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An Analysis of Barriers to Supply Chain Resilience Adoption in the Bangladesh Food Industries: A Fuzzy TOPSIS Approach

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Abstract

In the current unstable global economy, supply chain resilience (SCR) is essential for ensuring business continuation during disruptions. This study aims to identify and prioritize barriers to supply chain resilience (SCR) within the Bangladeshi food industry, a sector that has traditionally had difficulties due to inadequate resilience frameworks. This research utilizes the Fuzzy Technique for Order Preference by Similarity to the Ideal Solution (Fuzzy TOPSIS) to model the interrelationships among significant barriers, incorporating expert insights to provide a definitive hierarchy of barriers. The findings underscore the "non-availability of a cross-multi-tasking workforce" as the primary barrier, severely impacting the supply chain's flexibility and capacity to respond to disruptions. Furthermore, barriers such as "increased product stock time" were identified as impactful, but to a lower degree. This study presents a strategy framework to tackle these difficulties and delivers practical insights to improve SCR, especially in emerging markets such as Bangladesh. These findings are significant for practitioners and policymakers, endorsing proactive initiatives to enhance SCR and alleviate future risks.

Keywords
Supply chain resilience, Fuzzy TOPSIS, Bangladesh food industry, Risk Management

1. Introduction
The supply chain is a crucial part of every organization in the connected world of today, and supply chain resilience (SCR) is essential to maintaining operational continuity in the face of disruptions (Gorane and Kant 2015). The COVID-19 pandemic exposed the weaknesses in global supply systems, leading to the closure of numerous smaller firms owing to insufficient resilience. Disruptions, including natural disasters, political hazards, and human-induced crises, can significantly affect supply chains (Parkhi 2015). SCR is the capacity of a supply chain to foresee, plan for, react to, and recuperate from disruptive incidents while sustaining service levels at the preferred standard (Bayraktar et al. 2020). This study is significant due to its emphasis on improving SCR, which has been crucial for maintaining corporate operations during unexpected disruptions, as starkly demonstrated during the pandemic [30]. A supply chain is considered resilient if it can predict and surmount disturbances. Literature identifies several attributes, including flexibility, preparedness, a culture of adaptability, collaboration, innovation, and redundancy, that enhance supply chains (Parkhi 2015). Despite substantial research in SCR, a deficiency persists in complete models that integrate decision-making approaches for an in-depth examination of supply chain barriers, especially within the Bangladeshi food sector. This sector has had considerable difficulties because to its inadequate SCR procedures (Mouloudi and Samuel 2022). This study aims to elucidate the barriers and offer strategic insights for their resolution.

The primary research inquiry of this project is: What are the principal obstacles to SCR in the Bangladeshi food sector, and how can these barriers be systematically modeled and prioritized through decision-making methodologies? This research utilizes the Technique for Order Preference by Similarity to the Ideal Solution (Fuzzy TOPSIS) to identify and model the interconnections among barriers to SCR. This strategy was selected for its efficacy in managing intricate decision-making processes and its capacity to establish a clear hierarchy of issues informed by input from experts.

1.1 Objectives

The primary aim of this study is to identify the barriers to SCR, model these barriers through Fuzzy TOPSIS, and apply this methodology to categorize the barriers. The results offer a strategic framework for effectively addressing these barriers. This research advances the area by creating a complete model that employs Fuzzy TOPSIS to uniquely assess supply chain risk barriers within the Bangladeshi food industry. This innovative use of the technique aims to provide practical insights that might directly improve resilience in emerging economies.
The remainder of the paper is structured as follows: Section 2 examines the literature about the barriers to SCR and the strategies employed in its evaluation. Section 3 delineates the research approach; Section 4 encompasses data collecting and analytical techniques. Section 5 delineates the findings and discourse around the recognized obstacles and their prioritization. Finally, Section 6 closes the research by summarizing the findings and their practical implications.

2. Literature Review

Numerous studies have identified significant barriers to SCR (Gorane and Kant 2015) (Samvedi et al. 2011) (Dubey et al. 2012). The barriers can be classified into five categories: Outsourcing, Strategic, Technological, Individual, and Organizational. Table 1 summarizes the barriers and associated literature. For instance, outsourcing challenges such as poor supplier commitment and single sourcing have been noted as critical vulnerabilities. Technological challenges, such as insufficient ICT infrastructure and the bullwhip effect, intensify supply chain risks. Additionally, individual and organizational factors, including inadequate management capabilities and a deficiency in long-term planning, significantly contribute to the decline of SCR. Despite these findings, a gap persists in comprehensive models that identify barriers and prioritize them according to their relative importance in the decision-making process. Prior research frequently fails to adopt a comprehensive framework that accounts for the interconnections among barriers, especially in the context of the Bangladeshi food sector. This gap requires a decision-making framework that can effectively address the complexities and interrelationships of these barriers.

Table 1. Categorization of barriers to SCR

No	Category	Barriers	Leveling	Reference
1	Outsourcing	A problem in maintaining economical supplier	B1	(Jacob et al. 2020)
2		Complexity in measuring and monitoring supplier's policies	B2	(Zouari et al. 2021)
3		Poor supplier commitment	B3	(Zouari et al. 2021)
4		Lack of external sustainability audits for suppliers and vendors	B4	(Jacob et al. 2020)
5		Single sourcing	B5	(Ivanov 2017)
6		Higher capacity utilization at the source	B6	(Stewart et al. 2009)
7		Inability to quickly change inputs	B7	(Stewart et al. 2009)
8		Lack of collaboration across the supply chain with suppliers	B8	(Rana and Rana 2020)
9	Strategic	Centralization of resources	B9	(Rana and Rana)
10		Increased product stock time	B10	(Di Baldassarre et al. 2016)
11		No appropriate control of inventories	B11	(Ivanov 2017)
12		Risk in hazardous materials inventory	B12	(Di Baldassarre et al. 2016)
13		Territorial challenges in supply chain operations	B13	(Pettit et al. 2019)
14		Market competition and uncertainty	B14	(Pettit et al. 2019)

15		Financial constraints	B15	(Shemshadi et al. 2011)
16	Technological	Poor ICT structure	B16	(Lee et al. 2011)
17		Bullwhip effects due to vulnerabilities in the supply chain	B17	(Eydi and Fazli 2019)
18		Poor quality control	B18	(Lee et al. 2011)
19		Lack of new technology, materials, and processes	B19	(Lee et al. 2011)
20		Unwillingness to share information	B20	(Dubey et al. 2012)
21		Fear of failure	B21	(Dubey et al. 2012)
22		Lack of IT integration among partners	B22	(Dubey et al. 2012)
23	Individual	Wrong forecasts	B23	(Gorane and Kant 2015)
24		Lack of knowledge and experience	B24	(Gorane and Kant 2015)
25		Lack of corporate social responsibilities	B25	(Bayraktar et al. 2020)
26		Inadequate management capacities	B26	(Samvedi et al. 2011)
27		The direness of people to expand their level of responsibility	B27	(Samvedi et al. 2011)
28		Nature of the people working on self-interests	B28	(Samvedi et al. 2011)
29		Lack of integration among SC accomplices	B29	(Gorane and Kant 2015)
30	Organizational	Change in customer prerequisites	B30	(Gorane and Kant 2015)
31		Untrained workers	B31	(Bayraktar et al. 2020)
32		Lack of internal sustainability audits	B32	(Gorane and Kant 2015)
33		Lack of involvement of top management	B33	(Christopher and Peck 2004)
34		Extensive network complexity	B34	(Shemshadi et al. 2011)
35		Unclear hierarchical goal	B35	(Dubey et al. 2019)
36		Non-availability of the cross-multi-tasking workforce	B36	(Christopher and Peck 2004)
37		Lack of long-term vision and planning for implementing SCR	B37	(Shemshadi et al. 2011)

3. Methods

The Fuzzy TOPSIS method facilitated a thorough analysis of the barriers under investigation. The Fuzzy TOPSIS method is effective in addressing complex decision-making processes, facilitating an in-depth understanding of the interrelationships among barriers (Samvedi et al. 2012). This method facilitates the integration of expert input to prioritize barriers according to their significance, establishing a clear hierarchy of issues requiring attention. Alternative methodologies, including the AHP and SEM, were evaluated but found to be less suitable for this study. AHP is effective for prioritization; however, it has limitations in modeling interdependencies among criteria, rendering it less appropriate for contexts such as SCR, where barriers frequently interact with one another. SEM is effective in managing complex relationships between variables; however, it necessitates large datasets, which may not always be accessible in studies that depend on expert input (Si et al. 2018).

Fuzzy TOPSIS effectively handles smaller, expert-driven datasets and establishes a clear, ranked hierarchy of barriers, which is crucial for decision-making in supply chain management (Mouloudi and Samuel 2022). The primary benefit of employing Fuzzy TOPSIS lies in its capacity to address the ambiguity and uncertainty present in expert evaluations. This approach enhances the conventional TOPSIS by incorporating fuzzy logic, making it especially effective in contexts characterized by imprecise or subjective information. Fuzzy TOPSIS utilizes fuzzy logic to facilitate a more adaptable and realistic representation of real-world issues, thereby improving the robustness of the analysis (Dubey et al. 2019). Fuzzy TOPSIS was selected for this research because it effectively addresses the complexities associated with the SCR barriers in the Bangladeshi food industry. The method's capacity to manage multiple criteria and generate a ranking of barriers renders it a suitable option for this study. Fuzzy TOPSIS effectively captures the varied perspectives of stakeholders, which is essential for a thorough understanding of the barriers to SCR.

This research analyzes a supply chain in the food sector, focusing on barriers such as logistical issues, supplier dependability, and adherence to regulations. Data were obtained from industry reports and expert interviews. Evaluating alternatives requires an analysis of cost implications, time delays, and the feasibility of mitigation strategies. Selections were determined through expert input and relevant literature. The fuzzification process involved converting expert ratings into fuzzy numbers using linguistic terms like 'poor,' 'fair,' and 'good,' each linked to triangular membership functions (Chen and Hwang 1992).
The steps are as follows-

Step 1: Generate the direct decision matrix by scores
A range of 1–9 was adopted to score the criteria and the alternatives. Table 2 shows the linguistic variables and the corresponding Triangular Fuzzy Numbers (TFN) used for the criteria and barriers respectively.

Table 2. Lingual idioms to evaluate the barriers

Criteria	Alternatives	Criteria	Alternatives
Lingual Idioms		TFN	
No Influence (NI)	Very Poor (VP)	0,0,0	0,0,1
Very Low Influence (VLI)	Poor (P)	0,0.2,0.3	1,3,5
Low Influence (LI)	Fair (F)	0.4,0.6,0.8	2,5,7
High Influence (HI)	Good (G)	0.6,0.8,1.0	5,7,9
Very High Influence (VHI)	Very Good (VG)	0.8,0.9,1.0	7,9,9

Assume there are a group of k experts $(E_1, E_2, E_3 \cdots\cdots, E_k)$ with m possible barriers $(B_{1,}B_2 \cdots\cdots, B_m)$, which are are to be evaluated against alternative (A_1,A_2…….,A_n). The criteria weights are denoted by W_{NK} (N = 1,2, …, n; e = 1,2, …, k) and the performance ratings of barriers with respect to criteria by experts are denoted as X_{NKM} (N = 1,2, …, n; K = 1,2, …, k; M = 1,2, …, m).
Step 2: Combine the decision matrix
After constructing the decision matrix, the evaluation is degraded to one value and thus fuzzy decision matrix is built. we need to convert those linguistic idioms with fuzzy numbers. We assume fuzzy ratings and are describe as triangular fuzzy numbers (a_K,b_K,c_K) where K = 1,2, …, k. Then we will combine the matrixes with the formula.
$X'_{ij}= (a_K,b_K,c_K)$
Where,
$a_{ij}=\min\{a_K\}$
$b_{ij}=\frac{1}{k}\sum_{k=1}^{k} b_K$
$c_{ij}=\max\{c_K\}$
Step 3: Normalized the fuzzy decision matrix
Acquiring the combine decision matrix, first we need to identify the criteria of these barriers. Those barriers could be categorized into beneficial and non-beneficial criteria. Non-beneficial criteria could also be called cost criteria. Now we need to evaluate those values in the matrix and construct a normalized decision matrix. We will make this normalized form of this matrix with the formula,
For beneficial criteria,
$W_{NK}=\left(\frac{a_K}{c}, \frac{b_K}{c}, \frac{c_K}{c}\right)$ where, $c=\max\{c_K\}$
For cost criteria,
$W_{NK}= \left(\frac{a}{c_K}, \frac{a}{b_K}, \frac{a}{a_K}\right)$ where, $a=\min\{a_K\}$
Step 4: Weighted normalized fuzzy decision matrix
Next constructing normalized fuzzy decision matrix, we will make weighted normalized fuzzy decision matrix by multiplying weighted number with normalized decision matrix values. Calculate this with the formula,
Let the weighted normalized value be V_{NKM},
Where N = 1,2, …, n; K = 1,2, …, k; M = 1,2, …, m; the corresponding triangular fuzzy number of V_NKM is

$$a_{v_{knm}} b_{v_{knm}} c_{v_{knm}}$$

Step 5: Calculate fuzzy positive ideal solutions (FPIS) and fuzzy negative ideal solutions (FNIS)
In this stage of the method, fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution
(FNIS) are computed for all barriers. Calculate those with the formula,
FPIS = $\{c_V, c_V, c_V\}$ where, $c_V = \max\{c_{V_{NKM}}\}$
FNIS = $\{a_V, a_V, a_V\}$ where $a_V = \min\{a_{V_{NKM}}\}$
Step 6: Calculate the distance of each barrier from FPIS and FNIS
Above all these calculations lead to obtaining each barrier's distance from FPIS and FNIS denoted as d^+ and d^- respectively. Calculate them with the formula,

$$d^+ = \sqrt{\frac{1}{3}\left[\left(a_{V_{NKM}}-c_V\right)^2+\left(b_{V_{NKM}}-c_V\right)^2+\left(c_{V_{NKM}}-c_V\right)^2\right]}$$

$$d^- = \sqrt{\frac{1}{3}\left[\left(a_{V_{NKM}}-a_V\right)^2+\left(b_{V_{NKM}}-a_V\right)^2+\left(c_{V_{NKM}}-a_V\right)^2\right]}$$

Step 7: Calculate the closeness coefficient (CC_M)
Finally, the closeness coefficient (CC_M) of each barrier has been identified. The barrier which has higher is the most impact barrier we should look into. Calculate with this formula, $CC_M = \frac{d^-}{d^- + d^+}$

4. Data Collection

The identities of these prominent Bangladeshi companies, each possessing over 12 years of experience in their respective sectors, are not revealed here due to confidentiality considerations. Table 2 presents the linguistic idioms utilized to assess the barriers. A committee of four experts will evaluate the three alternative companies. The experts utilized Table 2 to derive preference weights for the criteria and to evaluate the thirty-seven criteria across three alternatives. Following extensive discussions, they designated specific periods for data collection within their companies. The questionnaire was included with a cover letter detailing the research purpose and a self-addressed stamped envelope. Additionally, seven industry experts and two academic experts engaged in a series of brainstorming sessions to refine and augment the concepts derived from the literature review. During this period, an initial matrix was provided to company experts with over five years of experience, and requested their ratings based on the triangular fuzzy numbers presented in Table 2.

Table 3. Expert's preference of each criterion weight in the linguistic term

Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3
B1	5,7,9	5,7,9	5,7,9	B20	5,7,9	7,9,9	7,9,9
B2	5,7,9	5,7,9	5,7,9	B21	5,7,9	5,7,9	5,7,9
B3	7,9,9	5,7,9	5,7,9	B22	5,7,9	5,7,9	2,5,7
B4	7,9,9	7,9,9	5,7,9	B23	5,7,9	5,7,9	2,5,7
B5	5,7,9	2,5,7	5,7,9	B24	5,7,9	5,7,9	2,5,7
B6	5,7,9	5,7,9	2,5,7	B25	5,7,9	5,7,9	5,7,9
B7	7,9,9	5,7,9	5,7,9	B26	5,7,9	2,5,7	2,5,7
B8	7,9,9	7,9,9	7,9,9	B27	2,5,7	2,5,7	2,5,7
B9	5,7,9	5,7,9	5,7,9	B28	2,5,7	2,5,7	5,7,9
B10	5,7,9	5,7,9	5,7,9	B29	5,7,9	5,7,9	5,7,9
B11	2,5,7	2,5,7	5,7,9	B30	2,5,7	2,5,7	2,5,7
B12	7,9,9	7,9,9	7,9,9	B31	2,5,7	2,5,7	2,5,7
B13	5,7,9	5,7,9	5,7,9	B32	2,5,7	2,5,7	2,5,7
B14	2,5,7	1,3,5	1,3,5	B33	5,7,9	5,7,9	5,7,9
B15	2,5,7	2,5,7	2,5,7	B34	2,5,7	2,5,7	2,5,7
B16	2,5,7	5,7,9	5,7,9	B35	2,5,7	2,5,7	5,7,9
B17	5,7,9	5,7,9	7,9,9	B36	2,5,7	5,7,9	2,5,7
B18	5,7,9	2,5,7	5,7,9	B37	5,7,9	5,7,9	5,7,9
B19	2,5,7	2,5,7	2,5,7				

Table 3 presents the expert preferences for criterion weights across three alternatives, utilizing fuzzy ratings to assess the impact of each barrier. Table 4 presents the consolidated decision matrix values across all criteria and alternatives, illustrating the aggregated fuzzy scores for each barrier. Table 7 presents FPIS and FNIS for each barrier, illustrating the optimal and least favorable scenarios. Table 8 calculates the distance of each barrier from FPIS and FNIS, presenting values for both positive and negative distances that quantify the relative proximity to ideal solutions. Table 9 presents the closeness coefficient (CC_M) for each barrier, reflecting their overall ranking in terms of impact on supply chain resilience.

Table 4. Combine the decision matrix

Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3
B1	2,6,9	2,6,9	1,5.5,9	B20	1,6.5,9	1,6.5,9	2,7,9
B2	2,6,9	2,6,9	1,5.5,9	B21	2,7,9	2,7,9	2,6.5,9
B3	5,8,9	1,5.5,9	2,7,9	B22	2,7.5,9	2,7.5,9	2,7,9
B4	2,6.5,9	2,79,	2,6.5,9	B23	5,7.5,9	5,7.5,9	2,6.5,9
B5	5,7.5,9	2,6.5,9	5,7,9	B24	2,6.5,9	5,7,9	5,7.5,9
B6	5,7.5,9	2,6.5,9	2,6.5,9	B25	2,5.5,9	2,5.5,9	2,5.5,9
B7	2,7.5,9	2,7,9	5,7.5,9	B26	2,7,9	2,7,9	2,6.5,9
B8	2,7.5,9	2,7.5,9	2,7,9	B27	2,7,9	2,6.5,9	2,6.5,9
B9	2,7,9	2,7,9	2,7,9	B28	1,5.5,9	1,5.5,9	0,5.25,9
B10	5,8,9	5,8,9	5,8,9	B29	5,7.5,9	5,7,9	2,6.5,9
B11	2,8,9	5,8.5,9	1,6.5,9	B30	2,6,9	2,7,9	2,6.5,9
B12	1,6.5,9	1,6.5,9	1,6.5,9	B31	2,7.5,9	2,8,9	2,8,9
B13	2,6.5,9	2,6,9	2,6,9	B32	2,7,9	2,6.5,9	2,6,9
B14	2,6,9	1,5.5,9	1,5,9	B33	2,6.5,9	2,7.5,9	5,7,9
B15	2,6.5,9	2,7,9	2,6.5,9	B34	1,5,9	1,5,9	2,6,9
B16	2,6,9	5,7,9	2,7,9	B35	2,6,9	2,5.5,9	2,6,9
B17	5,8.5,9	5,8.5,9	5,8.5,9	B36	2,6,9	2,7,9	2,6.5,9
B18	5,7,9	2,7,9	5,7,9	B37	5,7,9	5,7,9	2,6.5,9
B19	2,7,9	2,7,9	2,7,9				

Table 5. Normalized fuzzy decision matrix

Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3
B1	0.11,0.16,0.5	0.11,0.16,0.5	0.11,0.18,1	B20	0.11,0.61,1	0.11,0.61,1	0.22,0.78,1
B2	0.22,0.67,1	0.11,0.61,1	0.11,0.61,1	B21	0.22,0.78,1	0.22,0.78,1	0.22,0.78,1
B3	0.55,0.89,1	0.22,0.78,1	0.22,0.78,1	B22	0.22,0.83,1	0.22,0.83,1	0.22,0.78,1
B4	0.22,0.72,1	0.22,0.72,1	0.22,0.72,1	B23	0.55,0.83,1	0.55,0.83,1	0.55,0.83,1
B5	0.55,0.83,1	0.22,0.72,1	0.55,0.78,1	B24	0.22,0.72,1	0.55,0.78,1	0.55,0.83,1
B6	0.22,0.26,0.4	0.22,0.29,1	0.22,0.31,1	B25	0.22,0.61,1	0.22,0.61,1	0.22,0.61,1
B7	0.22,0.83,1	0.22,0.78,1	0.55,0.83,1	B26	0.22,0.78,1	0.22,0.78,1	0.22,0.72,1
B8	0.22,0.83,1	0.22,0.83,1	0.22,0.78,1	B27	0.22,0.78,1	0.22,0.78,1	0.22,0.78,1
B9	0.22,0.78,1	0.22,0.78,1	0.22,0.78,1	B28	0.11,0.61,1	0.11,0.61,1	0.11,0.61,1
B10	0.55,0.63,1	0.55,0.63,1	0.55,0.63,1	B29	0.55,0.81,1	0.55,0.81,1	0.55,0.81,1
B11	0.22,0.25,1	0.22,0.23,0.4	0.22,0.23,0.4	B30	0.22,0.33,1	0.22,0.29,1	0.22,0.31,1
B12	0.11,0.72,1	0.11,0.72,1	0.11,0.72,1	B31	0.22,0.83,1	0.22,0.89,1	0.22,0.89,1
B13	0.22,0.72,1	0.22,0.67,1	0.22,0.67,1	B32	0.22,0.78,1	0.22,0.72,1	0.22,0.67,1
B14	0.22,0.67,1	0.11,0.61,1	0.11,0.55,1	B33	0.22,0.72,1	0.22,0.83,1	0.55,0.78,1
B15	0.22,0.31,1	0.22,0.29,1	0.22,0.31,1	B34	0.11,0.55,1	0.11,0.55,1	0.22,0.67,1
B16	0.22,0.33,1	0.22,0.29,0.4	0.22,0.29,1	B35	0.22,0.67,1	0.22,0.67,1	0.22,0.67,1
B17	0.55,0.94,1	0.55,0.94,1	0.55,0.94,1	B36	0.22,0.67,1	0.22,0.78,1	0.22,0.72,1
B18	0.22,0.29,0.4	0.22,0.29,1	0.22,0.29,0.4	B37	0.55,0.78,1	0.55,0.78,1	0.22,0.72,1
B19	0.22,0.78,1	0.22,0.78,1	0.22,0.78,1				

Table 6. Weighted normalized fuzzy decision matrix

Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative/ Criteria	Alternative 1	Alternative 2	Alternative 3
B1	0.078,0.114, 0.355	0.078,0.114, 0.355	0.078,0.127, 0.71	B20	0.079,0.439 ,0.72	0.079,0.439 ,0.72	0.158,0.561 ,0.72
B2	0.156,0.475, 0.71	0.078,0.433, 0.71	0.078,0.433, 0.71	B21	0.176,0.624 ,0.8	0.176,0.624 ,0.8	0.176,0.576 ,0.8
B3	0.467,0.756, 0.85	0.187,0.663, 0.85	0.187,0.663, 0.85	B22	0.180,0.639 ,0.82	0.180,0.639 ,0.82	0.180,0.590 ,0.82
B4	0.158,0.518, 0.72	0.158,0.518, 0.72	0.158,0.518, 0.72	B23	0.451,0.680 ,0.82	0.451,0.680 ,0.82	0.180,0.590 ,0.82
B5	0.451,0.680, 0.82	0.180,0.590, 0.82	0.451,0.639, 0.82	B24	0.158,0.518 ,0.72	0.396,0.561 ,0.72	0.369,0.597 ,0.72
B6	0.176,0.208, 0.32	0.176,0.232, 0.8	0.176,0.248, 0.8	B25	0.143,0.396 ,0.65	0.143,0.396 ,0.65	0.143,0.396 ,0.65
B7	0.180,0.680, 0.82	0.180,0.639, 0.82	0.451,0.680, 0.82	B26	0.176,0.624 ,0.8	0.176,0.624 ,0.8	0.176,0.624 ,0.8
B8	0.180,0.680, 0.82	0.180,0.680, 0.82	0.180,0.639, 0.82	B27	0.176,0.624 ,0.8	0.176,0.576 ,0.8	0.176,0.576 ,0.8
B9	0.176,0.624, 0.8	0.176,0.624, 0.8	0.176,0.624, 0.8	B28	0.076,0.396 ,0.65	0.076,0.396 ,0.65	0,0.377,0.6 5
B10	0.467,0.535, 0.85	0.467,0.535, 0.85	0.467,0.535, 0.85	B29	0.451,0.664 ,0.82	0.451,0.664 ,0.82	0.180,0.590 ,0.82
B11	0.187,0.212, 0.85	0.187,0.195, 0.34	0.187,0.195, 0.34	B30	0.156,0.234 ,0.71	0.156,0.205 ,0.71	0.156,0.220 ,0.71
B12	0.079,0.518, 0.72	0.079,0.518, 0.72	0.079,0.518, 0.72	B31	0.180,0.680 ,0.82	0.180,0.729 ,0.82	0.180,0.729 ,0.82
B13	0.158,0.518, 0.72	0.158,0.482, 0.72	0.158,0.482, 0.72	B32	0.176,0.624 ,0.8	0.176,0.576 ,0.8	0.176,0.536 ,0.8
B14	0.156,0.475, 0.71	0.078,0.433, 0.71	0.078,0.390, 0.71	B33	0.158,0.518 ,0.72	0.158,0.597 ,0.72	0.396,0.561 ,0.72
B15	0.18,0.223,0. 72	0.158,0.208, 0.72	0.158,0.223, 0.72	B34	0.064,0.324 ,0.59	0.064,0.324 ,0.59	0.129,0.395 ,0.53
B16	0.156,0.234, 0.71	0.156,0.205, 0.284	0.156,0.205, 0.71	B35	0.156,0.476 ,0.71	0.156,0.433 ,0.71	0.156,0.476 ,0.71
B17	0.478,0.817, 0.87	0.478,0.817, 0.87	0.478,0.817, 0.87	B36	0.156,0.476 ,0.71	0.156,0.553 ,0.71	0.156,0.551 ,0.71
B18	0.158,0.208, 0.288	0.158,0.208, 0.288	0.158,0.208, 0.288	B37	0.478,0.678 ,0.87	0.478,0.678 ,0.87	0.191,0.628 ,0.87
B19	0.176,0.624, 0.8	0.176,0.624, 0.8	0.176,0.624, 0.8				

Table 7. FPIS and FNIS

Criteria	FPIS	FNIS	Criteria	FPIS	FNIS
B1	0.078,0.127,0.71	0.078,0.114,0.355	B20	0.1584,0.5616,0.72	0.0792,0.4392,0.72
B2	0.156,0.475,0.71	0.078,0.433,0.71	B21	0.176,0.576,0.8	0.176,0.576,0.8
B3	0.467,0.756,0.85	0.187,0.663,0.85	B22	0.1804,0.6396,0.82	0.1804,0.5904,0.82
B4	0.158,0.518,0.72	0.158,0.518,0.72	B23	0.451,0.6806,0.82	0.1804,0.5904,0.82
B5	0.451,0.680,0.82	0.180,0.590,0.82	B24	0.396,0.5976,0.72	0.1584,0.5184,0.72
B6	0.176,0.248,0.8	0.176,0.208,0.32	B25	0.143,0.3965,0.65	0.143,0.3965,0.65
B7	0.451,0.680,0.82	0.180,0.639,0.82	B26	0.176,0.624,0.8	0.176,0.576,0.8
B8	0.180,0.680,0.82	0.180,0.639,0.82	B27	0.176,0.624,0.8	0.176,0.576,0.8
B9	0.176,0.624,0.8	0.176,0.624,0.8	B28	0.0765,0.3965,0.65	0,0.377,0.65
B10	0.4675,0.5355,0.85	0.4675,0.5355,0.85	B29	0.451,0.6642,0.82	0.1804,0.5904,0.82
B11	0.187,0.2125,0.85	0.187,0.1955,0.34	B30	0.1562,0.2343,0.71	0.1562,0.2201,0.71
B12	0.0792,0.5184,0.72	0.0792,0.5184,0.72	B31	0.1804,0.7298,0.82	0.1804,0.6806,0.82
B13	0.1584,0.4824,0.72	0.1584,0.4824,0.72	B32	0.176,0.624,0.8	0.176,0.536,0.8
B14	0.1562,0.4757,0.71	0.0781,0.3905,0.71	B33	0.1584,0.5976,0.72	0.1584,0.5184,0.72
B15	0.1584,0.2232,0.72	0.1584,0.2088,0.72	B34	0.1298,0.3953,0.59	0.0649,0.3245,0.59
B16	0.1562,0.2343,0.71	0.1562,0.2059,0.284	B35	0.1562,0.4767,0.71	0.1562,0.4331,0.71
B17	0.4785,0.8178,0.87	0.4785,0.8178,0.87	B36	0.1562,0.5538,0.71	0.1562,0.4767,0.71
B18	0.1584,0.2088,0.72	0.1584,0.2088,0.288	B37	0.4785,0.6786,0.87	0.1914,0.6284,0.87
B19	0.176,0.624,0.8	0.176,0.624,0.8		0.1584,0.5616,0.72	0.0792,0.4392,0.72

Table 8. Compute distance from FPIS and FNIS

FPIS									
Alternatives/ Criteria	Alternative 1	Alternative 2	Alternative 3	$\sum d^{+}$	Alternatives/ Criteria	Alternative 1	Alternative 2	Alternative 3	$\sum d^{+}$
B1	0.205	0.205	0	0.41	B20	0.084	0.084	0	0.168
B2	0	0.051	0.051	0.102	B21	0	0	0.027	0.027
B3	0	0.17	0.17	0.34	B22	0	0	0.028	0.028
B4	0	0	0	0	B23	0	0	0.164	0.164
B5	0	0.164	0.024	0.188	B24	0.144	0.021	0	0.165
B6	0.278	0.009	0	0.287	B25	0	0	0	0
B7	0.156	0.158	0	0.314	B26	0	0	0.027	0.027
B8	0	0	0.023	0.023	B27	0	0.027	0.027	0.054
B9	0	0	0	0	B28	0	0	0.045	0.045
B10	0	0	0	0	B29	0	0.014	0.162	0.176
B11	0	0.295	0.295	0.59	B30	0	0.017	0.002	0.019
B12	0	0	0	0	B31	0.028	0	0	0.028
B13	0	0.021	0.021	0.042	B32	0	0.027	0.051	0.078
B14	0	0.051	0.067	0.118	B33	0.046	0	0.139	0.185
B15	0	0.008	0	0.008	B34	0.055	0.055	0	0.11
B16	0	0.252	0.016	0.268	B35	0	0.025	0	0.025
B17	0	0	0	0	B36	0.045	0	0.001	0.046
B18	0.249	0	0.249	0.498	B37	0	0	0.168	0.168
B19	0	0	0	0					
FNIS									
Alternatives/ Criteria	Alternative 1	Alternative 2	Alternative 3	$\sum d^{-}$	Alternatives/ Criteria	Alternative 1	Alternative 2	Alternative 3	$\sum d^{-}$
B1	0	0	0.211	0.211	B20	0	0	0.084	0.084

B2	0.051	0	0	0.051	B21	0	0	0.027	0.027
B3	0.17	0	0	0.17	B22	0	0	0.028	0.028
B4	0	0	0	0	B23	0	0	0.164	0.164
B5	0.165	0	0	0.165	B24	0.144	0.021	0	0.165
B6	0	0	0.278	0.278	B25	0	0	0	0
B7	0	0	0.319	0.319	B26	0.027	0.027	0	0.054
B8	0.024	0.024	0	0.048	B27	0.027	0	0	0.027
B9	0	0	0	0	B28	0.045	0.045	0	0.09
B10	0	0	0	0	B29	0.12	0.158	0	0.32
B11	0.295	0	0	0.295	B30	0.008	0.008	0	0.016
B12	0	0	0	0	B31	0	0.028	0.028	0.056
B13	0.021	0	0	0.021	B32	0.051	0.023	0	0.074
B14	0.067	0	0	0.067	B33	0	0.046	0.141	0.187
B15	0.008	0	0.008	0.016	B34	0	0	0.055	0.055
B16	0.24	0	0.246	0.492	B35	0.025	0	0.025	0.05
B17	0	0	0	0	B36	0	0.044	0.043	0.087
B18	0	0.249	0	0.249	B37	0.168	0.168	0	0.336
B19	0	0	0	0					

Table 9. Compute closeness coefficient

Criteria	CCM	Criteria	CCM	Criteria	CCM	Criteria	CCM
B1	0.339	B11	0.33	B21	0.667	B31	0.667
B2	0.33	B12	0	B22	0.667	B32	0.486
B3	0.33	B13	0.33	B23	0.667	B33	0.502
B4	0	B14	0.362	B24	0.466	B34	0.33
B5	0.467	B15	0.667	B25	0.667	B35	0.667
B6	0.492	B16	0.647	B26	0.33	B36	0.685
B7	0.504	B17	0	B27	0.667	B37	0.667
B8	0.676	B18	0.33	B28	0.645		
B9	0	B19	0	B29	0.457		
B10	0	B20	0.33	B30	0.667		

5. Results and Discussion

This study aims to identify and prioritize the primary barriers impacting SCR through the application of the Fuzzy TOPSIS method. The Fuzzy TOPSIS method offers a thorough assessment of the barriers impacting supply chain resilience, identifying the non-availability of the cross-multi-tasking workforce as the most significant factor. Addressing this barrier is crucial for improving the adaptability and resilience of supply chains amid diverse challenges. The Fuzzy TOPSIS method is utilized to assess and rank the identified barriers, serving as an efficient tool for pinpointing the most significant barriers impacting SCR. The Fuzzy TOPSIS method identified "Non-availability of the cross-multi-tasking workforce" as the most significant factor undermining SCR. This barrier was identified as the most significant because of its considerable effect on the flexibility and adaptability of the supply chain. A workforce deficient in cross-multi-tasking capabilities restricts the supply chain's capacity to respond promptly to disruptions, adapt to changes, and sustain operations during unforeseen events. This results in heightened vulnerabilities and an elevated risk of extended disruptions, ultimately impacting the overall efficiency and resilience of the supply chain. This study utilizes Fuzzy TOPSIS to establish a strategic framework for the identification and prioritization of barriers to SCR. The method employs a rigorous analytical process that guarantees robust and credible findings, providing valuable insights for improving SCR in the Bangladeshi food industry. The application of a singular, clearly defined methodology enhances clarity and transparency in the research process, reflecting a dedication to rigor and robustness in tackling complex research questions.

5.1 Numerical Results

Table 10 shows the ranking of the barriers that affects the SCR of Bangladesh food industry.

Table 10. Ranking of the barriers

Criteria	Rank	Criteria	Rank	Criteria	Rank	Criteria	Rank
B1	23	B11	24	B21	3	B31	3
B2	24	B12	32	B22	3	B32	18
B3	24	B13	24	B23	3	B33	16
B4	32	B14	22	B24	20	B34	24
B5	19	B15	3	B25	3	B35	3
B6	17	B16	13	B26	24	B36	1
B7	15	B17	32	B27	3	B37	3
B8	2	B18	24	B28	14		
B9	32	B19	32	B29	21		
B10	32	B20	24	B30	3		

5.2 Proposed Improvements

Based on the findings of this research, several key improvements can be recommended for organizations:

- Cross-functional training to improve workers' ability to adapt to diverse supply chain operations and assume several responsibilities during disruptions.
- Job rotation programs enhance employee familiarity with various aspects of the supply chain, thereby promoting agility in response to unforeseen disruptions.
- Integration of digital systems to enable smooth data interchange and guarantee supply chain visibility between manufacturers, distributors, and suppliers. Blockchain and cloud computing technologies can markedly improve transparency and traceability.
- Adopt Just-In-Time (JIT) or Just-In-Case (JIC) strategies according to market conditions to facilitate rapid adjustments in inventory levels in response to demand variations, while minimizing holding costs.

6. Conclusion

This study aimed to identify and analyze the most significant variables affecting SCR through the application of the Fuzzy TOPSIS method. Utilizing the Fuzzy TOPSIS methodology, this study identified and ranked critical barriers according to their impact, providing a framework for prioritized action. This research uncovers critical insights into the factors influencing SCR and their relative importance. Hence the objective of this study is fulfilled. Although this study focuses on the Bangladeshi food industry, the findings have broader implications for supply chain resilience in emerging markets and beyond. The barriers identified—such as workforce limitations are not unique to Bangladesh but are common challenges faced by industries worldwide, especially in developing economies. The insights from this study can be applied to other sectors in Bangladesh, as well as in other emerging markets with similar supply chain vulnerabilities. Furthermore, the framework developed through this research applies to different industries and regions. By addressing workforce flexibility, supply chain collaboration, and logistical efficiency, businesses worldwide can enhance their resilience to disruptions, making the study's findings relevant across various contexts, including manufacturing, agriculture, and retail sectors globally.

In conclusion, this study not only provides a deeper understanding of the barriers to SCR in the Bangladeshi food industry but also offers a foundation for future research that can extend these insights to other regions and industries. By taking a proactive approach to overcoming these barriers, organizations can build more resilient supply chains that are better equipped to withstand future disruptions.

6.1 Limitations and Future Work

While this study offers important insights into the barriers to SCR, there are several avenues for future research. Advanced modeling techniques, such as Interpretive Structural Modeling (ISM) or Structural Equation Modeling (SEM)**,** could be applied to further explore the complex interrelationships between barriers. These techniques could help clarify the causal relationships and cascading effects of various factors within the supply chain. For instance, SEM could reveal how specific barriers influence each other over time, helping to develop a dynamic model of SCR that accounts for both immediate and long-term disruptions. Moreover, future research could incorporate real-time data analytics and machine learning approaches to predict the impact of various disruptions on supply chains. These techniques would allow for a more data-driven understanding of how different barriers interact under changing conditions, providing a proactive tool for SCR enhancement. Additionally, studies could examine how external factors, such as changes in government policy or global supply chain trends, influence the relative importance of these barriers.

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Biography

Ruhaniayth Bin Afsar is a recent graduate from the Department of Industrial Engineering and Management at Khulna University of Engineering & Technology. He holds a deep interest in supply chain-related fields, focusing his research on enhancing supply chain resilience and performance. During his academic tenure, Ruhaniayth engaged in multiple research initiatives aimed at optimizing supply chain operations and addressing key challenges in the industry.

Istiaqe Ahamed has recently completed his studies at Khulna University of Engineering & Technology's Department of Industrial Engineering and Management. His research interests are in supply chain-related disciplines, with a particular emphasis on the optimization and resilience of supply chains. Istiaqe has participated in a variety of initiatives that seek to develop innovative solutions by investigating the complexities and challenges of supply chains throughout his academic career. His academic accomplishments and active involvement in related research activities are indicative of his commitment to this field.

Md. Omar Shadat Sarker is pursuing his undergraduate studies at Khulna University of Engineering and Technology (KUET). His academic focus lies in supply chain management and operations research, where he explores strategies to optimize supply chain efficiency. Omar is particularly interested in leveraging advanced technologies like blockchain to address challenges in logistics and enhance operational performance. Through his research, he seeks to contribute to the evolving landscape of supply chain management.