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A fuzzy AHP-TOPSIS framework for the risk assessment of green supply chain implementation in the textile industry

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Abstract

In the emerging supply chain environment, green supply chain risk management plays a significant role more than ever. Risk is an inherent uncertainty and has a tendency to disrupt the typical green supply chain management (GSCM) operations and eventually reduce the success rate of industries. In order to mitigate the consequences, a fuzzy multi-criteria group decision making modeling (FMCGDM) which could evaluate the potential risks in the context of (GSCM) is needed from the industrial point of view. Therefore, this research proposes a combined fuzzy analytical hierarchy process (AHP) to calculate the weight of each risk criterion and sub-criterion and technique for order performance by similarity to ideal solution (TOPSIS) methodology to rank and assess the risks associated with implementation of (GSCM) practices under the fuzzy environment. The proposed fuzzy risk-oriented evaluation model is applied to a practical case of textile manufacturing industry. Finally, the proposed model helps the researchers and practitioners to understand the importance of conducting appropriate risk assessment when implementing green supply chain initiatives.

Keywords: Fuzzy AHP; Fuzzy TOPSIS; Risk assessment; Green initiative; Textile sector

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1. Introduction

In recent years, green supply chain management (GSCM) has emerged as an organizational philosophy. GSCM helps organizations and their business to improve competitive advantages and profits in the high-risk supply chain environment. With the rapid changes and pressure of global trend of increased collaboration with international supply partners and expanded supply networks, implementing greener practices could also intensify the probable chances of experiencing disruptive events in supply chains that substantially threaten normal routine operations of the industries in the supply chain system. These obstacles and issues could include maximization of total costs and goodwill risk from failures along the supply chain. An extensive discussion about these issues tendencies can be found in Silbermayr et al. (2014) and Azevedo et al. (2011). The implementation of green initiatives can generate higher revenues in the textile industry as retailers green credentials are becoming an important differentiator that enables firms to secure greater customer satisfaction and loyalty. According to the proposed methodology of Mangla et al. (2014), the aspect of environmental consideration or going green needs to be considered in the various activities including supply and operations of organizations.

Kannan et al. (2014) proposed the fuzzy multi-attribute group decision making approach based on (GSCM) practices from the high risk supply chain perspectives. According to Gao et al. (2010), a green product designing may improve the brand image and power to stimulate demand from green consumers. In order to accomplish this transition, it might be required to use advanced technologies in the production-distribution and supply processes, as well as the rapid change of R&D and new quality systems. Procurement-wise, it might be concentrated on purchasing of innovative raw materials and the procedure for optimal supplier selection. Logistics-wise, it might require new external and internal logistics along with new packaging. Meanwhile, there is no guarantee of marketability, retail ability salability and future growth of the products in the competitive global market. Accordingly, it is significant to use an integrated multi-criteria approach and assess the risk involved in a supply chain context, thus enabling decision makers to grasp the capabilities and resources that need to be deployed so as to successfully implement a green supply chain in the textile industry.

According to Zhu et al. (2008) and Srivastava (2007), the implementation of green initiatives in the industries can increase the rate of cost savings by reducing energy consumption and packaging waste management in times of rising input costs, with rising commodities and energy costs being a particular concern. Deploying a proper green initiatives or policies could create a competitive advantage for a firm. Nazam et al. (2015) proposed a new model for risk evaluation of warehouse operations by using FMEA and combined AHP-TOPSIS approaches under fuzzy environment. Samvedi et al. (2013) quantified risks in a supply chain through integration of fuzzy AHP and fuzzy TOPSIS in Indian firms. Wang et al. (2012) proposed a two-stage Fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain. It is therefore clear that just like any strategic policy change, implementing green initiatives consists of a certain degree of risk, and hence a proper risk assessment tool is needed in that context. While more pressures are emerging from stakeholders, investors, government bodies to prompt companies and the entire textile supply chain to adopt green supply chain practices. To the best of our knowledge, a little effort has been paid on assessing the risk involved in implementing various green initiatives for managerial assessment purposes.

Nowadays, there is an increased wakefulness and concern about implementing the environment friendly aspect in various facets by various stakeholders of the manufacturing firms. The members included in stakeholders are consumers, non-profitable organizations, government regulatory bodies, competitors, investors, shareholders, etc. Due to globalization and competitive market, the expectations of stakeholders have become a driving force for the organizations to consider the aspect of going environment friendly in several functions of the organizations. Based on these facts, supply chain is considered as one of the important areas for the adoption or implementation of the green aspects. According to the proposed framework of Adler (2006), the aspect of environmental consideration needs to be considered in the various activities including physical distribution and operations of organizations. To accomplish the environmental responsibilities at industrial standpoint, the perception of greening the supply chain or green supply chain (GSC), and green supply chain management (GSCM) has been evolved (Min and Kim, 2012). GSCM initiatives may be of great value to the firms, as well as to the external environment, and they generate economic benefits in long run Kumar et al. (2012).

Ashish et al. (2014) developed a framework in the context of traditional versus green supply chain management to select the green suppliers and further investigate how to overcome the barriers in green supply chain. According to Ruimin et al. (2012), every business activity in supply chain process consists of various objective risk factors and issues. The occurrence of the different risks disturbs various operations and processes of GSC, and declines the overall performance of the industries (Qianlei, 2012). Thereby, in order to effectively manage (GSC), the background of the risks in GSC is important to discuss. Therefore, to help industries, it is recommended to evaluate the risks for an effective understanding and implementation of GSC business practices.

The current research context focuses on (GSCM) initiatives evaluation by determining their priority or rank, which is a multi-criteria decision type problem. For this, the methodologies of fuzzy AHP and fuzzy TOPSIS have been used in this research. The AHP method is flexibility based decision tool used to analyze the multi-criteria problem (Saaty, 1980). However, the process of prioritizing the initiative is not simple as there is vagueness and uncertainty due to human perception.

To deal with this imprecision in the decision-making, it is suggested to use the fuzzy set theory to handle the ambiguities and uncertainties (Tseng, Lin, and Chiu, 2009). A fuzzy based analytic hierarchy process (AHP) approach, therefore proposed in this study, which is useful in prioritizing or ranking alternatives in (GSCM) under fuzzy environment (Chang et al. 2007 and Chan et al. 2008). To test the ranking obtained through the fuzzy AHP, the methodology of technique for order performance by similarity to ideal solution (TOPSIS) is applied. Besides, it enables the policy makers to understand the fuzzy logic for dominance of one criterion over the other for each pairwise comparison, which otherwise, remains opaque to the implementer as if using the AHP method. Although such evaluation may possibly differ for industry to industry, for that reason, we try to keep the proposed model as generic as possible to facilitate its utility in real-world cases.

The (GSCM) case example of a Pakistani textile manufacturing company, however, is discussed in the research that shows the usefulness and validity of the proposed fuzzy AHP and fuzzy TOPSIS evaluation model. The chosen case example company seeks to prioritize the (GSCM) initiatives; it also wants to understand the fuzzy logic between the criterions for each paired comparison that will improve its green supply chain success rate. Making such judgment, however, is never an easy task as there are many qualitative factors concerned with the decision-making process. In the literature, analytic hierarchy process (AHP) and the technique for order performance by similarity to ideal solution (TOPSIS) are a widely employed methodologies to facilitate this kind of process. The traditional AHP is unable to deal with another realistic concern:

uncertainty. Without uncertainty, one may argue that risk assessment is not necessary. Uncertainty is a particular issue in the textile industry since demand is highly volatile. In view of this, a decision model that couples AHP with fuzzy logic, which is used to incorporate uncertain variables into the proposed model, is developed in this paper.

The most relevant study was conducted by Sarmiento and Thomas (2010), who proposed an AHP framework for evaluating different green initiatives. However, the framework they proposed is highly stylized and without an illustrative example. Moreover, their approach does not consider the peculiarities of the textile industry or consider any uncertain parameters (it was a traditional AHP, not a fuzzy AHP-TOPSIS approach). This paper addressed this gap in the literature by extending the established combined fuzzy AHP-TOPSIS framework to the textile industry. In order to extend the model to the peculiarities of the textile industry, our proposed model incorporates criteria suggested by Chan and Chan (2010), details of which are structured in the Figure 3.

The rest of the paper is organized as follows: Section 2 presents the problem. Section 3 briefly explains the methodology, and Section 4 formulates the combined fuzzy AHP-TOPSIS framework, for risk assessment when implementing green supply chain initiatives. Then, an illustrative example is presented in Section 5 to demonstrate how the model works. Section 6 concludes this paper.

2. Problem statement

In recent years, the risk assessment of implementing green initiatives in the textile sector has drawn increased attention from both researchers and practitioners. The main reason for implementing these (GSCM) practices is that organizations can generate more business opportunities than their competitors if they can address environmental issues successfully. A greener product design may improve brand image and stimulate demand from green consumers Peattie (2001). Using environmental friendly raw materials and green production process address issues such as environmental material substitution, waste reduction and decreasing the consumption of hazardous and toxic materials (Vachon, 2007; Holt and Ghobadian, 2009). Zhu et al. (2008) supposed that the financial performance is the main driver for organizations which seek to implement green initiatives. Luthra et al. (2013) studied the relationship between the implementation of green supply chains and the economic performance and competitiveness of a sample of different Indian manufacturing industries.

In this problem, a Pakistani vertically integrated textile manufacturing company is chosen for this study. The case company has approximately 6000 employees per shift; they manufacture garments products such as sportswear, sleepwear, underwear and trousers. The company is one of the leaders in its product segment in Pakistan; its main customers are major national and international retailers. This company has enacted various changes in the structure of the final product in order to make it comfortable, free of harmful chemicals and toxic materials, and to lower its price by providing good quality. These changes, in turn, meet both environmental legislation regulations and the demands of their customers. The company has also dedicated itself to an analysis of the life cycle assessment (LCA) of the product. Life cycle assessment (LCA) covering all aspects about the implementation of green initiatives in the textile supply chains which conducts a return of inventory, consumption of raw materials, and waste generation, and this inventory allows the company to evaluate its own usage of such resources and to implement reduction practices.

This problem deals in achieving the following highlighted objectives:

(1) To identify and understand the concept of risks associated with the green supply chain (GSC) at industrial context in textile firms.
(2) To evaluate the identified criterion to priority by determining and confirming of their relative importance in effective adoption and implementation of (GSCM).
(3) To interpret the fuzzy logic for dominance of one criteria over the other for the formulation of each pairwise comparison using fuzzy AHP technique.

In Pakistan, according to the 2015 National Policy on Solid Waste, all companies in the textile sector are now required to take responsibility for their post-consumer products take-back and environmental impacts. Because of the Pakistani government's mandate, companies recognize that offering greener textile products not only meets customer demand but also requires locating good green suppliers to improve their supply chain management.

Because of this new context in Pakistan, the company's production planning and risk managers seek a way to identify and to select the alternative time which will support the company's adoption of (GSCM) practices. Major supply chain actors have been identified as candidates for case company. With this company's objectives in mind, the authors of this paper prepared a survey questionnaire and submitted it for content analysis to three experts. Then, we asked the opinion of three experts who work with the marketing context of (GSCM) in order to check their preferences when using (GSCM) practices to implement green raw materials. Fig. 2 shows the step-wise framework of this research and the development of solution methodology adopted in this work.

The adoption of (GSCM) initiatives will lead to better economic performance through enhanced environmental performance such as less waste, enhanced energy efficiency and an improved recyclability of the end product. At the same time, new green initiatives might require organizations to redesign and improve various aspects of their exiting processes in order to adopt these innovations successfully. It is essential for the organization to identify those areas at both the individual organization and supply chain levels that are least prepared to handle the green innovation successfully. Sarminento and Thomas (2010) proposed a multi-tier AHP framework to assess supply chain resources and capabilities for implementing green initiatives. Nevertheless, the hierarchical model in Sarminento and Thomas's research only focuses on four main criteria: manufacturing, purchasing, logistics, and marketing.

In this research, we proposed a more generic model in which organizations have the flexibility to incorporate both environmental and operational aspects and include more criteria and relevant sub-criteria referring to their business concerns. Within each main criterion, the relevant sub-criteria are identified. The alternatives at the bottom end of the hierarchy are the time windows by which an organization could successfully implement the selected green initiatives in the condition of the potential limitations in internal processes and resource.

3. Methodology

This section proposes a methodology for risk assessment of implementing green supply chain initiatives or policies in the textile sector. The methodology consists of three main stages as given in Figure 2. The first step requires the firm to come up with a comprehensive hierarchy of all the criteria which may affect the firm. This is done by thoroughly studying the considered chain and identifying potential loopholes. These are then analyzed for overlaps and categorized using similar characteristics. This exercise should be repeated whenever a major change is made in the chain. The second step in the process involves assigning weights to the criteria according to their importance. Fuzzy AHP is used for this purpose and expert views are taken as input. The third step involves determining the scores of different criteria by analyzing them under five different criteria; namely manufacturing, procurement, logistics, flexibility, and retailing. In the fourth step, fuzzy TOPSIS approach is employed to evaluate the organization's readiness of implementing green raw material. Finally, comparison of results and managerial implications has been discussed.

3.1 Fuzzy AHP

The fuzzy AHP methodology extends Saaty's AHP by combining it with fuzzy set theory. In fuzzy AHP, fuzzy ratio scales are used to indicate the relative strength of the factors in the corresponding criteria. Therefore, a fuzzy judgment matrix can be constructed. The final scores of alternatives are also represented by fuzzy numbers. The optimum alternative is obtained by ranking the fuzzy numbers using special algebraic operators. In this methodology, all elements in the judgment matrix and weight vectors are represented by triangular fuzzy numbers.

Using fuzzy numbers to indicate the relative importance of one risk type over the other, a fuzzy judgment vector is then obtained for each criterion. These judgment vectors form part of the fuzzy pairwise comparison matrix which is then used to determine the weight of each criterion. Table 1 shows the meaning of linguistic expressions in the form of fuzzy numbers and Table 2 shows the random consistency index to calculate the consistency ratio (CR). Fig. 1. represents the fuzzy membership function for linguistic expressions for criteria and sub-criteria. Experts are asked to give their assessment in the form of these linguistic expressions which are then converted and analyzed to finally get the weights. Chang's extent analysis method has been used for determining weights from pairwise comparisons.

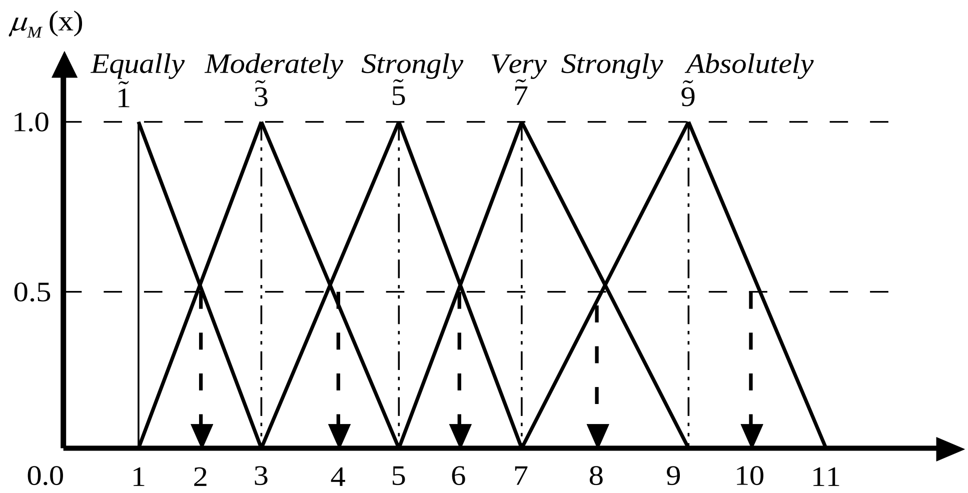

Figure 1. Fuzzy membership function for linguistic expressions for criteria and sub-criteria

Table 1. Scale for relative importance used in the pairwise comparison matrix.

Intensity of importance	Fuzzy number	Linguistic variables	Triangular fuzzy numbers (TFNs)	Reciprocal of TFNs
1	$\tilde{1}$	Equally important	(1, 1, 3)	(0.33, 1.00, 1.00)
3	$\tilde{3}$	Weekly important	(1, 3, 5)	(0.20, 0.33, 1.00)
5	$\tilde{5}$	Strongly important	(3, 5, 7)	(0.14, 0.20, 0.33)
7	$\tilde{7}$	Very strongly important	(5, 7, 9)	(0.11, 0.14, 0.20)
9	$\tilde{9}$	Extremely more important	(7, 9, 11)	(0.09, 0.11, 0.14)

Table 2. The random consistency index.

Size (n)	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

3.2 Fuzzy TOPSIS

Fuzzy set theory can be used to present linguistic value. For this reason, the fuzzy TOPSIS method is very suitable for solving real life application problems under a fuzzy environment. TOPSIS, one of the classical multi-criteria decision making methods was developed by Hwang and Yoon (1981). It is based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). TOPSIS also provides an easily understandable and programmable calculation procedure. It has the ability of taking various criteria with different units into account simultaneously (Buyukozkan and Cifci, 2012).

Fuzzy TOPSIS has been introduced for various multi-attribute decision-making problems. Yong (2006) used fuzzy TOPSIS for plant location selection and Chena et al. (2006) used fuzzy TOPSIS for supplier selection. Kahraman et al. (2007) utilized fuzzy TOPSIS for industrial robotic system selection. Ekmekcioglu et al. (2010) used a modified fuzzy TOPSIS to select municipal solid waste disposal method and site. Kutlu & Ekmekcioglu (2010) used fuzzy TOPSIS integrated with fuzzy AHP to propose a new FMEA failure modes & effects analysis' which overcomes the shortcomings of traditional FMEA. Kaya and Kahraman (2011) proposed a modified fuzzy TOPSIS for selection of the best energy technology alternative. Kim, Lee, Cho, and Kim (2011) used fuzzy TOPSIS for modeling consumer's product adoption process. Ertugrul, & Karakasoglu, (2008) conducted comparative analysis by using fuzzy AHP and TOPSIS methods for facility location selection.

Step 1: Choose the linguistic rating values for the alternative with respect to criteria

Let us assume there are m possible alternatives called $A = \{A_1, A_2 .....A_m\}$ which are to be valuated against the criteria, $C = \{C_1, C_2 .....C_n\}$. The criteria weights are denoted by $w_j = \{ j = 1, 2, ..., n\}$. The performance ratings of each expert $D_k\{k = 1, 2, ...K\}$ for each alternative $A_i\{i = 1, 2, ..., m\}$ with respect to criteria $C_j\{ j = 1, 2, ..., \text{n}\}$ are denoted by membership function. The scale used for solutions rating is given in linguistic variable table.

Table 3. Fuzzy evaluation scores for alternative.

Linguistic variables	Corresponding TFNs
Very poor (VP)	(1, 1, 3)
Poor (P)	(1, 3, 5)
Medium (M)	(3, 5, 7)
Good (G)	(5, 7, 9)
Very good (VG)	(7, 9, 11)

Step 2: Calculate aggregate fuzzy ratings for the alternatives

If the fuzzy ratings of all experts are described as TFN $\tilde{R}_k = (a_k, b_k, c_k),\ k = 1, 2, ..., K$ then the aggregated fuzzy rating is given by $\tilde{R} = (a, b, c)\ \ k = 1, 2, ..., K$ where

$$a = \min_k \{a_k\},\quad b = \frac{1}{K}\sum_{k=1}^{K} b_k,\quad c = \max_k \{c_k\} \tag{1}$$

If the fuzzy rating of the *k*th decision maker are $\tilde{X}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk}), \mathrm{i} = 1, 2, ...\mathrm{m}, \mathrm{j} = 1, 2, .., \mathrm{n}$ then the aggregated fuzzy ratings $\tilde{X}_{ij}$ of alternatives with respect to each criteria are given by $\tilde{X}_{ij}(a_{ij}, b_{ij}, c_{ij}),$ where

$$a_{ij} = \min_k \{a_{ijk}\},\quad b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ijk},\quad c = \max_k \{c_{ijk}\} \tag{2}$$

Step 3: Construct the fuzzy decision matrix
The fuzzy decision matrix for the alternatives $(\tilde{D})$ is constructed as follows:

$$\tilde{D} = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix} \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & .. & .. & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & .. & .. & \tilde{x}_{2n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ \tilde{x}_{m1} & \tilde{x}_{m2} & & & x_{mn} \end{bmatrix} \quad i = 1, 2, ..., m;\quad j = 1, 2, ..., n \tag{3}$$

Step 4: Construct the Normalize fuzzy decision matrix

The raw data are normalized using linear scale transformation to bring the various criteria scales into a comparable scale. The normalized fuzzy decision matrix $\tilde{R}$ is given by:

$$\tilde{R} = \left[r_{ij} \right]_{m\times n,}\quad i = 1, 2, ..., m;\quad j = 1, 2, ..., n, \tag{4}$$

Where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \quad and \quad c_j^* = \max_i c_{ij} \text{(benefit criteria)} \tag{5}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right) \quad and \quad a_j^- = \min_i a_{ij} \text{ (cost criteria)} \tag{6}$$

Step 5: Construct the weighted normalized matrix

The weighted normalized matrix (w_j) for criteria is computed by multiplying the weights (w_j) of evaluation criteria with the normalized fuzzy decision matrix $\tilde{r}_{ij}$.

$$\tilde{V} = \left[v_{ij} \right]_{m \times n,} \quad i = 1, 2, ..., \text{m; j} = 1, 2, ..., \text{n where } \tilde{\text{v}}_{ij} = \tilde{r}_{ij} (.) W_j \tag{7}$$

Note that $\tilde{v}_{ij}$ is a TFN represented by $\left(\tilde{a}_{ijk}, \tilde{b}_{ijk}, \tilde{c}_{ijk} \right)$

Step 6: Determine the fuzzy ideal solution (FPIS) and fuzzy negative ideal solution (FNIS)

The FPIS and FNIS of the alternatives is computed as follows:

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_n^* \right) \quad where \quad \tilde{v}_j^* = \left(\tilde{c}_j^*, \tilde{c}_j^*, \tilde{c}_j^* \right) \qquad \tilde{c}_j^* = \max_i \left\{ \tilde{c}_{ij} \right\} \tag{8}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^- \right) \quad where \quad \tilde{v}_j^- = \left(\tilde{a}_j^-, \tilde{a}_j^-, \tilde{a}_j^- \right) \quad a_j^- = \min_i \left\{ \tilde{a}_{ij} \right\} \tag{9}$$

i = 1,2,…,m; j=1,2,…,n

Step 7: Calculate the distance of each alternative from FPIS and FNIS

The distance $\left(d_i^+, d_i^- \right)$ of each weighted alternative i = 1, 2, ... , m from the FPIS and the FNIS is computed as follows:

$$d_i^+ = \sum_{j=1}^{n} dv \left(\tilde{v}_{ij,} \tilde{v}_j^* \right), \quad i = 1, 2, ..., \text{m} \tag{10}$$

$$d_i^- = \sum_{j=1}^{n} dv \left(\tilde{v}_{ij,} \tilde{v}_j^- \right), \quad i = 1, 2, ..., m \tag{11}$$

Step 8: Calculate the closeness coefficient CC_i of each alternative

The closeness coefficient CC_i represents the distances to the fuzzy positive ideal solution (A^*) and the fuzzy negative ideal solution (A^-) simultaneously. The closeness coefficient of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{12}$$

Step 9: Rank the alternatives

In step 9, the different alternatives are ranked or chosen according to the maximum closeness coefficient CC_i values in decreasing order.

4. Proposed hybrid fuzzy AHP-TOPSIS framework

The textile industry is highly diverse and heterogeneous due to various complex processes. In these days, the textile industry has experienced a great deal of dynamic change with global sourcing and rising of price competition. Therefore, the exceptional features to garment products such as short product life cycle, high volatility, less predictability and a level of impulse purchase add further uncertainty for those organizations want to green their supply chain operations. Keeping in view this background, we proposed the hybrid fuzzy AHP-TOPSIS approach for the risk assessment of green supply chain implementation in textiles sector which has the following five phases.

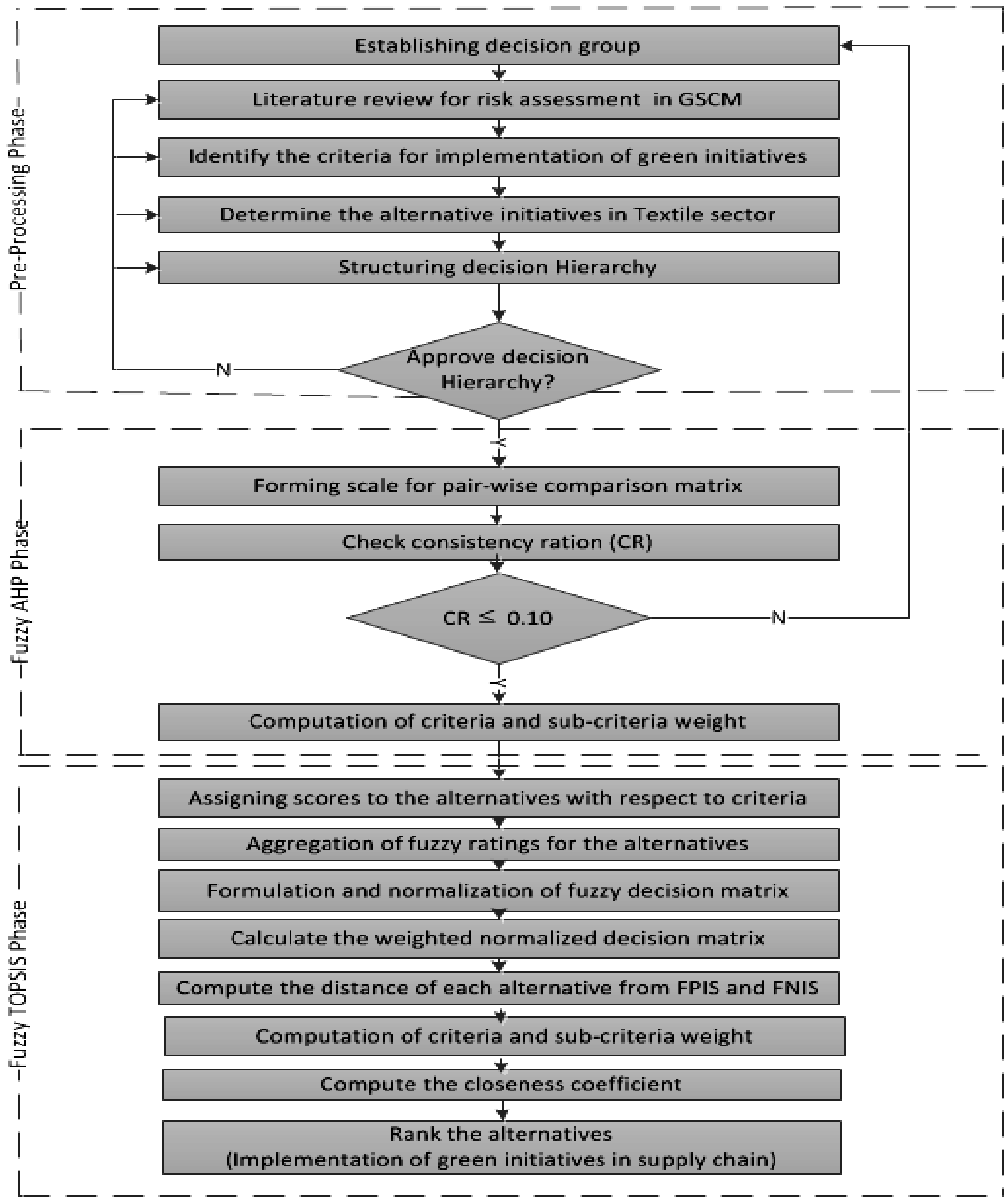

Figure 2. Proposed hybrid fuzzy AHP-TOPSIS framework for implementing GSCM initiatives

Phase 1: Identification of risks and implementation of green initiatives in supply chain

In the first phase, a decision group of expert panel which is comprised of planning, production and logistics managers are formed for the risk identification and evaluation while implementing the green initiatives in the supply chain. Then the criterion of (GSCM) initiative implementation in supply chain are determined through literature review and these experts opinion. Following the determination of criterion, another expert panel is formed for evaluation of solutions of (GSCM) implementation in supply chain. The expert panel is comprised of risk management and supply chain experts. Then the hierarchy structure is formed such that the objective is at the first level, main criterion in the second level, sub criterion at third level, and alternative initiatives solutions are in the fourth level.

Phase 2: Calculation of the criteria weight by using fuzzy AHP

After forming a decision hierarchy, the weights of the criteria of (GSCM) initiative in supply chain will be calculated by fuzzy AHP. Pairwise comparison matrices of expert's evaluations are constructed to acquire criteria weights by using the scale in Table 1-2. Computing arithmetic mean of the values found from their evaluation, the final evaluation matrix will be established. From this matrix, the weight of the criterion will be calculated as described in previous section.

Phase 3: Evaluation of the solutions of green supply chain management initiatives

The five alternative implementation time windows in Fig. 3 were evaluated with respect to detailed sub-criteria in terms of the readiness of implementing green raw material. Decision makers can provide a precise numerical value or a linguistic term to express their opinions. The qualitative explanation of rating level and its corresponding triangular fuzzy numbers is described in Table 3. The linguistics terms were then converted into triangular fuzzy numbers to formulate the fuzzy evaluation matrix.

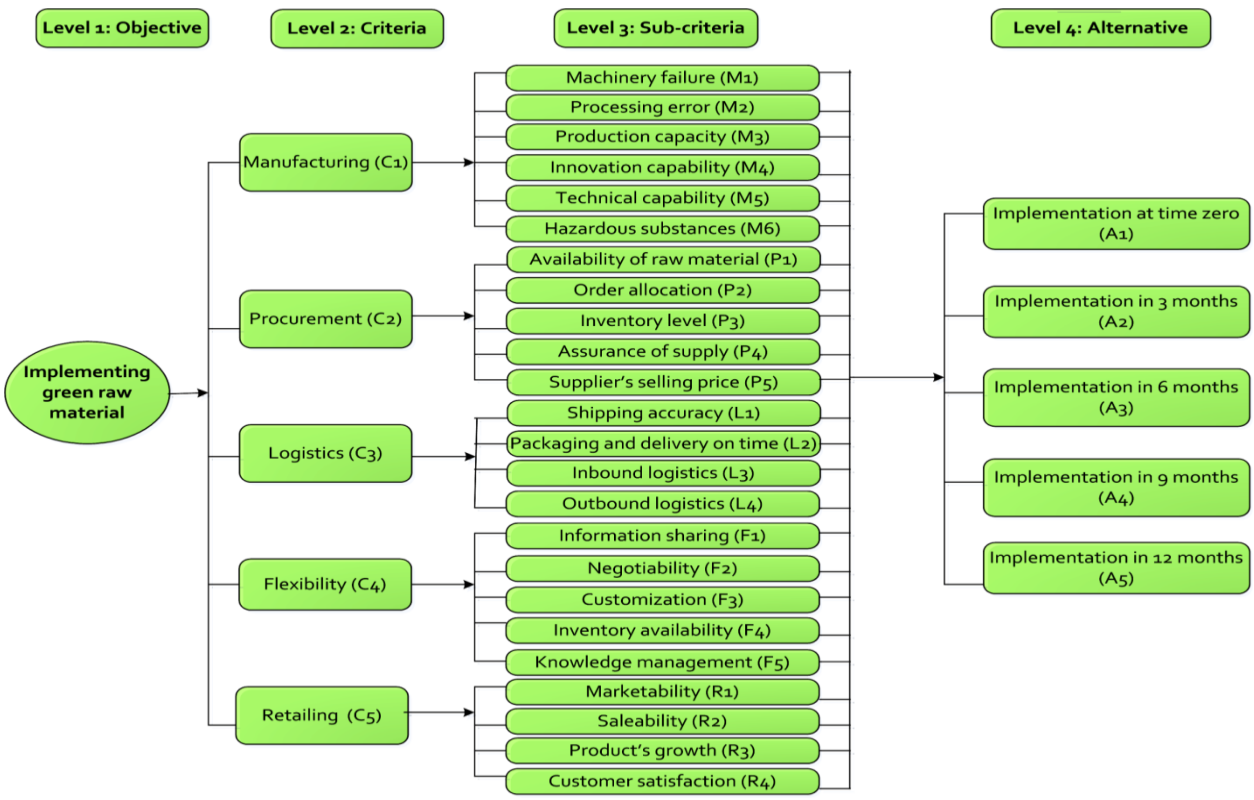

Figure 3. Decision hierarchy for the implementation of GSCM initiatives for five timescales.

Phase 4: Determination of final rank by fuzzy TOPSIS

Ranking the solutions of (GSCM) initiative in supply chain to overcome the risk will be determined by using fuzzy TOPSIS. The rating of solutions towards the criterion will be done by linguistic scale, which is shown in Table 3. Ranking of solutions will be finalized according to CC_i values calculated by fuzzy TOPSIS in descending order.

Phase 5: Comparison of results and managerial implications

In this section, a detailed comparative analysis of all alternative initiatives with respect to criterion and sub-criterion is conducted. In order to solve the problems of implementing green raw material, the experts suggest some valuable suggestions to assess the risk of the case company in high-risk supply chain environment. At the end of this paper, the experts suggested that (GSCM) is not limited to the green environment friendly technical aspects) but also on the non-environmental criteria. The decision-makers can be able to capture a fairly complete picture of the context of GSCM implementation through the assessment process which can pave the way to improve the productivity and sustain the competitive advantages.

5. Application of the proposed framework

The proposed framework is used to rank the solutions of (GSCM) initiatives in supply chain to overcome its risks. The application is based on five phases provided in previous section and explained with numerical results as follows.

5.1. Case presentation

Nowadays, more and more Pakistani organizations realize that risk management plays an important role in business success and that implementing green initiatives in supply chain is becoming a core activity. Few organizations have implemented green materials practices in integration with supply chain. But the success rate is very less due to risk of implementing green initiative in supply chain. To improve the success rate, it is essential to assess the risks and solutions to overcome them. It is difficult to implement all initiatives at the same time. Hence it is essential to prioritize these solutions of implementing green raw material in supply chain, hence, Pakistani organizations can concentrate on the high rank solutions and implement them in a stepwise manner.

5.2. Case analysis

Phase 1: Identification of risks and implementation of green initiatives in supply chain

The decision group is composed of the 3 expert panel which is comprised of planning manager, production manager, and logistics manager. In this study, through the panel discussion, the detailed sub-criteria under five main criteria (manufacturing, procurement, logistics, flexibility, and retailing) were identified. The results are illustrated in Fig. 3, in which the hierarchy is descended from the general criteria in the second level to more detailed sub-criteria.

There are four levels in decision hierarchy structure for this problem. The overall goal of decision process determined as “implementing green raw material in supply chain to assess its risks” is in the first level of hierarchy. The main criteria are on the second level, the sub-criteria at third level, and alternative windows time scale solutions in the fourth level of hierarchy (See Fig 3).

Phase 2: Calculation of the criteria weight by using fuzzy AHP

In this phase, the decision group is asked to make pair wise (pairwise) comparisons of five main criterion and 24 sub criterion by using linguistic variables by using Table 1-2. The arithmetic mean of these values is computed to obtain the pairwise comparison matrices of criteria and sub-criteria are given in Tables 4–9. The results obtained from the calculations based on pairwise comparison matrices provided in Table 4–9 are presented in Table 10. CR values of all the matrices are less than 0.1, hence these matrices are consistent.

Table 4. Pairwise comparison matrix of the major criterion.

	C_1	C_2	C_3	C_4	C_5
C_1	1	0.14	0.33	0.33	0.14
C_2	7	1	7	5	3
C_3	3	0.14	1	0.33	0.2
C_4	3	0.2	3	1	0.33
C_5	7	0.33	5	3	1

Table 5. Pairwise comparison matrix of the sub-criteria with respect to manufacturing criteria.

	M_1	M_2	M_3	M_4	M_5	M_6
M_1	1	3	3	0.33	0.33	0.33
M_2	0.33	1	0.33	0.11	0.14	0.14
M_3	0.33	3	1	0.14	0.33	0.33
M_4	3	9	7	1	3	3
M_5	3	7	3	0.33	1	0.33
M_6	3	7	3	0.33	3	1

Table 6. Pairwise comparison matrix of the sub-criteria with respect to procurement criteria.

	P_1	P_2	P_3	P_4	P_5
P_1	1	3	9	5	9
P_2	0.33	1	5	3	9
P_3	0.11	0.20	1	0.33	3
P_4	0.20	0.33	3	1	7
P_5	0.11	0.11	0.33	0.14	1

Table 7. Pairwise comparison matrix of the sub-criteria with respect to logistics criteria.

	L_1	L_2	L_3	L_4
L_1	1	0.14	0.14	0.11
L_2	7	1	1	0.33
L_3	7	1	1	0.33
L_4	9	3	3	1

Table 8. Pairwise comparison matrix of the sub-criteria with respect to flexibility criteria.

	F_1	F_2	F_3	F_4	F_5
F_1	1	3	7	3	7
F_2	0.33	1	7	3	3
F_3	0.14	0.14	1	0.33	0.33
F_4	0.33	0.33	3	1	3
F_5	0.14	0.33	3	0.33	1

Table 9. Pairwise comparison matrix of the sub-criteria with respect to retailing criteria.

	R_1	R_2	R_3	R_4
R_1	1	0.11	0.11	0.14
R_2	9	1	1	0.33
R_3	9	1	1	0.33
R_4	7	3	3	1

Table 10. Weights of criteria and sub-criteria for implementation of GSCM initiatives.

Major criterion	Major criterion weight	Sub-criteria	Consistency ratio (CR)	Ratio weight	Final weight	Ranking
Manufacturing	0.0392	**M1**	0.0830	0.0986	0.0039	21
		M2		0.0296	0.0012	24
		M3		0.0592	0.0023	23
		M4		0.4114	0.0161	12
		M5		0.1641	0.0064	19
		M6		0.2399	0.0094	17
Procurement	0.5020	**P1**	0.0995	0.5153	0.2587	1
		P2		0.2660	0.1335	3
		P3		0.0579	0.0291	10
		P4		0.0579	0.0291	10
		P5		0.0278	0.0140	15
Logistics	0.0655	**L1**	0.0502	0.0379	0.0025	22
		L2		0.2170	0.0142	14
		L3		0.2190	0.0143	13
		L4		0.5281	0.0346	8
Flexibility	0.1208	**F1**	0.0529	0.4799	0.0580	7
		F2		0.2605	0.0315	9
		F3		0.0415	0.0050	20
		F4		0.1414	0.0171	11
		F5		0.0766	0.0093	18
Retailing	0.2725	**R1**	0.0989	0.0359	0.0098	16
		R2		0.2325	0.0634	6
		R3		0.2450	0.0668	4
		R4		0.4990	0.1360	2

Phase 3: Evaluation of the solutions of green supply chain management initiatives (GSCM)

The expert panel members were asked to construct a fuzzy evaluation matrix by using linguistic variables presented in Table 3. It is established by comparing solutions under each of the criterion separately (See Table 11). Then they converted linguistic terms into corresponding TFN and constructed the fuzzy evaluation matrix (See Table 12). Aggregate fuzzy weights of the alternatives are computed using Eq. (2) and presented in Table 13. In this study, all the criteria are the risks of implementing green initiatives in supply chain, as per the goal minimization of these risks is required. Hence, all the risks are termed as cost criteria and normalization performed by Eq. (6) and for further detail (See Table14). The next step is to obtain a fuzzy weighted evaluation matrix. Using the criteria weight calculated by fuzzy AHP (See Table 10), the weighted evaluation matrix is established using the Eq. (7), which is shown in Table 15.

Table 11. Linguistic scale evaluation matrix for the implementation of GSCM initiatives.

Sub-criterion	M_1			M_2			….	….	R_1			R_2		
Experts	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**	….	….	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**
Alternatives A_1	VP	P	VP	G	P	P	….	….	M	VP	VG	VP	VP	M
A_2	M	VP	M	P	M	VG	….	….	G	P	P	P	P	VG
A_3	G	VG	M	VP	P	G	….	….	P	VP	M	G	VP	M
A_4	P	M	VP	P	M	VP	….	….	VP	P	VG	P	P	VP
A_5	M	G	P	P	VP	M	….	….	P	M	M	VP	G	P

Table 12. Fuzzy evaluation matrix for the implementation of GSCM initiatives.

	M_1			M_2			….	R_1			R_2		
	E1	**E2**	**E3**	**E1**	**E2**	**E3**	….	**E1**	**E2**	**E3**	**E1**	**E2**	**E3**
A_1	(1,1,3)	(1,3,5)	(1,1,3)	(5,7,9)	(1,3,5)	(1,3,5)	….	(3,5,7)	(1,1,3)	(7,9,11)	(1,1,3)	(1,1,3)	(3,5,7)
A_2	(3,5,7)	(1,1,3)	(3,5,7)	(1,3,5)	(3,5,7)	(7,9,11)	….	(5,7,9)	(1,3,5)	(1,3,5)	(1,3,5)	(1,3,5)	(7,9,11)
A_3	(5,7,9)	(7,9,11)	(3,5,7)	(1,1,3)	(1,3,5)	(5,7,9)	….	(1,3,5)	(1,1,3)	(3,5,7)	(5,7,9)	(1,1,3)	(3,5,7)
A_4	(1,3,5)	(3,5,7)	(1,1,3)	(1,3,5)	(3,5,7)	(1,1,3)	….	(1,1,3)	(1,3,5)	(7,9,11)	(1,3,5)	(1,3,5)	(1,1,3)
A_5	(3,5,7)	(5,7,9)	(1,3,5)	(1,3,5)	(1,1,3)	(3,5,7)	….	(1,3,5)	(3,5,7)	(3,5,7)	(1,1,3)	(5,7,9)	(1,3,5)

Table 13. Aggregate fuzzy decision matrix for the implementation of GSCM initiatives.

	M_1	M_2	……….	……….	R_1	R_2
A_1	(1.00,1.67,5.00)	(1.00,4.33,9.00)	……….	……….	(1.00,5.00,11.0)	(1.00,2.33,7.00)
A_2	(1.00,3.67,7.00)	(1.00,5.66,11.0)	……….	……….	(1.00,4.33,9.00)	(1.00,5.00,11.0)
A_3	(3.00,7.00,11.0)	(1.00,3.66,9.00)	……….	……….	(1.00,3.00,7.00)	(1.00,4.33,9.00)
A_4	(1.00,3.00,7.00)	(1.00,3.00,7.00)	……….	……….	(1.00,4.33,11.0)	(1.00,2.33,5.00)
A_5	(1.00,5.00,9.00)	(1.00,3.00,7.00)	……….	……….	(1.00,4.33,7.00)	(1.00,3.66,9.00)

Table 14. Normalized fuzzy decision matrix for the implementation of GSCM initiatives.

	M_1	M_2	……….	……….	R_1	R_2
A_1	(0.20,0.60,1.00)	(0.11,0.23,1.00)	……….	……….	(0.09,0.20,1.00)	(0.14,0.42,1.00)
A_2	(0.14,0.27,1.00)	(0.09,0.17,1.00)	……….	……….	(0.11,0.23,1.00)	(0.09,0.20,1.00)
A_3	(0.09,0.14,0.33)	(0.11,0.27,1.00)	……….	……….	(0.14,0.33,1.00)	(0.11,0.23,1.00)
A_4	(0.14,0.33,0.10)	(0.14,0.33,1.00)	……….	……….	(0.09,0.23,1.00)	(0.23,0.42,1.00)
A_5	(0.11,0.20,1.00)	(0.14,0.33,1.00)	……….	……….	(0.14,0.23,1.00)	(0.11,0.27,1.00)

Table 15. Weighted normalized fuzzy decision matrix for the implementation of GSCM initiatives.

	M_1	M_2	…..	R_1	R_2
A_1	(0.0008,0.0023,0.0039)	(0.0001,0.0003,0.0012)	…..	(0.0009,0.0020,0.0098)	(0.0091,0.0272,0.0634)
A_2	(0.0006,0.0011,0.0039)	(0.0001,0.0002,0.0012)	…..	(0.0011,0.0023,0.0098)	(0.0058,0.0127,0.0634)
A_3	(0.0004,0.0006,0.0013)	((0.0001,0.0003,0.0012)	…..	(0.0014,0.0033,0.0098)	(0.0070,0.0146,0.0634)
A_4	(0.0006,0.0013,0.0039)	(0.0002,0.0004,0.0012)	…..	(0.0009,0.0023,0.0098)	(0.0127,0.0272,0.0634)
A_5	(0.0004,0.0008,0.0039)	(0.0002,0.0004,0.0012)	…..	(0.0014,0.0023,0.0098)	(0.0070,0.0173,0.0634)

Phase 4: Determination of final rank by fuzzy TOPSIS

In this study, all the sub-criteria are the cost criteria. Hence, fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) as $\tilde{v}^* = (0,0,0)$ and $\tilde{v}^- = (1,1,1)$ for all these sub-criterion. Then compute the distance d_v of each alternative form FPIS $\left(A^*\right)$ and FNIS $\left(A^-\right)$

using the Eqs. (10), (11). For example, the distance $d_v\left(A_1, A^*\right)$ and $d_v\left(A_1, A^-\right)$ for alternative A_1 and sub-criteria M_1 from FPIS $\left(A^*\right)$ and FNIS $\left(A^-\right)$, are calculated as follows.

$$d\left(A_1, A^*\right) = \sqrt{\frac{1}{3}(0-0.0008)^2 + (0-0.0023)^2 + (0-0.0039)^2}$$

$$d\left(A_1, A^*\right) = 0.00264$$

$$d\left(A_1, A^-\right) = \sqrt{\frac{1}{3}(1-0.0008)^2 + (1-0.0023)^2 + (1-0.0039)^2}$$

$$d\left(A_1, A^-\right) = 0.99768$$

Similarly, calculations are done for other sub-criterion for solutions of alternative A_1 and the cumulative distances of d_i^+ and d_i^- as $d_i^+ = 0.4725$ and $d_i^- = 23.6246$ are computed. By using the Eq. (12), the closeness coefficient *(CC_i)* of alternative A_1 is computed as follows.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} = \frac{23.6246}{23.6246 + 0.4725} = 0.98039$$

The same procedure can be adopted to compute the distances and $\left(CC_i\right)$ values of remaining alternatives. The final results are summarized in Table 16. Based on $\left(CC_i\right)$ values rank the alternatives in descending order.

Table 16. Fuzzy TOPSIS results and final ranking for the implementation of GSCM initiatives.

Alternatives	d_i^+	d_i^-	CC_i	Rank
A_1	0.4725	23.6246	0.98039	2
A_2	0.5560	23.3963	0.97679	4
A_3	0.4461	23.6477	0.98148	1
A_4	0.5985	23.5331	0.97520	5
A_5	0.5494	23.1490	0.97682	3

Phase 5: Comparison of results and managerial implications

In this section, the results derived for the proposed hybrid AHP-TOPSIS framework show that A_3 has the highest coefficient closeness value, therefore implementation of green raw material in 6 months among the five alternative time windows should be recommended. Therefore, based on the (CC_i) values, the ranking of alternatives in descending order are A_3, A_1, A_5, A_2 and A_4. It is very difficult for the case company to implement green raw material at time zero or just now because a lot of potential gaps exist in capability and resources of supply chain. For instance, marketing-wise, the case company will generate more business opportunities if green new material can be implemented at time zero since few competitors have already launched a similar green initiative. The implementation will not only improve the company’s environmental performance, but also enhance the brand image in the market. Logistics-wise, it also brings a substantial amount of uncertainty as it requires potential adjustments in internal and external operations which may increase the risk of experiencing adverse events across the supply chain. However, manufacturing-wise, the company is less prepared in terms of manufacturing processes, production capacity and technical and innovation capabilities in implementing green new material at the moment. Such a movement requires alterations in their internal and external operations and, as a result, it may compromise the operations performance.

In fact, the company will be better positioned from the manufacturing perspective if implemented in 12-month time. The ideal solution is to implement the initiatives in 6-month time by which the company will still have the marketing advantages over its competitors while its operational resources are better prepared than now. It could be reflected in the further analysis of weighted performance ratings of five implementation time windows with respect to individual sub-criteria. The final results of all alternatives are described in Fig. 4. It does not indicate the important alternative ranking for implementing green initiatives, but also suggests the areas that the company is less prepared to handle the new requirements brought by the new (GSCM) initiative. Therefore, prompt actions and necessary modifications should be deployed to address these issues before the green initiative can be fully implemented.

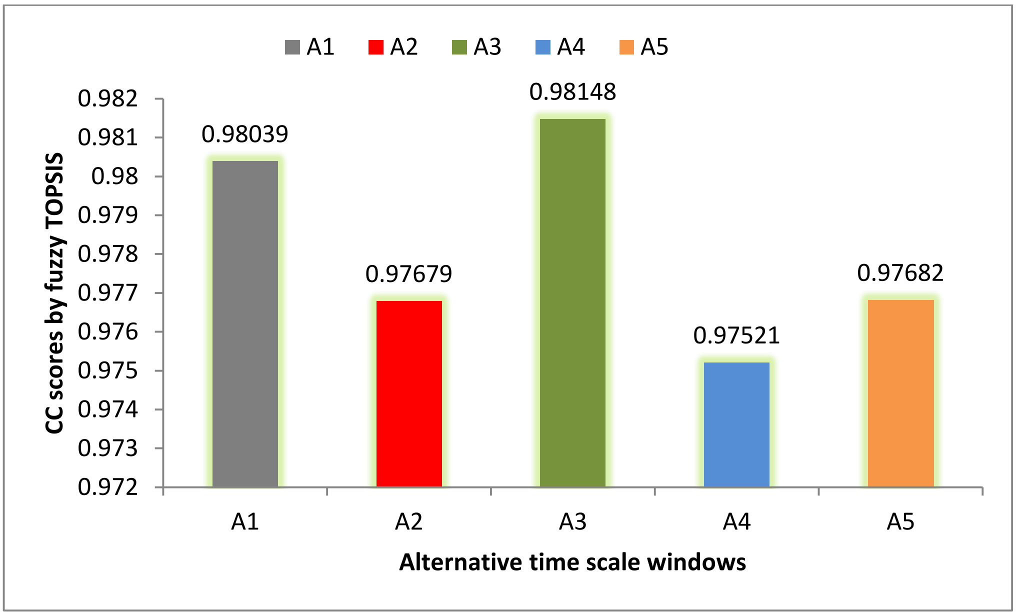

Figure 4. Closeness coefficient and final ranking of the alternative time windows

Based on the result analysis, the case study demonstrated that (GSCM) is not only limited to the green technical aspects, but also on the non-environment criteria. In this way, the managers and decision-makers are able to understand and capture a complete picture of the context of (GSCM) implementation through the risk assessment process. The proposed approach is useful for reviewing (GSCM) development, which can lead to improving productivity and sustaining the competitive advantages. The proposed hybrid fuzzy AHP-TOPSIS framework provides a practical decision support tool for (GSCM) implementation since it seeks to take explicit account of multi-criteria in aiding the decision making, and compares and ranks (GSCM) alternatives in indicator basis and as a system. The proposed model can be used for identifying improvement areas when implementing (GSCM) initiatives within the firm’s operational conditions. In this article, we presented the case study of a textile retail chain, the proposed approach can also be used by the firms in other industry sectors as it can be slightly modified and refined by set relevant criteria to their organization in order to implement it successfully.

6. Conclusions and future research

In this article, we formulated the fuzzy AHP-TOPSIS framework for the implementation of a new green initiative which could generate competitive advantages for the case company. It is also a risky process involving uncertainty and vagueness. The success rate of initiatives implementation in supply chain is relatively low due to its risks. Therefore, in order to minimize these risks and uncertainties, the companies should focus to assess their new green initiatives cautiously and evaluate the improvement areas when implementing green initiatives. It is difficult to implement all the solutions at the same time due to various constraints, therefore ranking the solutions is essential in stepwise implementation of these solutions. We used fuzzy AHP to calculate the weights of all criteria and sub-criteria, while fuzzy TOPSIS is utilized to rank the alternative time scale windows. The weights obtained from fuzzy AHP are included in fuzzy TOPSIS computations and the solution priorities are determined.

The illustrative industrial case study is presented to demonstrate the applicability of the proposed framework. The proposed method successfully extends the TOPSIS method by applying both linguistic variables and a fuzzy aggregation method which effectively avoids vague and imprecise judgments. From a practical point of view, the illustrative example of the textile retail chain helps the researchers and practitioners understand the importance of conducting appropriate risk assessment when implementing (GSCM) initiatives. A comparative analysis of alternatives with respect to criterion was performed to discuss and explain the results. The result shows that the proposed model is practical for ranking solutions of (GSCM) initiatives implementation in supply chain to overcome its risks. This proposed scientific framework gives a new valid and reliable approach prioritizing the solutions of green initiatives implementation in supply chain to assess its risks. It is the main contribution of this study in literature.

In the future, the researchers and practitioners can compare the results of this study with other fuzzy multi-objective and multi-criteria techniques such as fuzzy VIKOR, fuzzy ELECTRE, and fuzzy PROMETHEE. Additionally, the proposed hybrid fuzzy AHP and TOPSIS based evaluation model could be extended to any other organization that wants to reduce disruptions in their green supply chain (GSC) functioning due to various associated risk under fuzzy environment. The judgment of experts, however, may vary with regard to industry type, priorities, resources, etc.

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