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A Framework to Design a Green Supply Chain for the Steel Industry with a Strategic Approach (The case of Guilan province)

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Abstract

The present research aims to identify the factors affecting the green supply chain in the steel industry with a combined approach. The research is an applied study in type, an exploratory study in goal, a quantitative and qualitative study in data type, and a field study in procedure, in which questionnaire and interview were used as the research instrument. The statistical population was composed of the experts of the steel industry, out of whom 25 experts were selected as the statistical sample by the purposive technique. Data were analyzed by the fuzzy DEMATEL and fuzzy network process analysis in the SPSS21 and MS-Excel software packages. Then, the fuzzy Delphi technique was used, resulting in the identification of five criteria and 25 subcriteria. Then, the fuzzy DEMATEL was employed to determine the influence and dependence of the factors according to which among the main factors, the environment factor was the most influential with an influence value of 0.792 and the financial factor was the most dependent factor with a net dependence value of -0.996. Also, the identified factors were ranked by the fuzzy analytical network process. The results show that the financial factor has the highest weight. Also, the other factors are in the order of environmental, quality, environment, and technology in terms of importance.

Keywords:
Fuzzy DEMATEL
Fuzzy multi-attribute decision-making
Fuzzy network analysis process
Green Supply Chain
Supply cChain

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INTRODUCTION

The contemporary world is faced with an increasing rate of pollution and environmental problems, raising the concern of countries over the environment. This has been accompanied by increased environmental concerns of consumers, governments, and societies across the world and the manufacturing companies (Bayat & Madradi, 2016: 57). On the other hand, global organizations gain a competitive advantage by improving their environmental performance through complying with the environmental standards, increasing consumers' knowledge of the environment, and alleviating the adverse environmental impacts of their products and/or services (Koplin et al., 2016: 156). So, the need for a green supply chain arises from governments' instruments for environmental standards on the hand and the customers' demand for the supply of green products on the other (Babaei Meybodi & Delshad, 2018: 53).

Presently, green supply chain managers in progressive companies attempt to generate environmental utility and satisfaction throughout the supply chain in order to use the green logistics and their improved environmental performance in the entire supply chain as a strategic tool to gain a sustainable competitive advantage. As such, they establish their goals on three main axes: green design (product), green production (process), and product recycling. Indeed, a green supply chain is based on the integration of internal and external actions to control environmental impacts in a product's lifecycle by information sharing and the coordination and cooperation of all supply chain members (Raut et al., 2017: 206). Green supply chain management is the integration of supply chain management with environmental requirements at all stages. The internal and external actions in the supply chain including product design, material selection and supply, production and manufacturing, distribution and transfer processes, delivery, and finally, post-consumption recycling and re-use management to maximize energy and resources use productivity along with the enhancement of overall supply chain performance, in which the organization should consider environmentally-friendly factors (Zhu et al., 2013: 1045).

A review of the theoretical research shows that companies have growingly come to believe that the adoption of green supply chain management initiatives can be a key strategy with a huge impact on organizational performance. The result is manifested in the implementation of the ISO-14001 standard by most firms (Qorbanpour et al., 2017: 68). For instance, Lari et al. (2015) state that green management activities will enhance organizational performance in financial and environmental aspects. So, the identification of green supply chain management activities can be of crucial significance because organizations can enhance their performance in economic, social, and environmental dimensions by achieving green factors in green chains and following them. Govindan et al. (2015) argue that wastage reduction, total quality management, ISO-14001 certification, and reverse logistics, which are known as green supply chain management initiatives, have a significant positive impact on green productivity. Thus, it can be said that in today's environmentalist era, organizations and industries can readily achieve the goals of green productivity by identifying and adopting green management activities, such as the reduction of wastage, total quality management, green production, green design, reverse logistics, and so on.

Presently, the dramatic expansion of technology and industries is implicated as an essential cause of the environmental crisis (Kumar et al., 2015: 77). An overview of the development of the steel industry in recent years shows that this industry is one of the growing and progressive industries of the world.

METHODOLOGY

The present study is a developmental-explorative study in terms of goal and temporally a cross-sectional study. The population was composed of the experts of the studied industry and some experts of the green supply chain. Based on the definition of the statistical population, the statistical sample was established in two groups including the experts who were fully aware of the topic of green supply chain both scientifically and practically and those who had had operational or research activities in this field. The first group included managers and senior experts of the studied organization, amounting to 25 individuals, who were used to customize the model and check its content validity. They screened the factors using the fuzzy Delphi mathematical technique. The second group was used for the techniques of research in operation, fuzzy DEMATEL, and fuzzy network analysis process. According to Saaty (2002), it contained eight experts in the studied organization who were selected by the judgmental convenience technique. These participants had a master's or Ph.D. degree with over 12 years of work experience. Data were collected by a review of the literature and a poll from the experts to identify the factors. Also, two questionnaires, i.e., screening questionnaire and pairwise comparison questionnaire, were employed for the research. The reliability of the first questionnaire, used to determine the importance of criteria and sub-criteria, was measured with Cronbach's alpha, whose result showed that the reliability of the research variables was over 0.7.

Data analysis

The research used a fuzzy method for the pairwise comparison of the model's factors. The fuzzy methods are more capable than other similar methods since they consider subjective issues and uncertainty in decision-making. In addition to defining and identifying the factors underpinning a green supply chain for the analysis of the data collected by the questionnaire, the research employed the fuzzy Delphi technique for screening. Also, the relations and how and in what intensity they influence factors were determined by the fuzzy decision-making trial and evaluation laboratory (DEMATEL), they were ranked by the fuzzy analytical network process (fuzzy ANP), and it was solved by Tzeng et al.'s (2011) method. These methods are described below.

RESULT

Factors were derived from the literature. A weight constraint was applied to the model because the factors derived were too many and because it was necessary to customize the indices, reduce the number of inputs, determine their importance versus one another, and check their validity. So, a questionnaire was developed with 35 qualitative items responded to on a five-point scale from extremely important to unimportant. Then, the most important factors were determined with the fuzzy Delphi technique in three rounds. This technique was applied at the level of both factors and subfactors. Here, we present the rounds and results of the fuzzy Delphi at the subfactor level. To this end, a poll was first conducted among 25 experts in the first round to find out the importance of the criteria via a questionnaire based on the five-point Likert scale. Table 1 summarizes the results.

Second Round

At this stage, the second questionnaire was derived using the previous opinions of the panel and their difference from the opinions of the other members. Then, the questionnaire was sent to the panel members again. In this round, the members responded to the items again considering the opinions of the other members. The results are presented in Table 2.

Given the opinions in the first round and their comparison with the second round, as per the Pareto principle (20/80), if the difference between the two rounds is less than the threshold of 0.2, the process of the opinion poll is stopped. Table 2 shows that the panel members reached a consensus on some variables so that the difference between the first and second rounds was less than the threshold, so the opinion poll about these variables was stopped. Among these variables, those whose defuzzified average of the opinions was less than 8 were removed from the conceptual model of the research. Then, the opinion poll was conducted in the third round.

Third Round

In this round, the required modifications were applied to the model variables and then, a third questionnaire was developed and sent to the panel members along with the previous opinions of the individuals and their difference from the average opinion of the other members. The difference was that 30 items out of the items of the second round were stopped in this round, and the poll was conducted for the remaining five items. The results are shown in Table 3.

Table 1: The results of the first round of the poll along with the average opinion of the

Component	Sr. No.	Lingual value	Very high	High	Moderate	Low	Very low	Max	Mod	Min	Defuzzified average opinion
		Numerical value	9	7	8	3	1				
		Subcriteria – fuzzy value	7,9,10	5,7,9	3,5,7	1,3,5	0,1,3				
Financial factor	1	Suitability of material prices to market prices	17	6	2	0	0	9.52	8.20	6.20	8.09
	2	Transport cost	15	7	3	0	0	9.36	7.96	5.96	7.86
	3	Product price	18	5	2	0	0	9.56	8.28	6.28	8.16
	4	Order cost	17	4	4	0	0	9.36	8.04	6.04	7.93
	5	Defective rate	18	5	2	0	0	9.56	8.28	6.28	8.16
Quality factor	6	Management commitment to quality	15	8	2	0	0	9.44	8.04	6.04	7.94
	7	Warranties and policies	18	6	1	0	0	9.64	8.36	6.36	8.24
	8	Ability to achieve unusual quality	6	6	9	4	0	7.88	6.12	4.12	6.08
	9	ISO quality management system	14	7	3	1	0	9.16	7.72	5.72	7.63
	10	Quality assurance	15	8	2	0	0	9.44	8.04	6.04	7.94
	11	System of corrective and preventive measures	2	6	8	9	0	7.00	5.08	3.08	5.07
	12	Process improvement	0	8	2	15	0	6.44	4.44	2.44	4.44
	13	Timely delivery	0	7	2	16	0	6.28	4.28	2.28	4.28
Technology factor	14	Technology level	15	8	2	0	0	9.44	8.04	6.04	7.94
	15	Research and development capability	14	6	5	0	0	9.16	7.72	5.72	7.63
	16	Current production capabilities or facilities	7	9	7	2	0	8.40	6.68	4.68	6.63
	17	Development of supplier technology for ...	8	9	6	2	0	8.52	6.84	4.84	6.79
	18	Technology compatibility	16	5	3	1	0	9.24	7.88	5.88	7.77
	19	Technological capacity	1	1	13	9	1	6.32	4.36	2.40	4.36
Environmental factor	20	Ability to prevent pollution	17	6	3	0	0	9.80	8.40	6.32	8.29
	21	Environmental certification such as ISO 14000	17	7	1	0	0	9.60	8.28	6.28	8.17
	22	Environmental productivity	15	8	2	0	0	9.44	8.04	6.04	7.94
	23	Compliance with RoHS	0	7	2	16	0	6.28	4.28	2.28	4.28
	24	Program or policy for protection from …	0	5	2	16	3	5.92	3.84	1.88	3.86
	25	Environmental policies	19	5	1	0	0	9.68	8.44	6.44	8.31
	26	Continuous monitoring and compliance	18	6	1	0	0	9.64	8.36	6.36	8.24

Environment factor	27	Green process planning	14	7	4	0	0	9.24	7.80	5.80	7.71
	28	Internal environment inspection	18	5	2	0	0	9.56	8.28	6.28	8.16
	29	External environment inspection	16	5	4	0	0	9.32	7.96	5.96	7.85
	30	Environmental constraints	5	8	7	5	0	7.84	6.04	4.04	6.01
	31	Attention to uncertainty	0	4	8	9	4	5.96	3.96	2.12	3.99
	32	Waste reduction	16	9	0	0	0	9.64	8.28	6.28	8.17
	33	Waste recycling	15	8	2	0	0	9.44	8.04	6.04	7.94
	34	Product-based procurement	15	7	3	0	0	9.36	7.96	5.96	7.86
	35	Flexibility	5	8	7	5	0	7.84	6.04	4.04	6.01

Table 2: The results of the second round of the poll along with the average opinion of the experts (components)

Component	Sr. No.	Lingual value	Very high	High	Moderate	Low	Very low	Max	Mod	Min	Defuzzified average opinion	Difference between the averages	Result
		Numerical value	9	7	5	3	1						
		Subcriteria – fuzzy value	7,9,10	5,7,9	3,5,7	1,3,5	0,1,3						
Financial factor	1	Suitability of material prices to market prices	18	5	2	0	0	9.56	8.28	6.28	8.16	0.07	Accepted
	2	Transport cost	17	5	3	0	0	9.44	8.12	6.12	8.01	0.15	Accepted
	3	Product price	19	5	1	0	0	9.68	8.44	6.44	8.31	0.15	Accepted
	4	Order cost	21	3	0	0	0	9.76	8.60	6.60	8.46	0.53	Next
Quality factor	5	Defective rate	19	4	2	0	0	9.60	8.36	6.36	8.23	0.07	Accepted
	6	Management commitment to quality	17	6	2	0	0	9.52	8.20	6.20	8.09	0.15	Accepted
	7	Warranties and policies	20	4	1	0	0	9.72	8.52	6.52	8.39	0.15	Accepted
	8	Ability to achieve unusual quality	2	9	13	1	0	7.88	5.96	3.96	5.95	0.13	Discarded
	9	ISO quality management system	16	8	1	0	0	9.56	8.20	6.20	8.09	0.47	Next
	10	Quality assurance	16	7	2	0	0	9.48	8.12	6.12	8.01	0.07	Accepted
	11	System of corrective and preventive measures	0	6	12	7	0	6.92	4.92	4.92	4.92	0.15	Discarded
	12	Process improvement	0	7	3	15	0	6.36	4.36	2.36	4.36	0.08	Discarded
	13	Timely delivery	0	6	6	11	0	6.04	4.20	2.36	4.20	0.08	Discarded
Technol	14	Technology level	15	9	1	0	0	9.52	8.12	6.12	8.02	0.08	Accepted

	15	Research and development capability	18	6	1	0	0	9.64	8.36	6.36	8.24	0.61	next
	16	Current production capabilities or facilities	6	10	7	2	0	8.36	6.60	4.60	6.56	0.07	Discarded
	17	Development of supplier technology for ...	7	10	6	2	0	8.48	6.76	4.76	6.71	0.07	Discarded
	18	Technology compatibility	18	6	1	0	0	9.64	8.36	6.36	8.24	0.47	Next
	19	Technological capacity	0	0	15	10	0	6.20	4.20	2.20	4.20	0.16	Discarded
	20	Ability to prevent pollution	17	7	1	0	0	9.60	8.28	6.28	8.17	0.12	Accepted
	21	Environmental certification such as ISO 14000	18	7	0	0	0	9.72	8.44	6.44	8.32	0.15	Accepted
	22	Environmental productivity	15	9	1	0	0	9.52	8.12	6.12	8.02	0.08	Accepted
	23	Compliance with RoHS	0	5	5	15	0	6.20	4.20	2.20	4.20	0.08	Discarded
Environmental factor	24	Program or policy for protection from …	0	6	0	16	3	5.72	3.72	1.84	3.74	0.12	Discarded
	25	Environmental policies	20	5	0	0	0	9.80	8.60	6.60	8.47	0.15	Accepted
	26	Continuous monitoring and compliance	20	4	1	0	0	9.72	8.52	6.52	8.39	0.15	Accepted
	27	Green process planning	17	7	1	0	0	9.60	8.28	6.28	8.17	0.46	Next
	28	Internal environment inspection	19	5	1	0	0	9.68	8.44	6.44	8.31	0.15	Accepted
	29	External environment inspection	16	7	2	0	0	9.48	8.12	6.12	8.01	0.16	Accepted
	30	Environmental constraints	3	10	9	3	0	7.92	6.04	4.04	6.02	0.01	Discarded
Environment factor	31	Attention to uncertainty	0	2	10	11	2	5.96	3.96	2.04	3.97	0.01	Discarded
	32	Waste reduction	17	8	0	0	0	9.68	8.36	6.36	8.25	0.07	Accepted
	33	Waste recycling	15	10	0	0	0	9.60	8.20	8.20	8.10	0.16	Accepted
	34	Product-based procurement	17	5	3	0	0	9.44	8.12	6.12	8.01	0.15	Accepted
	35	Flexibility	5	8	9	3	0	8.00	6.20	4.20	6.17	0.16	Discarded

Table 3. The results of the third round of the poll along with the average opinion of the experts (components)

Component	Sr. No.	Lingual value	Very high	High	Moderate	Low	Very low	Max	Mod	Min	Defuzzified average opinion	Difference between the averages	Result
		Numerical value	9	7	5	3	1						
		Subcriteria – fuzzy value	7,9,10	5,7,9	3,5,7	1,3,5	0,1,3						
Financial factor	4	Order cost	19	6	0	0	0	6.76	8.52	6.52	8.39	0.07	Accepted
Quality factor	9	ISO quality management system	16	9	0	0	0	9.64	8.28	6.28	8.17	1.08	Accepted
Technology factor	15	Research and development capability	18	7	0	0	0	9.72	8.44	6.44	8.32	0.08	Accepted
Technology factor	18	Technology compatibility	20	4	1	0	0	9.72	8.52	6.52	8.39	0.15	Next
Environmental factor	27	Green process planning	16	8	1	0	0	9.56	8.20	6.20	8.09	0.07	

As is evident in Table 3, the difference in the opinions between the second and third rounds was lower than the threshold value of 0.2, so the opinion poll was stopped in this round. The fuzzy Delphi results showed that based on the weight of the criteria, 12 subcriteria out of the 35 subcriteria were removed from the final conceptual model, and a consensus was arrived at over five main indices and 23 sub-indices, which were selected as the primary factors for the final solution of the model. Now, the first research question as to what factors influence the green supply chain in the steel industry of Guilan province has been answered. Table 4 enumerates these factors.

Table 4. The factors and sub-factors affecting the green supply chain in the steel industry

Main factors	Sub-factors	Code
Financial factor (C_1)	Suitability of material prices to market prices	C_{11}
	Transport cost	C_{12}
	Product price	C_{13}
	Order cost	C_{14}
Quality factor (C_2)	Defective rate	C_{21}
	Management commitment to quality	C_{22}
	Warranties and policies	C_{23}
	ISO quality management system	C_{24}
	Quality assurance	C_{25}
Technology factor (C_3)	Technology level	C_{31}
	Research and development capability	C_{32}
	Technology compatibility	C_{33}
	Ability to prevent pollution	C_{34}
Environmental factor (C_4)	Environmental certification such as ISO 14000	C_{41}
	Environmental productivity	C_{42}
	Environmental policies	C_{43}
	Continuous monitoring and compliance	C_{44}
	Green process planning	C_{45}
Environment factor (C_5)	Internal environment inspection	C_{51}
	External environment inspection	C_{52}
	Waste reduction	C_{53}
	Waste recycling	C_{54}
	Product-based procurement	C_{55}

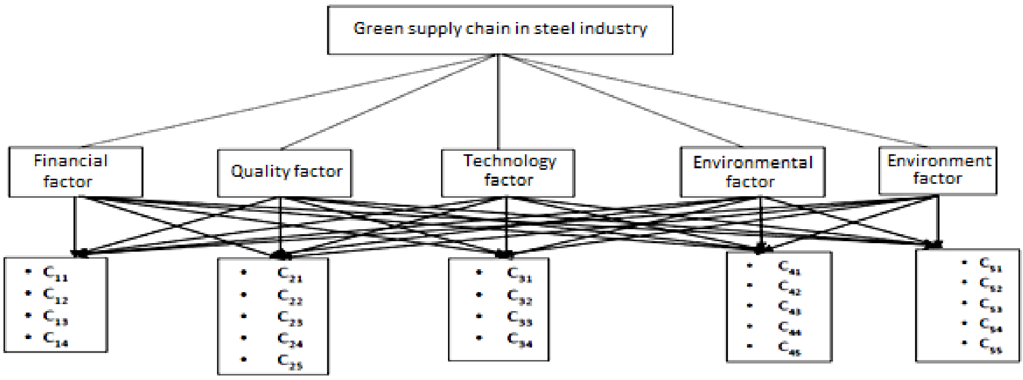

Fig. 1. The research model with a network structure

Finally, given the list of factors and sub-factors in Table 1, the decision model was formed as depicted in Figure 1.

DEMATEL Solution

The sums of the elements in the rows and columns of the matrix $\widetilde{T}$ were calculated for the main factors and sub-factors and were named the vectors $\widetilde{R}$ (influential) and $\widetilde{D}$ (dependent). The calculations are presented in Tables 5 and 6.

Table 5: The values of the criteria of $\widetilde{R}$, $\widetilde{D}$, $\widetilde{R}+\widetilde{D}$, and $\widetilde{R}-\widetilde{D}$

Factors	$\widetilde{D}$	$\widetilde{R}$	$\widetilde{R}+\widetilde{D}$	$\widetilde{D}-\widetilde{R}$	Result
Financial factor	-0.996	2.798	1.897	0.901	Most dependent
Quality factor	-0.028	2.614	1.321	1.293	Dependent
Technology factor	0.684	2.364	0.84	1.524	Influential
Environmental factor	-0.452	2.644	1.548	1.096	Dependent
Environment factor	0.792	2.509	0.858	1.651	Most influential

Table 6: The values of the non-criteria of $\widetilde{R}$, $\widetilde{D}$, $\widetilde{R}+\widetilde{D}$, and $\widetilde{D}-\widetilde{R}$

Main factors	Sub-factors	Symbol	$\widetilde{D}$	$\widetilde{R}$	$\widetilde{R}+\widetilde{D}$	$\widetilde{D}-\widetilde{R}$	Result
Financial factor (C_1)	Suitability of material prices to market prices	C_{11}	0.394	0.322	0.715	0.0717	Influential
	Transport cost	C_{12}	0.392	0.355	0.747	0.0364	Influential
	Product price	C_{13}	0.356	0.384	0.739	-0.028	Dependent
	Order cost	C_{14}	0.32	0.4	0.72	-0.08	Dependent
Quality factor (C_2)	Defective rate	C_{21}	0.373	0.373	0.746	0.0003	Influential
	Management commitment to quality	C_{22}	0.473	0.393	0.866	0.0794	Influential
	Warranties and policies	C_{23}	0.355	0.346	0.701	0.0093	Influential
	ISO quality management system	C_{24}	0.332	0.367	0.699	-0.035	Dependent
	Quality assurance	C_{25}	0.282	0.336	0.619	-0.054	Dependent
Technology factor (C_3)	Technology level	C_{31}	0.389	0.391	0.78	-0.002	Dependent
	Research and development capability	C_{32}	0.367	0.365	0.732	0.0012	Influential
	Technology compatibility	C_{33}	0.354	0.457	0.812	-0.103	Dependent
	Ability to prevent pollution	C_{34}	0.364	0.351	0.714	0.0131	Influential

Environmental factor (C_4)	Environmental certification such as ISO 14000	C_{41}	0.454	0.418	0.871	0.036	Influential
	Environmental productivity	C_{42}	0.392	0.391	0.783	0.0004	Influential
	Environmental policies	C_{43}	0.444	0.432	0.876	0.0115	Influential
	Continuous monitoring and compliance	C_{44}	0.393	0.357	0.75	0.0367	Influential
	Green process planning	C_{45}	0.336	0.42	0.756	-0.085	Dependent
Environment factor (C_5)	Internal environment inspection	C_{51}	0.355	0.312	0.667	0.0427	Influential
	External environment inspection	C_{52}	0.323	0.305	0.628	0.0179	Influential
	Waste reduction	C_{53}	0.325	0.306	0.631	0.0184	Influential
	Waste recycling	C_{54}	0.304	0.308	0.612	-0.004	Dependent
	Product-based procurement	C_{55}	0.282	0.357	0.64	-0.075	Dependent

Fig. 2 depicts the influence and dependence among the criteria. The horizontal axis displays the importance of the criteria and the vertical axis displays the influence or dependence of the criteria. So, the factors can be ordered as the ‘environment factor’, ‘technology factor’, ‘quality factor’, ‘environmental factor’, and ‘financial factor’ in terms of the importance and influence/dependence of the criteria. A positive $\tilde{R}-\tilde{D}$ in Table 4 shows that the factor is influential, but a negative $\tilde{R}-\tilde{D}$ shows that the factor is dependent on other factors. Based on the results, the ‘environment factor’ is the most influential factor with an influence value of 0.792, and the ‘financial factor’ is the most dependent index with a net dependence value of -0.996. Overall, factors with a positive $\tilde{R}-\tilde{D}$ constitute the causal factor and those with a negative $\tilde{R}-\tilde{D}$ constitute the dependent factors. Now, the second question as to how the cause-and-effect relation is among the factors affecting the green supply chain of the steel industry in Guilan province has been answered. Eventually, the cause-and-effect relations were plotted in a Cartesian coordinate system by drawing points with the coordinates of $\tilde{R}+\tilde{D}$ and $\tilde{R}-\tilde{D}$ based on the matrix $\tilde{T}$ and considering the influence of the factors on one another. Fig. 2 shows the cause-and-effect graph and the map of the network relations of the factors.

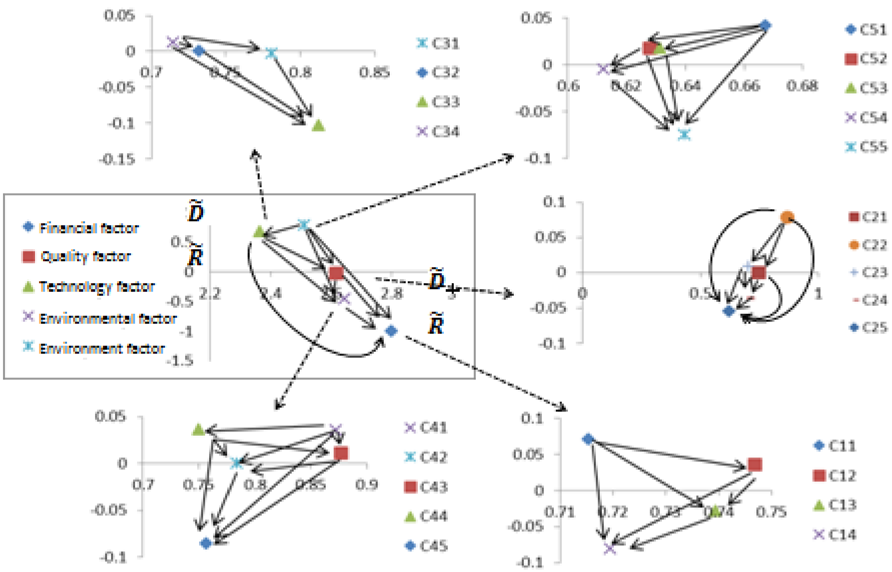

Fig. 2. The network map of the relations between the main criteria and sub-criteria

Criteria Weighting by Fuzzy Network Analysis Process

At this step, the relations determined in the matrix T were used to calculate the weighted supermatrix. Then, it was converged at the power of 17 and yielded in bounded supermatrix. This supermatrix was then employed to specify the weight and ranking of the factors. Finally, the weights were defuzzified by the gravity center method to find out the weight of the factors and sub-factors. The results are presented in Table 7.

Table 7: Weight and ranking of the criteria and sub-criteria underpinning the green supply chain

Weight and rank of the main criteria	Subcriteria	Code	Relative weight and rank of criteria	Final weight and rank of subcriteria	
Financial factor (0.311; 1)	Suitability of material prices to market prices	C_{11}	0.2076	0.06448	4
	Transport cost	C_{12}	0.2305	0.07159	3
	Product price	C_{13}	0.2549	0.07915	2
	Order cost	C_{14}	0.307	0.09533	1
Quality factor (0.22; 3)	Defective rate	C_{21}	0.2009	0.04424	10
	Management commitment to quality	C_{22}	0.2411	0.0531	5
	Warranties and policies	C_{23}	0.1931	0.04253	11
	ISO quality management system	C_{24}	0.1921	0.04229	13
	Quality assurance	C_{25}	0.1728	0.03806	14
Technology factor (0.104; 5)	Technology level	C_{31}	0.2633	0.02738	16
	Research and development capability	C_{32}	0.2497	0.02597	17
	Technology compatibility	C_{33}	0.2479	0.02578	18
	Ability to prevent pollution	C_{34}	0.2391	0.02487	19
Environmental factor (0.245; 2)	Environmental certification such as ISO 14000	C_{41}	0.2069	0.05079	8
	Environmental productivity	C_{42}	0.1933	0.04745	9
	Environmental policies	C_{43}	0.2152	0.05282	6
	Continuous monitoring and compliance	C_{44}	0.1731	0.04249	12
	Green process planning	C_{45}	0.2116	0.05194	7
Environment factor (0.12; 4)	Internal environment inspection	C_{51}	0.201	0.02407	20
	External environment inspection	C_{52}	0.1997	0.02391	21
	Waste reduction	C_{53}	0.1922	0.02301	22
	Waste recycling	C_{54}	0.1671	0.02001	23
	Product-based procurement	C_{55}	0.24	0.02874	15

As is seen in Table 7, the 'financial factor' was ranked the first with the highest weight among the criteria. Among the sub-criteria, the highest weight was assigned to 'product price', so it was ranked the first. The sub-criteria of 'transport cost', 'order cost', 'suitability of material prices to market prices', 'warranties and policies', and 'environmental certification such as ISO 14000' were ranked the second to the sixth, respectively. These sub-criteria together accounted for the total weight of all sub-criteria, implying their high significance. The rankings of the other factors are shown in Table 6. Figure 3 is the graph of the ranking of the main factor and Figure 4 is the graph of the final ranking of the sub-factors by the fuzzy ANP method.

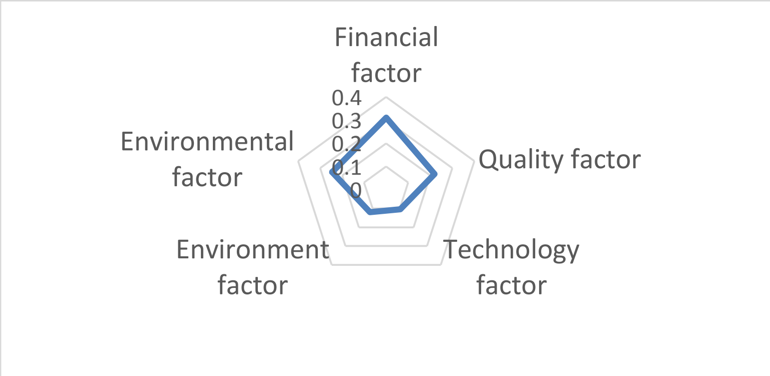

Fig. 3. The graph of the relative ranking of the main factors

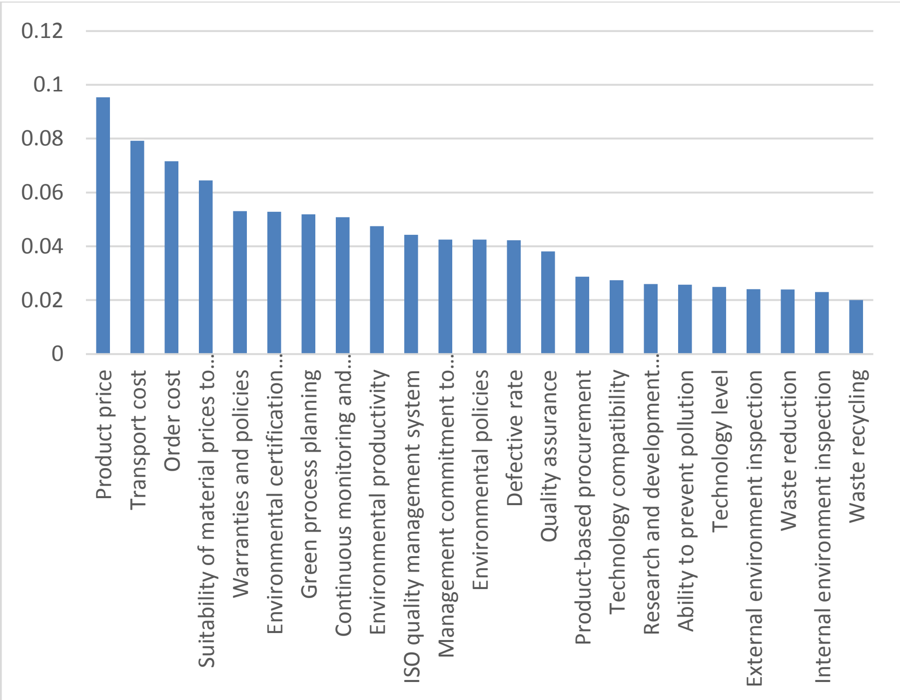

Fig. 4. The graph of the final ranking of the sub-factors

DISCUSSION AND RECOMMENDATIONS

The first objective of the research was to identify the factors influencing the green supply chain of the steel industry, especially in Guilan Foolad Private Company. Based on a review of the literature and after the screening, 23 important factors were identified whose main criteria included the financial, quality, technology, environmental, and environment factors.

The second objective was to find out the relations of the factors and their impacts on each other. This objective was accomplished by the fuzzy DEMATEL technique. The results showed that the financial factor was the most dependent factor influencing the green supply chain of the steel industry. In other words, this factor is the main problem and the bottleneck of the improvement of the green supply chain design in the organization, which can be solved by the influential factors. Indeed, the success or failure of the green supply chain is dictated by this factor. So, it can be concluded that to accomplish organizational productivity, the organization should pay serious attention to the financial factor in its green supply chain. This is consistent with the reports of Mahesh et al. (2018), Kumar et al. (2017), Govindan et al. (2014), Kannan et al. (2014), Tseng et al. (2013), and Wang et al. (2012). As well, the environment factor was most influential in the green supply chain. This means that this is the criterion that is of utmost importance and can solve the problem in question, so it should be prioritized in attempts to improve the system. It is inferred that the environment factor is significantly effective in the green supply chain. The management factor can also be effective in the green supply chain and its use in the organization by increasing efficiency and improving processes. This is in disagreement with Kumar et al. (2017), Azad and Modiri (2017), Omidvar et al. (2015), and Zaeri and Ramazani (2011), but in agreement with Mahesh et al. (2018), Govindan et al. (2014), Kannan et al. (2014), Tseng et al. (2013), Wang et al. (2012), Ansari and Sadeghi Moghaddam (2021), and Ahmadi et al. (2013). The research also resulted in some solution recommendations, which are presented here.

The results of the fuzzy DEMATEL showed that the financial factor is the most dependent factor in the green supply chain, so it should be tried to ensure the company's viability by some recommendations as the success or failure of the company depends on this criterion, so attempt should be made to reduce the intensity of the penetration of this factor in order to strengthen the system. Therefore, the senior management of the organization in question and its decision-makers of the steel industry, especially the study company in Guilan province, are recommended to reduce product price, decrease transport costs, improve order costs, ensure the suitability of material prices to market prices, and so on to increase and protect their competitive situation. In addition, the results of fuzzy DEMATEL reveal that the environment factor is the most influential factor on the green supply chain, so it is a scope in which recommendations can be made to contribute to the studied company's success because the success or failure of the company depends on this influential factor, and its influence should be exploited for the system empowerment. So, the senior management and decision-makers of the steel industry, especially the studied company, are recommended to employ the policy of procurement based on environmental products, increase wastage recycling, increase external environment inspection, reduce wastage, increase internal environment inspection, and so on to increase and protect their competitive situation.

The results of the fuzzy ANP revealed that the financial factor was the most important among all main criteria. Among the sub-criteria too, product price was the utmost factor influencing the green supply chain. Therefore, the senior management and decision-makers of the steel industry, especially the steel industry of Guilan province, are recommended to reduce product price, decrease transport costs, reduce order costs, increase the suitability of material prices to market prices, and so on to improve the green supply chain. The second most important criterion was found by fuzzy ANP to be the environmental factor among whose sub-criteria, the environmental certification such as ISO 14000 was the most important factor involved in the green supply chain. So, the green supply chain can be improved by the senior management and decision-makers of the steel industry, especially the one studied in Guilan province, by seeking environmental certification such as ISO 14000, improving green process planning, increasing continuous monitoring and complying with regulations, increasing environmental productivity, and improving environmental policies. The third most important criterion is the quality factor and its most important sub-criterion for the green supply chain is warranties and policies. As such, the senior management and decision-makers of the steel industry are recommended to consider improving warranties and policies, improving ISO quality management system, increasing management commitment to quality, reducing defective rate, enhance quality assurance in order to improve the green supply chain. The fuzzy ANP technique placed the environment factor in the fourth rank. The index of procurement based on the environment product was selected as the most important sub-factor influencing the green supply chain. In this regard, the recommendations for the improvement of the green supply chain include increasing procurement based on the environmental product, increasing external environment inspection, reducing wastage, increasing internal environment inspection, and improving waste recycling. Finally, the technology factor was found to be the least important factor. Out of the sub-factors of this factor, technology compatibility was found to be most influential on the green supply chain. In this respect, the senior management and decision-makers of the steel industry, especially the Steel Corporation of Guilan Province, are recommended to increase technology compatibility, enhance the research and development capability, increase the capability of pollution prevention, and improve technology level in order to improve the green supply chain**.**

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