7th Bangladesh Conference on Industrial Engineering and Operations Management
December 21-22, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/BA07.20240108
Published: December 21, 2024

Neutrosophic Analytic Hierarchy Process for Multi-Criteria Decision Making: Applied to Supply Chain Risk Management

Md. Mehedi Hasan Joy and Ferdous Sarwar
Department of Industrial and Production Engineering
Bangladesh University of Engineering and Technology
Dhaka, Bangladesh
joy520m@gmail.com, ferdoussarwar@ipe.buet.ac.bd

Abstract

Risk management is crucial for sustainability and competitiveness in Bangladesh's textile industry because of the substantial uncertainties that plague its supply chain. This thesis focuses on supply chain risk management in the textile sector by putting forth a Neutrosophic Analytic Hierarchy Process (NAHP) model for multi-criteria decision-making. Through the use of Neutrosophic logic, this model overcomes the shortcomings of conventional AHP and Fuzzy TOPSIS in managing subjectivity and ambiguity. The Research and Innovation Centre for Science and Engineering (RISE), BUET, provides financing assistance for the project, which uses data from the renowned textile industry in Dhaka to identify and rank the five main risk categories: operational, financial, environmental, social, and market. The study also assesses appropriate risk management plan durations, suggesting Immediate (within 1 month), Short-term (1 to 3 months), Medium-term (3 to 6 months), and Long-term (6 months to 1 year) as options. The results show that the best way to manage recognized risks is with a short-term plan. The results of this study offer significant perspectives for resilience and long-term risk reduction in Bangladesh's textile industry.

Keywords
Multi-criteria Decision Making; Uncertainty; Neutrosophic; SCRM; Textile

1. Introduction
Numerous supply chain risks threaten Bangladesh's textile industry, a vital pillar of the country's economy, and its capacity to remain sustainable and competitive globally. To overcome these obstacles, a strong framework for risk assessment that can handle the ambiguities and complexity of decision-making is needed. The use of the Neutrosophic Analytic Hierarchy Process (NAHP) for Supply Chain Risk Management (SCRM) in this industry is investigated in this study. Although popular, traditional techniques such fuzzy TOPSIS and the Analytic Hierarchy Process (AHP) frequently fail to take into consideration the subjectivities and ambiguities that are a part of risk assessment. Using neutrosophic sets, NAHP provides a sophisticated method that allows decision-makers to handle uncertainties more precisely and flexibly while expressing preferences.

Using a real-world case study of Bangladesh's textile industry, this study uses NAHP to rank and assess risk factors. Operational, financial, environmental, social, and market risk were the five main risk criteria that were evaluated. Other risk management strategies and pertinent sub-criteria were also examined. The study emphasizes how well a short-term (one to three months) risk management plan may reduce supply chain risks while striking a balance between viability and flexibility. This work improves decision-making under uncertainty and offers practical insights to manage the dynamic and constantly shifting corporate environment by incorporating neutrosophic logic into the AHP framework. By providing workable solutions that complement organizational objectives and international best practices, the findings help the textile sector create a more robust and sustainable supply chain.

1.1 Objectives
In order to address the challenges of risk prioritization in this unstable industry, the study offers a verified Neutrosophic Analytic Hierarchy Process (NAHP) model specifically designed for Supply Chain Risk Management (SCRM) in the textile sector of Bangladesh. The approach facilitates targeted mitigation actions that are in line with the particular difficulties faced by the business by identifying and ranking important risk categories, such as operational, financial, environmental, social, and market hazards. Additionally, it offers a strategic framework for improving resilience and crucial insights into how various risk factors affect the overall performance of the supply chain. The study also examines several time frames for SCRM plans and concludes that short-term approaches are best for efficiently managing short-term risks while preserving adaptability for long-term viability.

2. Literature Review
In recent years, multi-criteria decision-making (MCDM) models have become critical in addressing the complexities of supply chain risk management (SCRM) (Meziani et al. 2022). The textile industry, particularly in Bangladesh, faces unique challenges due to its dynamic and uncertain operational environment (Raian et al. 2022). This literature review synthesizes relevant studies on Analytic Hierarchy Process (AHP) adaptations, including Neutrosophic AHP (NAHP), and their applications within SCRM frameworks. By examining previous research, this review aims to contextualize the contribution of a Neutrosophic AHP model for managing risks in Bangladesh's textile sector. The traditional Analytic Hierarchy Process (AHP) is widely utilized for MCDM due to its structured approach for quantifying subjective and objective criteria. Studies by Saaty (1990), who developed AHP, reveal its efficacy in prioritizing risks across different levels in supply chains. However, traditional AHP is often limited in handling ambiguity and subjective interpretations, which are inherent in risk assessment scenarios within volatile sectors like textiles (Aruldoss et al. 2013).

In light of AHP's limitations, researchers have introduced fuzzy and neutrosophic logic to enhance its applicability in environments marked by high uncertainty (Smarandache 2016). Fuzzy AHP, an evolution of traditional AHP, uses fuzzy set theory to address vagueness but remains insufficient in handling indeterminacies and contradictions (Atanassov 1986). Neutrosophic AHP (NAHP), grounded in neutrosophic logic, overcomes these constraints by capturing three aspects of truth—truthiness, falsity, and indeterminacy (Ansari et al. 2013)—making it particularly suitable for risk-prone fields like the textile supply chain.Recent studies demonstrate the effectiveness of NAHP in multi-criteria decision-making across various fields. For instance, Abdel-Basset et al. (2019) illustrated A hybrid neutrosophic multiple criteria group decision-making approach for project selection by accounting for both uncertainty and ambiguity. Similarly, Radwan et al. (2016)highlighted NAHP's utility in the selection of a Learning Management System. Moreover, R et al. (2023) developed a decision-making tool to assist decision-makers in selecting the best supplier in the clothing sector within a neutrosophic environment with interval values.

The textile supply chain, particularly in regions like Bangladesh, is characterized by operational uncertainties and market fluctuations. Literature reveals that integrating NAHP into supply chain risk assessments offers a robust framework for evaluating risk categories. A study by Gómez et al. (2023) underscores the importance of incorporating both quantitative and qualitative factors in SCRM models. Their findings indicate that NAHP's triadic logic enables more comprehensive prioritization, allowing decision-makers to handle risks associated with operational, financial, environmental, social, and market factors.Moreover, research by Chowdhury & Quaddus (2016) on the textile supply chain in Bangladesh suggests that short-term strategies are frequently more effective in mitigating emergent risks in rapidly changing environments.

Comparing NAHP with other MCDM models like Fuzzy AHP and TOPSIS reveals distinct advantages in supply chain contexts requiring resilience and sustainability (Ye 2014). Fuzzy AHP models, while valuable in accounting for uncertainty, lack NAHP's capacity for managing indeterminate information (Wang et al. 2005). In contrast, NAHP's flexibility supports the identification of nuanced risk factors and aligns with resilience-building in supply chains facing volatile market conditions (Vafadarnikjoo & Scherz 2021), such as those in the textile sector (Aytekin et al. 2023).
The literature highlights the transformative potential of NAHP in supply chain risk management for the Bangladeshi textile sector. NAHP's ability to address ambiguity, coupled with its adaptability in short-term risk management planning, aligns well with industry needs. This review demonstrates that by enhancing traditional AHP, NAHP provides a powerful decision-making tool for mitigating supply chain risks in high-risk industries. The application of NAHP within the textile sector not only improves risk assessment accuracy but also contributes to the broader field of sustainable supply chain management.

3. Methods

This research applies a Neutrosophic Analytic Hierarchy Process (NAHP) model to assess and prioritize supply chain risks within the textile sector of Bangladesh. The methodology is structured in the following steps:

3.1 Identification of Criteria and Sub-Criteria

In the textile industry, supply chain risk management is centered on five main risk criteria: operational, financial, environmental, social, and market. To give a more detailed view of each risk factor, sub-criteria were further defined within each primary category.

3.2 Survey Design and Data Collection

About 17 industry professionals engaged in surveys at a textile industry in Gazipur to get their professional opinions and insights on the relative significance of each risk criterion and sub-criterion. Evaluations of alternative risk management approaches within the following durational categories were also included in the surveys: Immediate (within one month), Short-term (1 to 3 months), Medium-term (3 to 6 months), and Long-term (6 months to 1 year).

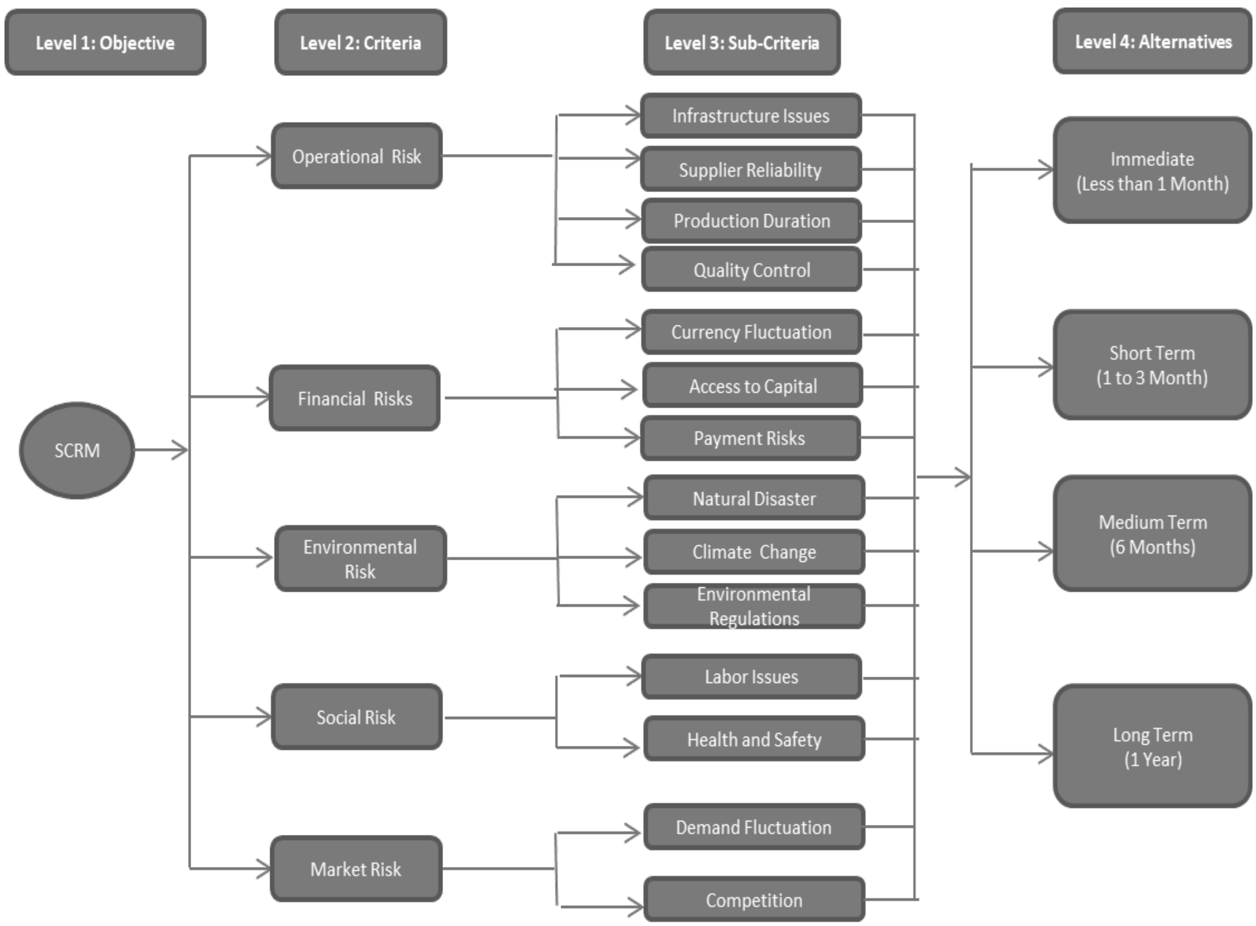

Figure 1. SCRM model representation of Criteria, Sub-Criteria and Alternatives

3.3 Representation of Neutrosophic Set

Neutrosophic values were used to handle the ambiguity and uncertainty inherent in expert assessments. Each criterion was represented by a neutrosophic value N = (t, i, f), where:

- t is the degree of truthfulness
- i is the degree of indeterminacy
- f is the degree of falsehood

Neutrosophic logic is able to deal with contradictions that are true and false at the same time, as the sum of the components is any number between –0 and 3+.
In this section, a general view of the neutrosophic logic set is presented here,

Let X be the space of the objects and $x \in X$. A neutrosophic set A in X is defined by three functions: a truthfulness-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsehood-membership function $F_A(x)$.
Where: $T_A(x), I_A(x), F_A(x) \in [0, 1]$, With $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$, the set A represents an SVNS, which is $A = \{(x; T_A(x), I_A(x), F_A(x): x \in X\}$.

Definition 1: If $N_1 = (t_1, i_1, f_1)$ and $N_2 = (t_2, i_2, f_2)$ are the two single valued neutrosophic numbers, so the addition of the two numbers will be: $N_1 + N_2 = (t_1+t_2-t_1t_2, i_1i_2, f_1f_2)$.

Definition 2: If $N_1 = (t_1, i_1, f_1)$ and $N_2 = (t_2, i_2, f_2)$ are the two single valued neutrosophic numbers, so the multiplication of the two numbers will be: $N_1 X N_2= (t_1t_2, i_1+i_2 -i_1i_2, f_1+f_2- f_1f_2)$.

Definition 3: If $N_1 = (t_1, i_1, f_1)$ and $N_2 = (t_2, i_2, f_2)$ are the two single valued neutrosophic numbers, so the Division of the two numbers will be: $N_2/ N_1= (t_2/t_1, i_2 -i_1/1-i_1, f_2-f_1/1-f_1)$.

Definition 4: If $N_1= (t_1, i_1, f_1)$ is a single-valued neutrosophic number and A is an arbitrary positive real number, then the multiplication of N1 and A can be expressed as follows: $A X N_1 = (1-(1-t_1)^A, i_1^A, f_1^A)$, Where $A >0$. Moreover, the division of N_1 over A can be expressed as follows: $N_1 / A = (1-(1-t_1)^{1/A}, i_1^{1/A}, f_1^{1/A})$, Where $A > 0$.

Definition 5: If N_1 is a single-valued neutrosophic number, a score function is mapped N_1 into the single crisp output as $S(N_1)$ follows: $S(N_1) = (3+t_1-2i_1-f_1)/4$.

3.4 Calculation of Priority Weight

The NAHP model determines the priority weights for each criterion and sub-criterion based on the total expert ratings. The criteria are ranked according to their significance in supply chain risk management using the scoring function S(N).

3.5 Evaluation of Risk Management Plan Alternatives

The appropriateness of various risk management plan durations (immediate, short-term, medium-term, and long-term) is evaluated by the NAHP model. The short-term strategy (1 - 3 months) is the most successful in controlling the risks that have been identified in the textile industry, according to the ratings.

4. Data Collection

With the help of experts, we carried out the survey and developed the pairwise comparison matrices of the first criteria versus the goal, then of the sub criteria versus the criteria, and finally of the alternatives versus each of the sub criteria. There are 11 pairwise comparison matrices in total. A table of pairwise comparison matrix for criteria, pairwise comparison matrix for the Sub-Criteria of (Operational Risks, Financial Risks and Environmental Risks) and Pairwise comparison matrix of Alternatives for (Operational Risks, Financial Risks) are shown here. But, two pairwise comparison matrix for the Sub-Criteria and three pairwise matrix for the Alternatives are not shown here.

Table 1. Pairwise comparison matrix for Criteria

Criteria	Operational	Financial	Environmental	Social	Market	Weight
Operational	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.80, 0.25, 0.20)	(0.60, 0.35, 0.40)	(0.64, 0.35, 0.36)
Financial	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.60, 0.35, 0.40)	(0.56, 0.43, 0.44)
Environmental	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.44, 0.57, 0.56)
Social	(0.20, 0.75, 0.80)	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.40, 0.65, 0.60)	(0.36, 0.65, 0.64)
Market	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.5, 0.5, 0.5)	(0.50, 0.50, 0.50)

Table 2. Pairwise comparison matrix for the Sub-Criteria of Operational Risks

Sub-Criteria	Infrastructure	Supplier Reliability	Production Disruptions	Quality Control	Weight
Infrastructure	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.60, 0.35, 0.40)	(0.60, 0.38, 0.40)
Supplier Reliability	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.53, 0.46, 0.48)
Production Disruptions	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.40, 0.65, 0.60)	(0.40, 0.63, 0.60)
Quality Control	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.5, 0.5, 0.5)	(0.48, 0.54, 0.53)

Table 3. Pairwise comparison matrix for the Sub-Criteria of Financial Risks

Sub-Criteria	Currency Fluctuations	Payment Risks	Weight
Currency Fluctuations	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.55, 0.425, 0.45)
Payment Risks	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.45, 0.575, 0.55)

Table 4. Pairwise comparison matrix for the Sub-Criteria of Environmental Risks

Sub-Criteria	Natural Disasters	Climate Change	Environmental Regulations	Weight
Natural Disasters	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.60, 0.38, 0.40)
Climate Change	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)
Environmental Regulations	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.40, 0.62, 0.60)

Table 5. Pairwise comparison matrix of Alternatives for Operational Risks

Alternatives	Immediate	Short-term	Medium-term	Long-term	Weight	Normalized Weight
Immediate	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.80, 0.25, 0.20)	(0.65, 0.35, 0.37)	(0.331, 0.1804, 0.2138)
Short-term	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.70, 0.30, 0.30)	(0.55, 0.45, 0.45)	(0.2806, 0.232, 0.26)
Medium-term	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.60, 0.35, 0.40)	(0.45, 0.56, 0.46)	(0.2296, 0.288, 0.2658)
Long-term	(0.20, 0.75, 0.80)	(0.30, 0.70, 0.70)	(0.40, 0.65, 0.60)	(0.5, 0.5, 0.5)	(0.31, 0.58, 0.45)	(0.158, 0.299, 0.26)

Table 6. Pairwise comparison matrix of Alternatives for Financial Risks

Alternatives	Immediate	Short-term	Medium-term	Long-term	Weight	Normalized Weight
Immediate	(0.5, 0.5, 0.5)	(0.40, 0.65, 0.60)	(0.30, 0.70, 0.70)	(0.20, 0.75, 0.80)	(0.375, 0.65, 0.675)	0.188, 0.36, 0.37
Short-term	(0.60, 0.35, 0.40)	(0.5, 0.5, 0.5)	(0.35, 0.65, 0.60)	(0.25, 0.70, 0.75)	(0.425, 0.3875, 0.3875)	0.213, 0.215, 0.21
Medium-term	(0.70, 0.30, 0.30)	(0.60, 0.35, 0.40)	(0.5, 0.5, 0.5)	(0.35, 0.65, 0.60)	(0.5375, 0.375, 0.375)	0.27, 0.208, 0.205
Long-term	(0.80, 0.25, 0.20)	(0.70, 0.30, 0.30)	(0.60, 0.35, 0.40)	(0.5, 0.5, 0.5)	(0.65, 0.3875, 0.3875)	0.327, 0.215, 0.21

4.1 Consistency Checking

Table 7. Linguistic variables and Importance weight based on neutrosophic values

Linguistic Term	Neutrosophic Set	Linguistic Term	Neutrosophic Set
Extremely Highly Preferred	(0.90, 0.10, 0.10)	Mildly Lowly Preferred	(0.10, 0.90, 0.90)
Extremely Preferred	(0.85,0.20, 0.15)	Mildly Preferred	(0.15,0.80, 0.85)
Very Strongly To Extremely Preferred	(0.80, 0.25, 0.20)	Mildly preferred to Very Lowly Preferred	(0.20, 0.75, 0.80)
Very Strongly Preferred	(0.75,0.25, 0.25	Very Lowly Preferred	(0.25,0.75, 0.75)
Strongly Preferred	(0.70, 0.30, 0.30)	Lowly Preferred	(0.30, 0.70, 0.70)
Moderately Highly To Strongly Preferred	(0.65, 0.30, 0.35)	Moderately Lowly Preferred to Lowly Preferred	(0.35, 0.70, 0.65)
Moderately Highly Preferred	(0.60, 0.35, 0.40)	Moderately Lowly Preferred	(0.40, 0.65, 0.60)
Equally To Moderately Preferred	(0.55, 0.40, 0.45)	Moderately to Equally Preferred	(0.45, 0.60, 0.55)
Equally Preferred	(0.50, 0.50, 0.50)	Equally Preferred	(0.50, 0.50, 0.50)

Checking consistency ratio for each pairwise comparison matrix is very important. In the conventional AHP, Saaty provided a consistency ratio CR to measure the degree of consistency for a multiplicative preference relation as to be less than 0.1.
In our work we converted the Neutrosophic values with the corresponding Saaty linguistic term, which is shown in table 12. After converting those Neutrosophic values into Saaty Scale, we calculated the Consistency Ratio of each pairwise comparison matrices.

Table 8. Consistency Ratio of the pairwise comparison matrices

Table 1	**Table 2**	**Table 3**	**Table 4**	**Table 5**	**Table 6**
0.0576	0.0671	0.00	0.0334	0.0439	0.043

4.2 Weight calculation

Here is the calculation of Overall Weight and Overall Normalized Weight. We did this calculation using Definition 2.

Table 9. The Overall Priority of the Criteria and the Sub-Criteria

Criteria	**Criteria Weight CW**	**Sub criteria**	**Sub criteria weight SCW**	**Overall Weight = CW × SCW**	**Overall Normalized Weight**
Operational Risks	(0.64, 0.35, 0.36)	Infrastructure Issues	(0.60, 0.38, 0.40)	0.384, 0.597, 0.616	0.257, 0.1804, 0.1819
		Supplier Reliability	(0.53, 0.46, 0.48)	0.339, 0.649, 0.667	
		Production Disruptions	(0.40, 0.63, 0.60)	0.256, 0.759, 0.744	
		Quality Control	(0.48, 0.54, 0.53)	0.307, 0.701, 0.699	
Financial Risks	(0.56, 0.43, 0.44)	Currency Fluctuations	(0.55, 0.425, 0.45)	0.308, 0.672, 0.692	0.223, 0.1905, 0.1922
		Payment Risks	(0.45, 0.575, 0.55)	0.25, 0.757, 0.748	
Environmental Risks	(0.44, 0.57, 0.56)	Natural Disasters	(0.60, 0.38, 0.40)	0.264, 0.733, 0.736	0.1759, 0.209, 0.208
		Climate Change	(0.50, 0.50, 0.50)	0.22, 0.785, 0.78	
		Environmental Regulations	(0.40, 0.62, 0.60)	0.176, 0.836, 0.824	
Social Risks	(0.36, 0.65, 0.64)	Labor Issues	(0.60, 0.38, 0.40)	0.216, 0.783 0.784	0.1439, 0.22, 0.217
		Compliance with International Standards	(0.50, 0.50, 0.45	0.18, 0.825, 0.802	
		Health and Safety	(0.40, 0.62, 0.60)	0.144, 0.867, 0.856	
Market Risks	(0.50, 0.50, 0.50)	Demand Fluctuations	(0.55, 0.425, 0.45)	0.275, 0.712, 0.725	0.2, 0.1998, 0.2
		Competition	(0.45, 0.575, 0.55)	0.225, 0.787, 0.775	

5. Results and Discussion

According to our research, the textile industry in Bangladesh benefits most from a short-term supply chain risk management plan (one to three months) since it strikes a balance between practicality and urgency, enabling quick but coordinated reactions to threats. Short-term plans allow for the implementation of successful strategies without the significant expenses or rigidity associated with medium- and long-term commitments, in contrast to immediate plans, which may result in hurried decisions. This strategy maintains cost-effectiveness and permits regular monitoring and adjustments while providing the flexibility required to adjust to the textile market's dynamic and turbulent nature.

5.1 Numerical Results

Table 10. Overall Score of Different Alternatives

Alternatives	Attributes and their weight					Neutrosophic Value	Crisp Value	Rank
	Operational 0.257, 0.1804, 0.1819	**Financial** 0.223, 0.1905, 0.1922	**Environmental** 0.1759, 0.209, 0.208	**Social** 0.1439, 0.22, 0.217	**Market** 0.2, 0.1998, 0.2			
Immediate	0.331, 0.1804, 0.2138	0.188, 0.36, 0.37	0.236, 0.326, 0.33	0.329, 0.186, 0.238	0.255, 0.24, 0.267	0.266, 0.258, 0.282	0.617	4
Short-term	0.2806, 0.232, 0.26	0.213, 0.215, 0.21	0.24, 0.196, 0.237	0.28, 0.24, 0.262	0.255, 0.21, 0.259	0.251, 0.218, 0.2458	0.642	1
Medium-term	0.2296, 0.288, 0.2658	0.27, 0.208, 0.205	0.27, 0.24, 0.23	0.23, 0.29, 0.262	0.238, 0.24, 0.236	0.247, 0.254, 0.238	0.625	2
Long-term	0.158, 0.299, 0.26	0.327, 0.215, 0.21	0.25, 0.23, 0.19	0.158, 0.28, 0.238	0.25, 0.30, 0.236	0.23, 0.264, 0.226	0.619	3

5.2 Graphical Results

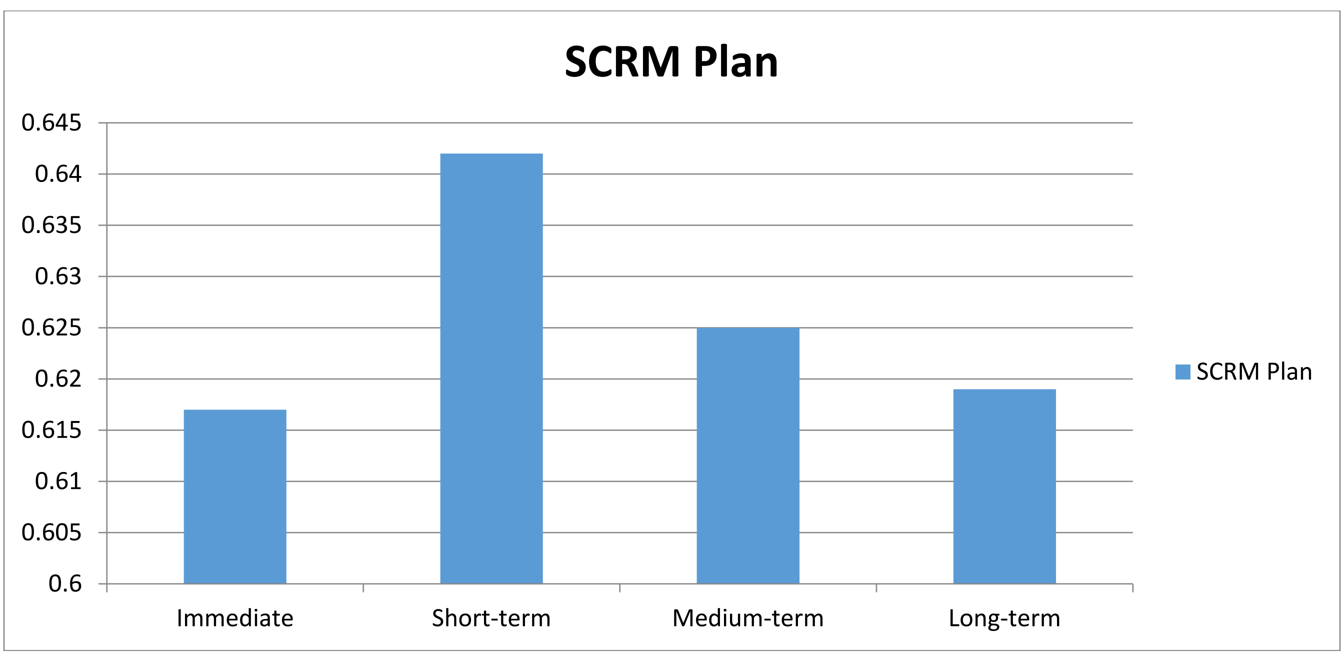

Figure 2. Weight Percentages of the Neutrosophic Scale Based on the Alternatives

5.3 Proposed Improvements

Future studies could broaden the data collection to include additional textile enterprises around Bangladesh in order to improve this research and make the results more reliable and representative. Incorporating additional factors, like Technology Development, Political Stability, or Regulatory Compliance, would improve the model's thoroughness in evaluating supply chain risks unique to the textile industry. Furthermore, investigating different neutrosophic aggregation strategies or including additional MCDM approaches, such as TOPSIS or Fuzzy AHP, could improve the model's sensitivity and accuracy and offer a more reliable framework for making decisions.
Creating a digital tool based on the model would increase the research's practical impact by enabling businesses to efficiently perform their own risk assessments. Last but not least, a longitudinal study might track changes over time, enabling the model to be dynamically adjusted to changing hazards and the best ways to manage them.

6. Conclusion

To sum up, this study effectively uses the Neutrosophic Analytic Hierarchy Process (NAHP) to assess and choose the best supply chain risk management strategy for Bangladesh's textile industry. A short-term risk management plan (1-3 months) offers the best balance between timeliness, feasibility, and flexibility, making it the best option for successfully mitigating supply chain risks, according to our assessment of five major risk criteria: operational, financial, environmental, social, and market risks. Validation methods, such as consistency checks, which show the model's resilience and dependability, provide more credence to this view. The incorporation of neutrosophic values into the AHP framework improves the model's capacity to manage uncertainty and offers a more thorough tool for supply chain risk.
This work could be further done in the future by adding more criteria and carrying out longitudinal studies to track the changing effects of particular risk management strategies. All things considered, this study advances the field of supply chain management by providing a refined, flexible, and verified model that may direct textile sector decision-makers toward efficient risk-reduction tactics.

Acknowledgement:

This work is funded by the Research and Innovation Centre for Science and Engineering (RISE), BUET. We would like to thank the RISE for their support in the achievement of this work.

References:

Abdel-Basset, M., Atef, A., & Smarandache, F. , A hybrid neutrosophic multiple criteria group decision making approach for project selection. *Cognitive Systems Research*, *57*, 216–227, 2019. https://doi.org/10.1016/J.COGSYS.2018.10.023

Ansari, A. Q., Biswas, R., & Aggarwal, S. , Extension to fuzzy logic representation: Moving towards neutrosophic logic - A new laboratory rat. *IEEE International Conference on Fuzzy Systems,2013*. https://doi.org/10.1109/FUZZ-IEEE.2013.6622412

Aruldoss, M., Lakshmi, T. M., & Venkatesan, V. P. ,. A Survey on Multi Criteria Decision Making Methods and Its Applications. *American Journal of Information Systems*, *1*(1), 31–43, 2013. https://doi.org/10.12691/AJIS-1-1-5

Atanassov, K. T. , Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, *20*(1), 87–96, 1986. https://doi.org/10.1016/S0165-0114(86)80034-3

Aytekin, A., Okoth, B. O., Korucuk, S., Karamaşa, Ç., & Tirkolaee, E. B. , A neutrosophic approach to evaluate the factors affecting performance and theory of sustainable supply chain management: application to textile industry. *Management Decision*, *61*(2), 506–529,2023. https://doi.org/10.1108/MD-05-2022-0588

Chowdhury, M. M. H., & Quaddus, M. (2016). Supply chain readiness, response and recovery for resilience. *Supply Chain Management*, *21*(6), 709–731. https://doi.org/10.1108/SCM-12-2015-0463

Gómez, G. A., Armijos, C. G., Fernández, A. J. R., & García, A. R. R. , Neutrosophic Analysis of Ethics in a Supply Chain. *Neutrosophic Sets and Systems*, *62*, 303–310, 2023. https://fs.unm.edu/nss8/index.php/111/article/view/3859

Meziani, A., Bourouis, A., & Chebout, M. S. (2022). Neutrosophic Data Analytic Hierarchy Process for Multi Criteria Decision Making: Applied to Supply Chain Risk Managment. *ICAASE 2022 - 5th Edition of the International Conference on Advanced Aspects of Software Engineering, Proceedings*. https://doi.org/10.1109/ICAASE56196.2022.9931541

Nouran Radwan, M. Badr Senousy, A. el-din mohamed R. (n.d.). *Neutrosophic AHP Multi Criteria Decision Making*

Method Applied on the Selection of Learning Management System. International Journal of Advancements in Computing Technology. Retrieved December 8, 2024, from https://www.researchgate.net/publication/312219290_Neutrosophic_AHP_Multi_Criteria_Decision_Making_Method_Applied_on_the_Selection_of_Learning_Management_System

R, V., Veeramani, C., & S, M. , *Enhancing Supply Chain Decision-Making in the Textile Industry: A Hybrid Interval-Valued Neutrosophic MCDM Approach, 2023*. https://doi.org/10.21203/RS.3.RS-3047561/V1

Raian, S., Ali, S. M., Sarker, M. R., Sankaranarayanan, B., Kabir, G., Paul, S. K., & Chakrabortty, R. K. , Assessing sustainability risks in the supply chain of the textile industry under uncertainty. *Resources, Conservation and Recycling*, *177, 2022*. https://doi.org/10.1016/J.RESCONREC.2021.105975

Saaty, T. L. , How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, *48*(1), 9–26, 190. https://doi.org/10.1016/0377-2217(90)90057-I

Smarandache, F. , *Neutrosophic Probability , Set , And Logic (first version) Neutrosophic Probability , Set , And Logic (first version) In Florentin Smarandache : " Collected Papers ", vol . III . Oradea*. *January 2000,2016*. https://doi.org/10.5281/zenodo.57726

Vafadarnikjoo, A., & Scherz, M. ,A Hybrid Neutrosophic-Grey Analytic Hierarchy Process Method: Decision-Making Modelling in Uncertain Environments. *Mathematical Problems in Engineering*, *2021*. https://doi.org/10.1155/2021/1239505

Wang, H., Smarandache, F., Zhang, Y.-Q., & Sunderraman, R. (2005). *Interval Neutrosophic Sets and Logic: Theory and Applications in Computing*. http://arxiv.org/abs/cs/0505014

Ye, J. , A multicriteria decision-making method using aggregation operators for simplified neutrosophic sets. *Journal of Intelligent and Fuzzy Systems*, *26*(5), 2459–2466, 2014. https://doi.org/10.3233/IFS-130916

Biographies

Ferdous Sarwar graduated from BUET with a B.Sc. and M.Sc. in Industrial & Production Engineering (IPE) and North Dakota State University (NDSU) in the United States with a Ph.D. in Industrial & Manufacturing Engineering (IME). He is a professor of Industrial and Production Engineering at BUET. Supply chain management and optimization are two areas of his study focus. He is a member of the Institute of Industrial Engineers (IIE), the Surface Mount Technology Association (SMTA), and the International Microelectronics and Packaging Society (IMAPS).

Md. Mehedi Hasan Joy is a final-year Industrial and Production Engineering student at Bangladesh University of Engineering and Technology (BUET). He is passionate about sustainable development and aims to advance industrial engineering practices that align with global sustainability goals.