text{-}2}$)		
	Pull incentives ($C_{4\text{-}3}$)		

3. Research Methodology

The current study has followed the process, as shown in Figure 1. A step-by-step process was followed for conducting the expert survey. An SLR was conducted to identify the supply chain innovation practices for building a resilient FSC. With the help of the literature review and experts' validation, four main criteria and twenty-one sub-criteria were finalized to be analyzed.

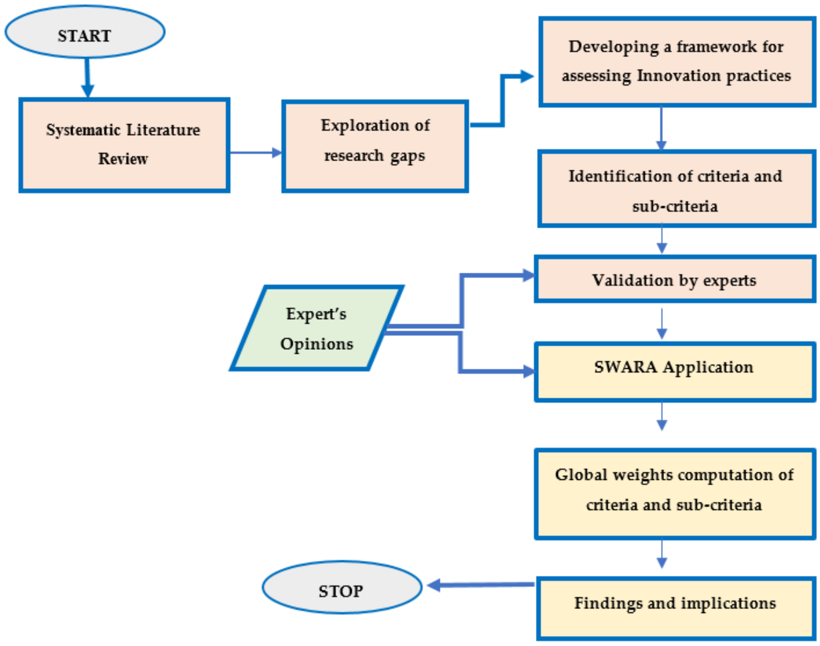

Figure 1. Proposed framework.

Decision makers deployed mathematical modeling and sophisticated statistical analysis to enhance the results' accuracy and solve multiple managerial issues [73–77]. Business and management [78–80], banking and insurance [81–83], computer science [84–86], health and medical [81–83], engineering [84], energy [85,86] and oil and gas [87–90], are among the scientific sectors that have employed it. Particularly, supply chain companies utilize various data analysis tools to evaluate the performance rating and criteria weights because of the dynamic nature of the business environment and its complexity. As a result, many mathematical modeling tools can be used to evaluate risks and develop policies. These methods, referred to as multi-criteria decision making (MCDM), have gained widespread acceptance as an effective way to balance several factors while choosing from a constrained set of possibilities. In the literature, various MCDM techniques (ANN, TOPSIS, fuzzy MICMAC, etc.) are used for various industries in their operations and decision-making in the supply chain, including the construction of supply chain management [85–87], process optimization [88,89], hospital and tourism [90], agri-food supply chain management and food security [91–93], supply chain risk assessment [94], supplier selection [95,96], and green and sustainable supply chain management [97–99], as well as systems for health [100].

This section discusses the approach for evaluating supply chain innovation to create a resilient food supply chain. The MCDM technique, the SWARA, is used to identify the preferred methods for constructing the resilient food supply chain. Various operations and supply chain management applications, such as risk assessment [101–103], humanitarian supply chain management [104–107], and environmental policies [108,109], have been studied in the past, as well as strategic relationships and product innovation [110–112] and operational performance [113]. The SWARA method is employed to determine the preferences of the enablers. Several steps have been taken to understand supply chain innovations in creating resilient agri-food supply chains, including designing questionnaires for experts and practitioners, having conversations with agri-food specialists, analyzing agri-farm reports, and searching relevant databases. This section includes the study's methodology, data collection, and expert selection.

This section discussed the process for assessing the supply chain innovations for building resilient food supply chains. The SWARA method is employed to ascertain the preferences of the enablers. Several procedures have been taken to understand further the enablers, including designed questionnaires for experts and practitioners, discussions with agri-food specialists, analysis of agri-food reports, and searches of pertinent databases. This section includes the study's methodology, information gathering, and expert selection.

The SWARA is employed to rank the practices that may enhance the resilience of FSCs. The SWARA is one of the methods that can overcome the issues related to pairwise comparisons. With the SWARA application, the strategies are analyzed and ranked. The SWARA application is explained in the subsequent sub-sections.

3.1. The Stepwise Weight Assessment Ratio Analysis (SWARA) Method

The SWARA method is advantageous over the other MCDM techniques, as it gives the experts a lot of opportunity for their selection based on the existing situation of world economies. The method uses small comparisons vis-à-vis other MCDM techniques, including AHP, ANP, etc. The process has the following steps:

- Step 1: The criteria are arranged based on expert opinion.

The study took the ideas of 20 experts and further sorted the criteria in descending chronology.

- Step 2: Weightage criteria specification.

Corresponding values of the jth criterion in correspondence with the previous $(j-1)$ criterion through comparative values of the average value (s_j) ratio.

- Step 3: Co-efficient calculations KJ:

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (1)$$

- Step 4: Recalculated weight w_j:

$$W_j = \begin{cases} 1 & j = 1 \\ \frac{x_j - 1}{k_j} & j > 1 \end{cases} \quad (2)$$

- Step 5: Final weights:

$$q_j = \frac{w_j}{\sum_{k=1}^{n} w_j} \quad (3)$$

where q_j is the relative weight of the wth criterion and n is the criteria number.

- Step 6: Synthesis.

The global weights are evaluated by multiplying (W_j) with sub-criteria weights.

3.2. Expert Selection and Data Collection

We shared the questionnaire with experts with vast industrial experience in supply chains. The domain areas of experience include procurement managers, production managers, suppliers, and operation managers. The author acquired the data from August–October 2022 from agri-food firms in northern India using a standardized questionnaire (Appendix A). The respondents, who mostly held administrative positions, were knowledgeable of supply chain innovations for building resilient food supply chains and their benefits. The professionals are employed by the agri-food sector, which offers various services. The questionnaire was distributed to 20 specialists. Based on gender, men make up 76% of the experts. The age distribution of experts is as follows: >30 years (40%) to >40 years

(15%), 30–35 years (27%), 36–40 years (18%), and >40 years (18%). Since India is one of the emerging economies expanding and becoming more aware of sustainable and innovative practices, it was chosen as the sample source. The technique has achieved acceptance on a global basis. Thus, the study's conclusions can be applied elsewhere [104,112,113].

Table 2 exhibits the demographics of the experts.

Table 2. Demographics of the experts.

Experts	Designation	Experience
E1	Production Planner	>8 years
E2	Manager, Global Supply Chains	>12 years
E3	Distribution Manager	>12 years
E4	Operations Managers	>12 years
E5	Food Control	>12 years
E6	Global Operations	>12 years
E7	Supply Chain Partner	>12 years
E8	Food Control	>12 years
E9	Manager, E-commerce Platform	<10 years
E10	Food Control	<10 years
E11	Global Operations	<10 years
E12	Supply Chain Partner	<10 years
E13	Distribution Manager	<10 years
E14	Supervisor, SMEs	<10 years
E15	Project Manager, SMEs	<10 years
E16	Analyst/Consultant, SMEs	>10 years
E17	Supply Chain Partner	<10 years
E18	Supply Chain Partner	<10 years
E20	Manager, E-commerce Platform	>8 years
E20	Manager, E-commerce Platform	>8 years

3.3. The Stepwise Weight Assessment Ratio Analysis (SWARA) Method

According to earlier research, the SWARA technique has been applied effectively in several fields, including design, production, sales, distribution, forward logistics and supply chains, and closed-loop activities. This approach is predicated on the implicit expertise, practical experience, and viewpoints of subject matter specialists [108]. Since there is no set rule, the number of experts varies and can be from three to fifteen in number [109]. This approach is based on the significance of factors determined by specialists. According to their knowledge, specialists rank each criterion [110]. The most crucial measure is rated 1; the others are ranked regarding the first criteria [111]. The steps elaborate on the SWARA methodology.

- Step 1: Putting parameters in ascending order is the first step. The expert prioritizes the criteria in that order. The requirements are arranged in a declining rank of importance, starting with the most important one. The criterion is the least important if it comes in last.
- Step 2: Giving the criteria a proportional weighting. Based on the overall rating, criteria are compared. As a result, the $(j + 1)$th criterion is contrasted with the j-th criterion. The mean value's comparative advantage is known as (s_j).
- Step 3: Calculating the coefficient k_j. Following the analysis, k_j is generated as a parameter. In the equation, the KJ formula is displayed in Equation (4):

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases} \quad (4)$$

- Step 4: The variable q_j is computed by Equation (5):

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{K_j - 1}{k_j} & j > 1 \end{cases} \quad (5)$$

- Step 5: Criteria weights are evaluated.

  Using Equation (6), the criteria weights were evaluated as:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} qk} \quad (6)$$

w_j is the j-th criterion's relative weight. Based on the criteria, the priority vector is determined.

3.4. Proposed Framework

The framework contains two sections. Experts define and validate the first phase's enablers to minimize carbon emissions. Phase two involves evaluating the SWARA enablers and assigning weights to each criterion and sub-criteria. After reviewing and finding 22 facilitators in the literature review, 20 experts were consulted. There are a total of six categories created from these enablers: social innovations (C1), business strategy innovations (C2), technological interventions and innovations (C3), and financial resilience innovations (C4). The details of 19 enablers are mentioned in Table 1. There are questions on a prepared questionnaire that each group must respond to (Appendix A). The two levels for which the relative weights are decided are the primary criteria level and the sub-criteria level. Experts establish the median values for the primary and secondary criteria. According to Section 3.2, the authors calculated the weight computation method.

The weights of the primary criterion determined using Equations (1)–(3) are displayed in Table 3.

Table 3. Main criteria.

Criteria (Main)	Weightage	Rank
C_1	0.1967	3
C_2	0.3836	1
C_3	0.2557	2
C_4	0.1639	4

4. Results

Initially, the weights of the main criteria were calculated using Equations (1)–(3) with the SWARA application. Subsequently, the weights were calculated with the sub-criteria. Based on the expert's opinion, the authors found the weightage of the criteria and the mean value of all the values. The results for the main criteria are exhibited in Table 3.

The experts also evaluated the sub-criteria and the results are shown in Table 4. Whereas, Table 5 discuss the Ranking of the criteria and sub-criteria

Table 4. Sub-criteria.

Main Criteria	Sub-Criteria	Weight Priorities
C_1	$C_{1\text{-}1}$	0.2624
	$C_{1\text{-}2}$	0.3674
	$C_{1\text{-}3}$	0.2019
	$C_{1\text{-}4}$	0.1682
C_2	$C_{2\text{-}1}$	0.1207
	$C_{2\text{-}2}$	0.1961
	$C_{2\text{-}3}$	0.2648
	$C_{2\text{-}4}$	0.0795
	$C_{2\text{-}5}$	0.1509
	$C_{2\text{-}6}$	0.1006
	$C_{2\text{-}7}$	0.0875
C_3	$C_{3\text{-}1}$	0.1485
	$C_{3\text{-}2}$	0.2907
	$C_{3\text{-}3}$	0.0928
	$C_{3\text{-}4}$	0.2005
	$C_{3\text{-}5}$	0.1160
	$C_{3\text{-}6}$	0.0714
	$C_{3\text{-}7}$	0.0800
C_4	$C_{4\text{-}1}$	0.4567
	$C_{4\text{-}2}$	0.3150
	$C_{4\text{-}3}$	0.3150

Table 5. Ranking of the criteria and sub-criteria.

Major Criteria	Relative Weight (Main Criteria)	Sub-Criteria	Relative Weight (Sub-Criteria)	Global Weights	Ranking
C_1	0.1967	$C_{1\text{-}1}$	0.2624	0.0516	6
		$C_{1\text{-}2}$	0.3674	0.0723	4
		$C_{1\text{-}3}$	0.2019	0.0397	9
		$C_{1\text{-}4}$	0.1682	0.0331	14
C_2	0.3836	$C_{2\text{-}1}$	0.1207	0.0463	8
		$C_{2\text{-}2}$	0.1961	0.0752	2
		$C_{2\text{-}3}$	0.2648	0.1016	1
		$C_{2\text{-}4}$	0.0795	0.0305	15
		$C_{2\text{-}5}$	0.1509	0.0579	4
		$C_{2\text{-}6}$	0.1006	0.0386	10
		$C_{2\text{-}7}$	0.0875	0.0336	13
C_3	0.2557	$C_{3\text{-}1}$	0.1485	0.0380	11
		$C_{3\text{-}2}$	0.2907	0.0743	3
		$C_{3\text{-}3}$	0.0928	0.0237	16
		$C_{3\text{-}4}$	0.2005	0.0513	7
		$C_{3\text{-}5}$	0.1160	0.0297	15
		$C_{3\text{-}6}$	0.0714	0.0183	18
		$C_{3\text{-}7}$	0.0800	0.0205	17
C_4	0.1639	$C_{4\text{-}1}$	0.4567	0.0749	2
		$C_{4\text{-}2}$	0.3150	0.0516	5
		$C_{4\text{-}3}$	0.2283	0.0374	12

Sensitivity Analysis

To determine the working of the model, it must be examined in different situations, according to Kumar et al. [112]. In this study, a sensitivity analysis is performed by adjusting experts' inputs and then looking at how the results change. Based on changes in C2 weights, other weights have been calculated; these are presented in Tables 6 and 7. The sensitivity analysis is further explained in Figure 2.

Table 6. Weights in different situations.

	Normal	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9
C1	0.197	0.209	0.221	0.233	0.246	0.258	0.270	0.282	0.295	0.307
C2	0.384	0.345	0.307	0.269	0.230	0.192	0.153	0.115	0.077	0.038
C3	0.256	0.272	0.288	0.303	0.319	0.335	0.351	0.367	0.383	0.399
C4	0.164	0.174	0.184	0.194	0.205	0.215	0.225	0.235	0.246	0.256

Table 7. Sensitivity analysis.

	Normal	Run1	Run 2	Run 3	Run4	Run5	Run6	Run7	Run8	Run9
C_{1-1}	6	6	5	6	5	6	5	5	5	5
C_{1-2}	4	4	3	4	4	4	3	4	4	4
C_{1-3}	9	11	10	10	11	9	9	10	10	10
C_{1-4}	14	13	12	11	13	12	13	12	12	13
C_{2-1}	8	10	8	8	9	9	8	8	8	8
C_{2-2}	2	3	3	2	2	3	2	2	2	2
C_{2-3}	1	1	2	1	2	1	1	1	1	1
C_{2-4}	15	18	17	14	15	16	15	14	15	15
C_{2-5}	4	8	6	7	6	5	4	6	5	6
C_{2-6}	10	14	14	11	10	11	12	10	11	11
C_{2-7}	13	17	16	13	15	13	14	13	13	14
C_{3-1}	11	9	9	9	12	10	10	11	9	9
C_{3-2}	3	2	3	3	3	3	3	2	3	3
C_{3-3}	16	15	15	15	16	16	17	15	16	16
C_{3-4}	7	7	6	6	7	6	7	7	7	7
C_{3-5}	15	16	13	16	17	17	16	17	16	16
C_{3-6}	18	20	19	18	19	19	20	19	19	19
C_{3-7}	17	19	18	20	18	18	18	18	20	18
C_{4-1}	2	2	2	2	2	3	2	2	2	2
C_{4-2}	5	6	5	4	5	5	5	6	5	5
C_{4-3}	12	12	11	12	14	14	13	15	15	13

The sensitivity analysis shows consistency in the ranking. The incremental change has not changed any of the results, demonstrating the robustness of the model. Figure 2 illustrates the sensitivity analysis using a radar diagram.

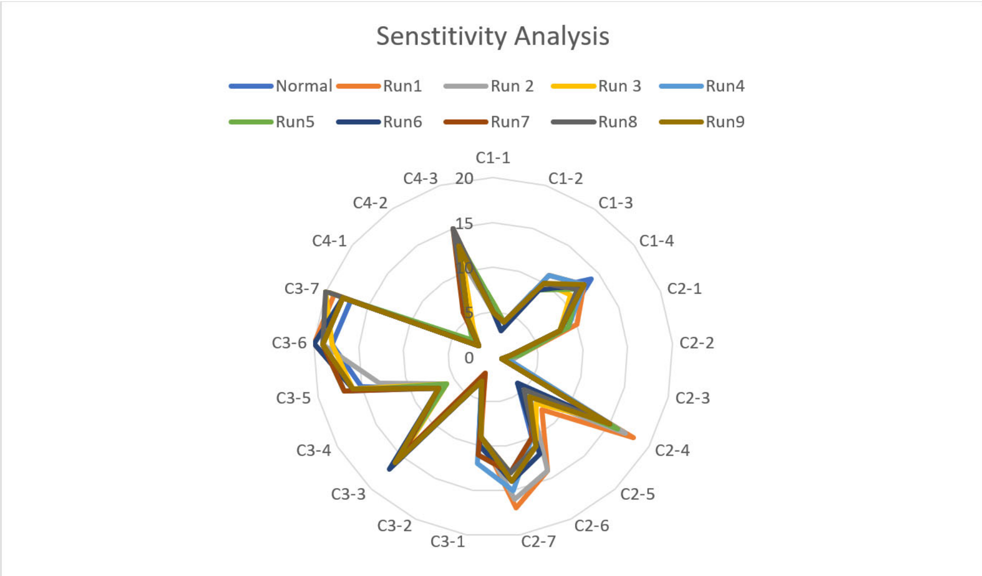

Figure 2. Sensitivity Analysis.

5. Discussion of Findings

The research study evaluated the supply chain innovations for developing resilient FSCs and ranked the practices using the SWARA method. The work can be proven significant for agri-food firms, decision-makers, and other stakeholders to strengthen their FSCs. Table 3 presents results for the main criteria and according to the obtained weights, 'Business strategy innovation' (C_2) is the most significant supply chain innovation needed to build a resilient FSC. Based on the weights obtained for all criteria, the order of the criteria is $C_2 > C_3 > C_1 > C_4$. The weights obtained by the criteria are C_1 (0.1967), C_2 (0.3836), C_3 (0.2557), and C_4 (0.1639). Similarly, the sub-criteria's weightage is calculated and presented in Table 4. Table 5 shows the value obtained for the main criteria and their rankings, exhibiting that business strategy innovation (C_2) is the most important criterion and inventory and capacity buffers ($C_{2\text{-}3}$) are the most significant sub-criteria. The study found that industries worldwide are profoundly disrupted due to the extreme effect of the pandemic. Thus, there is a need for innovations in the supply chains that can deal with the new environment and develop resilient FSCs [113]. The FSC needs to change its supply chain practices and focus on enhancing buffer capacity. This buffer capacity may be in the form of underutilized production facilities or excess inventory/safety stock requirements. This enhanced capacity is the most straightforward way to enhance resilience in FSCs, as this will help to balance the supply in the most disturbing time. Capacity development SMEs ($C_{4\text{-}1}$) are ranked as the second most crucial sub-criteria for developing resilience in the food supply chains. It is also known that supply chain resilience is vital for food security in emerging economies, as SMEs mostly dominate the market. Due to the vulnerability to COVID-19 disaster-related effects and the lack of large enterprises and global value chains, SMEs are disrupted. Multisource, diversifying input is also ranked second in the ranking ($C_{2\text{-}2}$). The study highlights that multiple supply locations are also required to reduce risk ($C_{2\text{-}4}$). With the increase in the size of multisource, the dependency has to be limited for resilience in the FSC. Today's FSCs needs to be developed with collaboration across supply chain partners capable of coordinating with food producers, trading firms, corporates, and other external parties that gradually strengthen the value chains and make them more agile and resilient. Additionally, integration in the food supply chain helps the stakeholder to increase their financial performance by creating more value and competitive advantage, along with ecological sustainability. Overall sustainability leads to lowering carbon footprints and the risk of food waste [114–117]; thus, multisource, diversifying input ($C_{2\text{-}2}$) is the topmost priority.

The impact of digital technologies on data management, real-time decision-making, and innovative practices are the significant changes that have positively changed the end-of-life of the products. If organizations implement digital technologies, it may enhance their resilience and reduce food loss and wastage [118]. The firms are introducing technologies that improve hygiene for customers [119]. The pandemic has changed people's lives, and thus technological innovation needs to redesign their practices according to the customers' choices [120,121]. Customers are the main stakeholders in bringing change in consumption; hence, firms should implement digital technologies to communicate and interact directly with them and aim to reduce contact to a minimum for the delivery of the products and communication [122]. Additionally, green technology is needed to bring sustainable outcomes in the future [123–128]. E-commerce communication will help promote sustainable consumption education and arouse a sense of responsibility among them [129–134].

The current study highlights the need for green technology and traceability in food supply chains, which are practical technology innovations that may bring significant results in supply chains. Mensi and Udenigwe [135] discuss how multi-sector collaboration can help various food retail Internet economies contribute significantly toward sustainable food waste recovery and reducing food waste. Jagtap and Duong [136] discuss using big data to enhance product network design. Further, Anshu et al. [137] explain various applications of data modeling techniques, managing inventory turnovers, improving sales volumes and increasing the food retailing experience of consumers (product offerings and cash discounts) in superstores, and improving food security. The usage of data analytics for predicting demand, sustainable supplier selection, and engagement has been an area of extensive research [128–137]. A few empirical works have proven that big data contributes positively to sustainable food supply chains [138–143].

Implications

The study identified the main areas where innovation practices can be undertaken to build resilience in the FSC. The supply chains need to introduce flexibility in multiple locations, sources and labor access, selection of sustainable technology, financial stability, e-platforms, tax credits, etc., to make agri-food SMEs and domestic supply chains more resilient. Additionally, the emergence of e-commerce for B2C is helping agri-food food SMEs to spread the scope.

Food waste is a significant challenge for developing nations and developed countries. Only some forms of food waste are appropriate for consumption and hence require re-processing for value recovery. Additionally, there are environmental threats and hygiene problems related to food waste management. The inclusion of advanced technologies can support firms in addressing challenges and value creation. With the help of digital technologies such as BDA, IoT, and AI, food waste reduction can be minimized through traceability, information sharing, and appropriate decision-making support.

Governments and development need to support growth toward infrastructure that can enable a business environment for agri-food SMEs and global supply chains to collectively contribute to resilience, enhance food security, and reduce food waste during the recovery phase to rebuild the future. This study also suggests that digital technologies can enlighten supply chain actors and accept initiatives in food supply chains. Apps and digital campaigns may enhance the capabilities of food supply chains. This study gives a foundation for the platform to generate awareness among stakeholders toward adopting a resilient pathway for the AFSC. This study offers insights into decision-makers, policymakers, and industry decision-makers to manage the identified significant barriers that affect the implementation of digital technologies for sustainable production and consumption in food supply chains.

6. Conclusions and Limitations

The study has shown the assessment of the supply chain innovation toward developing resilient food supply chains. Supply chains have been evaluated from a different perspective, but more data are needed on innovative practices that may build resilient FSCs in developing nations. The study aims to explore and assess the supply chain innovations of resilient FSCs. The current study proposed a framework to identify and evaluate the innovation practices to develop a resilient FSC in an emerging economy, such as India. The proposed framework has been assessed based on the judgment of decision-makers from the food industry using the SWARA method. The critical implications of the study are the pioneering work exploring ways to bring resilience to FSCs. This study benefits the firms, decision-makers, and other stakeholders to strengthen their FSCs and consider the areas to be focused on. The study's findings suggest that 'Business strategy innovation' (C_2) is the most significant supply chain innovation needed to build resilient FSCs, followed by technological innovations (C_3). Inventory and capacity buffers (C_2-$_3$) were found to be the most considerable sub-criteria. The study found that the FSCs need to introduce flexibility in multiple locations, sources and labor access, selection of sustainable technology, financial resilience, e-platforms, tax credits, etc., to make SMEs and domestic supply chains resilient.

This is likely the first study to examine how supply chain innovation works toward developing resilient food supply chains. Given the methodology employed, this study has certain drawbacks. First of all, even though the present study has taken into account several studies to identify the components of the AFSC and resilient supply chains utilizing innovations, agri-food supply chains are complex, complicated in their structure, and may differ from stakeholders' perspectives. The supply chain and associated procedures will also undergo fundamental changes as a result of upcoming advancements in digital technology, which will directly impact supply chain innovation and agri-food resilience. Second, the study's approach, which focused on AFSCs and related industries in India, can only be directly transferred to other sectors with modifications. As a result, research in other fields should be conducted to ascertain how these enablers affect other industries. Third, the findings of this study can be statistically confirmed in further research. There are some limitations, specifically to the analyzed setting, which is limited to a sample of firms operating in the supply chain integration, food waste management, digitalization management, and information sharing. Future studies can further extend the proposed model to other industries sectors, such as manufacturing and services, for enhancing resiliency.

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Appendix A

1. Industry and Designation ____
2. Age _______
3. Experience_________
4. Please complete Table A2 as per the following steps based on the codes mentioned in Table A1

i. *Arrange criteria (j) in descending order based on their relative significance.*
ii. *Assign the criteria with value; 1 (the highest importance).*
iii. *From the second criterion onwards, please rate the relative significance of criterion j w.r.t the (j + 1) criterion.*

Table A1. List of the main criteria and sub-criteria.

Main Criteria	Implied Meaning	Sub Criteria	References
Social innovations (C_1)	The involvement of the workforce in the creation and sustaining of the value chains have become a prominent feature in food supply chains. The purpose of the transformation is to improve the labor shortfall challenge and also to improve worker safety.	$C_{1\text{-}1}$: Awareness and technological education	[49–51]
		$C_{1\text{-}2}$: Safety of labor workforce	
		$C_{1\text{-}3}$: Workforce replacement flexibility with automated machines	
		$C_{1\text{-}4}$: Workforce sourcing flexibility	
Business strategy innovations (C_2)	A strategic framework for multiple alternatives sourcing, and supply is required. Additionally, the strategic vision of a collaborative environment is needed	$C_{2\text{-}1}$: Customer segmentation and marketing flexibility	[52–54]
		$C_{2\text{-}2}$: Multisource to mitigate supply chain risk	
		$C_{2\text{-}3}$: Inventory and capacity buffers	
		$C_{2\text{-}4}$: Logistics planning and shipment flexibility	
		$C_{2\text{-}5}$: Collaboration with the government	
		$C_{2\text{-}6}$: Multiple supply locations to reduce risk	
		$C_{2\text{-}7}$: Emergency food hubs	
		$C_{2\text{-}8}$: Governance	
Technological interventions and innovations (C_3)	Development and usage of digital solutions for emergency situations. With advanced technological innovations, customer satisfaction can be enhanced. Additionally, the increasing concern toward green and sustainable technology among the stakeholder needs to be implemented for developing resilient agri-food supply chains	$C_{3\text{-}1}$: Data analytics	[55–58]
		$C_{3\text{-}2}$: Digital technologies for improving customer hygiene	
		$C_{3\text{-}3}$: Usage of E-commerce platforms for contactless delivery	
		$C_{3\text{-}4}$: Food processing	
		$C_{3\text{-}5}$: Green technology	
		$C_{3\text{-}6}$: Traceability	
		$C_{3\text{-}7}$: Regenerative agriculture infrastructure	
Financial resilience innovations (C4)	Support to the domestic, agri-food supply chains which are struggling in the post-pandemic situation. Incentives and tax credits for agri-food firms that are willing to transform their system in the face of economic vulnerabilities.	$C_{4\text{-}1}$: Capacity development SMEs	[59–62]
		$C_{4\text{-}2}$: Tax credits for digitally enabled supply chains	
		$C_{4\text{-}3}$: Pull incentives	

Table A2. Main Criteria and Sub-Criteria.

Main Criteria					Sub Criteria				
Social Innovations (C1)	Relative Significance	…….	Financial Resilience Innovations (C4)	Relative Significance	$C_{1\text{-}1}$: Awareness and Technological Education	Relative Significance	…	$C_{4\text{-}3}$: Pull Incentives	Relative Significance

- Computations for the experts group using the SWARA method

Table A3. Calculation of the main criteria.

Main Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C2	—	1.000	1.000	
C3				
C1				
C5				
C6				
C4				

Table A4. Sub-criteria C1.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C1-1				
C1-2				
C1-3				
C1-4				
C1-5				
C1-6				

Table A5. Sub-criteria C2.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C2-1				
C2-2				

Table A6. Sub-criteria C3.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C3-1				
C3-2				

Table A7. Sub-criteria C4.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C4-1				
C4-2				

Table A8. Sub-criteria C5.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C5-1				
C5-2				
C5-3				
C5-4				
C5-5				

Table A9. Sub-criteria C6.

Sub Criteria	Comparative Importance of Average Value (Sj)	Coefficient (K_j = Sj + 1)	Recalculated Weight (W_j = Xj − 1/Kj)	Weight qj = Wj/∑ W_j
C6-1				
C6-2				
C6-3				

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