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Supplier Selection for the Adoption of Green Innovation in Sustainable Supply Chain Management Practices: A Case of the Chinese Textile Manufacturing Industry

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Abstract: Globally, increasing environmental issues are gaining attention to facilitate the adoption of green innovation for sustainable supply chain management (SSCM). Sustainable environmental practices have been well-considered in the literature; however, no study has focused on adopting green innovation practices for sustainable development. Thus, environmental management authorities are putting pressure on industries to implement green innovation criteria for SSCM operations. Moreover, it is important to select traditional suppliers to transform its practices to that of sustainable supply chains in order to achieve the industry's sustainable supply chain goals. In response, this research identified and analyzed the green innovation criteria for SSCM and then selected a supplier that could implement green aspects in the SSCM. This study developed an integrated multi-criteria decision making (MCDM) model using the fuzzy analytical hierarchy process (FAHP) and the fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS). The objective of this study was to analyze suppliers to implement green innovation criteria for SSCM practices in the textile manufacturing companies of China. This study reviewed and identified three green innovation criteria and seventeen sub-criteria. Then, the FAHP technique was employed to analyze and rank green innovation criteria and sub-criteria. Finally, the FTOPSIS method was used to investigate and rank eight suppliers. The findings of the FAHP indicated that economic (EC) criteria were the most vital green innovation criteria in the SSCM. Furthermore, the FTOPSIS results revealed that supplier 5 was the most suitable supplier for implementing green innovation criteria in the SSCM. These findings will help managers, practitioners, and policymakers implement green innovation criteria in sustainable manufacturing supply chains.

Keywords: supplier selection; green innovation; sustainable supply chain management; manufacturing industry; MCDM; FAHP; FTOPSIS

1. Introduction

Green innovation has become a familiar and popular topic of interest throughout the world due to increasing environmental concerns [1]. Furthermore, increasing population, globalization, urbanization, and industrialization have presented numerous problems, such as damage to the environment, economy, and living conditions of society [2]. Sustainable supply chain management (SSCM) practices can help industries reduce their environmental issues and increase sustainable activities by making them obligated to consider green innovation aspects. The concept of green innovation is appearing in many industries because of growing public awareness, market pressure, stringent governmental policies, and environmental practitioners who seek to integrate sustainability into their own supply chain operations [3]. In this regard, various industrial sectors, such as those of agriculture, manufacturing, mining, and construction, are applying green innovation practices to SSCM [4,5]. Industries are keenly responsible for their supply chain operations since they are significant contributors to polluting the environment. Thus, to prevent such hazardous environmental practices, industries should apply more eco-standards and regulations for adopting green innovation and sustainable supply chain operations [6].

Sustainable innovation mainly relies on three criteria: economic, environmental, and social [7]. These terms can be defined as the industrial supply chain practices needed to increase profit, reduce negative eco impacts, and enhance social well-being [8]. Moreover, the manufacturing sector's production process is considered to be very complex, as it involves many phases [9]. However, many practitioners have criticized this industry due to its unfriendly supply chain practices. Consequently, the manufacturing sector faces high pressure from environmental regulatory bodies, industrial managers, governments, and policymakers to implement sustainable innovation processes in its supply chain management [10]. In this context, it is important for industries to transform their current supply chains into sustainable supply chain operations. This will lead to fewer adverse impacts on the environment via sustainable supply chain practices [11]. The successful adoption of green innovation aspects can assist manufacturing companies in ameliorating their operational and production losses through SSCM practices [12]. Asian countries like China, Bangladesh, Vietnam, and India are producing a large number of textile products; however, few are concerned about eco-friendly supply chain operations.

The present research targeted eight textile manufacturing companies in China due to their vast supply chain operations and future growth potential [13]. Notably, the manufacturing sector is one of the leading sectors in the country, and it provided almost 29.41% of China's total GDP in 2018 [14]. The production value of the textile manufacturing industry comprised 7% of China's GDP in 2015 [15]. Furthermore, the country's manufacturing sector is considered the pillar for the national economy and is ranked as the third-largest manufacturing market in the world [16]. However, further industrial practices and technological improvements are needed for sustainable supply chain operations. This will increase future production potential with more investments because traditional supply chains are affecting the environment [17]. Sustainable supply chain practices, along with green innovation, can help industries grow in the competitive market for sustainable economic, environmental, and social development [18]. This study investigated a relevant decision framework by introducing green innovation criteria into the sustainable supply chain practices of the industry. The objective of this research was to identify green innovation criteria to develop an integrated decision model for SSCM practices in the context of Chinese manufacturing companies. Then, this study identified and evaluated how traditional suppliers of raw materials and products can adopt green innovation in the SSCM. Theoretical background information is also provided for a better understanding of the aim of the current study, i.e., green innovation implementation into sustainable supply chains of the manufacturing industry. To accomplish the aims of this study, we reviewed the most relevant studies on green innovation and SSCM practices. From the literature, we identified and finalized the green innovation criteria and sub-criteria for SSCM practices. These identified green innovation criteria were then assessed by experts. Finally, we selected a supplier that could implement these green innovation criteria into the SSCM practices of the manufacturing industry.

Selecting a significant supplier is a very crucial problem because this industry completely relies on the supplier to implement green practices in the SSCM. Moreover, the selection of a supplier for the adoption of green innovation criteria in the SSCM of the manufacturing industry remains a crucial problem since it involves numerous uncertainties and complexities. Thus, in this research, we developed a decision methodology that can enable industries to analyze green innovation criteria for SSCM and prioritize the supplier for green practices. This study used the fuzzy analytical hierarchy process (FAHP) and fuzzy technique for order of preference by similarity to ideal solution

(FTOPSIS) approaches to analyze and prioritize sustainable suppliers based on green innovation criteria. This research contributes to the state of the art in two ways. First, this study's FAHP method evaluates and ranks the green innovation criteria framework for SSCM in the manufacturing industry. The employed the FTOPSIS approach to investigate and rank suitable suppliers based on green innovation criteria for implementing SSCM practices. These proposed FAHP and FTOPSIS are novel multi-criteria decision making (MCDM) methods for examining decision making problems. We applied the proposed decision methodology using empirical data in the context of the manufacturing industry in China.

The rest of this paper is organized as follows: Section 2 provides the theoretical background. Section 3 presents the research methodology of the study. Section 4 shows the results and discussion. Finally, Section 5 presents the conclusions.

2. Theoretical Background

This section provides a theoretical background for the green innovation criteria of SSCM practices. In the sub-sections, we conduct further analyses.

2.1. Green Innovation in Sustainable Supply Chain Management

Green innovation is an innovative term that defines how industries can move towards greener supply chain operations for sustainable development [19]. The main purpose of implementing green innovation in industries is to operate sustainable supply chain practices and eliminate the adverse environmental implications of traditional supply chains. Moreover, industries are required to achieve sustainability targets through sustainable economic, environmental, and social development [20]. These industries can only accomplish sustainability by integrating these three important sustainability factors, which will also help industries reduce their contributions to air pollution, climate change, ecological danger, and other harmful industrial activities [21]. The integration of green innovation and sustainability initiatives into industrial supply chain practices developed from the eco-friendly policies of the government will be caused by social pressures, market pressures, and the corporate image of the industry [22].

2.2. Applications of the MCDM in Green Innovation

It is very important to implement green innovation criteria for SSCM practices. Various studies have used green innovation practices for sustainable supply chain operations. These studies employed MCDM methods to identify, analyze, and rank the green innovation criteria for sustainable supply management. Table 1 shows the relevant studies on green innovation for sustainable supply chains in the context of numerous studies.

Table 1. Relevant multi-criteria decision making (MCDM) based studies on the assessment of green innovation for sustainable supply chains.

Research Focus	Industry	Research Finding	Method	Year	Reference
Modeling green innovation enablers	Manufacturing	The results of this study revealed that developing green manufacturing capabilities is the most important green innovation enabler among the twenty-one enablers.	Grey decision making trial and evaluation laboratory (DEMATEL)	2018	[23]
A decision model to overcome green innovation barriers	Small and medium enterprises (SMEs)	The research findings of this study showed that technological/resource and financial/economic barriers are the two most vital issues that impede the development of green innovation in SMEs.	Best worst method (BWM) and fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS)	2018	[24]

Table 1. *Cont.*

Research Focus	Industry	Research Finding	Method	Year	Reference
Evaluating supply chain sustainability innovation	Manufacturing	This research indicated that financial availability is the most crucial sub-criteria for the development of sustainable supply chain innovation.	BWM	2019	[25]
Sustainable supplier selection based on green innovation ability	SMEs	The results of this study showed that resource availability and green competencies are the most significant green innovation abilities for selecting the supplier in SMEs.	BWM and FTOPSIS	2017	[26]
Analyzing barriers of sustainable supply chains	Auto ancillaries	The findings showed that organization barriers are the most significant barriers that obstruct the adoption of sustainable supply chains.	Fuzzy analytical hierarchy process (FAHP)	2017	[27]
Analysis of barriers and policy strategies to implement green innovation	SMEs	The results revealed that political barriers are the most influential barriers, while developing R&D practices to conduct green innovation is the most suitable strategy for SMEs.	FAHP and FTOPSIS	2020	[28]
Assessing and ranking the strategies for the adoption of green supply chains	Manufacturing	The findings showed that the environmental management system is the most significant strategy for achieving green practices in the manufacturing industry.	AHP	2013	[29]
Supplier selection based on green innovation	SMEs	The analysis showed that green innovation initiatives are the most vital criteria for the selection of a green supplier in SMEs.	FAHP and grey TOPSIS	2020	[30]
Enhancing green innovation performance	Manufacturing	The findings showed that management innovation is the most suitable green innovation factor for improving the innovation performance of the manufacturing industry.	AHP and entropy weight	2013	[31]

Previous studies have mainly focused on using green innovation for implementing sustainable supply chain operations in the industry. Because most industrial supply chain practices have relied on traditional practices, green innovation offers the ability to adopt sustainable practices. Furthermore, environmental regulatory authorities are putting pressure on implementing sustainable supply chain practices into the manufacturing industry for sustainable development [32]. Different studies have used different MCDM methods to analyze this complex decision making problem. Some researchers have used individual MCDM approaches, while others have integrated various methodologies to analyze the problem. Moreover, AHP and TOPSIS are the most widely used methods for MCDM; in this study, we used the FAHP and FTOPSIS methodologies to analyze and rank suppliers for the adoption of green innovation criteria in the sustainable supply chain practices of the manufacturing industry in China. Since fuzzy set theory helps to reduce uncertainty and complexity in decision making, as well as to obtain more feasible and significant results, we used the FAHP and TOPSIS methods to analyze this decision making problem.

2.3. Proposed Green Innovation Criteria

In this study, we propose several important green innovation criteria and sub-criteria for sustainable supply chain practices in the manufacturing industry of China. These green innovation criteria were identified after conducting a thorough literature survey. Nezami et al. [33] proposed a detailed maintenance strategy selection model based on sustainability metrics for environmental, social, and economic criteria. This study finalized the three important green innovation criteria and seventeen green innovation sub-criteria for sustainable supply chain operations. These sustainability-based criteria are the economic (EC), social (SO), and environmental (EN) criteria. Six green innovation sub-criteria were identified under EC, six sub-criteria were identified under SO, and five sub-criteria were identified under EN. Table 2 displays the green innovation criteria and sub-criteria for sustainable supply chain practices.

Table 2. Green innovation criteria and sub-criteria for sustainable supply chains.

Criteria	Sub-Criteria	Brief Description	Reference
Economic (EC) criteria	Financial availability for green innovation (EC1)	This economic sub-criterion shows that the industry should obtain funding from financial institutions to adopt green innovation practices.	[24,30,34,35]
	Investment in research and development for green practices (EC2)	This is a vital sub-criterion that shows that the research and development facilities allow for an industry to manage and complete green practices by providing a sufficient amount of financial resources.	[23,28,30,31]
	Reducing the green product cost (EC3)	This sub-criterion shows the industry's ability to decrease production costs through green innovation practices to provide low-cost green products.	[23,24,28,30,31]
	Designing green products to decrease material costs and consumption (EC4)	This is significant economic sub-criterion that indicates industrial efforts to design sustainable products to reduce material costs and consumption for sustainable production.	[30,31,36]
	Return on investment for green practices (EC5)	The return on financial investment into resources for the development of green innovation practices in the industry through reusing, recycling, scrap selling, and waste material. This green process helps obtain a return on investment for green practices.	[28,30,36]
	Improving sustainability value to customers (EC6)	This sub-criterion refers to how industries improve sustainability by providing greater value to their customers by enhancing a product's functions and reducing a product's price.	[23,28,30,31]

Table 2. *Cont.*

Criteria	Sub-Criteria	Brief Description	Reference
Social (SO) criteria	Improving the social image of the industry (SO1)	This sustainable innovation sub-criterion refers to how industries enhance their social image in the market by producing eco-friendly products.	[30,36,37]
	Response to customers and market demand for green products (SO2)	This sub-criterion indicates that the industry should quickly respond to the customer according to the market demands for a green product, and it should also be aware of the benefits of using eco-friendly products.	[23,28,30,38]
	Adopting socio–environmental policies in industries (SO3)	This social sub-criterion indicates that it is essential to adopt socio–eco policies and standards in industry for sustainable development.	[25,28,31,36]
	Response to stakeholders who are pressured to produce green products (SO4)	This sub-criterion identifies that industries respond to pressure from various stakeholders, such as suppliers, customers, employees, and competitors, to produce green products.	[23–25,30,31]
	Health and safety of the employees (SO5)	This sub-criterion shows that the industry should focus on the rights of its employees by enhancing occupational health and safety for the sustainable development of the industry.	[23,30,36,39]
	Cultural norms and social values (SO6)	This is an important social sub-criterion that indicates that the industry should take care of social and cultural norms, allowing society to obtain more benefits over the interests of the industry or individual.	[23,25,36,40]
Environmental (EN) criteria	Commitment to develop an environmental management system (EN1)	This is very significant sub-criterion from an environmental perspective, showing that the implementation of various environmental policies via standards is necessary for the development of SSCM in the industry.	[20,25,30,36]
	Designing and developing green products (EN2)	This indicates that industries should develop environmentally friendly products to eliminate environmental degradation and provide for the easier disposal of the product at the end of life.	[23,28,30,31]
	Developing green manufacturing and operational practices (EN3)	This sub-criterion shows that implementing sustainable and innovative manufacturing practices can help in reducing energy consumption and waste in production during industrial operations.	[28,30,36,41]
	Availability of technical expertise (EN4)	This environmental sub-criterion requires that the industry have available technical experts/human resource who can assist in managing industrial activities in a sustainable manner.	[25,30,36,41]
	Collaboration among industries (EN5)	This sub-criterion shows that industries should coordinate with each other by sharing resources and technologies to produce green products.	[28,30,31,36,42]

2.4. Research Gap Analysis

In this section, we identify the relevant research gaps since green innovation demonstrably plays an essential role in sustainable indusial supply chain practices. Though most researchers have focused on the identification and evaluation of green innovation criteria for adopting SSCM activities, increasingly important environmental issues like global warming, the scarcity of natural resources, and climate change have forced policymakers to promote sustainable supply chain practices [30]. In this regard, it is important to transform industrial traditional supply chain practices into a sustainable supply chain. After analyzing a detailed literature survey, this study was able to fill the research gaps by analyzing the decision problem. Various studies have identified green innovation criteria for sustainable supply chain practices. However, none of these studies have analyzed green innovation criteria (i.e., economic, social, and environmental) or the seventeen sub-criteria for sustainable supply chain practices. Moreover, this study identifies and evaluates the eight suppliers that should continue adopting sustainable supply chain practices in the manufacturing industry of China. Moreover, numerous studies have used MCDM approaches to evaluate the decision making problem. Therefore, in this study, we decided to use hybrid FAHP and FTOPSIS methods to investigate the decision problem. Firstly, this research used the FAHP method to assess and rank three sustainable innovation criteria and sub-criteria that could help in adopting sustainable supply chain practices. Then, we employed the FTOPSIS method to analyze suppliers based on green innovation criteria for sustainable supply chain practices in the context of the manufacturing industry of China. This research will be very significant for managers, governments, and practitioners for adopting sustainable supply chain practices based on green innovation criteria.

3. Research Methodology

This research proposes a research framework comprised of the FAHP and FTOPSIS methodologies to assess and rank suppliers who can implement green innovation criteria for sustainable supply chain practices in the manufacturing industry of China. Figure 1 presents the research methodology of this study. Initially, this study conducted a thorough review to finalize the three green innovation criteria and seventeen sub-criteria. Then, we used the FAHP approach to analyze and prioritize these green innovation criteria and sub-criteria for sustainable supply chain practices. Finally, we employed the FTOPSIS technique to evaluate and rank the eight suppliers to identify a suitable supplier for implementing green innovation criteria in the SSCM practices of the industry.

This research mainly focused on the textile manufacturing industry of China, although information on the industries is not revealed here due to legal rights issues. The aim of this study was to reduce the negative environmental impacts of industrial supply chain practices by adopting innovative green technologies. This study engaged seven experts to assign weights to each green innovation criteria and sub-criteria and to identify a suitable supplier. The consulted experts were very experienced and well aware of the economic, environmental, and social conditions of the country. A questionnaire survey was also distributed to each of the experts through a webmail service to provide a meaningful opinion. The questionnaire survey distributed to the experts is provided in Appendix A. The experts' details are given in Appendix B.

3.1. FAHP Method

The AHP is one of the core methods of MCDM. The AHP is a four-staged hierarchically structured decision model that consists of a goal, criteria, sub-criteria, and alternatives [43]. However, we used a fuzzy-based AHP technique to obtain more reliable, consistent, and symmetrical results since fuzzy set theory helps to reduce the uncertainty under a fuzzy environment [44]. The AHP method can be used with quantitative and qualitative data [45]. The FAHP method can reduce a complicated decision problem into small ones. In this research, a pairwise comparison matrix was operated as triangular fuzzy numbers (TNFs) to assess the supplier for implementing green innovation in the sustainable supply chain system. Table 3 shows the TFN scale used in this study [46].

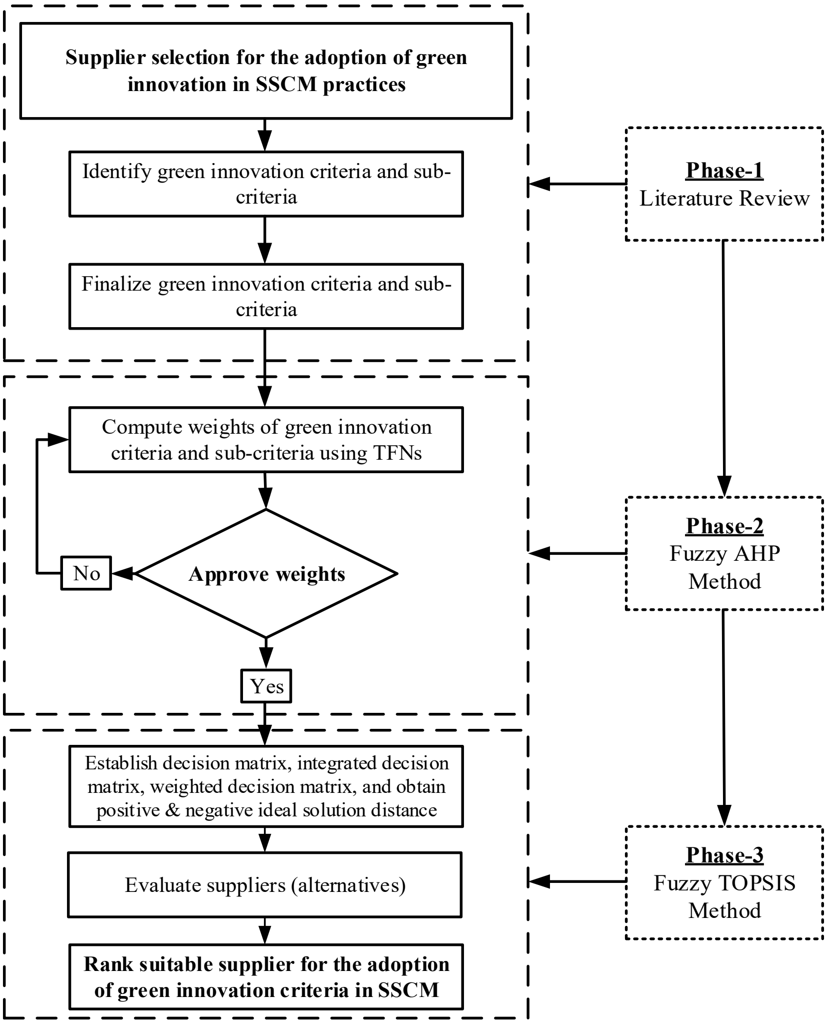

Figure 1. The decision methodology of the study.

Table 3. The triangular fuzzy number (TFN) scale.

Code	Linguistic Variable	TFNs
1	Equally dominant	(1,1,1)
2	Equally to averagely dominant	(1,2,3)
3	Averagely dominant	(2,3,4)
4	Averagely to strongly dominant	(3,4,5)
5	Strongly dominant	(4,5,6)
6	Strongly to very strongly dominant	(5,6,7)
7	Very strongly dominant	(6,7,8)
8	Very strongly to extremely dominant	(7,8,9)
9	Extremely dominant	(9,9,9)

The steps in the FAHP method to compute the inconsistency ratio of the fuzzy pairwise comparison matrix, as proposed by Gogus and Boucher, were presented in [47].

Fuzzy matrices are considered valid and symmetric if the values of both consistency ratios (CR_m) and (CR_g) are less than 0.10. Nevertheless, if the range exceeds 0.10, then the matrices do not provide meaningful results and are considered invalid or inconsistent. In this study, we provide a random consistency index (RI) scale (presented in Table 4). This RI scale was proposed by Gogus and Bouche and is different from Saaty's RI scale.

Table 4. Random consistency index (RI) scale.

n	RI_m	RI_g
1	0	1
2	0	2
3	0.4890	0.1796
4	0.7937	0.2627
5	1.0720	0.3597
6	1.1996	0.3818
7	1.2874	0.4090
8	1.3410	0.4164
9	1.3793	0.4348
10	1.4095	0.4455
11	1.4181	0.4536
12	1.4462	0.4776
13	1.4555	0.4691
14	1.4913	0.4804
15	1.4986	0.4880

3.2. FTOPSIS Method

TOPSIS is one of the most essential methods of MCDM. This approach provides the distance between the positive ideal and negative ideal solution to determine alternatives [48]. However, similar to the FAHP, this TOPSIS method is also used with fuzzy set theory to form FTOPSIS. Therefore, this research assessed the weights of the alternatives using linguistic variables and TFNs. TFNs were used to analyze the alternatives based on the sub-criteria of the study. The TFNs scale is provided in Table 5.

Table 5. The TFNs scale [49].

No	Linguistic Variables	TFNs
1	Very unsatisfactory	(1,2,3)
2	Unsatisfactory	(2,3,4)
3	Somewhat unsatisfactory	(3,4,5)
4	Highly unsatisfactory	(4,5,6)
5	Satisfactory	(5,6,7)
6	Somewhat satisfactory	(6,7,8)
7	Highly satisfactory	(7,8,9)

The steps of the FTOPSIS technique were given in [50].

After accomplishing the steps of the FAHP and FTOPSIS methods, we next analyzed the green innovation criteria, sub-criteria, and alternatives to achieve the goals of this study.

4. Results and Discussion

In the research, we adopted a hybrid decision methodology based on the FAHP and FTOPSIS to evaluate green innovation criteria for the SSCM. Figure 2 presents the hierarchically structured decision framework for this study. To achieve this objective, the FAHP approach was used to analyze and rank the three green innovation criteria and seventeen green innovation sub-criteria. Then, the FTOPSIS technique was utilized to identify suitable suppliers for implementing SSCM practices in the manufacturing industry in China.

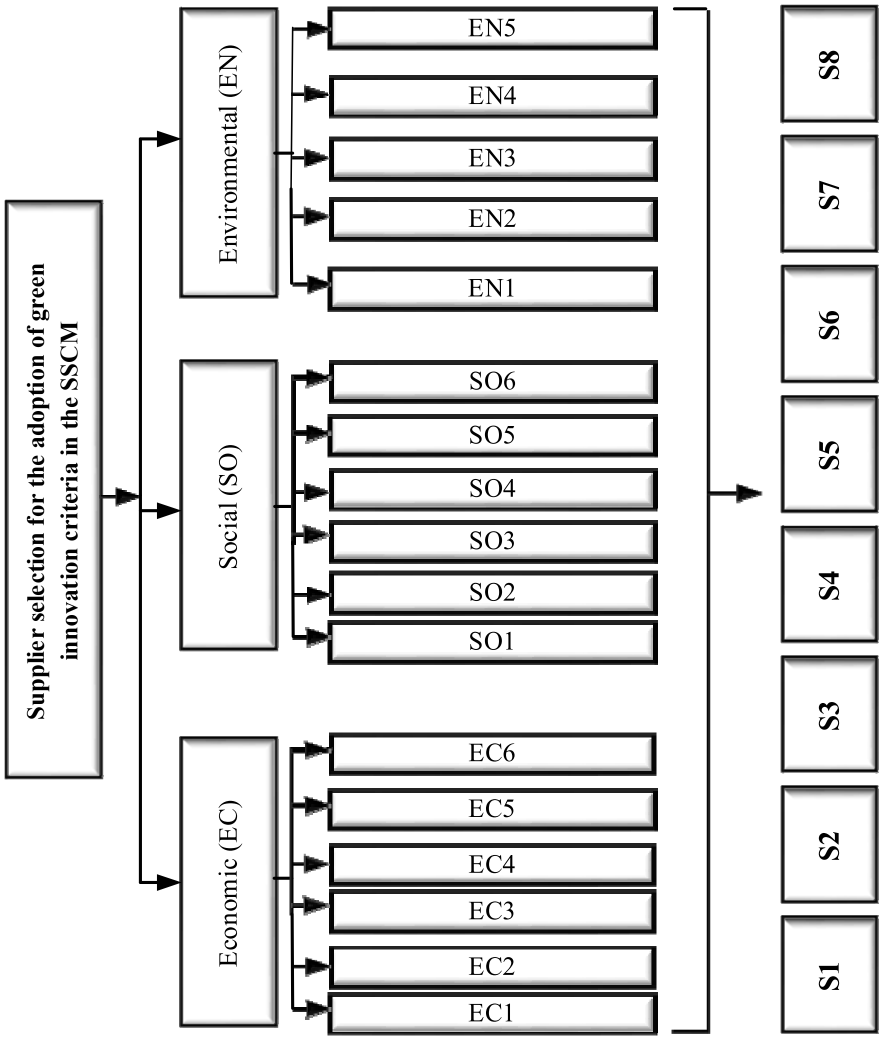

Figure 2. The hierarchically structured decision framework.

4.1. Case Analysis

This case study used eight suppliers from Chinese textile manufacturing companies. These companies belong to the textile industry and have been operating over the last thirty years. We selected companies whose aim is to reduce their environmental degradation activities, increase their socio–economic development, and improve the impact of their products using green technologies. It was ensured that these selected textile manufacturing companies had continuously operated over the last twenty years and that each had more than five thousand employees. To avoid any conflict, the managers of the companies were not consulted to avoid conflicts of interest. In this regard, professional and experienced managers, analysts, professors, and stakeholders were consulted to provide their feedback on the questionnaire. The details of each criterion, sub-criterion, and objective of the research were presented to each expert through a webmail service. The experts were asked to compare the fuzzy pairwise comparison matrices of the criteria to those of other criteria using TFNs scales. A similar process was applied to the sub-criteria. After obtaining feedback from all experts, the average of the weights and final ranking of the sub-criteria, as well as the main criteria, were obtained. Finally, the experts were asked to provide feedback for alternatives based on the overall sub-criteria.

4.2. FAHP Results

In this section, the results of three green innovation criteria and seventeen sub-criteria are identified using the FAHP methodology. These determined green innovations are suitable for SSCM practices in the manufacturing industry. Detailed results are provided in the following sub-sections.

4.2.1. Green Innovation Criteria Results

This section provides the green innovation criteria results for the adoption of sustainable supply chain practices. The three green innovation results were analyzed using the FAHP method. Table 6 presents a ranking of the green innovation criteria. As shown in Table 6, EC was the most suitable green innovation criterion with a weight of 0.386 (38.60%). The EN criterion was ranked second with a weight of 0.346 (34.60%), whereas the SO criteria had the least importance with a weight of 0.268 (26.80%). The analysis showed that all these green innovation criteria are important for implementing sustainable supply chain practices in the manufacturing industry.

Table 6. Ranking of the green innovation criteria.

Code	Main Criteria	Criterion Weight	Weight %	Rank
EC	Economic	0.386	38.60%	1
SO	Social	0.268	26.80%	3
EN	Environmental	0.346	34.60%	2

The detailed results, i.e., the fuzzy pairwise comparison matrix of the green innovation criteria and sub-criteria, were then constructed and are presented in Appendix C.

4.2.2. Green Innovation Sub-Criteria Results

This section provides the results of the green innovation sub-criteria with respect to each main criteria after analyzing the green innovation criteria results. Figure 3 presents a ranking of the green innovation sub-criteria with respect to the EC criteria. According to the results, financial availability (EC1), with a weight of 0.186 (18.60%), was the priority green innovation sub-criterion. Investment in research and development for green practice (EC2) sub-criterion, with a weight of 0.184 (18.40%), was the second important green innovation sub-criterion. Designing green products to decrease material costs and consumption (EC4) was the third most vital sub-criterion, with a weight of 0.171 (17.10%). The return on investment for green practices (EC5) and reducing green product cost (EC3) were considered moderately necessary for SSCM practices in the manufacturing industry of China. Finally, improving the sustainability value to customers (EC6) obtained the least importance, with a weight of 0.12 (12%). The results indicated that all these economic sub-criteria are very significant for the development of SSCM practices.

Figure 4 displays the ranking of the green innovation sub-criteria under the SO criteria. The findings showed that adopting socio–environmental policies in industry (SO3), with a weight of 0.19 (19.20%) was the highest-ranked green innovation sub-criterion. The response to stakeholders who pressure companies to produce green products (SO4), with a weight of 0.191 (19.10%), was the second most crucial green innovation sub-criterion. Responses to customers and the market demand for green products (SO2) was the third highest sub-criterion. Improving the social image of the industry (SO1) was recognized as the fourth most important green innovation sub-criterion, whereas the health and safety of employees (SO5) and cultural norms and social values (SO6) were considered the least significant green innovation sub-criteria.

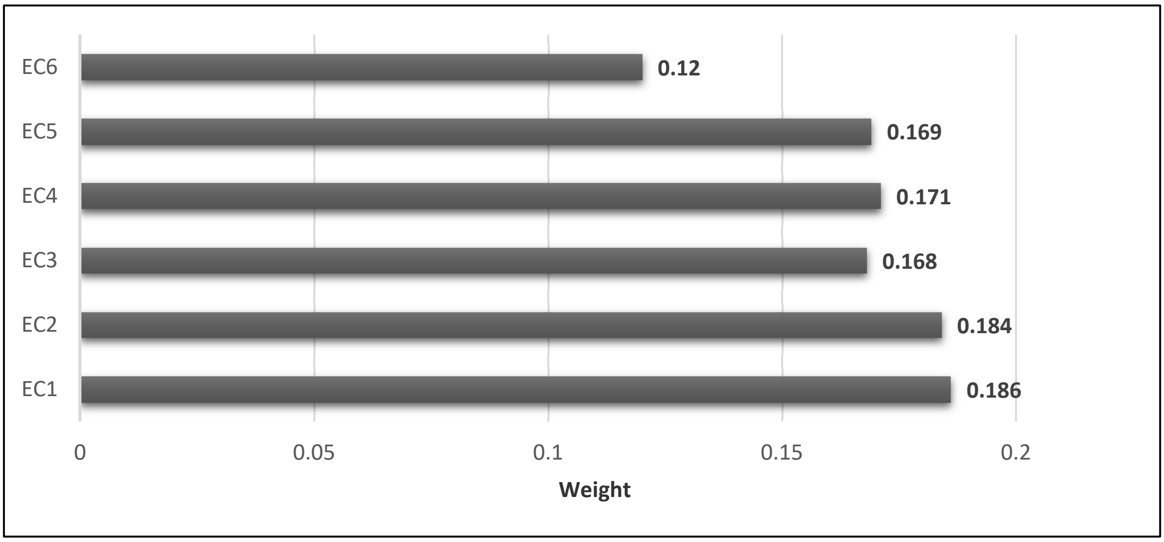

Figure 3. Ranking of green innovation sub-criteria with respect to the economic (EC) criteria.

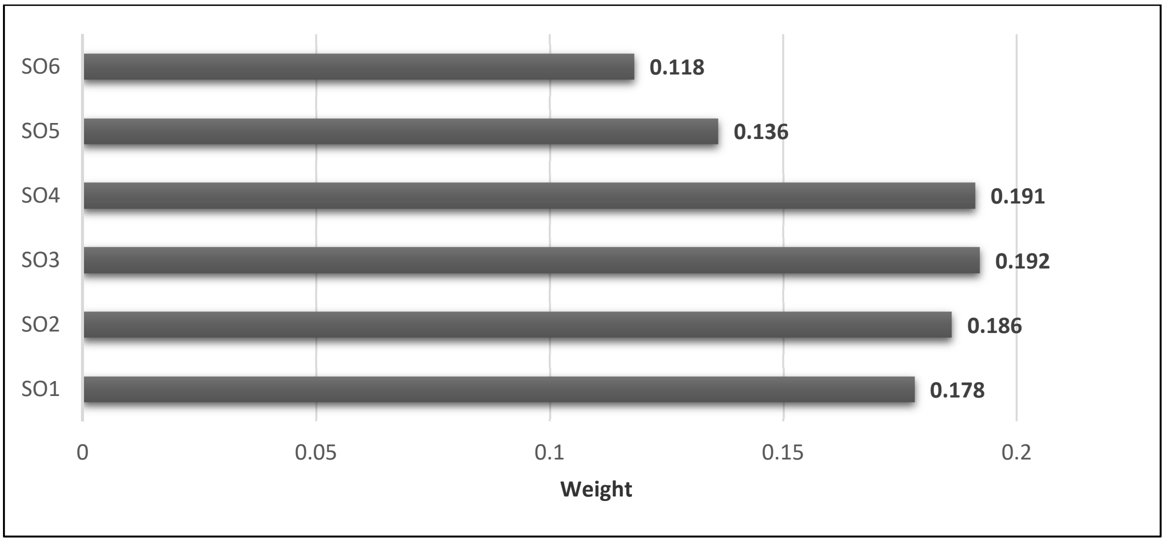

Figure 4. Ranking of green innovation sub-criteria with respect to the social (SO) criteria.

Figure 5 presents the ranking of sub-criteria under the EN criteria. The results indicated that the commitment to develop an environmental management system (EN1) was the top-ranked green innovation sub-criterion, with a weight of 0.208 (20.80%). The availability of technical expertise (EN4) was considered the second most important green innovation sub-criterion, with a weight of 0.202 (20.20%). Furthermore, the designing and developing green products (EN2) and developing green manufacturing and operational practices (EN3) were found to have equal weights of 0.201 (20.10%). The collaboration among industries (EN5) was the least important sub-criterion, with a weight of 0.188 (18.80%). Thus, most green innovation sub-criteria with respect to the environmental criteria are very important for the implementation of SSCM processes.

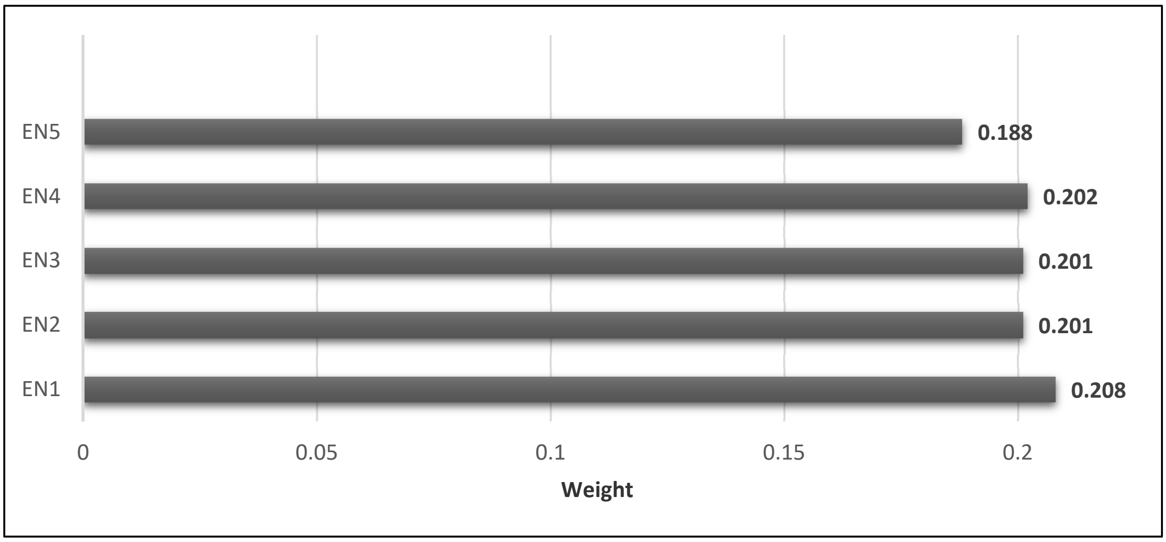

Figure 5. Ranking of green innovation sub-criteria with respect to the environmental (EN) criteria.

4.2.3. Overall Green Innovation Sub-Criteria Results

Table 7 shows the priority order of the overall sub-criteria based on the goals of this study. The final weights of the seventeen sub-criteria were obtained by multiplying the local weight of the sub-criteria with those of each green innovation criterion. The analysis showed that the commitment to developing an environmental management system (EN1) sub-criterion achieved the highest weight at 0.0720 (7.20%). The financial availability of the green innovation (EC1) sub-criterion achieved the second-highest weight at 0.0718 (7.18%). Investment in research and development for green practices (EC2) was the third most vital green innovation sub-criterion.

Table 7. Final weights of the overall sub-criteria.

Code	Criterion Name	Criterion Final Weight	Rank
EC1	Financial availability for green innovation	0.0718	2
EC2	Investment in research and development for green practices	0.0710	3
EC3	Reducing green product cost	0.0648	9
EC4	Designing green products to decrease material costs and consumption	0.0660	6
EC5	Return on investment for green practices	0.0652	7
EC6	Improving sustainability value to customers	0.0463	14
SO1	Improving the social image of the industry	0.0477	13
SO2	Response to customers and market demand for green products	0.0498	12
SO3	Adopting socio–environmental policies in industries	0.0515	10
SO4	Response to stakeholders who pressure companies to produce green products	0.0512	11
SO5	Health and safety of the employees	0.0364	15
SO6	Cultural norms and social values	0.0316	16
EN1	Commitment to developing an environmental management system	0.0720	1
EN2	Designing and developing green products	0.0695	5
EN3	Developing green manufacturing and operational practices	0.0695	5
EN4	Availability of technical expertise	0.0699	4
EN5	Collaboration among industries	0.0650	8

The remaining green innovation sub-criteria were prioritized as follows: EN4 < EN2 < EN3 < EC4 < EC5 < EN5 < EC3 < SO3 < SO4 < SO2 < SO1 < EC6 < SO5 < SO6. Most green innovation sub-criteria are thus very important for the sustainable adoption of supply chain operations in the manufacturing industry of China. Based on these analyses, the FTOPSIS approach was used to analyze and rank suitable suppliers for the adoption of SSCM activities.

4.3. FTOPSIS Results

In this section, we used the FTOPSIS approach to analyze and prioritize eight suppliers (alternatives) for the adoption of SSCM practices in the manufacturing industry of China. The ranking of the suppliers was identified after evaluating the green innovation criteria and sub-criteria. The suppliers were mainly ranked by the green innovation sub-criteria. In the FTOPSIS process, the experts were again asked to rate each supplier's performance with respect to the seventeen green innovation sub-criteria. The detailed analyses, i.e., the fuzzy decision matrix, the fuzzy normalized decision matrix, and the fuzzy integrated normalized decision matrix, are presented in Appendix D. The final step of the FTOPSIS method was to obtain the closeness coefficient (CCi) scores of the suppliers. Table 8 shows the ranking of suppliers based on their CCi scores. The results indicated that supplier 5 (S5) obtained the highest CCi score of 0.727, which means that S5 is the most suitable supplier for implementing green innovation criteria in the SSCM practices of the manufacturing industry. Supplier 7 (S7) was ranked second with a CCi score of 0.691. Supplier 1 (S1) was the third most vital alternative with a score of 0.638. The order ranking of the remaining suppliers was as follows: S6 < S8 < S2 < S3 < S4. S6 and S8 obtained the same CCi, which means that both are equally important in implementing green innovation practices. The final analysis showed that S5, S7, and S1 are the top priority suppliers, while the others are considered moderately important to unimportant for implementing green innovation criteria in SSCM practices.

Table 8. The ranking of suppliers based on the closeness coefficient CCi score.

Code	Alternative	d^+	d^-	CCi	Final Ranking
S1	Supplier 1	6.436	11.379	0.638	3
S2	Supplier 2	9.504	8.297	0.466	6
S3	Supplier 3	9.779	8.014	0.450	7
S4	Supplier 4	10.384	7.450	0.417	8
S5	Supplier 5	4.845	12.949	0.727	1
S6	Supplier 6	8.836	8.934	0.502	4
S7	Supplier 7	5.497	12.314	0.691	2
S8	Supplier 8	8.859	8.947	0.502	4

4.4. Sensitivity Analysis

In this study, we conducted a sensitivity analysis to assess the feasibility and reliability of the obtained results from the FAHP and FTOPSIS methods. This was done by changing the weights of the main criteria to check the final ranking of the suppliers (alternatives). In the sensitivity process, the main criteria weights were varied to analyze the order ranking of the alternatives. In total, six cases were proposed and assessed by changing the weights of the main criteria to investigate the final ranking of the alternatives. The varying weights of the main criteria in the six cases are shown in Table 9. The main criteria weights are provided in column 2 of Table 9, followed by six other cases evaluated under a sensitivity analysis. After varying the weights, we observed that the priority order of alternatives remained the same with no changes in the final rankings. Table 10 presents the final ranking of alternatives based on the six cases of the sensitivity analysis. The rankings of the alternatives remained identical to the original case results. Thus, the sensitivity analysis showed that the obtained results were significant and reliable.

Table 9. Weights of main-criteria with actual and different cases.

Main Criteria	Actual Weight	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Economic (EN) criteria	0.386	0.40	0.40	0.20	0.25	0.25	0.50
Social (SO) criteria	0.268	0.40	0.20	0.40	0.25	0.50	0.25
Environmental (EN) criteria	0.346	0.20	0.40	0.40	0.50	0.25	0.25

Table 10. Results of the sensitivity analysis.

Alternative	Current Case (Rank)	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
S1	3	3	3	3	3	3	3
S2	6	6	6	6	6	6	6
S3	7	7	7	7	7	7	7
S4	8	8	8	8	8	8	8
S5	1	1	1	1	1	1	1
S6	4	4	4	4	4	4	4
S7	2	2	2	2	2	2	2
S8	4	4	4	4	4	4	4

4.5. Discussion

This research identified the critical green innovation criteria and sub-criteria for sustainable supply chain practices. Previously, it was very complex to identify and evaluate such criteria. However, the present study was able to properly analyze this decision making problem by using the FAHP and FTOPSIS methodologies. This research conducted a detailed literature study to select the most vital green innovation criteria for the selection of a suitable supplier in sustainable supply chain practices. Assessing any decision making problem in real-life cases is very complicated. In this regard, an integrated decision model was proposed to assess and rank suppliers in terms of green innovation criteria. The developed model can assist in minimizing uncertainties and inadequacies during the decision making process.

The main results of the FAHP method are provided in the above sections. Among the three green innovation criteria, the EC criteria were found to be the most suitable options for sustainable supply chain practices. The overall (seventeen) green innovation sub-criteria results showed that commitment to developing an environmental management system (EN1) is the most crucial sub-criterion. At the same time, cultural norms and social values (SO6) was found to be the least significant sub-criterion for the adoption of sustainable supply chain practices in the manufacturing industry of China. After evaluating the green innovation criteria and sub-criteria, this study further assessed eight suppliers using the FTOPSIS method. The findings showed that supplier 5 (S5) is a suitable supplier for implementing sustainable supply chain practices.

In previous studies, authors have analyzed similar types of research problems pertaining to green innovation for SSCM practices in industry. However, the goal of the decision making problem in each study was different. For example, some authors identified the important aspects of green innovation, green innovation barriers, green strategies, and sustainable dimensions to implement green supply chain operations in the industry. Moreover, researchers have used several MCDM methods to investigate decision problems. In a previous study, Gupta and Barua [23] analyzed the use of green innovation enablers for sustainable supply chain operations in the manufacturing industry by using the grey decision making trial and evaluation laboratory (DEMATEL) technique; their study results showed that developing green manufacturing capabilities is the most vital green innovation enabler for the adoption of green supply chain practices. Another study by Gupta and Barua [24] revealed the barriers that impede the development of green innovation in small and medium enterprises (SMEs) using the best worst method (BWM) and FTOPSIS methodologies; their research findings showed that technological, resource, financial, and economic factors are the most significant barriers that obstruct green innovation. These findings are improved by the current study results. Moreover, the sustainability innovation dimensions were analyzed in the SSCM of the manufacturing industry based on the BWM method [25]. The research revealed that financial availability is the most crucial sustainable innovation sub-criterion. The findings of the current study also demonstrated that financial availability for the development of green innovation is the most suitable sub-criteria for SSCM practices. A recent study by Almalki et al. [28], which identified the barriers and strategies to implementing green innovation in SMEs, showed that political barriers impede the adoption of green innovation practices, while developing R&D practices is considered to be a significant strategy for overcoming barriers to the sustainable development of SMEs. Another study by Almalki et al. [30] revealed that green innovation initiatives are a top priority for the selection of green suppliers among SMEs in Saudi Arabia.

Furthermore, several important studies, along with their findings, have already been provided in the theoretical background section. This makes it easy to compare the results and analyze the feasibility of the current study. This study will be very useful for industrial managers and decision-makers to select a suitable supplier for the adoption of green innovation criteria in sustainable supply chains. Several previous studies have analyzed the green innovation criteria for implementing sustainable supply chain practices. Nevertheless, none of these studies identified the green innovation criteria themselves (i.e., EN, SO, and EN) to identify and analyze suppliers on the basis of these criteria. This proposed integrated decision framework thus provides meaningful insights to help managers and policymakers adopt sustainable supply chain practices in the manufacturing industry of China.

5. Conclusions

At present, many manufacturing companies are facing sustainability problems throughout their supply chain systems. Green innovation helps industries overcome sustainability issues in supply chains by adopting green practices. This research accordingly developed a green innovation criteria decision framework comprising economic, social, and environmental factors to help ameliorate the green innovation problems within the manufacturing industry of China. SSCM practices could help companies reduce their environmental damage. In this study, the FAHP and FTOPSIS methods were used to analyze and prioritize the three green innovation criteria, seventeen sub-criteria, and eight suppliers to implement green innovation into the sustainable supply chain practices of the industry. The findings indicated that economic criteria are the most important green innovation criteria for implementing SSCM practices in the manufacturing industry of China because China is a developing country. Environmental criteria were ranked second because the industrial manufacturing system fully relies on traditional supply chain practices. These supply chain practices are, however, dangerous to the environment. Social criteria were considered the least important for the implementation of green innovation practices.

Moreover, the evaluation of the FAHP method indicated that economic criteria are the most significant green innovation criteria, followed by environmental and social criteria, for adopting sustainable chain practices in the manufacturing industry of the country. Commitment to developing an environmental management system (EN1), financial availability for green innovation (EC1), and investment in research and development for green practices (EC2) were found to be important sub-criteria for implementing green innovation in sustainable supply chain operations. The FTOPSIS results revealed that supplier 5 (S5) is the best-suited supplier for the adoption of green innovation criteria in the SSCM practices of the manufacturing industry. The findings of this study revealed that green innovation criteria and sub-criteria are very important for developing sustainable industrial practices in the manufacturing sector. These criteria could help the industry achieve sustainable development and a competitive advantage.

Furthermore, this research offers several key contributions that have been discussed. Though the presented concerns of this study will be very significant and useful for future research on the given subject, there were some limitations. Firstly, this research used the FAHP and FTOPSIS methods to analyze the decision problem. However, there are several other important MCDM methods that can be used to determine the decision making problem. Secondly, in this study, we identified the green innovation criteria pertaining to the manufacturing sector of China. Therefore, in future research, we could identify and assess more green innovation criteria for some other sectors.

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Appendix A. Questionnaire Survey

Questions related to main criteria for analyzing the green innovation practices for sustainable supply chain management.

Table A1. Please rate the importance of four main criteria against each criterion.

Criteria	Score 1–9	Criteria
Economic (EC)		Social (SO)
Economic (EC)		Environmental (EN)
Social (SO)		Environmental (EN)

Questions related to sub-criteria for analyzing the green innovation practices for sustainable supply chain management.

Table A2. Please rate the importance of sub-criteria (EC1–EC6) against each sub-criteria (EC1–EC6) relating to the economic (EC) criteria.

Sub-Criteria	Score 1–9	Sub-Criteria
Financial availability for green innovation (EC1)		Investment in research and development for green practices (EC2)
Financial availability for green innovation (EC1)		Reducing the green product cost (EC3)
Financial availability for green innovation (EC1)		Designing green products to decrease material cost and consumption (EC4)
Financial availability for green innovation (EC1)		Return on investment for green practices (EC5)
Financial availability for green innovation (EC1)		Improving sustainability value to customers (EC6)
Investment in research and development for green practices (EC2)		Reducing the green product cost (EC3)
Investment in research and development for green practices (EC2)		Designing green products to decrease material cost and consumption (EC4)
Investment in research and development for green practices (EC2)		Return on investment for green practices (EC5)
Investment in research and development for green practices (EC2)		Improving sustainability value to customers (EC6)

Table A2. *Cont.*

Sub-Criteria	Score 1–9	Sub-Criteria
Reducing the green product cost (EC3)		Designing green products to decrease material cost and consumption (EC4)
Reducing the green product cost (EC3)		Return on investment for green practices (EC5)
Reducing the green product cost (EC3)		Improving sustainability value to customers (EC6)
Designing green products to decrease material cost and consumption (EC4)		Return on investment for green practices (EC5)
Designing green products to decrease material cost and consumption (EC4)		Improving sustainability value to customers (EC6)
Return on investment for green practices (EC5)		Improving sustainability value to customers (EC6)

Table A3. Please rate the importance of sub-criteria (SO1–SO6) against each sub-criteria (SO1–SO6) relating to social (SO) criteria.

Sub-Criteria	Score 1–9	Sub-Criteria
Improving the social image of the industry (SO1)		Response to customers and market demand for green products (SO2)
Improving the social image of the industry (SO1)		Adopting the socio–environmental policies in industries (SO3)
Improving the social image of the industry (SO1)		Response to stakeholders who pressure to produce green products (SO4)
Improving the social image of the industry (SO1)		Health and safety of the employees (SO5)
Improving the social image of the industry (SO1)		Cultural norms and social values (SO6)
Response to customers and market demand for green products (SO2)		Adopting the socio–environmental policies in industries (SO3)
Response to customers and market demand for green products (SO2)		Response to stakeholders who pressure to produce green products (SO4)
Response to customers and market demand for green products (SO2)		Health and safety of the employees (SO5)
Response to customers and market demand for green products (SO2)		Cultural norms and social values (SO6)
Adopting the socio–environmental policies in industries (SO3)		Response to stakeholders who pressure to produce green products (SO4)
Adopting the socio–environmental policies in industries (SO3)		Health and safety of the employees (SO5)
Adopting the socio–environmental policies in industries (SO3)		Cultural norms and social values (SO6)
Response to stakeholders who pressure to produce green products (SO4)		Health and safety of the employees (SO5)
Response to stakeholders who pressure to produce green products (SO4)		Cultural norms and social values (SO6)
Health and safety of the employees (SO5)		Cultural norms and social values (SO6)

Table A4. Please rate the importance of sub-criteria (EN1–EN6) against each sub-criteria (EN1–EN6) relating to environmental (EN) criteria.

Sub-Criteria	Score 1–9	Sub-Criteria
Commitment to develop an environmental management system (EN1)		Designing and developing green products (EN2)
Commitment to develop an environmental management system (EN1)		Developing green manufacturing and operational practices (EN3)
Commitment to develop an environmental management system (EN1)		Availability of technical expertise (EN4)
Commitment to develop an environmental management system (EN1)		Collaboration among industries (EN5)
Designing and developing green products (EN2)		Developing green manufacturing and operational practices (EN3)
Designing and developing green products (EN2)		Availability of technical expertise (EN4)
Designing and developing green products (EN2)		Collaboration among industries (EN5)
Developing green manufacturing and operational practices (EN3)		Availability of technical expertise (EN4)
Developing green manufacturing and operational practices (EN3)		Collaboration among industries (EN5)
Availability of technical expertise (EN4)		Collaboration among industries (EN5)

Appendix B. Survey Respondents

Table A5. Demographic information of experts.

Designation	Gender	Age	Qualification	Experience in Years	Organization
Senior Manager	Male	42	Graduate	12	Shanghai Yangteng Supply Chain Management Co. Limited
Manager	Male	38	Ph.D.	10	Shanghai Longwin Supply Chain Management Co. Limited
Professor	Male	44	Ph.D.	11	Nanjing University of Aeronautics and Astronautics
Professor	Male	55	Ph.D.	21	Nanjing University
Analyst	Female	45	Graduate	14	Department of Commerce
Analyst	Male	42	Ph.D.	12	International cooperation on environment and development
Stakeholder	Male	40	Graduate	10	- - -

Note: The names of the respondents are not disclosed on due to privacy and legal rights.

Appendix C. FAHP Results

Table A6. Fuzzy pairwise comparison matrix with respect to the green innovation criteria.

	EC	SO	EN
EC	(1.000,1.000,1.000)	(1.000,3.994,7.000)	(0.250,1.486,5.000)
SO	(0.143,0.250,1.000)	(1.000,1.000,1.000)	(0.167,0.504,3.000)
EN	(0.200,0.673,4.000)	(0.333,1.984,5.988)	(1.000,1.000,1.000)
	$CR_m = 0.023 < 0.10$ and $CR_g = 0.060 < 0.10$ (Consistent)		

Table A7. Fuzzy pairwise comparison matrix with respect to the economic (EC) sub-criteria.

	EC1	EC2	EC3	EC4	EC5	EC6
EC1	(1.000,1.000,1.000)	(0.333,1.170,4.000)	(1.000,1.625,6.000)	(1.000,1.369,4.000)	(0.333,1.574,4.000)	(1.000,2.481,7.000)
EC2	(0.250,0.855,3.003)	(1.000,1.000,1.000)	(1.000,1.512,4.000)	(0.333,1.369,4.000)	(0.333,1.576,5.000)	(1.000,2.415,6.000)
EC3	(0.167,0.615,1.000)	(0.250,0.661,1.000)	(1.000,1.000,1.000)	(0.333,1.000,3.000)	(0.250,1.150,3.000)	(1.000,2.154,4.000)
EC4	(0.250,0.730,1.000)	(0.250,0.730,3.003)	(0.333,1.000,3.003)	(1.000,1.000,1.000)	(0.250,1.219,4.000)	(1.000,1.843,4.000)
EC5	(0.250,0.635,3.003)	(0.200,0.635,3.003)	(0.333,0.870,4.000)	(0.250,0.820,4.000)	(1.000,1.000,1.000)	(1.000,1.574,4.000)
EC6	(0.143,0.403,1.000)	(0.167,0.414,1.000)	(0.250,0.464,1.000)	(0.250,0.543,1.000)	(0.250,0.635,1.000)	(1.000,1.000,1.000)
CR_m = 0.029 < 0.10 and CR_g = 0.066 < 0.10 (Consistent)						

Table A8. Fuzzy pairwise comparison matrix with respect to the social (SO) sub-criteria.

	SO1	SO2	SO3	SO4	SO5	SO6
SO1	(1.000,1.000,1.000)	(0.250,0.944,3.000)	(0.200,0.661,4.000)	(0.200,0.662,3.000)	(1.000,1.738,5.000)	(1.000,1.738,5.000)
SO2	(0.333,1.059,4.000)	(1.000,1.000,1.000)	(0.200,0.905,3.000)	(0.250,0.807,3.000)	(1.000,2.285,4.000)	(1.000,2.602,6.000)
SO3	(0.250,1.513,5.000)	(0.333,1.105,5.000)	(1.000,1.000,1.000)	(1.000,1.219,3.000)	(1.000,2.380,5.000)	(1.000,2.736,5.000)
SO4	(0.333,1.511,5.000)	(0.333,1.239,4.000)	(0.333,0.820,1.000)	(1.000,1.000,1.000)	(1.000,2.522,5.000)	(1.000,2.784,5.000)
SO5	(0.200,0.575,1.000)	(0.250,0.438,1.000)	(0.200,0.420,1.000)	(0.200,0.397,1.000)	(1.000,1.000,1.000)	(1.000,1.219,3.000)
SO6	(0.200,0.575,1.000)	(0.167,0.384,1.000)	(0.200,0.365,1.000)	(0.200,0.359,1.000)	(0.333,0.820,1.000)	(1.000,1.000,1.000)
CR_m = 0.028 < 0.10 and CR_g = 0.075 < 0.10 (Consistent)						

Table A9. Fuzzy pairwise comparison matrix with respect to the environmental (EN) sub-criteria.

	EN1	EN2	EN3	EN4	EN5
EN1	(1.000,1.000,1.000)	(0.333,1.292,4.000)	(0.333,1.292,4.000)	(0.200,1.169,4.000)	(1.000,1.219,3.000)
EN2	(0.250,0.774,3.003)	(1.000,1.000,1.000)	(0.333,0.906,3.000)	(0.333,1.346,3.000)	(0.333,1.104,3.000)
EN3	(0.250,0.774,3.003)	(0.333,1.104,3.003)	(1.000,1.000,1.000)	(0.250,0.944,3.000)	(0.333,1.346,3.000)
EN4	(0.250,0.855,5.000)	(0.333,0.743,3.003)	(0.333,1.059,4.000)	(1.000,1.000,1.000)	(1.000,1.426,4.000)
EN5	(0.333,0.820,1.000)	(0.333,0.906,3.003)	(0.333,0.743,3.003)	(0.250,0.701,1.000)	(1.000,1.000,1.000)
CR_m = 0.039 < 0.10 and CR_g = 0.056 < 0.10 (Consistent)					

Appendix D. FTOPSIS Results

Table A10. Fuzzy decision matrix.

	EC1	EC2	EC3	EC4	EC5	EC6	SO1	SO2	SO3	SO4	SO5	SO6	EN1	EN2	EN3	EN4	EN5
S1	4.71,5.71,6.71	5.43,6.43,7.43	5.86,6.86,7.86	5,6,7	6,7,8	5.43,6.43,7.43	6.14,7.14,8.14	3.57,4.57,5.57	5.57,6.57,7.57	5.43,6.43,7.43	3.86,4.86,5.86	4.29,5.29,6.29	3,4,5	4.86,5.86,6.86	4.86,5.86,6.86	5.29,6.71,8.14	3.29,4.29,5.29
S2	3.29,4.29,5.29	5.71,6.71,7.71	5.71,6.71,7.71	5.57,6.57,7.57	5.57,6.57,7.57	3,4,5	4.57,5.57,6.57	3.29,4.29,5.29	3.14,4.14,5.14	4.57,5.57,6.57	4.14,5.14,6.14	4,5,6	5.57,6.57,7.57	3.57,4.57,5.57	4.29,5.29,6.29	5.29,6.57,7.86	3.57,4.57,5.57
S3	5.43,6.43,7.43	5.14,6.14,7.14	4.29,5.29,6.29	4.86,5.86,6.86	5.29,6.29,7.29	4,5,6	3.29,4.29,5.29	4.57,5.57,6.57	5.43,6.43,7.43	4.29,5.29,6.29	3.29,4.29,5.29	2.71,3.71,4.71	5,6,7	4.71,5.71,6.71	4.43,5.43,6.43	4,5,6	4.29,5.29,6.29
S4	3,4,5	6.14,7.14,8.14	5.43,6.43,7.43	3.14,4.14,5.14	3.14,4.14,5.14	4.71,5.71,6.71	2.71,3.71,4.71	5,6,7	5.86,6.86,7.86	4.86,5.86,6.86	3.14,4.14,5.14	5.57,6.57,7.57	3.71,4.71,5.71	3.43,4.43,5.43	5.71,6.71,7.71	3.43,4.43,5.43	4.57,5.57,6.57
S5	4.29,5.29,6.29	4.43,5.43,6.43	5.43,6.43,7.43	3.29,4.29,5.29	4.57,5.57,6.57	6.29,7.29,8.29	5.57,6.57,7.57	5.71,6.71,7.71	5.57,6.57,7.57	5.71,6.71,7.71	6.29,7.29,8.29	5.14,6.14,7.14	5.14,6.14,7.14	4.57,5.57,6.57	3,4,5	6.86,8.57,10.29	4.14,5.14,6.14
S6	3.57,4.57,5.57	6,7,8	3.43,4.43,5.43	4.86,5.86,6.86	4.29,5.29,6.29	5.29,6.29,7.29	5.14,6.14,7.14	3.43,4.43,5.43	5.29,6.29,7.29	3.86,4.86,5.86	4.86,5.86,6.86	5,6,7	4.43,5.43,6.43	4.43,5.43,6.43	4.29,5.29,6.29	4.71,5.71,6.71	5.29,6.29,7.29
S7	4.43,5.43,6.43	5.86,6.86,7.86	3.57,4.57,5.57	5.57,6.57,7.57	4.57,5.57,6.57	6,7,8	5.14,6.14,7.14	6.57,7.57,8.57	3.43,4.43,5.43	4.86,5.86,6.86	6.43,7.43,8.43	4.71,5.71,6.71	5,6,7	5.43,6.43,7.43	4.71,5.71,6.71	6.86,8.43,10	5.71,6.71,7.71
S8	5.43,6.43,7.43	4,5,6	4,5,6	5,6,7	3.14,4.14,5.14	5.43,6.43,7.43	4.57,5.57,6.57	6,7,8	3.57,4.57,5.57	5.43,6.43,7.43	4.14,5.14,6.14	3.57,4.57,5.57	5.14,6.14,7.14	6.14,7.14,8.14	4.14,5.14,6.14	8.14,10,11.86	5.14,6.14,7.14

Table A11. Fuzzy normalized decision matrix.

	EC1	EC2	EC3	EC4	EC5	EC6	SO1	SO2	SO3	SO4	SO5	SO6	EN1	EN2	EN3	EN4	EN5
S1	0.63,0.77,0.90	0.67,0.79,0.91	0.75,0.87,1	0.66,0.79,0.92	0.75,0.88,1	0.66,0.78,0.90	0.75,0.88,1	0.42,0.53,0.65	0.71,0.84,0.96	0.70,0.83,0.96	0.46,0.58,0.69	0.57,0.70,0.83	0.40,0.53,0.66	0.60,0.72,0.84	0.63,0.76,0.89	0.45,0.57,0.69	0.43,0.56,0.69
S2	0.44,0.58,0.71	0.70,0.82,0.95	0.73,0.85,0.98	0.74,0.87,1	0.70,0.82,0.95	0.36,0.48,0.60	0.56,0.68,0.81	0.38,0.50,0.62	0.40,0.53,0.65	0.59,0.72,0.85	0.49,0.61,0.73	0.53,0.66,0.79	0.74,0.87,1	0.44,0.56,0.68	0.56,0.69,0.81	0.45,0.55,0.66	0.46,0.59,0.72
S3	0.73,0.87,1	0.63,0.75,0.88	0.55,0.67,0.80	0.64,0.77,0.91	0.66,0.79,0.91	0.48,0.60,0.72	0.40,0.53,0.65	0.53,0.65,0.77	0.69,0.82,0.95	0.56,0.69,0.81	0.39,0.51,0.63	0.36,0.49,0.62	0.66,0.79,0.92	0.58,0.70,0.82	0.57,0.70,0.83	0.34,0.42,0.51	0.56,0.69,0.81
S4	0.40,0.54,0.67	0.75,0.88,1	0.69,0.82,0.95	0.42,0.55,0.68	0.39,0.52,0.64	0.57,0.69,0.81	0.33,0.46,0.58	0.58,0.70,0.82	0.75,0.87,1	0.63,0.76,0.89	0.37,0.49,0.61	0.74,0.87,1	0.49,0.62,0.75	0.42,0.54,0.67	0.74,0.87,1	0.29,0.37,0.46	0.59,0.72,0.85
S5	0.58,0.71,0.85	0.54,0.67,0.79	0.69,0.82,0.95	0.43,0.57,0.70	0.57,0.70,0.82	0.76,0.88,1	0.68,0.81,0.93	0.67,0.78,0.90	0.71,0.84,0.96	0.74,0.87,1	0.75,0.86,0.98	0.68,0.81,0.94	0.68,0.81,0.94	0.56,0.68,0.81	0.39,0.52,0.65	0.58,0.72,0.87	0.54,0.67,0.80
S6	0.48,0.62,0.75	0.74,0.86,0.98	0.44,0.56,0.69	0.64,0.77,0.91	0.54,0.66,0.79	0.64,0.76,0.88	0.63,0.75,0.88	0.40,0.52,0.63	0.67,0.80,0.93	0.50,0.63,0.76	0.58,0.69,0.81	0.66,0.79,0.92	0.58,0.72,0.85	0.54,0.67,0.79	0.56,0.69,0.81	0.40,0.48,0.57	0.69,0.81,0.94
S7	0.60,0.73,0.87	0.72,0.84,0.96	0.45,0.58,0.71	0.74,0.87,1	0.57,0.70,0.82	0.72,0.84,0.97	0.63,0.75,0.88	0.77,0.88,1	0.44,0.56,0.69	0.63,0.76,0.89	0.76,0.88,1	0.62,0.75,0.89	0.66,0.79,0.92	0.67,0.79,0.91	0.61,0.74,0.87	0.58,0.71,0.84	0.74,0.87,1
S8	0.73,0.87,1	0.49,0.61,0.74	0.51,0.64,0.76	0.66,0.79,0.92	0.39,0.52,0.64	0.66,0.78,0.90	0.56,0.68,0.81	0.70,0.82,0.93	0.45,0.58,0.71	0.70,0.83,0.96	0.49,0.61,0.73	0.47,0.60,0.74	0.68,0.81,0.94	0.75,0.88,1	0.54,0.67,0.80	0.69,0.84,1	0.67,0.80,0.93

Table A12. Fuzzy weighted normalized decision matrix.

	EC1	EC2	EC3	EC4	EC5	EC6	SO1	SO2	SO3	SO4	SO5	SO6	EN1	EN2	EN3	EN4	EN5
S1	0.046,0.055,0.065	0.047,0.056,0.065	0.048,0.057,0.065	0.044,0.052,0.061	0.049,0.057,0.065	0.030,0.036,0.042	0.036,0.042,0.048	0.021,0.027,0.032	0.037,0.043,0.050	0.036,0.043,0.049	0.017,0.021,0.025	0.018,0.022,0.026	0.029,0.038,0.048	0.042,0.050,0.059	0.044,0.053,0.062	0.031,0.040,0.048	0.028,0.036,0.045
S2	0.032,0.041,0.051	0.050,0.059,0.067	0.047,0.055,0.064	0.049,0.057,0.066	0.045,0.054,0.062	0.017,0.022,0.028	0.027,0.033,0.039	0.019,0.025,0.031	0.021,0.027,0.034	0.030,0.037,0.044	0.018,0.022,0.027	0.017,0.021,0.025	0.053,0.063,0.072	0.031,0.039,0.048	0.039,0.048,0.057	0.031,0.039,0.046	0.030,0.039,0.047
S3	0.053,0.062,0.072	0.045,0.054,0.062	0.035,0.044,0.052	0.042,0.051,0.060	0.043,0.051,0.059	0.022,0.028,0.034	0.019,0.025,0.031	0.027,0.032,0.038	0.036,0.042,0.049	0.028,0.035,0.042	0.014,0.019,0.023	0.011,0.016,0.020	0.048,0.057,0.067	0.040,0.049,0.057	0.040,0.049,0.058	0.024,0.030,0.035	0.036,0.045,0.053
S4	0.029,0.039,0.048	0.054,0.062,0.071	0.045,0.053,0.061	0.027,0.036,0.045	0.026,0.034,0.042	0.026,0.032,0.038	0.016,0.022,0.028	0.029,0.035,0.041	0.038,0.045,0.052	0.032,0.039,0.046	0.014,0.018,0.022	0.023,0.027,0.032	0.035,0.045,0.054	0.029,0.038,0.046	0.052,0.061,0.070	0.020,0.026,0.032	0.039,0.047,0.055
S5	0.041,0.051,0.061	0.039,0.047,0.056	0.045,0.053,0.061	0.029,0.037,0.046	0.037,0.045,0.054	0.035,0.041,0.046	0.033,0.039,0.044	0.033,0.039,0.045	0.037,0.043,0.050	0.038,0.045,0.051	0.027,0.032,0.036	0.022,0.026,0.030	0.049,0.058,0.068	0.039,0.048,0.056	0.027,0.036,0.045	0.040,0.051,0.061	0.035,0.043,0.052
S6	0.035,0.044,0.054	0.052,0.061,0.070	0.028,0.037,0.045	0.042,0.051,0.060	0.035,0.043,0.051	0.030,0.035,0.041	0.030,0.036,0.042	0.020,0.026,0.032	0.035,0.041,0.048	0.026,0.032,0.039	0.021,0.025,0.030	0.021,0.025,0.029	0.042,0.052,0.061	0.038,0.046,0.055	0.039,0.048,0.057	0.028,0.034,0.040	0.045,0.053,0.061
S7	0.043,0.053,0.062	0.051,0.060,0.069	0.030,0.038,0.046	0.049,0.057,0.066	0.037,0.045,0.054	0.034,0.039,0.045	0.030,0.036,0.042	0.038,0.044,0.050	0.023,0.029,0.036	0.032,0.039,0.046	0.028,0.032,0.036	0.020,0.024,0.028	0.048,0.057,0.067	0.046,0.055,0.063	0.043,0.052,0.061	0.040,0.050,0.059	0.048,0.057,0.065
S8	0.053,0.062,0.072	0.035,0.044,0.052	0.033,0.041,0.050	0.044,0.052,0.061	0.026,0.034,0.042	0.030,0.036,0.042	0.027,0.033,0.039	0.035,0.041,0.047	0.023,0.030,0.037	0.036,0.043,0.049	0.018,0.022,0.027	0.015,0.019,0.023	0.049,0.058,0.068	0.053,0.061,0.070	0.037,0.046,0.055	0.048,0.059,0.070	0.043,0.052,0.060

References

1. Arnette, A.N.; Brewer, B.L.; Choal, T. Design for sustainability (DFS): The intersection of supply chain and environment. *J. Clean. Prod.* **2014**, *83*, 374–390. [CrossRef]
2. Ageron, B.; Gunasekaran, A.; Spalanzani, A. Sustainable supply management: An empirical study. *Int. J. Prod. Econ.* **2012**, *140*, 168–182. [CrossRef]
3. Bastas, A.; Liyanage, K. Sustainable supply chain quality management: A systematic review. *J. Clean. Prod.* **2018**, *181*, 726–744. [CrossRef]
4. Kannan, D.; De Sousa Jabbour, A.B.L.; Jabbour, C.J.C. Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a brazilian electronics company. *Eur. J. Oper. Res.* **2014**, *233*, 432–447. [CrossRef]
5. Matić, B.; Jovanović, S.; Das, D.K.; Zavadskas, E.K.; Stević, Z.; Sremac, S.; Marinković, M. A new hybrid MCDM model: Sustainable supplier selection in a construction company. *Symmetry* **2019**, *11*, 353. [CrossRef]
6. Chatterjee, K.; Pamucar, D.; Zavadskas, E.K. Evaluating the Performance of Suppliers Based on Using the R'AMATEL-MAIRCA Method for Green Supply Chain Implementation in Electronics Industry. *J. Clean. Prod.* **2018**, *184*, 101–129. [CrossRef]
7. Piccarozzi, M. Does social innovation contribute to sustainability? The case of italian innovative start-ups. *Sustainability* **2017**, *9*, 2376. [CrossRef]
8. Hassini, E.; Surti, C.; Searcy, C. A literature review and a case study of sustainable supply chains with a focus on metrics. *Int. J. Prod. Econ.* **2012**, *140*, 69–82. [CrossRef]
9. Beton, A.; Dias, D.; Farrant, L.; Gibon, T.; Le Guern, Y.; Desaxce, M.; Perwueltz, A.; Boufateh, I.; Wolf, O.; Kougoulis, J.; et al. *Environmental Improvement Potential of Textiles (IMPRO Textiles)*; Scientific and Technical Research Reports; Publications Office of the European Union: Sevilla, Spain, 2014.
10. Diabat, A.; Kannan, D.; Mathiyazhagan, K. Analysis of Enablers for Implementation of Sustainable Supply Chain Management—A Textile Case. *J. Clean. Prod.* **2014**, *83*, 391–403. [CrossRef]
11. Keshavarz Ghorabaee, M.; Zavadskas, E.K.; Amiri, M.; Esmaeili, A. Multi-Criteria Evaluation of Green Suppliers Using an Extended WASPAS Method with Interval Type-2 Fuzzy Sets. *J. Clean. Prod.* **2016**, *137*, 213–229. [CrossRef]
12. Santos, H.; Lannelongue, G.; Gonzalez-Benito, J. Integrating Green Practices into Operational Performance: Evidence from Brazilian Manufacturers. *Sustainability* **2019**, *11*, 2956. [CrossRef]
13. Liu, Y.; Srai, J.S.; Evans, S. Environmental Management: The Role of Supply Chain Capabilities in the Auto Sector. *Supply Chain Manag.* **2016**, *21*, 1–19. [CrossRef]
14. China—Manufacturing, Value Added (% Of GDP). Available online: https://tradingeconomics.com/china/manufacturing-value-added-percent-of-gdp-wb-data.html (accessed on 5 May 2020).
15. Business Wire. China Textile Industry Overview 2017–2021—Research and Markets|Business Wire. Available online: https://www.businesswire.com/news/home/20161003006057/en/China-Textile-Industry-Overview-2017-2021---Research (accessed on 31 May 2020).
16. Čech, M.; Yao, W.; Samolejová, A.; Li, J.; Wicher, P. Human Resource Management in Chinese Manufacturing Companies. *Perspect. Sci.* **2016**, *7*, 6–9. [CrossRef]
17. Yu, W.; Chavez, R.; Feng, M.; Wiengarten, F. Integrated Green Supply Chain Management and Operational Performance. *Supply Chain Manag.* **2014**, *19*, 683–696. [CrossRef]
18. Zeng, H.; Chen, X.; Xiao, X.; Zhou, Z. Institutional Pressures, Sustainable Supply Chain Management, and Circular Economy Capability: Empirical Evidence from Chinese Eco-Industrial Park Firms. *J. Clean. Prod.* **2017**, *155*, 54–65. [CrossRef]
19. Chang, C.H.; Chen, Y.S. Green Organizational Identity and Green Innovation. *Manag. Decis.* **2013**, *51*, 1056–1070. [CrossRef]
20. Zailani, S.; Govindan, K.; Iranmanesh, M.; Shaharudin, M.R.; Sia Chong, Y. Green Innovation Adoption in Automotive Supply Chain: The Malaysian Case. *J. Clean. Prod.* **2015**, *108*, 1115–1122. [CrossRef]
21. Le, T.T. Performance Measures and Metrics in a Supply Chain Environment. *Uncertain Supply Chain Manag.* **2020**, *8*, 93–104. [CrossRef]
22. Esfahbodi, A.; Zhang, Y.; Watson, G. Sustainable Supply Chain Management in Emerging Economies: Trade-Offs between Environmental and Cost Performance. *Int. J. Prod. Econ.* **2016**, *181*, 350–366. [CrossRef]

23. Gupta, H.; Barua, M.K. A Grey DEMATEL-Based Approach for Modeling Enablers of Green Innovation in Manufacturing Organizations. *Environ. Sci. Pollut. Res.* **2018**, *25*, 9556–9578. [CrossRef]
24. Gupta, H.; Barua, M.K. A Framework to Overcome Barriers to Green Innovation in SMEs Using BWM and Fuzzy TOPSIS. *Sci. Total Environ.* **2018**, *633*, 122–139. [CrossRef] [PubMed]
25. Kusi-Sarpong, S.; Gupta, H.; Sarkis, J. A Supply Chain Sustainability Innovation Framework and Evaluation Methodology. *Int. J. Prod. Res.* **2019**, *57*, 1990–2008. [CrossRef]
26. Gupta, H.; Barua, M.K. Supplier Selection among SMEs on the Basis of Their Green Innovation Ability Using BWM and Fuzzy TOPSIS. *J. Clean. Prod.* **2017**, *152*, 242–258. [CrossRef]
27. Mangla, S.K.; Govindan, K.; Luthra, S. Prioritizing the Barriers to Achieve Sustainable Consumption and Production Trends in Supply Chains Using Fuzzy Analytical Hierarchy Process. *J. Clean. Prod.* **2017**, *151*, 509–525. [CrossRef]
28. Musaad, O.; Sultan, A.; Zhuo, Z.; Musaad, O.; Otaibi, A.; Siyal, Z.A.; Hashmi, H.; Shah, S.A.A. A Fuzzy Multi-Criteria Analysis of Barriers and Policy Strategies for Small and Medium Enterprises to Adopt Green Innovation. *Symmetry* **2020**, *12*, 116. [CrossRef]
29. Luthra, S.; Garg, D.; Haleem, A. Identifying and Ranking of Strategies to Implement Green Supply Chain Management in Indian Manufacturing Industry Using Analytical Hierarchy Process. *J. Ind. Eng. Manag.* **2013**, *6*, 930–962. [CrossRef]
30. Zhuo, Z.; Siyal, Z.A.; Shaikh, G.M.; Shah SA, A.; Solangi, Y.A. An integrated multi-criteria decision support framework for the selection of suppliers in small and medium enterprises based on green innovation ability. *Processes* **2020**, *8*, 418.
31. Tseng, M.L.; Wang, R.; Chiu, A.S.F.; Geng, Y.; Lin, Y.H. Improving performance of green innovation practices under uncertainty. *J. Clean. Prod.* **2013**, *40*, 71–82. [CrossRef]
32. Li, Y.; Mathiyazhagan, K. Application of DEMATEL approach to identify the influential indicators towards sustainable supply chain adoption in the auto components manufacturing sector. *J. Clean. Prod.* **2016**, *172*, 2931–2941. [CrossRef]
33. Nezami, F.G.; Yildirim, M.B. A sustainability approach for selecting maintenance strategy. *Int. J. Sustain. Eng.* **2013**, *6*, 332–343. [CrossRef]
34. Mathivathanan, D.; Kannan, D.; Haq, A.N. Sustainable supply chain management practices in Indian automotive industry: A multi-stakeholder view. *Resour. Conserv. Recycl.* **2018**, *128*, 284–305. [CrossRef]
35. Govindan, K.; Muduli, K.; Devika, K.; Barve, A. Investigation of the influential strength of factors on adoption of green supply chain management practices: An indian mining scenario. *Resour. Conserv. Recycl.* **2016**, *107*, 185–194. [CrossRef]
36. Zhou, Y.; Xu, L.; Shaikh, G.M. Evaluating and prioritizing the green supply chain management practices in pakistan: Based on delphi and fuzzy AHP approach. *Symmetry* **2019**, *11*, 1346. [CrossRef]
37. Zhu, Z.; Chu, F.; Dolgui, A.; Chu, C.; Zhou, W.; Piramuthu, S. Recent advances and opportunities in sustainable food supply chain: A model-oriented review. *Int. J. Prod. Res.* **2018**, *56*, 5700–5722. [CrossRef]
38. Awasthi, A.; Govindan, K.; Gold, S. Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach. *Int. J. Prod. Econ.* **2018**, *195*, 106–117. [CrossRef]
39. Abu Seman, N.A.; Govindan, K.; Mardani, A.; Zakuan, N.; Mat Saman, M.Z.; Hooker, R.E.; Ozkul, S. The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. *J. Clean. Prod.* **2019**, *229*, 115–127. [CrossRef]
40. Jia, F.; Zuluaga-Cardona, L.; Bailey, A.; Rueda, X. Sustainable supply chain management in developing countries: An analysis of the literature. *J. Clean. Prod.* **2018**, *189*, 263–278. [CrossRef]
41. Luthra, S.; Govindan, K.; Kannan, D.; Mangla, S.K.; Garg, C.P. An integrated framework for sustainable supplier selection and evaluation in supply chains. *J. Clean. Prod.* **2017**, *140*, 1686–1698. [CrossRef]
42. Chen, Y.-S. The driver of green innovation and green image–green core competence. *J. Bus. Ethics* **2008**, *81*, 531–543. [CrossRef]
43. Saaty, T.L. The analytic hierarchy process. *Eur. J. Oper. Res.* **1990**, *45*, 378.
44. Banaeian, N.; Mobli, H.; Fahimnia, B.; Nielsen, I.E.; Omid, M. Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry. *Comput. Oper. Res.* **2018**, *89*, 337–347. [CrossRef]
45. Mohammed, A.; Harris, I.; Soroka, A.; Nujoom, R. A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design. *Comput. Ind. Eng.* **2019**, *127*, 297–312. [CrossRef]

46. Kaganski, S.; Majak, J.; Karjust, K. Fuzzy AHP as a tool for prioritization of key performance indicators. *Procedia CIRP* **2018**, *72*, 1227–1232. [CrossRef]
47. Gogus, O.; Boucher, T.O. Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons. *Fuzzy Sets Syst.* **1998**, *94*, 133–144. [CrossRef]
48. Hwang, C.-L.; Yoon, K. Methods for multiple attribute decision making. In *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey*; Springer: Berlin/Heidelberg, Germany, 1981; pp. 58–191.
49. Han, H.; Trimi, S. A fuzzy TOPSIS method for performance evaluation of reverse logistics in social commerce platforms. *Expert Syst. Appl.* **2018**, *103*, 133–145. [CrossRef]
50. Cayir Ervural, B.; Zaim, S.; Demirel, O.F.; Aydin, Z.; Delen, D. An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey's energy planning. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1538–1550. [CrossRef]