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Development and Prioritization of Green Supply Chain Strategies and Renewable Energies in Uncertainty Conditions

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Abstract

The trend of the fourth industrial revolution in the field of energy, like other sectors, indicates that the path of production, development, and approaches to energy use in the world is changing every day. This change can be seen in the growth of new energy production in the developed countries by renewable energy. Owing to the global energy crisis all around the world and the exhaustible non-renewable energy resources, as well as increasing the pollution and green supply chain due to the indiscriminate use of fossil fuels, the need to use sustainable energy, especially in the industrial sector, which accounts for 40% of energy consumption in Iran, has been paid attention to. The present work develops and prioritizes green supply chain strategies with uncertainty over time under fuzzy conditions in the Mobarakeh Steel Company. First, the internal strengths, weaknesses, opportunities, and threats are identified based on the theoretical foundations and experts' opinions. Then the green supply chain strategies of the Mobarakeh Steel Company are developed using the SWOT method. The fuzzy Analytical Network Process (ANP) method is used for weighing the dimensions of sustainability, while the Technique for Order Preference by Similarity to Ideal Solution TOPSIS and TODIM methods are used for weighing the strategies. The results obtained indicate that among the indicators of sustainability, the "social" indicator has the first rank, the "environmental" indicator has the second rank, and the "economic" indicator has the third rank. In addition, the strength opportunity (SO) strategies have the first rank, the strength threat (ST) strategies have the second rank, the weakness opportunity (WO) strategies have the third rank, and the weakness threat (WT) strategies have the fourth rank. The results of the partial strategies related to each one of the four strategies show that among the WO strategies, "buying and using new production technologies" has the highest rank; among the SO strategies, "using the information system to increase public awareness on the importance of the environment and sustainable development," and "modifying the energy consumption pattern based on the use of new technologies and experienced consultants"; among the ST strategies, "injecting culture in the society to collaborate with waste collection in public places, parks, and green spaces"; and among the defense strategies (WT), cooperation with the relevant organizations in order to identify and cope with the accidents and emergencies for preventing and reducing the environmental consequences (fires of Mobarakeh Steel Company buildings) as well as cooperation with the relevant organizations to develop annual specific environmental goals like banning tree felling besides concluding contracts with construction companies for renovating the city, adhering to the green principles, and produce new energy in architecture and construction are of the fundamental priority and importance.

Keywords: *Green Supply Chain Strategies, Renewable Energies, Fuzzy Conditions, Mobarakeh Steel Company.*

1. Introduction

Environmental pollution has become a challenging issue for business organizations in the recent years [1-3]. The technical and environmental studies besides station rankings are the parameters studied for the first time in the previous study. The results of weighting using the best-worst method (BWM) have revealed that the total solar fraction and the avoided CO_2 emission, respectively, have the highest and lowest weights [4].

The business activities such as marketing and production are known as the main factors in this field [5]. Such activities have led to increased pressure on the internal and external shareholders

such as the governments, workers, and non-profit groups [6-8]. Thus this issue has led to the demand for increasing the consumers and environmental communities for environmentally-friendly products [9]. Such challenges and pressures make the companies to consider the environmental effects of products and the creation of green products while performing their business activities [10, 11]. The concept "green" is the visualization of environmentally-friendly products, processes, systems, and technologies that affect the business activities [12, 13]. Generally, heat transfer between indoor and outdoor space is reduced by about 0.15 through installing PCMs like Enerciel 22, C16-C18, paraffin C18, and decanoic (capric) acid (with thermal conductivity) inside the wall [14].

In general, the role of organizations in the society and their responsibility in minimizing their effect on the environment has found more significance [15-18]. The strategies to implement GSCM include suitable policies by excellent management to incorporate practices such as innovative green design, green procurement, green packaging, green distribution, and even end-of-life management, which play a cardinal role in emission reduction [19]. A previous research work examined the effectiveness of installing PCM inside the wall on the thermal performance of an air handling unit (AHU). Given the solar radiation effects on the building covering, we examined the sensitivity of reducing heat transfer to wall positions to the main direction according to the numerical results, compared to the PCM close to the interior, placing the PCM closer to the outside space performs better [20].

Nowadays, with the fast development of manufacturing and service areas, there are new expectations in the process of green supply chain, and the competition of companies in this environment and market is improving [21]. A previous study investigated the effect of installing a hybrid PCM inside the wall on reducing the heat transfer in the hottest (July) and coldest months (January) in three climatic zones. In all three climates, over the hot and cold months, PCM installing into the wall decline heat transfer [22].

The production sector may significantly contribute to the economic growth of any country through adopting innovative methods that can decline the negative environmental effects. A previous research work employed a three-level approach in order to identify the strategies and barriers for sustainable production in manufacturing organizations. The financial and strategic barriers are the fundamental barriers preventing the acceptance of sustainable production [23].

The increasing complexity of highly variable activities and environments has made the managers to encounter the difficulties that have irreversible consequences. In such conditions, strategic planning and management are required for survival, growth, and dynamism, while it needs more attention as the most significant need of each company [24].

Reducing fossil fuel consumption and meeting the requirements for declining the environmental pollutants, from the perspective of the whole country, has attracted increasing attention due to creating opportunities [25].

The strategy is a qualitative process based on the ideas. The data that is not necessarily confirmed as quantitative such as experiences integrate the thoughts and ideas, enter the organization into a continuous negotiation, and provide the organizational vision and goal explicitly [26]. The analysis shows that advertising enterprise can substantially increase the product greening level and manufacturer's benefit [27].

The supply chain strategy is a repetitive process evaluating the cost-benefit analyses of the operational components. In the recent years, many reasons have made the managers realize that the role of the green supply chain should be taken into account in defining the long-term strategies and goals as a new competitive strategy in the governments, organizations, and societies. Due to the rapid trend of changes, there is a need to identify the effective and changing strategies to implement green supply chain management in the best way. SWOT is used for environmental evaluation in order to achieve a systematic approach and support decision-making. The SWOT model is one of the strategic tools for adapting the intra-system strengths and weaknesses in the system to the extra-system opportunities and threats. Based on this model, an effective strategy maximizes the strengths and opportunities but minimizes the weaknesses and threats. The case study identifies appropriate SSCIs and differentiates them among peer suppliers to gain a competitive advantage [28].

The SWOT analysis fails at providing an analytical tool for determining the relative importance of the factors and also cannot evaluate the appropriateness of decision-making alternatives based on such factors [29]. However, the result of the SWOT analysis is often as a list or insufficient qualitative review of the internal and external factors. For this reason, the SWOT analysis cannot evaluate the strategic decision-

making process comprehensively. Thus the researchers combined it with other techniques, especially the multi-criteria decision-making techniques [30-35]. A previous research work reported the most suitable solutions for the establishment of solar energy in Iran. The strengths, weaknesses, opportunities, and threats of four various strategies including the offensive, conservative, competitive, and defensive strategies were considered through using internal-external matrices and SWOT matrix [36].

In this work, the SOWT matrix was used with ANP and TOPSIS-TODIM in the fuzzy state for supporting the strategic analysis as well as developing and prioritizing the attractiveness of the strategies under uncertain conditions. Such a combination can somewhat solve the inherent ambiguity and uncertainty in the strategic decision-making process of the green supply chain in the Mobarakeh Steel Company.

2. Review of literature

Supply chain management is relatively a new concept, while green supply chain management is a new concept. There is little structured literature about green supply chain management, while only a few review studies have been published on this area during the recent years. An AHP-FIDSS involves the factor screening, hierarchical structure modeling, quantification of qualitative factors, and their conversion to the quantitative values [37].

In the supply chain, there is a set of generally accepted environmental indicators for monitoring the environmental objectives. It is important to consider these elements in the integrated operation of the green supply chain. A previous research work proposes a general indicator of environmental performance including the operational, financial, and environmental aspects enabling the integrated monitoring of supply chain performance by means of principal component analysis of the composite data [38].

Çankaya and Sezen (2019) have introduced the green supply chain as a critical component of environmental strategies and supply chains, and studied its different dimensions such as the procurement of raw materials, input logistics, transformation, output logistics, marketing, after-sale, and good product disposal [39].

Malviya *et al*. (2018) have presented a model for selecting sustainable strategies in implementing the green supply chain. This study aimed to review the strategies of green supply chain strategy (GSCM) and select the best GSCM strategy using the fuzzy network analysis (ANP). This study was formed on the basis of an empirical case study from an Indian automobile organization in order to verify the model function. The results obtained indicate that the resource-based strategy is at the first position, and specifies the maximum effect on each factor. The desired organization should improve the green management system using an appropriate GSCM strategy, i.e. a resource-based strategy [40]. Scrutiny based on multi-tier supply chain modeling is used to recognize the environmental supply chain bottlenecks [41].

Malek *et al*. (2017) have developed the improved grey relational analysis (GRA) method for evaluating a flexible green supply chain network. In this study, the evaluation and selection of suppliers in a flexible green supply chain were dealt with using the improved and combined grey relational analyses. This study approves a structured literature review in conjunction with content analysis in order to specify whether the existing strategic planning encourages sustainability in international shipping [42].

Masoumik *et al*. (2015) have dealt with strategic planning for developing the green supply chains. Based on the natural resource-based view (NRBV), they presented a conceptual model for prioritizing the green supply chain strategy, and used a combination of the ANP and SEM methods to prepare the proposed conceptual model [43].

Wu and Wu. (2014) have studied the integration of green supply chain management and operational performance. They aimed at developing green supply chain management research work and analyzing it in a conceptual framework in order to evaluate the relationship between the dimensions of green supply chain management and the multiple dimensions of operational performance in the organization [44].

Product quality betterment, integration of permanency principles into decision making, and pressure from the consumers and investors are the three most significant drivers for achieving sustainability in the supply chain network [45].

Winter and Knemeyer (2013) have studied the integration of sustainability and supply chain management by considering the current conditions and future opportunities. Their purpose was the extensive review of the literature on the supply chain management sustainability, and the results obtained indicated that the studies conducted until that time individually focused more on the sustainability and management of supply chain while the integration of these two concepts together had a significant effect on the supply chain management decisions [46]. The social

dimension, which is a very significant factor besides the economic and biophysical environment within the social structure, is one of the most essential pillars of sustainability [47].

Fraj *et al*. (2011) have conducted a study "Green marketing strategy and corporate performance: the moderating role of environmental culture", studying the integration of environmental values in the company internal culture and determination of the effect of green strategies on the corporate performance. Their findings showed that the green marketing strategy led to the improvement of profitability in the companies through the optimization of marketing performance and reduction of costs. Nevertheless, the dimensions of organizational results such as process performance are not positively related to the economic boom. In addition, they revealed that the companies with better operational and marketing performance of environmental practices were more successful to achieve competitive advantage [48].

Simpson and Samson (2008) have presented a range of green supply chain management strategies including risk-based strategy, efficiency-based strategy, innovation-based strategy, and closed loop strategy [49]. Ramudhin *et al*. (2010) have presented a strategic planning model, emphasizing on the high significance of the internal and external control mechanisms for the decision-makers while designing a sustainable supply chain network [50].

As indicated in Table 1, many studies have been conducted in the field of green supply chain, supply chain strategies, and strategic planning. However, little research work has been conducted on the green supply chain strategies, and among this limited number of studies, good prioritization and selection using the SWOT and fuzzy multi-criteria decision-making methods, and a combination of the TOPSIS and TEDDIM and ANP methods has been considered, and this is a research gap. The present study was significant in this term, and was developed in line with the filling of this research gap.

Table 1. Summary of previous studies.

Ref.	Green supply chain	Strategy	SWOT	TOPSIS	TOPDIM	ANP	Fuzzy logic
[41]	*	*					
[42]	*	*					
[40]	*	*					
[36]		*					
[35]	*	*				*	
[34]	*						*
[32]	*	*				*	*
[31]	*	*					
Present study	*	*	*	*	*	*	*

3. Research methodology

3.1. Method

The method used in this was analytical-survey. A combination of library and field research methods was used for data collection. The library method was used for collecting the data about research literature and research background, while the field method was used for collecting the data to answer the research questions.

3.2. Statistical population and sample

The statistical population of this work included all the managers, experts, and stakeholders of the Mobarakeh Steel Company. In order to determine the sample size based on the limited statistical population, the following formula was used:

$$\boldsymbol{n = \frac{N \times Z^2_{\alpha/2} p(1-p)}{d^2(N-1) + Z^2_{\alpha/2} P(1-P)}} \quad (1)$$

where:

n is the sample size;

N is the population size;

Z is the value of standard normal variable as 1.96 at 95% confidence level;

P is the value of the attribute ratio in the population. It could be considered as 0.5 if it was not available. In this case, the variance value will reach its maximum value;

q is the percent of members without the attribute in the population (q = 1 - p);

d is the allowed error value equal, which was considered as 0.05.

In the present work, the number of subjects in the statistical population was reported as 200. Based on N = 200, the sample size was calculated as 131.755 using the Cochran formula, which was equal to 132.

$$\boldsymbol{\frac{200 \times 1.96^2 \times 0.5 \times 0.5}{0.05^2 \times 199 + 1.96^2 \times 0.5 \times 0.5} = 131.755}$$

3.3. Data collection method and tools

In this work, the library and field methods were used for data collection. The library method was used for collecting the data about the research literature and research background, while the field method was used for collecting the data to answer the research questions. In reviewing the theoretical foundation and literature, the Internet, scientific articles, and similar theses were used. In the field phase, which was the most significant phase of data collection, a questionnaire was used in order to collect the data.

3.4. Data analysis method

In the present work, first, the internal and external strategic factors were investigated for developing a green supply chain strategy in the Mobarakeh Steel Company. The SWOT matrix analysis was used in order to develop the strategies. After developing the green supply chain strategies, the hybrid multi-criteria decision-making methods were used to prioritize and provide the final model. The fuzzy ANP method was used for determining the weight of sustainability indicators, and then the TOPSIS and Fuzzy TODIM methods were used to prioritize the green supply chain strategies.

4. Results

4.1. Results of SWOT method

In order to develop the strategies, first, the internal factors (strengths and weaknesses) and the external factors (opportunity and threat) were determined by referring to the case study place and identifying the internal and external environment in cooperation with the experts. First, a preliminary list was prepared for each one of the above-mentioned factors, and then a consultation meeting was held with the experts, and the final factors were selected as the most critical factors.

First, 21 strengths were determined, as displayed in Table 2. This list was given to the experts, and according to them, 11 items were removed from the list, and the final strengths were determined based on Table 3. According to the experts' viewpoints, the deleted strengths were either not true in the studied organization or overlapped with the other points.

First, 10 weaknesses were determined, as indicated in Table 4. Then this list was presented to the experts, and according to their opinions, two items were deleted from the list, and the final weaknesses were determined based on Table 5.

Table 2. Preliminary list of strengths.

Description (strengths)	Factor
Manager's attention to modify energy consumption pattern	S_1
Manager's attention to present an instant plan for reducing occupational injuries	S_2
Having sufficient experts	S_3
Responsibility of managers	S_4
Having reasonable documents	S_5
Regarding reduction of waste	S_6
Using modern technologies	S_7
Regarding ISO 14001 certificate of suppliers	S_8
Holding business planning meetings with other stakeholders in relation to prediction and resolution of environmental problems	S_9
Sustainable consumption pattern of renewable resources	S_{10}
Regarding measurement of pollutant emissions	S_{11}
Addressing complaints of people in society on environmental issues	S_{12}
Joining local recycling organization	S_{13}
Total quality environmental management	S_{14}
Appropriate use of natural resources (mines)	S_{15}
Managers' commitment to green processes of supply chain management	S_{16}
Presence of information systems	S_{17}
Sourcing, green procurement, green packaging, green distribution, and sales	S_{18}
Measures of produced waste disposal	S_{19}
Optimized planning of transport fleet	S_{20}
Energy efficiency measures for lighting and heating	S_{21}

Table 3. Final list of strengths.

Description (strengths)	Factor
Manager's attention to modify energy consumption pattern	S_1
Manager's attention to present an instant plan for reducing occupational injuries	S_2
Having sufficient experts	S_3
Regarding reduction of waste	S_4
Using modern technologies	S_5
Regarding ISO 14001 certificate of suppliers	S_6

Holding business planning meetings with other stakeholders in relation to prediction and resolution of environmental problems	S_7
Regarding measurement of pollutant emissions	S_8
Addressing complaints of people in society on environmental issues	S_9
Presence of information systems	$S1_0$

Table 4. Preliminary list of weaknesses.

Description (weaknesses)	Factor
Poor performance in designing an appropriate landscape (green space)	W_1
Poor performance in preventing environmental degradation	W_2
Not regarding safety tips in businesses and using ergonomic designs	W_3
Failed regular and periodic measurement of pollutant concentration	W_4
Poor and irregular monitoring on production	W_5
Lack of employees' group participation in relation to issues such as energy, water, and pollution prevention	W_6
Lack of sufficient plan and regular practice of renovating buildings related to company to join green principles of architecture	W_7
Lack of using experts' opinions about ideas of energy conservation	W_8
Lack of chemical and microbial monitoring of all discharged materials to municipal sewage system	W_9
Not regarding safety procedure in the design of workplace	W_{10}

Table 5. Final weaknesses.

Description (weaknesses)	Factor
Poor performance in preventing environmental degradation	W_1
Not regarding safety tips in businesses and using ergonomic designs	W_2
Failed regular and periodic measurement of pollutant concentration	W_3
Poor and irregular monitoring on production	W_4
Lack of employees' group participation in relation to issues such as energy, water, and pollution prevention	W_5
Lack of sufficient plan and regular practice of renovating buildings related to company to join green principles of architecture	W_6
Lack of using experts' opinions about ideas of energy conservation	W_7
Lack of chemical and microbial monitoring of all discharged materials to the municipal sewage system	W_8

Table 6. Preliminary list of opportunities.

Description (opportunity)	Factor
Familiarity of companies and contractors of the private sector with optimization process of energy consumption, policies, and rules developed in this regard	O_1
Presence of new technologies for optimizing extraction and production	O_2
Providing a national guide for managing CO_2 emissions	O_3
Presence of a regulation on green management	O_4
Article 190 of 5th five-year plan of the Islamic Republic of Iran on green management plan	O_5
Presence of the Law on Air Pollution Prevention approved in 1995 in relation to the sources of commercial pollutants	O_6
Government's attention to environmental pollutants and budget allocation in this area	O_7
Government's attention to environmental management standards	O_8
Allocating credits by government for implementing green management	O_9
Promoting culture in society in line with the environment preservation in recent years	O_{10}

First, 10 opportunities were determined as indicated in Table 6. Then this list was provided to the experts, and according to their opinions, four items were deleted from the list, and the final list was determined based on Table 7.

First, nine threats were identified, as indicated in Table 8. Then this list was presented to the experts, and based on their opinions, 3 items were deleted from the list, and the final list was determined based on Table 9.

In this work, after identifying the internal and external factors, they were analyzed using the evaluation matrix. The data collected from 132 members of the statistical population were used for collecting the values of the checklist. Based on the collected data, one weight was calculated for each internal and external factor (in fact, the average of the opinions was considered as a weight). After calculating the average of the opinions, the normal weight was obtained using the following equation:

$$\boldsymbol{W_i} = \frac{\boldsymbol{d_i}}{\sum_i \boldsymbol{d_i}} \qquad \forall \boldsymbol{i} \qquad (2)$$

in which W_i represents the normal weight of the i-th factor, and $\boldsymbol{d_i}$ represents the average of opinions for the i-th factor.

In the next step, a number between 1 and 4 was assigned to each external and internal factor indicating the score of the current status. Then the above-mentioned score (between 1 and 4) was multiplied by the normal weight of the factor and included in the weighted score column for determining the weighted score of each factor. Then four strategies were presented using the SWOT matrix.

As indicated in Table 10, eighteen factors were studied as the internal factors, of which 11 factors were identified as the strengths and 8 factors were

identified as the weaknesses. Among the strengths, "the presence of information systems" with a weighted score of 0.1354 was the most significant strength in the company. In addition, among the weaknesses, "the lack of chemical and microbial monitoring of all discharged materials to the municipal sewage system" with a weighted score of 0.1366 was the most significant weakness of this company.

As indicated in Table 11, twelve factors were considered as the external factors, of which 6 factors were introduced as the opportunities and 6 factors were introduced as the threats. Among the opportunities, "the familiarity of the companies and contractors of the private sector with the optimization process of energy consumption, policies, and rules developed in this regard" with a weighted score of 0.1004 was the most important opportunity, and among the threats, "the absence of annual special environmental goals" with a weighted score of 0.1375 was the most important threat to the municipality of Tehran's 6th district. After preparing the weighted scores and determining the most significant strengths, weaknesses, opportunities, and threats, green management strategies were developed in four methods as SO, ST, WO, and WT using the SWOT matrix in order to create a sustainable development. Based on the results obtained, the four strategies of SO, WO, ST, and WT were listed in Table 12.

Table 7. Final list of opportunities.

Description (opportunity)	Factor
Familiarity of companies and private contractors with optimization process of energy consumption, policies, and rules developed in this regard	O_1
Presence of new technologies for optimizing extraction and production	O_2
Providing a national guide for managing CO_2 emissions	O_3
Government's attention to environmental management standards	O_4
Allocating credits by government for implementing green management	O_5
Promoting culture in society in line with environment preservation in recent years	O_6

Table 8. Preliminary list of threats.

Description (threat)	Factor
Absence of annual special environmental goals	T_1
Failure to present executive instruction for identifying and coping with emergencies to prevent and reduce environmental consequences	T_2
Lack of attention to prevalence of diseases caused by contaminations caused by production	T_3
Non-cooperation of government and other institutions in field of environmental protection	T_4
Insufficient awareness of people in society to implement green supply chain	T_5
Absence of technology and access to ergonomic work environment	T_6
Failure to predict required prerequisites in energy carrier sector	T_7
Economic sanction and lack of access to new technologies	T_8
Lack of adequate budget in implementation of waste separation and waste disposal plan	T_9

Table 9. Final list of threats.

Description (threat)	Factor
Absence of annual special environmental goals	T_1
Failure to present executive instruction for identifying and coping with emergencies to prevent and reduce environmental consequences	T_2
Lack of attention to prevalence of diseases caused by contaminations caused by production	T_3
Absence of technology and access to ergonomic work environment	T_4
Economic sanction and lack of access to new technologies	T_5
Lack of adequate budget in implementation of waste separation and waste disposal plan	T_6

Table 10. Evaluation matrix of internal factors.

Weighted score	Normalized weight	Current score	weight	Description (strengths)	Factor
0.0995	0.0332	3	2.993	Manager's attention to modify energy consumption pattern	1
0.0999	0.0333	3	3.004	Manager's attention to present an instant plan for reducing occupational injuries	2
0.0653	0.0326	2	2.945	Having sufficient expert	3

0.1316	0.0329	4	2.967	Regarding reduction and disposal of waste	4
0.0346	0.0346	1	3.124	Using modern technologies	5
0.0964	0.0321	3	2.898	Regarding ISO 14001 certificate of suppliers	6
0.0340	0.0340	1	3.069	Holding business planning meetings with other stakeholders in relation to prediction and resolution of environmental problems	7
0.1028	0.0343	3	3.091	Regarding measurement of pollutant emissions	8
0.0656	0.0328	2	2.959	Addressing complaints of people in society on environmental issues	9
0.1354	0.0337	4	3.055	Presence of information systems	10
Weighted score	Normalized weight	Current score	wright	Description (weakness)	Factor
0.1363	0.0341	4	3.073	Poor performance in preventing environmental degradation	1
0.0660	0.0330	2	2.978	Not regarding safety tips in businesses and using ergonomic designs	2
0.1023	0.0341	3	3.077	Failed regular and periodic measurement of pollutant concentration	3
0.1034	0.0345	3	3.109	Poor and irregular monitoring on production	4
0.1011	0.0337	3	3.040	Lack of employees' group participation in relation to issues such as energy, water, and pollution prevention	5
0.0663	0.0332	2	2.993	Lack of sufficient plan and regular practice of renovating buildings related to company to join green principles of architecture	6
0.0994	0.0331	3	2.989	Lack of using experts' opinions about ideas of energy conservation	7
0.1366	0.0341	4	3.080	Lack of chemical and microbial monitoring of all discharged materials to municipal sewage system	8

Table 11. Evaluation matrix of external factors.

Weighted score	Normalized weight	Currents core	weight	Description (opportunity)	Factor
0.1004	0.0335	3	3.018	Familiarity of companies and contractors of private sector with optimization process of energy consumption, policies, and rules developed in this regard	1
0.0993	0.0331	3	2.985	Government's attention to environmental management standards	2
0.0975	0.0325	3	2.931	Provide Country Guide for managing CO_2 emissions	3
0.0639	0.0319	2	2.883	Government Attention to Environmental Management Standards	4
0.0983	0.0328	3	2.956	Allocating credits by government for implementing green management	5
0.0981	0.0327	3	2.949	Promoting culture in society in line with environment preservation in recent years	6
Weighted score	Normalized weight	Current score	weight	Description (threat)	Factor
0.1375	0.0344	4	3.102	Absence of annual special environmental goals	1
0.0992	0.0331	3	2.982	Failure to present executive instruction for identifying and coping with emergencies to prevent and reduce environmental consequences	2
0.0968	0.0323	3	2.912	Lack of attention to prevalence of diseases caused by contaminations caused by production	3
0.1349	0.0337	4	3.044	Absence of technology and access to the ergonomic work environment	4
0.1341	0.0335	4	3.026	Economic sanction and lack of access to new technologies	5
0.0661	0.0331	2	2.982	Lack of adequate budget in implementation of waste separation and waste disposal plan	6

Table 12. Green supply chain strategies of Mobarakeh Steel Company.

Description	Name
Using experienced contractor companies to optimize energy consumption and using their ideas	WO strategy
Buying and using new technologies	
Injecting strategic thinking in employees by expert advisors and contractors for production using new technologies	
Institutionalizing culture in line with green management regulations	
Creating a developed program to modernize buildings of Mobarakeh Steel Company based on green principles in architecture and construction	
Using government budget to reduce environmental contaminants	
Using information system to increase awareness of society about importance of environment and sustainable development	SO strategy
Using information system to introduce society members to annual environmental goals of company and using their opinions	
Providing a strategy for designing a disposal system based on the environmental issues and green management	

national code	
Providing an appropriate program and strategy for designing and using ergonomic tools	
Modifying pattern of energy consumption based on use of new technologies and experienced consultants	
Defining increase of community satisfaction and providing a strategy for addressing complaints of people on environmental issues and sending complaints to competent government authorities and also providing solutions to reduce complaints	
Using contractor companies and experienced consultants to implement appropriate and new waste collection systems	
Responding complaints along with presenting a manual for training and familiarizing people with environmental protection	(ST) strategy
Using different educational tools to familiarize people with environmental pollution consequences and disadvantages	
Injecting culture among people in society to collaborate on collecting waste in public places, parks, and green spaces	
Injecting culture among people and providing a strategy for modifying energy consumption pattern	
Creating awareness among people to use public transportation vehicles through advertising	
Cooperation with relevant organizations in formulation of annual special environmental goals such as preventing cutting of trees, signing contracts, and cooperating with construction companies to modernize city and join green principles of architecture and construction	WT strategy
Using results of scientific research such as production planning and timing, human resources, allocation, job turnover, minimization of cost and ergonomic risk reduction, and increased productivity of production	
Cooperation with relevant organizations to identify and deal with emergencies to prevent and reduce environmental consequences (fire burning of buildings related to Mobarakeh Steel)	
Using educated labor in country and using their talents to design ergonomic tools	
Monitoring company performance in field of waste separation and waste disposal	

4.2. Results of strategy ranking

In this section, the sustainability dimensions were first weighed using the ANP method, and then the TOPSIS and TODIM methods were used in order to rank the supply chain strategies.

4.2.1. ANP method

In this section, first, the social, economic, and environmental components that were related to sustainable development were ranked using the fuzzy ANP method. After collecting the data that was as numbers 1 to 5, the expression values were converted to fuzzy numbers using the values in Table 13, and the mean fuzzy values were calculated using the fuzzy number rules.

As the managers and experts responded to the questionnaire indices qualitatively, and the data provided by them was not accurate, a fuzzy set was used in order to consider uncertainty of information sharing, and supply the chain performance indices.

Table 13: Equivalent linguistic variables.

Fuzzy equivalent	Definitive equivalent	Linguistic variable
(0, 0, 0.25)	1	Very low
(0, 0.25, 0.5)	2	Low
(0.25, 0.5, 0.75)	3	Average
(0.5, 0.75, 1)	4	High
(0.75, 1, 1)	5	Very high

Table 14: Fuzzy decision super matrix.

Environmental	Economic	Social	Indicator
(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	0	Social
(0.75, 1, 1)	0	(0, 0, 0.25)	Economic
0	(0, 0, 0.25)	(0.25, 0.5, 0.75)	Environmental

Table 15: Final weights of sustainability indicators.

Rank	Normalized weight	Non-normalized weight	Indicator
1	0.347	1	Social
2	0.326	0.939	Economic
3	0.328	0.946	Environmental

As shown in Table 14 after determining the relative weights, it was time to form an unbalanced super-matrix, which was prepared based on the relative weights calculated in the previous step.

As shown in Table 15 among the indicator of sustainability, the "social" indicator with a weight of 0.347 was ranked first, the "environmental" indicator with a weight of 0.328 was ranked second, and the "economic" indicator with a weight of 0.326 was ranked third.

4.2.2. Results of Fuzzy TODIM and TOPSIS

In this section, four strategies were weighed and ranked using the fuzzy TOPSIS method, and then

this method was used for weighting and prioritizing the components of each strategy. In the fuzzy TOPSIS method, the importance of four strategies was surveyed from the experts based on the "economic", "social", and "environmental" dimensions, and based on Table 16, they were converted into fuzzy triangular numbers. After calculating the mean, the results obtained were presented as the fuzzy multi-criteria decision-making matrix.

Table 16: Linguistic variables of weights $\widetilde{w}_j$ for each criterion.

Very Low (VL)	(0,0,0,2)
Low (L)	(0,0,2,0,4)
Medium	(0,3,5,0,7)
High (H)	(0,6,0,8,1)
Very High (VH)	(0,8,1,1)

In the above matrix, $\boldsymbol{x_{ij}}$ represents the importance of the i-th option to the j-th criterion, which is expressed as a triangular fuzzy number.

The steps of the preferences prioritization decision-making based on similarity to the fuzzy ideal solution are as follow:

Step 1: First, the answers given to each question should be evaluated, and the qualitative terms should be used to weigh the criteria.

Step 2: Normalization of decision matrix (GFMADM): Since the components forming the matrix of the GFMADM group decision are fuzzy numbers, the following two formulas should be used in terms of the cost or benefit of ranking criteria in order to normalize the decision matrix.

$$\tilde{\boldsymbol{r}}_{\boldsymbol{jl}} = \left(\frac{\boldsymbol{a_{jl}}}{\boldsymbol{c_l^*}}, \frac{\boldsymbol{b_{jl}}}{\boldsymbol{c_l^*}}, \frac{\boldsymbol{c_{jl}}}{\boldsymbol{c_l^*}}\right); \boldsymbol{l} \in \boldsymbol{B}; \quad \boldsymbol{c_l^* = max_j c_{jl}\ if\ \ l \in B} \tag{3}$$

$$\tilde{\boldsymbol{r}}_{\boldsymbol{jl}} = \left(\frac{\boldsymbol{a_l^-}}{\boldsymbol{c_{jl}}}, \frac{\boldsymbol{a_l^-}}{\boldsymbol{c_{jl}}}, \frac{\boldsymbol{a_l^-}}{\boldsymbol{c_{jl}}}\right); \boldsymbol{l} \in \boldsymbol{C}; \quad \boldsymbol{a_l^- = min_j c_{jl}\ if\ \ l \in C} \tag{4}$$

B is a set of benefit criteria and the set of cost criteria. It should be noted that the normalized method used has this C feature that the normalized triangular fuzzy ranges belong to [0, 1].

Step 3: Negative ideal solution (A^-) and positive ideal solution (A^+) were obtained using the following equations:

$$\mathbf{A^+} = (\tilde{\mathbf{v}}_1^*, \tilde{\mathbf{v}}_2^*, \tilde{\mathbf{v}}_3^*, \ldots, \tilde{\mathbf{v}}_n^*) = \left\{\max \mathbf{v_{ij}} \,\middle|\, (\mathbf{i} = 1, 2, \ldots, \mathbf{m}, \mathbf{j} = 1, 2, \ldots, \mathbf{n})\right\} \tag{5}$$

$$\mathbf{A^-} = (\tilde{\mathbf{v}}_1^-, \tilde{\mathbf{v}}_1^-, \tilde{\mathbf{v}}_1^-, \ldots, \tilde{\mathbf{v}}_1^-) = \left\{\min \mathbf{v_{ij}} \,\middle|\, (\mathbf{i} = 1, 2, \ldots, \mathbf{m}, \mathbf{j} = 1, 2, \ldots, \mathbf{n})\right\} \tag{6}$$

Step 4: The desired intervals were calculated in this step. The interval of each component from the positive and negative ideal solutions is obtained from the following equations:

$$\mathbf{d_i^*} = \sum_{\mathbf{j=1,\ldots,n}} \mathbf{d}(\tilde{\mathbf{v}}_{\mathbf{ij}}, \tilde{\mathbf{v}}_{\mathbf{j}}^*); \ \mathbf{i} = 1, 2, \ldots, \mathbf{m} \tag{7}$$

$$\mathbf{d_i^-} = \sum_{\mathbf{j=1,\ldots,n}} \mathbf{d}(\tilde{\mathbf{v}}_{\mathbf{ij}}, \tilde{\mathbf{v}}_{\mathbf{j}}^-); \ \mathbf{i} = 1, 2, \ldots, \mathbf{m} \tag{8}$$

where $d(\cdot,\cdot)$ represents the interval between two fuzzy numbers.

Step 5: At this stage, the proximity of each component to the ideal solution was calculated, and the priority of options was determined (Table 17):

$$\mathbf{cc_i} = \frac{\mathbf{d_i^-}}{\mathbf{d_i^* + d_i^-}}, \ \mathbf{A_i(i = 1, 2, \ldots, m)} \tag{9}$$

Table 17: Option ranking.

Rank	cc_i	Option
3	0.2466	WO strategies
1	0.3247	SO strategies
2	0.2506	ST strategies
4	0.1781	WT strategies

As it is obvious in the above table, the SO strategies were ranked first, the ST strategies were ranked second, the WO strategies were ranked third, and the WT strategies were ranked fourth.

In the last step, the four green supply chain strategies were ranked using the fuzzy TOPSIS method. Each strategy included more detailed strategies. The fuzzy TODIM method was used in order to prioritize the components.

In the fuzzy TODIM method, the fuzzy decision matrix that included the options (strategy) and criteria (economic, social, and environmental) was formed as a fuzzy TOPSIS method, and then normalized. In order to normalize the decision matrix, for the positive criteria, Equation 10 was used for the positive criteria but Equation 11 was used for the negative criteria.

$$\mathbf{x_{ij}} = \frac{\mathbf{y_{ij}} - \mathbf{min}(\mathbf{y_{ij}})}{\mathbf{max}(\mathbf{y_{ij}}) - \mathbf{min}(\mathbf{y_{ij}})} \tag{10}$$

$$\mathbf{x_{ij}} = \frac{\mathbf{max}(\mathbf{y_{ij}}) - \mathbf{y_{ij}}}{\mathbf{max}(\mathbf{y_{ij}}) - \mathbf{min}(\mathbf{y_{ij}})} \tag{11}$$

After forming the normal fuzzy decision matrix, the relative weights were obtained. In order to calculate the relative weight, the weight of the criteria had to be divided by the largest weight in order to calculate the relative weights. In this case, at least one criterion had the weight 1. The next step involved determining the degree of

dominance. The degree of dominance in option A_i to option A_j that is the degree of dominance for each option can be calculated using the following equation:

$$\boldsymbol{\delta(A_i, A_j) = \sum_{c=1}^{m} \varphi_c(A_i, A_j), \quad \forall (i, j)} \tag{12}$$

In the above equation, the value of preferences index is calculated as follows:

$$\varphi_c(A_j, A_i) = \begin{cases} \sqrt{\frac{w_{rc}(p_{ic} - p_{jc})}{\sum_{c=1}^{m} w_{rc}}}, & \text{if } (p_{ic} - p_{ic}) > 0 \\ 0 & \text{if } (p_{ic} - p_{ic}) = 0 \\ -\frac{1}{\theta}\sqrt{\frac{\sum_{c=1}^{m} w_{rc}(p_{jc} - p_{ic})}{w_{rc}}}, & \text{if } (p_{ic} - p_{jc}) > 0 \end{cases} \tag{13}$$

In the above equation, θ represents the factor of deficit. If θ < 1, then the decision-maker seeks to select an option with the minimum losses that can be applied to all criteria. However, if θ > 1 is chosen, it means that the decision-maker wants to select a more profitable option even if there is a considerable loss is applied to some criteria. In most studies, θ = 1 is considered. At the final step, the total value of each option was determined based on Equation 14, by which the options could be ranked. Each option having a higher total value gained a better rank.

$$\boldsymbol{\varepsilon_i = \frac{\sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{j=1}^{n} \delta(A_i, A_j)}{\max \sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{j=1}^{n} \delta(A_i, A_j)}} \tag{14}$$

Table 18 shows that among the WO strategies, "buying and using new production technologies" has the highest rank; among the SO strategies, "using the information system to increase public awareness on the importance of the environment and sustainable development," and "modifying the energy consumption pattern based on the use of new technologies and experienced consultants"; among the ST strategies, "injecting culture in the society to collaborate with waste collection in public places, parks, and green spaces"; and among the WT strategies, "cooperating with relevant organizations to identify and cope with emergencies to prevent and reduce environmental consequences (the fire of buildings in the Mobarakeh Steel Company)" have the greatest importance and prioritization.

5. Conclusions

In this paper, the green supply chain strategies of the Mobarakeh Steel Company were identified and evaluated. In order to achieve the research goal, first the internal factors (Internal strengths and weaknesses) and then the external factors (external opportunities and threats) were identified. Then the green supply chain strategies of the Mobarakeh Steel Company were divided into the four strategies of SO, ST, WO, and WT. Finally, the fuzzy multi-criteria decision-making methods of ANP, TOPSIS, and TODIM were used in order to rank and weight the strategies. The results obtained indicated that the SO strategies were ranked first, the ST strategies were ranked second, the WO strategies were ranked third, and the WT strategies were ranked fourth. In addition, the results of the partial strategies related to each one of the four strategies indicated that among the WO strategies, "buying and using new production technologies" had the highest rank; among the SO strategies, "using the information system to increase public awareness on the importance of the environment and sustainable development," and "modifying the energy consumption pattern based on the use of new technologies and experienced consultants"; among the ST strategies, "injecting culture in the society to collaborate with waste collection in public places, parks, and green spaces"; and among the WT strategies, "cooperating with relevant organizations to identify and cope with emergencies to prevent and reduce the environmental consequences (the fire of buildings in the Mobarakeh Steel Company)" had the greatest importance and prioritization.

Given the results of ranking each strategy's dimensions and components, the following are suggested to be considered more than the others and their executive plans to be prioritized:

1- Provision of an appropriate plan to strengthen the transport fleet, the use of government budget to execute environmental measures, and convincing the government agencies and financial institutions through provision of an appropriate justification plan.

2- Modification of energy consumption pattern based on the use of new technologies as well as using experienced consultants, hiring experienced and specialized people, allocating funds to develop and implement suitable production plans besides optimal use of resources.

3- Encouraging people in the society for environmental cooperation and holding free training courses for people in the society at the regional level.

4- Cooperating with the relevant organizations in order to identify and cope with the accidents and emergencies for preventing and reducing the environmental consequences: identifying the key

and critical areas and buildings besides taking preventive measures.

Table 18. Results of the fuzzy TODIM method.

Weight	Description	Name
0.163	Using experienced contractor companies to optimize the energy consumption and using their ideas	WO strategy
0.177	Buying and using new technologies	
0.160	Injecting strategic thinking in employees by expert advisors and contractors for production using new technologies	
0.172	Institutionalizing culture in line with the green management regulations	
0.165	Creating a developed program to modernize the buildings of Mobarakeh Steel Company based on green principles in architecture and construction	
0.163	Using the government budget to reduce environmental contaminants	
0.148	using the information system to increase public awareness on the importance of the environment and sustainable development	SO strategy
0.141	Using the information system to introduce the society members to the annual environmental goals of the company and using their opinions	
0.141	Providing a strategy for designing a disposal system based on the environmental issues and green management national code	
0.140	Providing an appropriate program and strategy for designing and using ergonomic tools	
0.148	Modifying the pattern of energy consumption based on the use of new technologies and experienced consultants	
0.139	Defining the increase of community satisfaction and providing a strategy for addressing the complaints of people on environmental issues and sending the complaints to competent government authorities and also providing solutions to reduce the complaints	
0.142	Using contractor companies and experienced consultants to implement appropriate and new waste collection systems	
0.200	Responding complaints along with presenting a manual for training and familiarizing people with environmental protection	ST strategy
0.176	Using different educational tools to familiarize people with environmental pollution consequences and disadvantages	
0.218	Injecting culture among people in society to collaborate on collecting waste in public places, parks, and green spaces	
0.208	Injecting culture among people and providing a strategy for modifying energy consumption pattern	
0.198	Creating awareness among people to use public transportation vehicles through advertising	
0.194	Cooperation with relevant organizations in formulation of annual special environmental goals such as preventing the cutting of trees, signing contracts, and cooperating with construction companies to modernize city and join green principles of architecture and construction	WT strategy
0.199	Using results of scientific research such as production planning and timing, human resources allocation, job turnover, minimization of cost and ergonomic risk reduction, and increased productivity of production	
0.214	Cooperation with relevant organizations to identify and deal with emergencies to prevent and reduce environmental consequences (fire burning of buildings related to Mobarakeh Steel)	
0.181	Using educated labor in country and using their talents to design ergonomic tools	
0.163	Monitoring company performance in field of waste separation and waste disposal	

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