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Selection of green suppliers with the approach of integrating economic, environmental and social decisions (Case study of Sazeh Gostar Saipa Photovoltaic Company)

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Abstract

Supply chain network design is one of the key issues in strategic chain planning that refers to the supply chain network configuration and as an infrastructure issue in its management, will have lasting effects on other tactical and operational decisions. In other words, the proper design of the supply chain network leads to the achievement of an optimal structure, which makes effective and competitive supply chain management possible. In this study, a problem of selecting a green supplier in terms of sustainability, under uncertainty based on three economic, environmental and social responsibility dimensions are studied by a case study of Sazeh Gostar Saipa Photovoltaic Company active in the PV industry. One of the environmental dimensions of the problem is the design of an efficient and flexible model for evaluating and selecting suppliers based on environmental indicators. One of the features of the proposed model is the use of environmental criteria in the process of selecting a green supplier and also the flexibility of the model in the number of sub-criteria. In this research, the theory of Rough sets has been used to find the weight of sub-environmental criteria. The obtained results confirm the efficiency of the multi-objective mathematical planning model in this research in evaluating suppliers and also using the theory of Rough sets to weight environmental indicators to achieve the above objectives.

Keywords: there objective green supply chain network, uncertainty, environment, social responsibility, PV industry.

1. Introduction

With the advent of the industrial age, green supply chain management can be considered as a strategy in which all members of the chain pay more attention to value.As organizations become

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more dependent on suppliers, the direct and indirect consequences of poor decision-making in supplier selection are becoming more serious [2] .On the other hand, today's competitive markets to increase the value level of the supply chain, have led companies to focus on environmental issues on a par with other important factors (cost, quality, level of service, etc.); Therefore, choosing a green supplier to reduce purchasing risk is one of the most important decision issues [18]. In fact, supplier selection is a complex decision-making process. Today, most researchers consider a combination of factors that must be tailored to both the technical and economic needs and the strategy of the company before making decisions based on price or quality [3]. Therefore, organizations today must consider the environmental awareness of suppliers and the demand in which suppliers act on the basis of reducing environmental impacts [10]. Therefore, choosing a green supplier to reduce the risk of buying is one of the most important decision issues. In this regard, many studies have been dedicated to selecting a supplier based on common criteria [2] However, most of these studies [6, 4]. have focused on evaluating the green supplier or the work in which the environmental criteria are considered. Also different methods is a choice of supplier to decide [18] based on data envelopment analysis, cluster analysis, decision models for the final selection phase, linear weighting models, statistical models, mathematical programming models and artificial intelligence models [4]. Lee et al. [17] used Rough set theory to select a supplier. In this study, using Rough theory, the verbal variable based on gray theory was converted to a gray number and suppliers were ranked. In his research, Mavi [19] used fuzzy hierarchical analysis method to review the most important criteria of green supply chain management based on the opinions of experts. The results of his research show that resource consumption is one of the most important features in choosing a green supplier.In another study,Quan et al . [5]. Used the gray theory with the aim of developing an applied methodology for selecting a green supplier in the refining industry. In this study, economic and environmental criteria have been considered. In general, although deciding on supplier selection is one of the most important responsibilities of managers and one of the most complex and serious issues they deal with, and measuring the performance of the green supply chain should be considered in the supplier selection process, but the decision to select supplier The green matter has rarely been studied in terms of stability conditions. Due to the importance of the issue, in this study, the issue of selecting a green supplier in sustainable conditions with the approach of integrating economic, environmental and social decisions is studied.

2. Problem description

2.1. Research method

The method of data collection in this study is field, which has been done by referring to the documentation center of the company under study.In the present study, statistics and information are related to Ayandeh Sazan Green Planet Company, which has about 10 years of experience in the field of solar systems. The size of the statistical population is 30 suppliers.In this research, in order to rank and solve the model, the combined method of Rough theory and fuzzy hierarchical analysis has been used (Section 3-4).

2.2. Proposed models

Given the wide range of decisions in the field of supply chain network design, the combination and integration of decisions play an important role in the optimality of the final decision. In this research, the design of green supply chain network is done with the approach of integrating economic, environmental and social responsibility decisions in the selection of green suppliers.The proposed model to achieve an integrated design of the green supply chain network pursues goals such as minimizing costs and maximizing environmental goals and social responsibility in choosing a green supplier, and ultimately help to sustainable decision-making to keep balance economic, Environmental and social goals in the chain green.In the continuation of this section, the model is described, the problem symbols are introduced, and finally, the goal functions and constraints are formulated.

2.3. Problem symbols

The model presented in this study is a multi-objective model considering the three functions of economic, environment and social responsibility goal. In this model, it is assumed that the buyer has n option to select a supplier, the capacity of all of them is limited, and based on this, the objective functions and constraints are defined in the model.

2.3.1. Model parameters

D : Annual demand
n : Number of suppliers
A_i : The cost of ordering from i supplier
X_i : Percentage of total demand allocated to i supplier
C_i : Maximum annual capacity of i supplier
P_i : i Supplier Cost Index is the sum of the cost of purchasing and the cost of transporting each unit of goods declared by i supplier.
S_i : i Supplier Social Responsibility Index, which is the sum of i supplier scores for the sub criteria in delivery flexibility and delivery time.
r : Inventory maintenance rate
Y_i : The variable is zero and one, so that if $X_i \geq 0$ is equal to 1, otherwise it is equal to 0.
In general, when the demand is definite and X_i is the percentage Q, allocated to **i** supplier (the values of X_i and Q are the same in all periods) the following equation is true:

$$0 \leq X_i \leq 1 \qquad i = 1, 2, \ldots, n \tag{2.1}$$

2.3.2. Objective Functions

In this model, three objective functions are considered to optimize the main criteria of green supplier selection: quality, price, social responsibility and environmental performance of suppliers.

Economic objective function

The total cost function ($TAPC$) includes the total purchase costs in the supply phase, including the purchase cost, maintenance costs, transportation and ordering, which is sum of the three cost groups, including annual ordering costs, annual maintenance costs, annual purchase costs are calculated as follows:

$$\min Z_1 = \left(\sum_{i=1}^{n} A_i Y_i\right) \frac{D}{Q} + \frac{rQ}{2} \left(\sum_{i=1}^{n} X_i^2 P_i\right) + \sum_{i=1}^{n} X_i P_i D \tag{2.2}$$

Since in this research, the choice of green supplier is considered, in the cost function only the purchase cost is used, so the function is defined as follows.

$$\min Z_1 = \sum_{i=1}^{n} X_i P_i D \tag{2.3}$$

Environmental performance function

Another criterion that has been considered by organizations in selecting suppliers today is the criterion of environmental performance. Suppose that for each of the environmental indicators involved in supplier selection such as green design, environmental management, recycling, reverse logistics, etc., a function is defined as follows. It should be noted that these indicators and criteria can be converted from a specific situation to another industry.

$$f_i = \alpha_{i1}x_1 + \alpha_{i2}x_2 + \cdots + \alpha_{in}x_n \qquad i = 1, 2, \ldots, n \tag{2.4}$$

Where the n the number of suppliers, m the number of indicators and environmental criteria are involved in the selection of a green supplier.
α_{ij} is a coefficient that shows the performance of j supplier in i criteria. It should be noted that α_{ij} are obtained in this research using the Likert spectrum technique. After obtaining the m sub-criteria function of the environment, the function of environmental performance can be defined as follows:

$$Z_2 = \beta_i f_i \tag{2.5}$$

Where i is the degree of impact of each of the criteria m on the function of environmental effects, which in this study is obtained from the theory of Rough sets theory. Therefore, the Z_2 function for maximization will be transformed as follows, which can be said that E_i be obtained from the combinations of $\beta_i$and means and α_{ij}, means the relative advantages of suppliers over each other in terms of their environmental performance.Therefore, the Z_2 function to maximize environmental performance is defined as follows:

$$\max Z_2 = \sum_{i=1}^{n} X_i D E_i \tag{2.6}$$

Social responsibility function

The third criterion in selecting suppliers is the level of service and social responsibility of the supplier. If, the S_i is percentage of parts that the supplier delivers on time and the X_i is purchase ratio from this supplier, the Z_3 function to maximize service is defined as follows:

$$\max Z_3 = \sum_{i=1}^{n} X_i D S_i \tag{2.7}$$

Limitations

Demand constraints:

$$\sum_{i=1}^{n} X_i D = D \rightarrow \sum_{i=1}^{n} X_i = 1 \tag{2.8}$$

capacity of suppliers:

$$X_i D \leq C_i \qquad i = 1, 2, \ldots, n \tag{2.9}$$

Constraint of variables zero and one:
To model this constraint, we must use constraints if –then, where ε is a small number and slightly greater than zero.

$$X_i \leq Y_i, \quad X_i \geq \varepsilon Y_i \quad i = 1, 2, \ldots, n \tag{2.10}$$

2.4. Solve algorithm

In most MCDM issues, especially MADM, there is a need to have and know the relative importance of existing indicators; So that the sum of them is equal to one and this relative importance measured the degree of preference of each indicator over other items for the desired decision. To solve multi-objective optimization problems, various methods such as Rough set theory, entropy technique, normalized total weight, constraint method, etc. are used.

A hybrid approach to the green supplier selection problem is proposed. This algorithm consists of 3 phases and 6 steps. Phase (a) defines the system and the boundaries of the system under study. In phase (b), the main indicators are determined and data are collected. In this phase, first the indicators are selected based on the opinions of experts and previous studies and then the quantification of the indicators is done using questionnaire and field data. In phase (c), this algorithm deals with the combined approach of the rough and fuzzy sets to solve the multi-criteria decision problem. The steps of the combined method of rough and fuzzy sets are presented as follows:

step1. Build the initial decision matrix

step2. Construction of secondary matrix

step3. Normalize the secondary decision matrix and convert the trapezoidal fuzzy number to an interval value

step4. Construction of a normalized decision matrix (pairwise comparison matrix in Table 4)

step5. Determining the compatibility ratio and fuzzy weight of the index

step6. Convert fuzzy weights to definite weights

In order to define the proposed approach, Rough and fuzzy sets are first defined.

2.4.1. Rough Theory

The Rough Set is a tool that can be used in conditions of ambiguity and uncertainty, first proposed by Pawlak (1982). This theory is a valuable mathematical tool related to ambiguity and uncertainty. Rough is an approach to artificial intelligence that includes cognitive science, machine learning, knowledge acquisition, decision analysis, knowledge discovery, decision support systems, inferential reasoning, and pattern recognition.[5]. According to Rough set theory, Rough numbers were proposed by Zhai et al. (2008). A Rough number usually includes a high and low limit and a Rough border distance that depends only on the original data. Therefore, no auxiliary information is needed and it can better understand the concepts desired by experts and improve the objectivity of decision making [13]. A Rough number has a lower limit (L), upper limit (U) and middle limit known as the Rough boundary distance. Suppose a decision set U includes all members of the set Y. An arbitrary member of the set U and R, is a set of classes t that covers all members of the area U. If these classes are sequential $G_1 < G_2 < \cdots < G_t$, then the lower, upper, and boundary areas of the class G are defined as follows:

$$\underline{Apr}G_q = \coprod \{Y \in G \mid R(Y) \leq G_q\} \tag{2.11}$$

$$\overline{Apr}G_q = \coprod \{Y \in G \mid R(Y) \geq G_q\} \tag{2.12}$$

$$BndG_q = \coprod \{Y \in G \mid R(Y) \neq G_q\} = \{Y \in G \mid R(Y) > G_q\} \bigcup \{Y \in G \mid R(Y) < G_q\} \tag{2.13}$$

This class G can then be represented as a Rough number in the upper and lower bounds as the following equation:

$$\underline{Lim}\left(G_q\right) = \frac{1}{M_L}\sum R\left(Y\right)|\,Y \in \underline{Apr}\left(G_q\right) \tag{2.14}$$

$$\overline{Lim}\left(G_q\right) = \frac{1}{M_U}\sum R\left(Y\right)|\,Y \in \overline{Apr}\left(G_q\right) \tag{2.15}$$

$$\mathrm{RN}\left(G_q\right) = \left\lfloor \underline{Lim}\left(G_q\right), \overline{Lim}\left(G_q\right)\right\rfloor \tag{2.16}$$

It is clear that the lower limit and the upper limit determine the mean value of the elements associated with the upper and lower approximations, respectively. Their difference is defined as the Rough boundary distance [13]. Also, the Rough boundary distance is calculated from the following equation. This boundary distance expresses the ambiguity, so that the larger the number, the greater the ambiguity, and the smaller the number, the greater the accuracy.

$$(IRBnd\left(G_q\right) = \overline{Lim}\left(G_q\right) - \underline{Lim}\left(G_q\right) \tag{2.17}$$

Rough border distance expresses the ambiguity of Gq, so that a larger number means more ambiguity while a smaller number means more accuracy. Therefore, mental information can be expressed by Rough numbers. Because the generated Rough numbers are similar to distance numbers, the arithmetic rules of distance numbers can be applied to even numbers.

2.4.2. Fuzzy Hierarchical Analysis Process

Fuzzy theory was presented quantitatively for verbal variables and approximate concepts. Verbal metrics for evaluating indicators by decision makers are presented in Table 1. Suppose X is a reference set.Then view of the fuzzy set $\tilde{A}$ in X is expressed as a set of two members $\{(x, \mu_{\tilde{A}}(x) \mid x \in X)\}$, where $\mu_{\tilde{A}}(x)$ indicates the degree of membership of x in the fuzzy $\tilde{A}$ and numerical set between zero and one. A generalized fuzzy number from a normal number with the following features is convex, normal and continuous fragment. Famous fuzzy numbers include triangular and trapezoidal fuzzy numbers.

A fuzzy number $\tilde{A} = (a, b, c, d)$ is a trapezoidal fuzzy number that is formulated as follows:

$$\mu_{\tilde{A}}\left(x\right) = \begin{cases} 0 & x < a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{d-x}{d-c} & b \le x \le d \\ 0 & x > d \end{cases} \tag{2.18}$$

Table 1: Verbal variables Evaluation of indicators by decision makers

Defination	Fuzzy number
Equal importance	1
relatively important	3
very important	5
Very very important	7
Extremely important	9
the value between judgments	2,4,6,8

In this research, the combined algorithm of Rough and fuzzy set theory will be used.

3. Mining cases of Sazeh Gostar Saipa Photovoltaic Company (Green)

The company studied in this research is Ayandeh Sazan Green Planet Company (*Solar GIFT*), a subsidiary of Pardis Sanat Siyareh Sabz Company (**Green**). Utilizing technical knowledge and human capital and obtaining representation from several reputable international companies, this company has been able as a green supplier in the field of supply and supply of solar equipment, design and construction of solar power plants and solar systems (distributed generation) in the area of Country to operate.Its activity in the field of renewable energy in the beginning of 1393 in the field of construction and operation of industrial solar power plants and power systems as well as production, supply and sale of various solar modules began and now is as the official representative of the company. Yingli - Distribution and after-sales service and the exclusive representative of growatt products in Iran. 250 hectares of the site of the International Trading Company are allocated to the solar energy production farm with a capacity of 150 MW (in three phases) and 83 hectares of it are related to the production complexes 1. Solar cell and panel with a capacity of 30 MW. Silicon wafers and ingots with an annual production capacity of 300 MW; 3. Photovoltaic cell from wafer with an annual production capacity of 150 MW; 4. Panel of photovoltaic cells with an annual production capacity of 150 MW; 5. Inverter and charge controller with an annual production capacity of 150 MW, the total rated power of the devices; 6. Solar Securite Glass with an annual production capacity of 600,000 Solar Panel Glass; 7. Structures and civil structures are dedicated to the annual production capacity of 200,000 units of solar panel structures.

3.1. Implementation of the proposed model

The present study is applied in terms of purpose and field type in terms of implementation. A questionnaire was used to collect data in this study. In fact, in the first step, the criteria were identified using the research literature and the opinion of experts. After identifying the criteria and research strategies, a hierarchical structure of the research was formed and in the next step, the evaluation criteria were evaluated using confirmatory factor analysis, and after confirming the research criteria, a pairwise comparison matrix was formed. Using the concept of Rough set theory, the pairwise matrix of experts is converted into distance numbers and then the weight of the criteria is obtained by the process of fuzzy hierarchical analysis and the fuzzy weights are converted to definite weights.

The basis of the model used to review and improve supplier selection is the generalized model of Amid et al. (2006) that the environmental objective function has been added, and each of the criteria of price, level of service and quality is divided into two sub-criteria. The values of the cost sub-criteria are quantitative in nature and the other two main criteria are qualitative in nature which are converted into quantitative values by Tables 2 and 3. It should be noted that a higher score indicates more desirability.To do this, using the database of the company's suppliers, information about 30 parts manufacturers (suppliers) was checked.

Regarding quality and service level criteria, the four purchasing managers of the company were surveyed based on the following tables and suppliers' scores were calculated for all sub-criteria. The demand for the desired piece is estimated at 100,000 per year. Then, in order to determine the performance coefficient of suppliers in each sub-environmental criterion, a survey was conducted from purchasing managers and the weight of indicators was calculated.

The result of the calculations is as follows:

Table 2: calculate the score of suppliers - service level standard

flexibility in delivery of items	delivery time (days)	Score
If the buyer needs, the supplier will deliver the goods up to 5 days earlier	**5-10**	5
If the buyer needs, the supplier will deliver the goods up to 3 days earlier	**11-15**	4
If the buyer needs, the supplier will deliver the goods up to 1 days earlier	**16-20**	3
The supplier lacks flexibility	**21-25**	2
there is a possibility of delayed delivery time	**26>**	1

Table 3: calculate the score of suppliers – quality criterion

average percentage of defective goods	Average problem handling time (days)	score
>1%	1-2	5
1-1.5%	3-4	4
1.6-2%	5-6	3
2.1-2.5%	7-8	2
<2.5%	>8	1

The result of the calculations is as follows:

$$\begin{aligned}
&W = [0.4, 0.1, 0.2, 0.2, 0.1]\\
&P_1 = 6.5 \qquad q_1 = 9 \qquad S_1 = 6 \qquad E_1 = 2.1\\
&P_2 = 6.8 \qquad q_1 = 9 \qquad S_2 = 8 \qquad E_1 = 3.9\\
&\vdots\\
&P_{30} = 6.2 \qquad q_{30} = 8 \qquad S_{30} = 6 \qquad E_{30} = 2.5
\end{aligned}$$

According to the above information, the multi-objective linear model will be as follows:

$$\begin{aligned}
&\min Z_1 = 650000X_1 + 680000X_2 + \cdots + 620000X_{30}\\
&\max Z_2 = 600000X_1 + 800000X_2 + \cdots + 600000X_{30}\\
&\max Z_3 = 210000X_1 + 390000X_2 + \cdots + 250000X_{30}\\
&s.t\\
&100000X_1 \leq 8000; 100000X_2 \leq 8000; \ldots ; 100000X_{30} \leq 100000X_i \leq Y_i \quad i = 1, 2, \ldots , 30\\
&X_i \geq \varepsilon Y_i \quad i = 1, 2, \ldots , 30\\
&\sum X_i = 130 \qquad i = 1, \quad X_i \geq 0,\ Y_i = 0, 1 \quad i = 1, 2, \ldots , 30
\end{aligned} \tag{3.1}$$

To solve the above model, the algorithm of section 3.4 is used. Object weights are compared in pairs using the fuzzy hierarchical analysis process method and the results are presented as trapezoidal fuzzy numbers in Table 4. In the expression of the ratio $\frac{w_1}{w_2}$, for example, there may be a limit $\frac{5}{1}$ that is given as (4,5,5,6) or an interval $\frac{6}{1}$ to $\frac{8}{1}$ which is presented as fuzzy (5,6,8,9). Therefore, using equation (3.2), the following values are obtained:

$$\begin{aligned}&\beta_1 = 3.343;\ \beta_2 = 0.8801;\ \beta_3 = 0.3545;\ \beta_4 = 0.7400;\\&\gamma_1 = 3.6371;\ \gamma_2 = 0.3860;\ \gamma_3 = 0.8801\\&\delta_1 = 4.1195;;\quad \delta_2 = 0.4518;;\ \delta_3 = 1\end{aligned} \tag{3.2}$$

Table 4: Paired comparison matrix

	Z_1	**Z_2**	**Z_3**	**Z_4**
Z_1	**1**	**(4,5,5,6)**	**(4,5,7,8)**	(4,5,5,6)
Z_2	**(1.8,1.7,1.5,1.4)**	**(1.3,1.3,1.3,1.3)**	**1**	1
Z_3	**(1.6,1.5,1.5,1.4)**	**(1.2,1.2,1,1)**	**(2,3,3,4)**	1

Finally, the following values are yielded to obtain fuzzy weights:

$$\alpha = 4.6273 \qquad \beta = 5.3183 \qquad \gamma = 5.9498 \qquad \delta = 6.6779 \qquad (21) \tag{3.3}$$

Using the relations (3.2) and (3.3) fuzzy weights of the goals are obtained:

$$\begin{aligned}W_1 &= \left(\frac{2.8284}{6.6779}, \frac{3.3437}{5.9498}, \frac{3.6371}{5.3183}, \frac{4.1195}{4.6273}\right) = (0.4235, 0.5619, 0.6838, 0.8902)\\W_2 &= \left(\frac{0.3193}{6.6779}, \frac{0.3545}{5.9498}, \frac{0.3860}{5.3183}, \frac{0.4518}{4.6273}\right) = (0.0478, 0.0595, 0.0725, 0.0976)\\W_3 &= \left(\frac{0.6388}{6.6779}, \frac{0.7400}{5.9498}, \frac{0.8801}{5.3183}, \frac{1}{4.6273}\right) = (.0956, 0.1243, 0.1654, 0.2161)\end{aligned}$$

And then the above fuzzy weights become definite weights:

$$W_1 = 0.6190 \qquad W_2 = 0.0655 \qquad W_3 = 0.1438 \tag{3.4}$$

In the following, the best values of the objective functions are obtained.

The best values of the objective function of cost

The values of the cost objective function and the optimal values x_i will be as follows:

$$\begin{aligned}&\mathrm{Z}_1^- = 618700\\&x_7^* = 0.08;\ x_{10}^* = 0.09;\ x_{11}^* = 0.08;\ x_{15}^* = 0.06;\ x_{16}^* = 0.07;\ x_{17}^* = 0.11;\\&x_{19}^* = 0.06;\ x_{20}^* = 0.08;\ x_{24}^* = 0.12;\ x_{26}^* = 0.08;\ x_{28}^* = 0.07;\ x_{30}^* = 0.1\end{aligned} \tag{3.5}$$

The best values of the objective function of environmental performance

$$\begin{aligned}&Z_4^* = 367000\\&x_2^* = 0.08;\ x_6^* = 0.1;\ x_9^* = 0.11;\ x_{10}^* = 0.09;\ x_{13}^* = 0.1;\ x_{16}^* = 0.07;\quad x_{18}^* = 0.09\\&x_{20}^* = 0.08;\ x_{22}^* = 0.05;\ x_{23}^* = 0.08;\ x_{26}^* = 0.08;;\ x_{29}^* = 0.07\end{aligned} \tag{3.6}$$

The best value of the objective function of social responsibility

$$
\begin{aligned}
&Z_3^* = 811000\\
&x_2^* = 0.08;\ x_3^* = 0.11;\ x_5^* = 0.1;\ x_7^* = 0.08;\ x_8^* = 0.07;\ x_9^* = 0.11;\\
&x_{10}^* = 0.09;;\ x_{16}^* = 0.039;\ x_{18}^* = 0.09;\ x_{19}^* = 0.09;\ x_{26}^* = 0.08;\\
&x_{28}^* = 0.07
\end{aligned} \tag{3.7}
$$

Finally, by determining the worst values of the objective functions as well as the values of the membership functions, the final answer of the model is obtained as follows:

$$
\begin{aligned}
&Z_1 = 618700;; \quad Z_2 = 694576.7;; \quad Z_3 = 295528.1\\
&x_7 = 0.08;\ x_{10} = 0.06751;; x_{11} = 0.08;\ x_{15} = 0.00838;\ x_{16} = 0.07;\ x_{17} = 0.11\\
&x_{18} = 0.09;\ x_{20} = 0.08; x_{24} = 0.12;\ x_{26} = 0.08;\ x_{27} = 0.0441;\ x_{28} = 0.07\\
&x_{30} = 0.1
\end{aligned} \tag{3.8}
$$

As can be seen, due to the better performance of suppliers 7, 11, 16, 17, 18, 20, 24, 26, 28 and 30 in all targets are ordered as much as their total capacity. In other words, orders are assigned to suppliers in such a way that the result of the total purchase corresponds to the preferences of the decision maker.

In this sample, the weight of goals is economic cost, environmental and social responsibility, respectively, and as a result, the level of achievement of criteria in higher weight goals is higher.

4. Discussion and conclusion

The model presented in this research is a multi-objective linear planning model for selecting green suppliers in conditions of uncertainty with real constraints in mind. Due to the importance of green supply chain and the need to comply with environmental standards and its high importance in various industries, including the photovoltaic industry as a green industry, this model can be used to provide various parts needed in that industry to Considering all the conditions, divide the organization's request for the desired piece among the candidate suppliers to provide it. The main purpose of the model is to examine economic, environmental and social criteria in selecting green suppliers. Since the theory of Rough sets can also be used when some data is not available, in this study, considering the importance of green suppliers in the supply chain and increasing the accuracy of the model, a regular method based on the theory of Rough sets has been used. In short, this theory is one of the tools that researchers and decision makers can use in various issues such as evaluation and selection of suppliers in the supply chain and other activities in the supply chain. The results show that the proposed model is effective for different stages of green supplier selection programs such as planning, design, maintenance and auditing and will be especially useful in improving and advancing the management of green suppliers in development programs and identifying suppliers.

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