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ASSESSMENT OF MAJOR RISKS IN APPAREL SUPPLY CHAIN USING FUZZY AHP METHOD – A CASE STUDY IN BANGLADESH

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ABSTRACT
Supply chain risk management is a crucial part of any strategy across all sorts of industries. The apparel industry in Bangladesh have a great contribution on its total GDP (gross domestic product). Due to the sophisticated nature of the industry, a number of risks have been associated to its supply chain. These risks and their sources disturb the apparel supply chain to function optimally and decline its overall performance. Therefore, identifying the critical risks of apparel supply chain and its prioritization is very important. The present research aims at identifying and prioritizing the risks relevant to apparel supply chain. The major risks were identified based on the literature review and responses from the industrial experts. The fuzzy analytic hierarchy process (fuzzy AHP) was employed to analyze the risks and determine their ranking. In this work, the results indicate that supply risk is the most critical one followed by operational risk and demand risk. The least importance is given to the environmental risk. A sensitivity analysis is also conducted to examine the stability of the priority ranking made and the results show that the rankings remain unchanged due to any variations of the normalized weight for a particular criterion.

KEYWORDS: Supply chain management (SCM), supply chain risks, fuzzy AHP method, risk prioritization.

1. INTRODUCTION
The blessings of technology and globalization results in an environment in which organizations operate and encounter a rising trend of risks. Nowadays, organizations are becoming vulnerable in their supply chain due to irregularities of materials supply, product demand, skills needed and equipment requirements. These risks or supply chain failures can be costly and lead to significant delays in customer deliveries. Therefore, managing supply chain risk is an important component of managing the supply chain. Supply chain risk has been defined as the unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain, and causes operational and financial risks [1]. It is important for an organization's success to understand the sources of supply chain risks and to manage them better [2]. Supply chain risk management is an essential part of any strategy across all industries or corporate structures.

The garments industry is one of the fastest growing industry in Bangladesh. Within a single decade it has emerged as the single dominant industry in Bangladesh. It makes a significant contribution to the national economy by creating generous employment opportunities and reducing poverty through socioeconomic development [3]. The ready-made garments (RMG) industry is also the leading sector in Bangladesh in terms of foreign currency earnings. Bangladesh is the second largest exporter of garments next to china contributing 80% of total export earnings [4]. Because of enormous economic importance in the economy of Bangladesh, the growth of RMG industry is to be sustained by improving supply chain management (SCM) [5]. Supply chain management plays as a key factor for the successful functioning of the apparel industry. The apparel supply chain in Bangladesh is highly complex because of its diversity and involvement of large number of stages. In this sense, any risk affecting the apparel supply chain could affect the total economic condition of the nation. To manage such vulnerabilities, it is vital to identify the related risks and to reduce their occurrence for best practices in the apparel supply chain. And so, improving apparel supply chain needs proper risk management which incorporates identifying the risks associated, evaluating the risks for determining their priority and suggesting proper remedies for reducing their occurrence. That's why the core focus of top management is to develop an effective supply chain management system. From a number of previous works [5-9], the risks associated to apparel supply chain were identified as supply risk, demand risk, operational risk and environmental risk. Supply risk is the probability that an inbound supply problem will disrupt a supply chain. It is caused by any interruptions to the flow of product, whether raw material or parts, within the supply chain. Demand related risk is the potential for a loss due to a gap between forecast and actual demand. It is caused by unpredictable or misunderstood customer or end-customer demand or sudden change in factors associated with market. Operational risk is the prospect of loss resulting from inadequate or failed procedures, systems or policies, employee errors etc. Environmental risks occur from outside the supply chain.

Despite this sector is receiving increasing researcher's attention, in particular concerning supply chain management literature does not show relevant studies related to risk identification and prioritization. A number of research works [6-13] has been conducted investigating supply chain risk worldwide. Routroy and Shankar [6], Ji and Chen [7], Liljander et al. [8] and Hasan and Appel [9] worked on their research work mainly on identifying the risks which are relevant to the apparel supply chain but did not attempt to prioritize the risks. On the other hand, Venkatesh et al. [10], Martino et al. [11] prioritizing the supply chain risks for various industries in their research work. Shen et al. [12] worked on the effect of the supply chain risks and Khan [13] discussed how design is used as a strategic tool for managing risks. So far, very few research works are found to investigate supply chain risks dealing with a detailed and structured picture of the whole supply chain process. The present research work aims at identifying all the relevant and important risks and prioritizing the risks as well as suggesting some remedies. Moreover, this work focuses on apparel supply chain risks in the context of Bangladesh.

2. METHODOLOGY

Figure 1 illustrates how this research work has been proceeded. At first, an extensive literature survey has been conducted to understand the importance of supply chain risks for the apparel industry. A number of risks were identified from the literature survey and the responses collected from 30 industrial and academic experts. A shortlist containing the most relevant supply chain risks has been developed on the basis of their greater significance given by the experts. Furthermore, experts' opinions giving relative importance and relevancy of the supply chains risks associated with the apparel industry are collected through a structured questionnaire. Responses from 7 industrial experts and 3 academic experts were utilized for this purpose. To validate the data collected, a consistency test has been conducted. For the ranking of the risks, those 10 respondents from a number of the apparel manufacturers and Department of Industrial and Production Engineering, Shahjalal

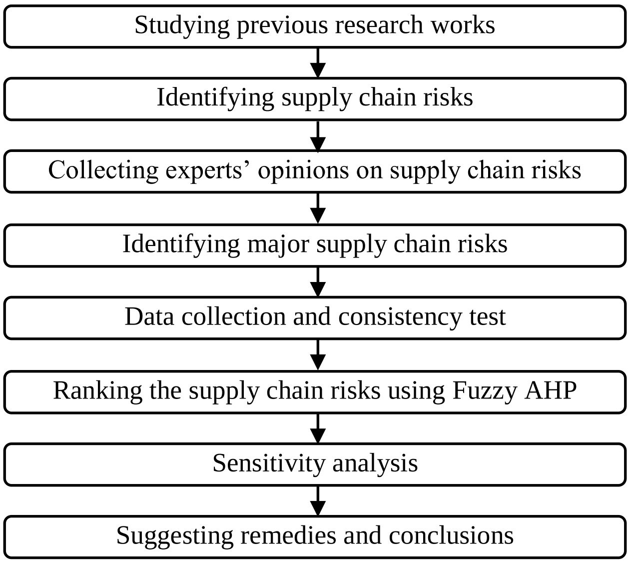

Figure 1. Major stages of the present research work.

University of Science and Technology, Sylhet, Bangladesh have been selected who are mainly working on various positions linked with the supply chain management. Their responses were collected with the help of an appropriate questionnaire through email responses and several personal interviews. Based on their responses, the ranking of the main risks was performed using the Fuzzy analytic hierarchy process (AHP) method. Finally, a sensitivity analysis was performed to examine the result.

Fuzzy AHP model

In order to rank the main risks, a model was developed using the Fuzzy Analytic Hierarchy Process (AHP). The Fuzzy AHP embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP) which was developed by Saaty [14]. AHP is a widely used decision making tools in various multi-criteria decision making methods. It takes the pair-wise comparisons of different alternatives with respective to various criteria and provides a decision support tool for multi-criteria decision making approaches. In a general AHP model, the objective is in the first level, the criteria and sub criteria are in the second and third levels, respectively. Finally, the alternatives are found in the fourth level. In the present work, the Buckley's method is used to determine the relative importance weights for both the criteria and the alternatives. The procedure of the Fuzzy AHP are given briefly as follows [15].

Decision Maker compares the criteria or alternatives via linguistic terms [16, 17] as shown in Table 1. According to the corresponding triangular fuzzy numbers of these linguistic terms, for example if a decision maker states that Criterion 1 (C1) is moderately more important than Criterion 2, then it takes the fuzzy triangular scale as (2, 3, 4). On the contrary, in the pair wise contribution matrix of the criteria, comparison of C2 to C1 will take the reciprocal fuzzy triangular number as (1/4, 1/3, 1/2). The pair wise contribution matrices is shown in

Equation 1, where $\widetilde{d_{ij}^{k}}$ indicates the kth decision maker's preference of ith criterion over jth criterion, via fuzzy triangular numbers. Here, "tilde" represents the triangular number demonstration and for example, $\widetilde{d_{12}^{1}}$ represents the first s maker's preference of first criterion over second criterion, a choice could be as $\widetilde{d_{12}^{1}}$ = (2,3,4). If there is more than one decision maker, then geometric mean calculated using Microsoft Excel software is used to summarize the responses. The consistency test is done using the geometric mean values to find out the consistency of the responses. According to geometric mean values found earlier, pair wise contribution matrices is updated from Equation 1. To find the fuzzy weights of each criterion, necessary manipulations are performed as detailed in the research work by Najib and Abdullah. The same above mentioned procedure is followed to find the normalized weights of both criteria and the alternatives. Then by multiplying each alternative weight with related criteria, the scores for each alternative is calculated. According to these results, the alternative with the highest score is suggested to the decision maker.

Table 1. Linguistic terms and the corresponding triangular fuzzy numbers

Saaty AHP scale	Linguistic terms	Fuzzy AHP scale	
		Fuzzy triangular numbers	Reciprocal fuzzy triangular numbers
1	Equally important (E. Imp.)	(1, 1, 1)	(1, 1, 1)
3	Moderately important (M. Imp.)	(2, 3, 4)	(1/4, 1/3, 1/2)
5	Strongly important (S. Imp.)	(4, 5, 6)	(1/6, 1/5, 1/4)
7	Very strongly important (V. Imp.)	(6, 7, 8)	(1/8, 1/7, 1/6)
9	Absolutely important (A. Imp.)	(9, 9, 9)	(1/9, 1/9, 1/9)
2	The important values between two adjacent scales	(1, 2, 3)	(1/3, 1/2, 1)
4		(3, 4, 5)	(1/5, 1/4, 1/3)
6		(5, 6, 7)	(1/7, 1/6, 1/5)
8		(7, 8, 9)	(1/9, 1/8, 1/7)

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$$\widetilde{A^k} = \begin{bmatrix} \widetilde{d_{11}^k} & \widetilde{d_{12}^k} & \dots & \widetilde{d_n^k} \\ \widetilde{d_{21}^k} & \dots & \dots & \widetilde{d_{2n}^k} \\ \dots & \dots & \dots & 1 \\ \widetilde{d_{n1}^k} & \widetilde{d_{n2}^k} & \dots & \widetilde{d_{nn}^k} \end{bmatrix} \quad (1)$$

3. RESULTS AND DISCUSSION

As mentioned earlier in methodology, 10 responses from the attempted industrial and academic experts were collected for comparing the major risks. The questionnaires were based on Table 1 and the repsondents were asked to fill the upper triangular elements of an identity matrix asked to fill. A typical response of an industrial expert is shown in Table 2. The table is a comparison matrix of the main four risks: supply risks, operational risks, demand risks and environmental risks. The comparison matrix values are decided by the supply chain expert based on the satty scale mentioned in the Table 1. The values indicate the importance of the row with respect to the column. Based on the Table 1, the pair wise comparison values of the main risks against Saaty AHP scale are converted into fuzzy triangular numbers and reciprocal fuzzy triangular numbers. The converted values are tabulated in Table 3. Similarly, nine more responses collected were processed to form all the comparison values into triangular fuzzy numbers. Using these 10 responses, the geometric means $\widetilde{r_i}$ of the fuzzy comparison values were calculated using Microsoft Excel and are shown in the Table 4.

Table 2. A typical response for the comparison matrix of main supply chain risks for the apparel industry.

Risks	Supply	Operational	Demand	Environmental
Supply	1	2	2	3
Operational	1/2	1	2	3
Demand	1/2	1/2	1	1
Environmental	1/3	1/3	1	1

Table 3. Pair wise comparison matrices for main risks in triangular fuzzy numbers.

Risks	Supply			Operational			Demand			Environmental		
Supply	1.00	1.00	1.00	1.00	2.00	3.00	1.00	2.00	3.00	2.00	3.00	4.00
Operational	0.33	0.50	1.00	1.00	1.00	1.00	1.00	2.00	3.00	2.00	3.00	4.00
Demand	0.33	0.50	1.00	0.33	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Environmental	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	1.00	1.00	1.00

Table 4. Geometric means of fuzzy comparison values for 10 responses.

Risk	$\widetilde{r_i}$											
	Supply			Operational			Demand			Environmental		
Supply	1.00	1.00	1.00	1.15	2.02	2.85	1.47	2.52	3.54	1.76	2.81	3.84
Operational	0.35	0.49	0.87	1.00	1.00	1.00	1.20	1.81	2.48	2.11	3.10	4.13
Demand	0.28	0.40	0.68	0.40	0.55	0.84	1.00	1.00	1.00	1.32	2.05	2.70
Environmental	0.26	0.36	0.57	0.24	0.32	0.47	0.37	0.49	0.76	1.00	1.00	1.00

To check if the opinions of the selected experts are consistent in their scoring, Saaty's proposition on the basis of Consistency Ratio is utilized. Lambda max model [15] is used to calculate the numerical value of the consistency ratio of our collected data. For this purpose, the geometric means of the fuzzy comparison values are employed at first to calculate the value of the λ_{max} and consistency index, CI as below. The value of Random Consistency Index, RI for the number of items being compared in the matrix as 4 is found to be 0.9 from Table 5. The consistency ratio for this matrix is calculated as the ratio between CI and RI and is found to be 0.0129. This consistency value does not exceed the standard rate of Saaty's rate which is 0.1. Thus, the opinions of the experts represented by the matrix is consistent and thereby can be used for the later fuzzy AHP procedures.

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$$\lambda_{max} = 4 + det \begin{vmatrix} 1 & 2.02 & 2.52 & 2.81 \\ .49 & 1 & 1.81 & 3.10 \\ .40 & .55 & 1 & 2.05 \\ 0.36 & .32 & .49 & 1 \end{vmatrix} = 4.0348$$

$$\text{Consistency Index, CI} = \frac{\lambda max - n}{n - 1} = \frac{4.0348 - 4}{4 - 1} = 0.0116$$

$$\text{Consistency Ratio, CR } = \frac{CI}{RI} = \frac{0.0116}{0.9} = 0.0129$$

Table 5. Random Consistency Index for number of items compared in a matrix

Number of items, n	1-2	3	4	5	6	7	8	9
Random Consistency Index, RI	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

After the consistency test, the fuzzy triangular values given in Table 4 are again converted into the geometric means of fuzzy values of all criteria, namely R_i. They are displayed in Table 6 and a calculation for the first row to be obtained is shown only as below. In addition, the total and reverse values are also tabulated. Since the fuzzy triangular number should be in increasing order, the order of the numbers is modified in the last row of the given table.

$R_1 = [(1*1.15*1.47*1.76)^{1/4}; (1*2.02*2.52*2.81)^{1/4}; (1*2.85*3.54*3.84)^{1/4}] = [1.31; 1.94; 2.49]$

Table 6. Geometric means (R_i) of fuzzy comparison values ($\tilde{r}_i$)

Criteria	R_i		
Supply risks	1.31	1.95	2.49
Operational risks	0.97	1.29	1.73
Demand risks	0.62	0.82	1.11
Environmental risks	0.39	0.49	0.67
Total values	3.30	4.54	6.01
Reverse values ($Total^{-1}$)	0.30	0.22	0.17
Increasing order (Reverse values)	0.17	0.22	0.30

The geometric means of fuzzy values were then converted to relative fuzzy of weight as shown in Table 7 by multiplying them with reverse fuzzy geometric means in increasing order. The calculation is shown for values of the first row in Table 7 as follows.

$$\widetilde{W_i} = [1.31 * 0.17;\ 0.95 * 0.22;\ 2.49 * 0.30] = [0.22; 0.43; 0.75]$$

Finally, the relative non-fuzzy weight of each criteria (M_i) is calculated by averaging the fuzzy numbers for each criteria or risks in Table 7. The normalized weights of each criterion, (N_i) were calculated by dividing each value of relative non-fuzzy weights with their total value. Hence, the averaged and normalized weight of criteria are shown in Table 8. Figure 2 shows the rankings of the main supply chain risks plotted from the values given in Table 8. The figure clearly shows that the supply risk is ranked first and is followed by operation, demand and environmental risks, respectively. The ranking of the main risks of apparel supply chain can be written in a form: Supply risks >Operational risks > Demand risks > Environmental risks. In this research, among four main risks, supply related risk holds the utmost priority weight. Moreover, multi-criteria decision analysis method cannot deal perfectly to prioritize risk due to human judgment. Mangla et al. [18] proposed that small change in relative

Table 7. Relative fuzzy weights of each supply chain risks

Risks	$\widetilde{W_i}$		
Supply	0.22	0.43	0.75
Operational	0.16	0.28	0.52
Demand	0.11	0.18	0.33
Environmental	0.07	0.11	0.20

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Table 8. Averaged and normalized relative weight of risks

Risks	Averaged relative weight M_i	normalized relative weight N_i
Supply	0.47	0.42
Operational	0.32	0.29
Demand	0.21	0.18
Environmental	0.13	0.11

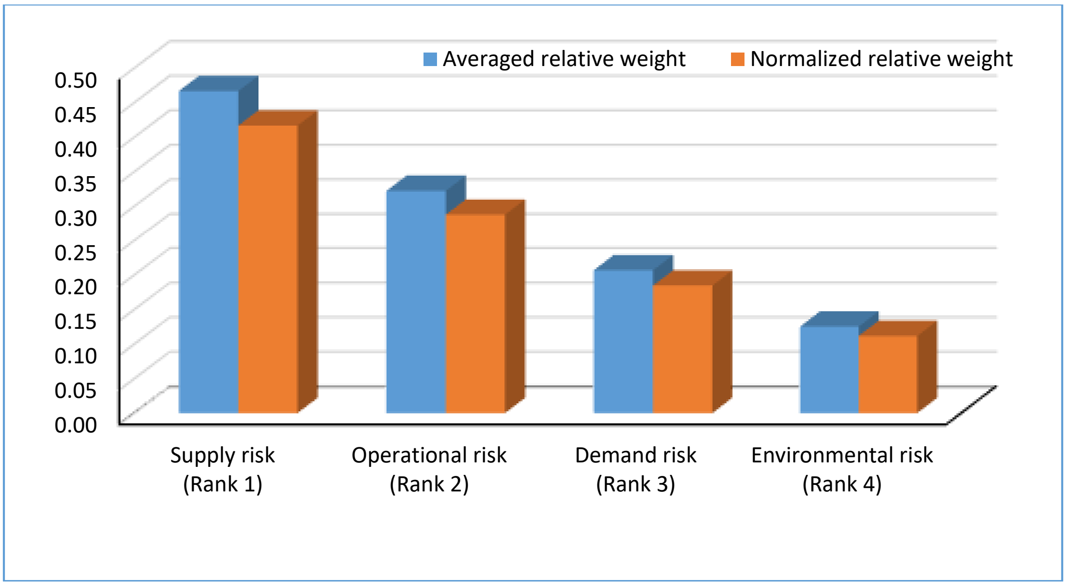

Figure 2. Ranking of the risks based on normalized weight

Weights of risks may show the large change in final ranking. Therefore, it is necessary to investigate the ranking for stability of result [19]. A sensitivity analysis as shown in Table 9 was performed by changing weight from 0.1 to 0.9 with 0.1 as incremental value to supply related risk to examine the changes in ranking of supply chain risks. At the same time, corresponding changes in the weights of other risks are also examined. Sensitivity analysis results show that maximum change occurred in the operational risks (O) weights as seen in Table 9. From the table, it can be also seen that the rankings do not change and the fluctuation of the weights does not sharply changes.

Table 9. Changes in priority weights of the other main risks due to the change of supply risk weights

Main risks	Priority weights for main risks									
Supply	0.420	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
Operational	0.290	0.450	0.400	0.350	0.300	0.250	0.200	0.150	0.100	0.050
Demand	0.180	0.279	0.248	0.217	0.186	0.155	0.124	0.093	0.062	0.031
Environmental	0.110	0.171	0.152	0.133	0.114	0.095	0.076	0.057	0.038	0.019
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Some of the policies can be recommended in reducing the occurrence of the supply chain risks for the apparel industry in Bangladesh as below:

- Realizing the actual nature of risk is a pre-requisite to mitigate the risk. This research can be useful to managers for introducing risk mitigation strategies.

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- Managers in the apparel sectors must develop resilient capabilities to tackle supply chain risks with a proper understanding of the existing supply chain risks and can formulate decision strategies on the basis of fuzzy AHP method.
- Since the supply chain depends mainly on the production of the commodities, to maintain the proper flow of it, it is to be ensured that the production process faces no disruption.
- As the apparel sector involves a greater degree of dependency on the suppliers, therefore, supplying of necessary materials related to apparel production should be on time.

4. CONCLUSION

Now-a-days, supply chain risk and its management have got heightened attentions for various industries. Identifying and prioritizing of a number of supply chain risks is very important for effective and optimal management of a supply chain. In this present work, for the great contribution of the apparel industry on Bangladesh economy, the risk factors in its apparel supply chains are studied. Although there are a variety of techniques explored previously for ranking the supply chain risks, the Analytical Hierarchy Process (AHP) technique empowered with fuzzy approach has been selected. Based on the literature review and experts' opinions, four main risks were initially selected. Then 10 respondents from the academic and industrial experts gave the importance as Satty scale values based on the structured questionnaires. Using these 10 set of values, the Fuzzy AHP model was used to prioritize the identified risks. The ranking of main risks for the apparel supply chain reveals their importance: Supply risks >operational risks > Demand risks > Environmental risks. The supply risk is the most important among the considered major risks in apparel supply chain followed the operational risk. The consistency test and sensitivity analysis shows the consistency of our collected data and the stability of the findings in this research. In further studies, a number of sub-criteria against the studied major risks can be addressed to rank a greater number of supply chain risks using the fuzzy AHP technique. Our ongoing research is being carried out to address these extensions.

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