J. Fuzzy. Ext. Appl. Vol. 1, No. 1 (2020) 1–14

J. Fuzzy. Ext. Appl

Journal of Fuzzy Extension & Applications
www.journal-fea.com

Supplier Selection Using Fuzzy AHP Method and D-Numbers

Payam Shafi Salimi*, *Seyyed Ahmad Edalatpanah*

Ayandegan Institute of Higher Education, Tonekabon, Iran.

P A P E R   I N F O

Chronicle:
Received: 15 November 2019
Revised: 16 December 2019
Accepted: 15 February 2020

Keywords:
Supply Chain Management.
Suppliers.
Fuzzy AHP Method.

A B S T R A C T

Success in supply begins with the right choice of suppliers and in the long run is directly related to how suppliers are managed, because suppliers have a significant impact on the success or failure of a company. Multi-criteria decisions are approaches that deal with ranking and selecting one or more suppliers from a set of suppliers. Multi-criteria decisions provide an effective framework for comparing suppliers based on the evaluation of different criteria. The present research is applied based on the purpose and descriptive-survey based on the nature and method of the research. In the present study, two library and field methods have been used to collect information. According to the objectives of this study, suppliers will be evaluated using two methods of fuzzy hierarchical analysis with D-numbers. In order to better understand these two methods, a case study is presented in which suppliers are ranked using two methods and then the results are compared with each other. For manufacturing companies, 4 categories of parts were considered and based on the classification, the suppliers of the manufacturing company were evaluated and analyzed. In the results of suppliers of type A and B components in hierarchical analysis, D and fuzzy methods have many differences in the evaluation and ranking of suppliers, and this shows the lack of expectations of experts in D and fuzzy analysis. On the other hand, in type C and D components, the classification and ranking of suppliers have been matched in two ways and shows that the opinions in the evaluation of these suppliers are the same.

1. Introduction

In recent years, much attention has been paid to the importance of selecting suppliers and supply chain management to allocate orders. Thus, in this regard, it focuses on identifying the key factors affecting the optimal selection of suppliers in the supply chain in industries [1]. Also, with the acceleration of the process of globalization and the increasing facilitation of communication, the manager's perception of the environment becomes more complex, uncertain and ambiguous [2]. Existence of numerous and unstable information and variables affecting the consequences of the decision, challenges the manager to make the right and fast decision. Although human beings have always faced the challenge of decision making, it is no exaggeration to say that the subject of decision making has never been so complicated [3]. Therefore, along with the growth of human knowledge, various thinkers have addressed the issue of decisions and methods that can make this process easier and safer. One of the most important multi-criteria decisions that has attracted the attention of researchers in the organization is the choice of

*Corresponding author
E-mail address: Saedalatpanah@aihe.ac.ir
DOI: 10.22105/jfea.2020.248437.1007

supplier in the supply chain of the organization [4]. This is due to the fact that in the current competitive environment, the process of effective selection of suppliers is very important in the success of any production organization [5]. In fact, success in procurement begins with the right choice of suppliers and in the long run depends directly on how suppliers are managed, because suppliers have a significant impact on the success or failure of a company [6]. Choosing the right supplier requires consideration of several criteria. Many decision makers or experts choose suppliers based on their own experiences and tastes, which are purely subjective and personal. Multi-criteria decisions are approaches that deal with ranking and selecting one or more suppliers from a set of suppliers. Multi-criteria decisions provide an effective framework for comparing suppliers based on the evaluation of different criteria [7]. At present, in order to solve the problem of evaluating supplier performance according to one criterion or determining the importance of a number of criteria with high accuracy, multi-criteria decision-making vocabulary is used by both researchers and experts [8]. On the other hand, multiple criteria decision making technique and besides multiple objective decision making can consider several goals in order of the decision maker's priority. In multi-objective planning, the decision maker has the ability to formulate conflicting goals in the form of a linear equation under the objective function and on the other hand to formulate real constraints such as purchase budget, capacity, etc. under the constraints of suppliers. Solving this model can determine the amount of materials received from each supplier in a way that provides the maximum amount of optimization and also covers the amount of aspirations for each goal [9]. The combination of these two techniques can create a model that takes into account different ideals while considering different criteria. For more than two decades, supply chain management and the supplier selection process have received considerable attention in the literature. Many factories and industry owners have been looking for ways to partner with suppliers to increase their management performance and competitiveness on the global stage. The quality of the supplier base affects the competitiveness of companies. The continuity of the relationship between suppliers and industry owners causes the company's supply chain to be a serious and strong obstacle in the way of competitors. Also, establishing a long-term relationship with the supplier will reduce the costs of the supplier and reduce the costs of the supplier will lead to a reduction in the costs of the organization (employer) (mutual benefit). On the other hand, a stable relationship causes the supplier to follow the rules and standards of the employer and the organization uses the facilities available to the suppliers such as engineering technical facilities (benefit to the organization). Therefore, the decision to select the best supplier for supply chain management is essential [10]. One of the most important issues in designing a supply chain is the issue of supplier selection. The complexity of this issue is in fact because each of the suppliers meets part of the buyer criteria, and the choice between them is in fact a Multiple Criteria Decision Making (MCDM) that requires a structured and systematic approach, and without it an important decision is likely to fail. With the help of computers, decision-making techniques have become very acceptable in all areas of the decision-making process. Therefore, the application of multi-criteria decision making methods for users, due to the mathematical complexity, has become very easy to implement. Decision making is the process of finding the best option from a range of available options. In fact, choosing the right set of suppliers to work with is crucial to a company's success, and the emphasis on supplier selection has been emphasized for many years [11]. There are different techniques and methods for making multiple fuzzy criteria that have different advantages and disadvantages over each other. A supply chain is a series of organizations involved in the production and delivery of a product or service. This chain starts with raw material suppliers and continues to the end customer. Supply chain management is one of the effective and efficient approaches that reduces production costs and waiting time. This attitude facilitates the provision of better customer service and ensures the opportunity for effective monitoring of transportation systems, inventory and distribution networks. In this way, the organization can exceed the expectations and demands of customers. Today, organizations are facing customers who want high product diversity, low costs, high quality and fast response. Organizations are well aware that they need an efficient supply chain to be able to compete in today's global marketplace and interconnected network economy [12]. Many experienced companies believe that choosing a supplier is the most important activity of an organization. Also, since the performance of suppliers has a major impact on the success or failure of a chain, selecting a supplier is now considered a strategic task. As a result, wrong decisions in choosing suppliers will have many negative consequences and losses for the company. Therefore, finding the right methods to select the right suppliers, which are the most important components of the supply chain, is very important. On the other hand, because raw materials and parts are the most important part of a company's costs, proper purchasing management is of considerable importance to the efficiency, effectiveness and profitability of an organization. On the other hand, today, due to new concepts of supply chain management and similar cases that lead to partnerships with suppliers and the company's close relationship with suppliers, suppliers and customers are no longer recognized as competitors of the organization. Rather, they are members of a core set called the supply chain, each of which aims to maximize profits and increase the productivity of the entire chain. Nosrati and Jafari Eskandari [13] in their research to design a supply chain network considering sustainability. The supply chain network model is considered to be uncertain and includes uncertain parameters (demand, shipping costs, and operating activity) that exist, which is a pessimistic possibility to control the model through robust optimization method. Therefore, by considering the conflicting goals of the supply chain network, including minimizing the total network costs and minimizing the amount of greenhouse gas emissions, the community-based multi-objective decision-making methods and refrigeration simulation algorithm have been used to solve the model. The results of T-Test statistical test on the means of the first, second, and computational objective functions show that there is a significant difference between the means of computational time. Sensitivity analysis performed on some parameters of the model also shows that reducing network costs and reducing greenhouse gas emissions increases the supply capacity and reduces the discount period for the purchase of raw materials.

Qasbeh [14] in his research stated that the key to success in the competition scene is to focus more on the main activities and goals of the organization. Since the 1980s, many managers of large organizations have decided to outsource activities that are not of strategic importance to the organization.

In their research, Shafia et al. [15] presented a new framework for evaluating suppliers by considering risk factors using decision-making techniques and two-level data envelopment analysis approach. In the first step, the criteria of the hierarchical analysis process were weighted with the opinion of experts and then used the data envelopment analysis approach to evaluate.

Mardani [16] stated in their research that frequent discussions related to supply chain sustainability events show that companies with a global presence are trying to improve the environmental, social and economic outcomes of global supply chains. They proposed sustainable supply chain management to improve the results of sustainability in supply chains.

Ghadimi [17] stated in his research that in the last two decades, the issue of sustainable supply chain has attracted the attention of many academics and professionals. In this regard, resources, maintenance and recycling, as well as their pairs (i.e., resources and maintenance, maintenance and recycling) have provided a platform for the exchange of technical, economic, institutional and policy aspects to help move societies towards sustainability.

Rifaki [18] stated in his research that the supply chain plays an important role in today's global economy. Therefore, in order to closely pursue sustainable business, a dynamic understanding of the issues affecting sustainability in supply chains must be formed. However, this field of research is still unknown due to limited theoretical knowledge and practical application.

2. Research Method

The approach of the present research is quantitative and qualitative according to the intended objectives. Therefore, the present research is of an applied type. Also, the present research is a field research in terms of implementation. Because in this research, the relationships between variables are expressed in the form of decision model, using fuzzy techniques and D numbers and variables are observed, measured and described, so the type of research method is descriptive-analytical. According to the objectives of this study, supplier evaluation will be evaluated using two methods of fuzzy hierarchical analysis and D-numbers. First, using the common and widely used method of multi-criteria decision making, namely the Analytical Hierarchy Process (AHP) using mathematics based on fuzzy sets, a method has been proposed to select the suppliers of a supply chain. Then this problem is evaluated again by combining the two methods of AHP and D numbers. Finally, in order to achieve the desired results, the results of these two methods will be compared with each other. In order to better understand these two methods, a case study is presented in which suppliers are ranked using two methods and then the results are compared with each other.

2.1. Basic Concepts in Dempster-Scheffer Theory or Belief Function

The detection framework in Dempster-Scheffer theory is a set of two by two separated elements or propositions, and if the set $x=\{x_1, x_2,\ldots,x_n\}$is a set of elements or propositions, the sample space or detection framework is displayed as $\Omega = 2^x$. This set is a set of all sub-sets of *X* as follows:
$\Omega = \{\{X_1\}, \{X_2\},\ldots,\{X_n\},\{X_1, X_2\},..., \{X_1, X_2,\ldots,X_n\}\}$.
If A1 = {X1}, A2 = {X2},... are sets belonging to the detection frame, the probability mass function or the detection function of the set Ai on the detection frame is displayed as m (Ai), which has the following conditions:

$$\mathrm{m(Ai)} \geq 0\ , \qquad \mathrm{Ai} \in \Omega$$

$$\mathrm{m}(\emptyset) = 0$$

$$\sum_{A\in 2^x} \mathrm{m(Ai)} = 1\ .$$

The most accurate belief that can be obtained from the correctness or occurrence of set A from the framework of diagnosis and based on the available evidence is called belief function. This function is the sum of the mass of probabilities determined for the elements in set A and is calculated as follows:

$$\mathrm{bel(A)} = \sum_{\mathrm{A_i}} \mathrm{m(b)}.$$

Contrary to the probability theory, *bel* (A) = 0 means lack of evidence about set A; While p (A) = 0 means the impossibility of this set, while bel (A) = 1 means the certainty of the occurrence of event A and it is similar to the probability p (A) = 1, which means the certainty of the correctness of the set A.
The maximum possible belief for the correctness of set A, which is determined on the basis of evidence, is called the possibility function. This function is the sum of the total probability masses of the existing elements of the detection framework with zero inter section by set A. It is defined as follows:

$$\mathrm{pl}(\mathrm{A}) = \sum_{\mathrm{A_i}} \mathrm{m}(\mathrm{b}).$$

The probability value of set A can be defined as the complement of not being belief of A, or in other words, lack of evidence showing A is true:

$$\mathrm{pl}(\mathrm{A}) = 1 - \mathrm{bel}(\sim\mathrm{A}).$$

$pl(\mathrm{A}) = 0$ means that the set A is impossible or similarly $p(\mathrm{A}) = 0$. Also $pl(\mathrm{A}) = 0$is equal to $bel(\sim A) = 1$. This means that if event A is impossible based on the evidence, then A is certainly not true. The degree of uncertainty or degree of doubt in determining the magnitude of belief and possibility based on available evidence is the distance between belief in the occurrence or correctness of set A and unbelief in the occurrence or inaccuracy of set A in the context of diagnosis and is defined as follows:

$$\mathrm{U} = 1 - \mathrm{bel}(\mathrm{A}) - \mathrm{bel}(\sim\mathrm{A}).$$

Suppose A∈Ω, set A is defined according to the above definitions and using the belief sizes $bel(A), U(A)$ and $bel(\sim A)$ as follows:

$$\mathrm{s} = \{(\mathrm{bel}(\mathrm{A}), \mathrm{u}(\mathrm{A}), \mathrm{bel}(\sim\mathrm{A})/\mathrm{A} \in \Omega\}.$$

So that for each set A of the detection framework, and $bel(\sim A)\in [0,1]$ and U (A) and $bel(A)$and their sum for A∈Ω is as follows:

$$0 \leq \mathrm{bel}(\mathrm{A}) + \mathrm{u}(\mathrm{A}) + \mathrm{bel}(\sim\mathrm{A}) \leq 1.$$

Hence, according to Dempster-Schaffer theory, the generated D numbers will be as follows:
For the discrete set Ω= {b1, b2, …, bi, …, bn} such that bi ϵ R and bi ≠ bj if i ≠ j, a special form of numbers is expressed as follows:

D({b1}) = v1,
D({b2}) = v2,
D({bi}) = vi,
D({bn}) = vn.

Or more simply D = {(b1, v1), (b2, v2),…, (bi, vi),… (bn, vn)} such that vi> 0 and if two numbers D, D1 and D2 exist, they will be as follows:

$$D_1 = \left\{\left(b_1^1, v_1^1\right), \dots, \left(b_i^1, v_i^1\right), \dots, \left(b_n^1, v_n^1\right)\right\},$$

$$D_2 = \left\{\left(b_1^2, v_1^2\right), \dots, \left(b_j^2, v_j^2\right), \dots, \left(b_m^2, v_m^2\right)\right\}.$$

The combination of D1 and D2 is shown and calculated as follows:

$$b(b) = v,$$

$$b = \frac{b_i^1 + b_j^2}{2},$$

$$v = \frac{V_i^1 + V_j^2}{2} / C,$$

$$\begin{cases} \sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{V_i^1 + V_j^2}{2}\right), & \sum_{i=1}^{n} V_i^1 = 1 \quad \text{and} \sum_{j=1}^{m} V_j^2 = 1; \\ \sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{V_i^1 + V_j^2}{2}\right) + \sum_{j=1}^{m}\left(\frac{V_c^1 + V_j^2}{2}\right), & \sum_{i=1}^{n} V_i^1 < \text{ and } \sum_{j=1}^{m} V_j^2 = 1; \\ \sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{V_i^1 + V_j^2}{2}\right) + \sum_{i=1}^{n}\left(\frac{V_i^1 + V_c^2}{2}\right), & \sum_{i=1}^{n} V_i^1 < \text{ and } \sum_{j=1}^{m} V_j^2 = 1; \\ \sum_{j=1}^{m}\sum_{i=1}^{n}\left(\frac{V_i^1 + V_j^2}{2}\right) + \sum_{j=1}^{m}\left(\frac{V_c^1 + V_j^2}{2}\right) & \\ + \sum_{i=1}^{n}\left(\frac{V_i^1 + V_j^2}{2}\right) + \frac{V_c^1 + V_c^2}{2} & \sum_{i=1}^{n} V_i^1 < \text{ and } \sum_{j=1}^{m} V_j^2 < 1; \end{cases}$$

such that $V_c^1 = 1 - \sum_{i=1}^{n} V_i^1$, $V_c^2 = 1 - \sum_{i=1}^{m} V_i^2$.

It should be noted that hybrid operations do not maintain corporate property, so D numbers can be combined correctly and efficiently:

$$(D1 \oplus D2) \oplus D3 \neq (D1 \oplus D3) \oplus D2 \neq (D2 \oplus D3) \oplus D1.$$

If D = {(b1, v1), (b2, v2),…, (bi, vi),… (bn, vn)} is a D number, the consensus operator D is defined as follows:

$$I(D) = \sum_{i=1}^{n} b_i v_i.$$

3. Findings

3.1. Evaluation of Suppliers Based on AHP Method with Theory D

To evaluate suppliers based on approach D in AHP method, we perform the following steps: In this section, 8 expert opinions will be evaluated and analyzed based on three criteria of cost, time and quality, and based on the collected opinions; first the opinions will be evaluated. We will scale and then formulate a decision matrix in which experts present their views to each supplier at a brainstorming session. According to the evaluation of suppliers for the classification of parts, this section evaluates and weighs the indicators based on the average opinions of experts, which is the final weight from the experts' point of view (*Table 1* values are calculated based on the percentage of importance).

Table 1. *Weight of criteria from the perspective of experts.*

	C1	C2	C3		C1	C2	C3
Expert 1	*0.0778*	*0.4868*	*0.4355*	**Expert 5**	*0.0993*	*0.5109*	*0.3897*
Expert 2	*0.1694*	*0.4431*	*0.3875*	**Expert 6**	*0.2411*	*0.2101*	*0.5488*
Expert 3	*0.3278*	*0.2611*	*0.4111*	**Expert 7**	*0.1186*	*0.6123*	*0.2691*
Expert 4	*0.1146*	*0.4798*	*0.4057*	**Expert 8**	*0.4002*	*0.233*	*0.3668*

Hence the display of D numbers for A1 is as shown in *Table 2*.

According to *Table 2*, evaluations are performed for the other 25 suppliers. According to the evaluation, in the next step, the combination of D numbers will be done. Therefore, based on the following relation, the numbers will be combined as *Table 3*.

$$DA1 = D11 + D12 + D13 + D14 + D15 + D16 + D17 + D18.$$

Table 2. *Display of D numbers.*

A1	D numbers
Expert 1	*D11= [(0.56,0.4355), (0.66,0.4868), (0.28,0.0778)]*
Expert 2	*D12= [(0.25,0.3875), (0.4,0.4431), (0.2,0.1694)]*
Expert 3	*D13= [(0.09,0.4111), (0.71,0.2611), (0.41,0.3278)]*
Expert 4	*D14= [(0.46,0.4057), (0.61,0.4798), (0.24,0.1146)]*
Expert 5	*D15= [(0.33,0.3897), (0.65,0.5109), (0.43,0.0993)]*
Expert 6	*D16= [(0.34,0.5488), (0.45,0.2110), (0.46,0.2411)]*
Expert 7	*D17= [(0.08,0.2691), (0.72,0.6123), (0.25,0.1186)]*
Expert 8	*D18= [(0.43,0.3668), (0.82,0.2330), (0.45,0.4002)]*

According to the accepted evaluation, the suppliers' ranking for category A parts is as shown in *Table 3*.

Table 3. *Ranking of suppliers of category A parts.*

Suppliers	A1	A2	A3	A4	A5	A6
I (D)	*0.3869*	*0.2886*	*0.3420*	*0.2024*	*0.2032*	*0.3640*
ranking	*4*	*8*	*7*	*12*	*11*	*5*
Suppliers	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**
I (D)	*0.2483*	*0.3981*	*0.4378*	*0.3908*	*0.2716*	*0.3616*
ranking	*10*	*2*	*1*	*3*	*9*	*6*

As can be seen, supplier A9 with a weight of 0.4378 was in the first place and supplier A8 with a weight of 0.3981 were in the second place. Also, the ranking of suppliers of category B parts is as shown in *Table 4*.

Table 4. *Ranking of suppliers of parts category B.*

Suppliers	A13	A14	A15	A16	A17	A18
I (D)	*0.3526*	*0.3077*	*0.3377*	*0.2326*	*0.3826*	*0.3829*
ranking	*3*	*5*	*4*	*6*	*1*	*2*

According to the evaluation performed on the category B parts, supplier A17 with a weight of 0.3826 was in the first place and supplier a18 with a weight of 0.3829 were in the second place. The rating of suppliers of category C parts is as shown in *Table 5*.

Table 5. *Ranking of suppliers of parts category C.*

Suppliers	**A19**	**A20**	**A21**	**A22**
I (D)	*0.4916*	*0.4892*	*0.3038*	*0.3731*
ranking	*1*	*2*	*4*	*3*

For category C, suppliers A19 with a weight of 0.4916 were ranked first and A20 with a weight of 0.4892 were ranked second. The ranking of suppliers of D parts is as shown in *Table 6*.

Also, suppliers were classified for type D components and all suppliers were evaluated and analyzed by D numbers in the hierarchical analysis method. In the next step, suppliers were ranked using the fuzzy AHP method approach.

Table 6. *Ranking of suppliers of parts category D.*

Suppliers	**A23**	**A24**	**A25**
I (D)	*0.5851*	*0.5400*	*0.4441*
ranking	*1*	*2*	*3*

3.2. Evaluation and Ranking of Suppliers Based on F-AHP Method

In this section, 25 suppliers identified for 4 types of parts required for supply in manufacturing companies will be evaluated and analyzed based on the fuzzy AHP method, which are in three steps as shown in *Figs. (1)-(3)*.

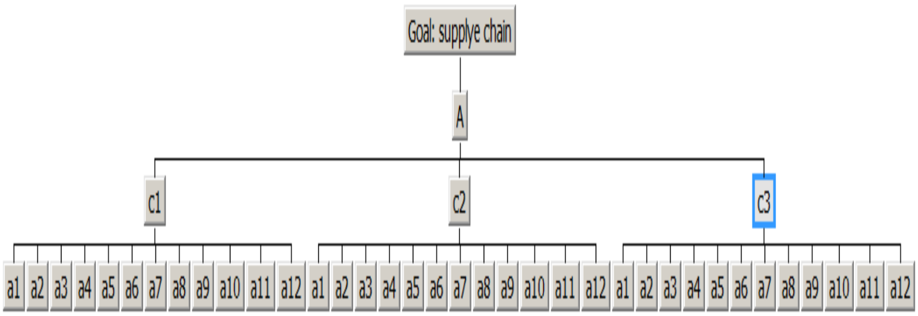

Fig. 1. *Step1: cluster the levels in expert choice software.*

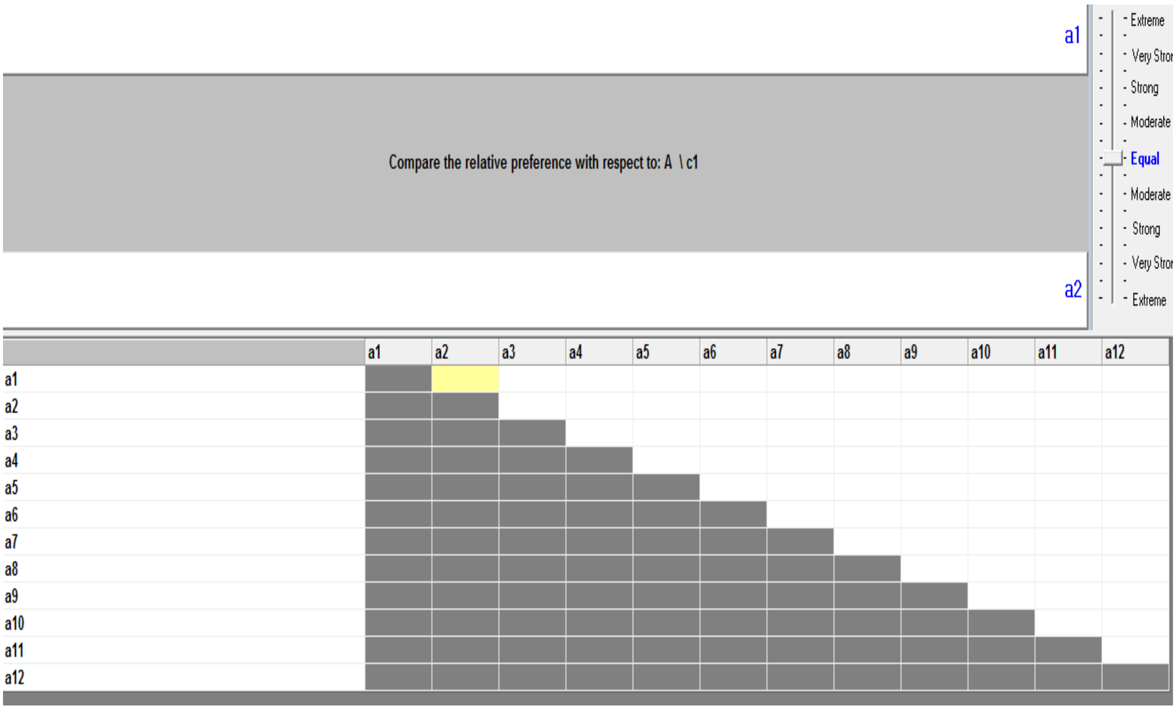

Fig. 2. *Step 2: matrix of pairwise comparison of indicators based on the mode of expert opinions.*

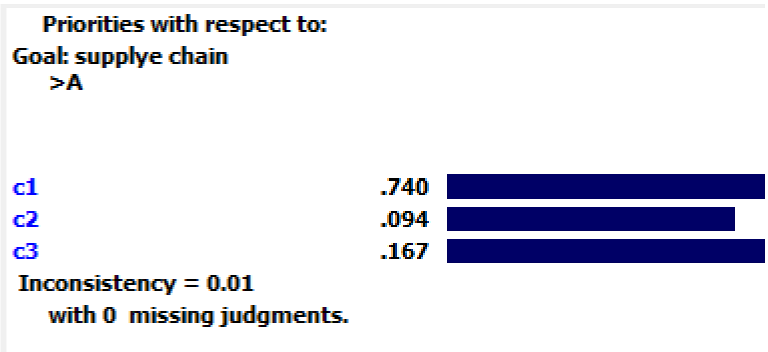

Fig. 3. *Step 3: obtain the weight of the indicators.*

As can be seen, the cost index with a weight of 0.740 was in the first place and the delivery time index with a weight of 0.167 was in the second place and the quality index with a weight of 0.094 were in the third place.

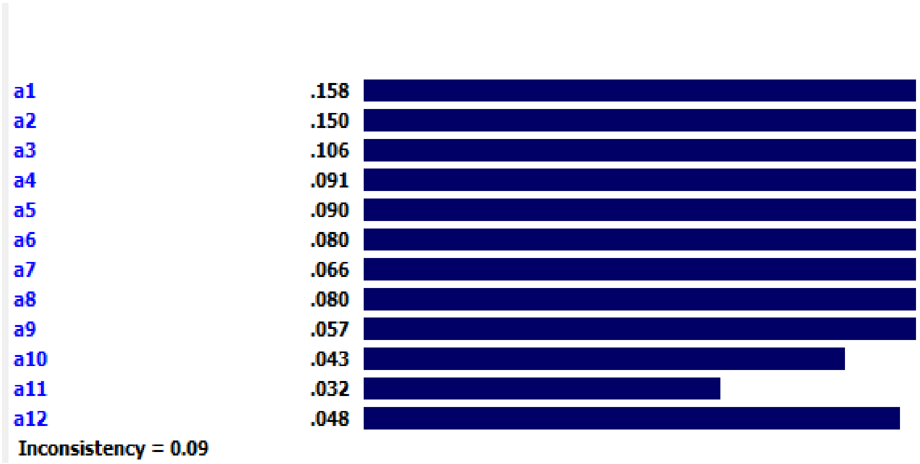

Fig. 4. *Supplier ratings for category A components.*

According to *Fig. 4*, Supplier A1 with a weight of 0.158 was in the first place and supplier A2 with a weight of 0.150 was in the third place and A3 with a weight of 0.106 was in the third place. Also, the sensitivity analysis of indicators and suppliers is as shown in *Fig. 5*.

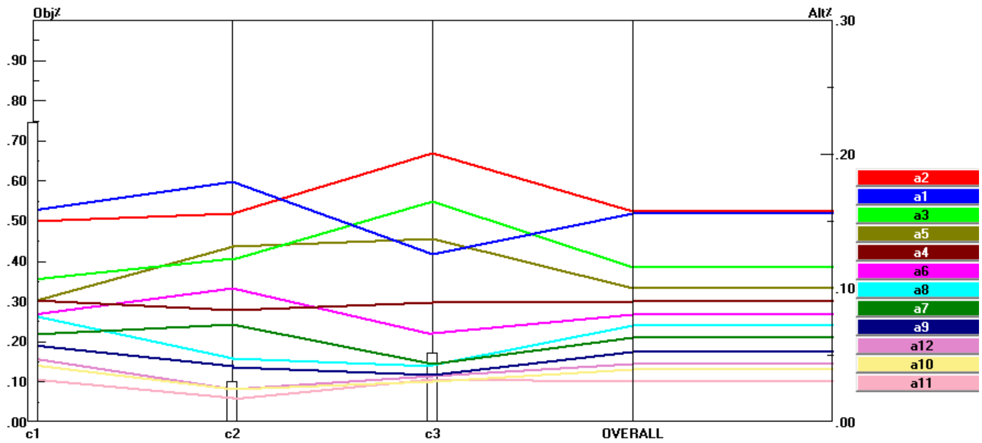

Fig. 5. *The sensitivity analysis of indicators and suppliers for category A.*

Supplier ratings for Type B components are shown in *Fig. 6*.

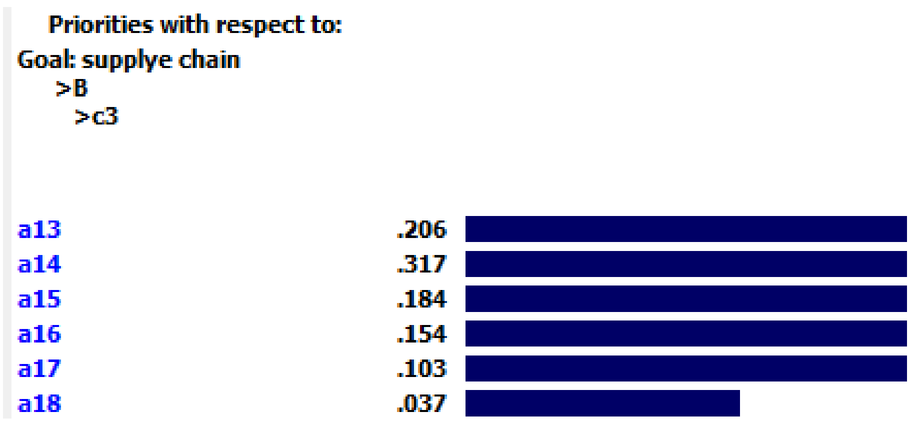

Fig. 6. *Supplier ratings for category B components.*

As can be seen, supplier 14 with a weight of 0.317 was in the first place and supplier A13 with a weight of 0.206 were in the second place. The sensitivity analysis of the assessment is as shown in *Fig. 7*.

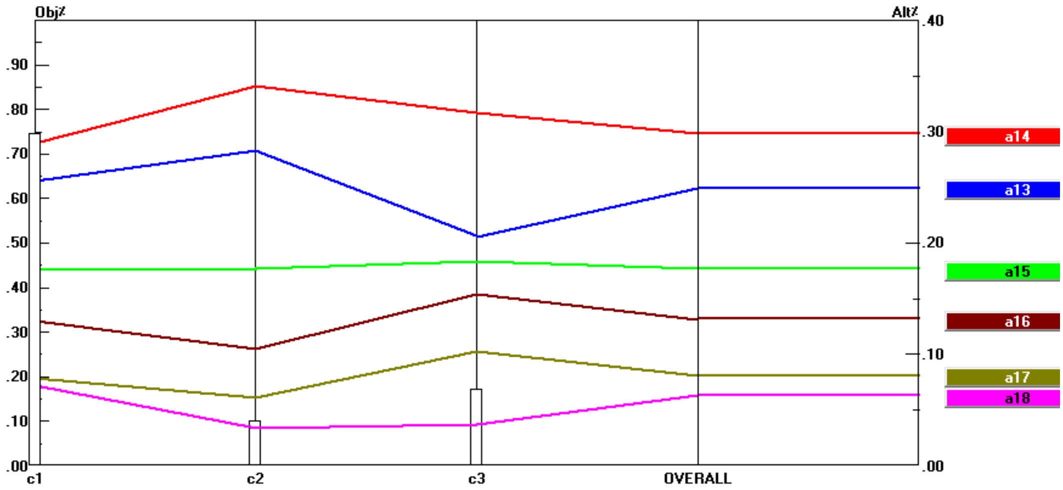

Fig. 7. *The sensitivity analysis of indicators and suppliers for category B.*

The evaluation for category C parts is shown in *Fig. 8*.

Fig. 8. *The evaluation for category C parts.*

According to the evaluation, supplier A19 with a weight of 0.473 was in the first place and A20 with a weight of 0.332 were in the second place. The sensitivity analysis indicators and suppliers for category C is as shown in *Fig. 9*.

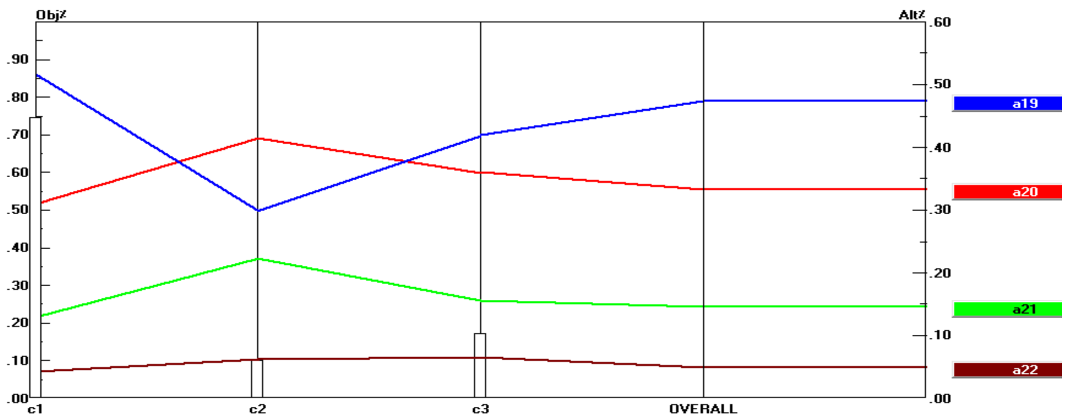

Fig. 9. *The sensitivity analysis of indicators and suppliers for category C.*

Then, for the category of type D parts, the evaluation is as *Fig. 10*.

Fig. 10. *The evaluation for category D parts.*

We also have a sensitivity analysis performed for category D which is shown in *Fig. 11*.

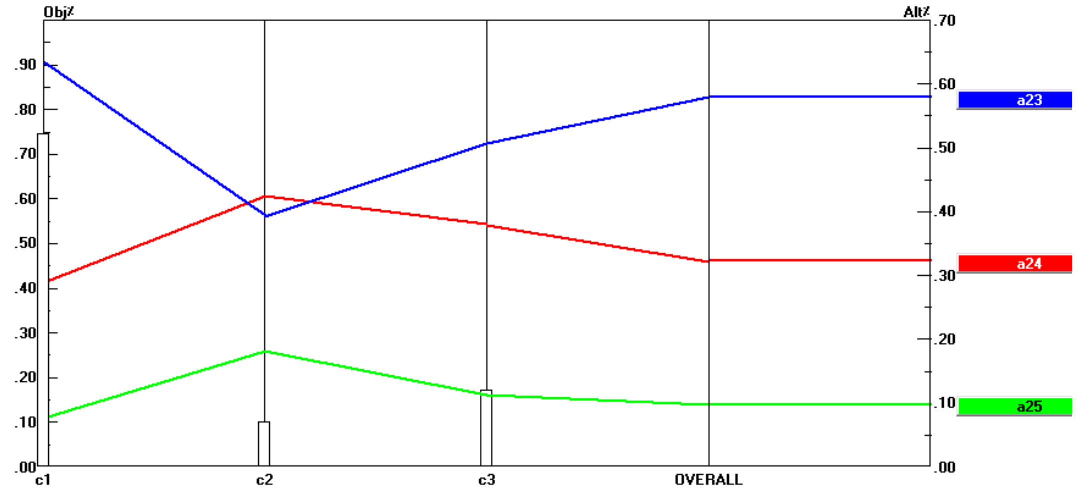

Fig. 11. *The sensitivity analysis of indicators and suppliers for category D.*

As shown in *Fig. 11*, suppliers A23 with a weight of 0.579 were in first place and A24 with a weight of 0.322 were in third place.

4. Conclusion

Today, the demands of customers along with the advancement of technology, are widely and constantly changing. This has caused the life cycle of products to be shorter and business organizations must launch a variety of products with desirable features to attract customer attention and satisfaction [19]. For this reason, in order to stay competitive, most organizations consider outsourcing the product parts to suppliers who have the technology and special ability in that field in their management, and design and produce the main parts themselves. They pay. This solution requires effective communication with suppliers and has made the issue of selecting and evaluating suppliers an important principle in the supply chain [20]. In evaluating suppliers, the most important criteria that have the greatest impact on this process must first be identified. In previous studies, criteria and indicators such as price, quality, and delivery time have been considered important in evaluating and selecting suppliers [21].Wang [22] concluded from customer research that price and quality, delivery time, and performance history are important factors. Therefore, based on two models of hierarchical analysis with D and fuzzy numbers in the evaluation of the supply chain of the manufacturing company was discussed. Therefore, 4 categories of parts were considered for manufacturing companies and based on the classification; the suppliers of the manufacturing company were evaluated and analyzed. In the results obtained from suppliers of type A and B components in the hierarchical analysis of D and fuzzy methods, there are many differences in the evaluation and ranking of suppliers, and this shows the lack of expectations of experts in D and fuzzy analysis. On the other hand, in type C and D components, the classification and ranking of suppliers have been matched in two ways and it has been shown that the opinions in the evaluation of these suppliers are the same. Like any other research, conducting this research was faced with many obstacles and problems, some of which were eliminated and some others changed the direction of the research or limited the application of the results. These restrictions include:

- Some of the contracts between the manufacturing company and the suppliers of raw materials are related to previous years, which make the price and other influential factors of these suppliers different from other suppliers that have signed a contract this year and makes it influential in choosing suppliers.
- Due to price fluctuations and market demand, it is possible to change the company's production volume. Therefore, what is considered in this study as the technical requirements of the product is without considering the product development.
- Due to the current currency situation, some suppliers are not willing to cooperate with the company due to the export of their products, which can complicate the research process and affect the choice of supplier by the company.

Considering that so far, the selection of suppliers has been done according to the needs of the company and in order to meet it, based on the intuitive judgments of experts, and the experts used to compare suppliers based on their own judgments. It is suggested that from now on, using the results of this study, the selection of suppliers in this company and other similar companies be done by collecting the required information of the models in a systematic and scientific manner. During the different stages of this research, new points were realized and as the research progressed, more ambiguities were created in front of the researcher, which due to the existing limitations, their study requires more research. Therefore, for the research of future researchers who intend to work in this field, some topics are suggested:

- To increase accuracy and reduce uncertainty in prioritizing criteria and suppliers and allocating the optimal order amount to each supplier, it is suggested to combine this model with neural network models and fuzzy logic and compare it with the results of this study.
- It is suggested to provide a comprehensive model related to similar organizations and large companies by examining other similar companies that covers all the criteria of the companies involved.
- It is suggested that the indicators be tested in similar companies based on the conceptual model or structural model in order to identify the supply framework.
- Using the gray approach to develop the accuracy of the answers obtained
- Using the heuristic factor analysis approach to identify customers' technical requirements.
- Use of fuzzy Delphi approach in order to identify the technical requirements of the product.

References

[1] Mazaheri, A. Saljuqi, M. & Seljuk, T. (2017). Identifying the key factors affecting the optimal selection of green suppliers in the green supply chain in the manufacturing industry. *Fifth international conference on economics, management, accounting with value creation approach*. Shiraz, Narun Expert Managers Training Institute.

[2] Fallah, S. Qadir, A. H., & Qadir, H. (2017). Two-objective mathematical planning model for the integrated problem of stacked size and sustainable supplier selection under fuzzy conditions. *2nd international conference on industrial management*. Babolsar, Mazandaran University.

[3] Genovese, A., Acquaye, A., Ibn-Mohammed, T., Afrifa, G. A., Yamoah, F. A., & Oppon, E. (2018). A quantitative model for environmentally sustainable supply chain performance measurement. *European journal of operational research*, *269*(1), 188-205.

[4] Tamošaitienė, J., Valipour, A., Yahaya, N., Md Noor, N., & Antuchevičienė, J. (2017). Hybrid SWARA-COPRAS method for risk assessment in deep foundation excavation project: An Iranian case study. *Journal of civil engineering and management*, *23*(4), 524-532.
[5] Liu, R. & Hai, L. (2005). The voting analytic hierarchy process method for selecting supplier. *International journal of production economics*, *97*(3), 308-317.
[6] Chen, C. T., Lin, C. T. & Huang, S. F. (2006). A fuzzy approach for supplier evaluation and selection in supply chain managemen. *International journal of production economics, 102*(2), 289-301.
[7] Lim, J. J., & Zhang, A. N. (2016). A DEA approach for supplier selection with AHP and risk consideration. In Big Data (Big Data). *2016 IEEE international conference on*, 3749-3758.
[8] Su, C. M., Horng, D. J., Tseng, M. L., Chiu, A. S., Wu, K. J., & Chen, H. P. (2016). Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach. *Journal of cleaner production*, *134*, 469-481.
[9] Momeni, M. (2006). *New topics in operations research*. First Edition, Tehran: University of Tehran School of Management Publications.Management, Accounting with Value Creation Approach, Shiraz, Narun Expert Managers Training Institute.
[10] Shahgholian, K., Shahraki, A., Waezi, Z. (2011). Multi-criteria group decision for supplier selection with fuzzy approach. *11th Iranian fuzzy systems conference.*
[11] Ming, Z. H. A., Xing. L. I. U. (2008). Research on mobile supply chain management Based Ubiquitous Network. *IEE*, 33-51.
[12] Maleki, M., Cruz Machadi, V., (2013). Development of supply chain integration model through application of analytic network process and Bayesian Network. *International journal of integrated supply management*
[13] Nosrati, F. & Jafari Eskandari, M.(2009), stable optimization method pessimistic possibility in designing a multilevel supply chain network under uncertainty.*2nd International Conference on Management, Industrial Engineering, Economics and Accounting*. Tbilisi-Georgia, Permanent Secretariat in collaboration with Imam Sadegh University
[14] Tabakhi Qasbeh, E., &Sediq, M. (2017). Evaluation of Overseas Suppliers with Emphasis on Risk Indicators Using Hierarchical Analytical Process, *6th national conference on management, economics and accounting*. Tabriz, East Azarbaijan Technical and Vocational University-Organization Tabriz Industrial .
[15] Shafia, M. A., Mahdavi Mazdeh, M., Pournader, M., &Bagherpour, M. (2016). Presenting a two-level data envelopment analysis model in supply chain risk management in order to select a supplier.
[16] Mardani, A., Kannan, D., Hooker, R. E., Ozkul, S., Alrasheedi, M., & Tirkolaee, E. B. (2020). Evaluation of green and sustainable supply chain management using structural equation modelling: A systematic review of the state of the art literature and recommendations for future research. *Journal of cleaner production*, *249*, 119383.
[17] Ghadimi, P., Wang, C., & Lim, M. K. (2019). Sustainable supply chain modeling and analysis: Past debate, present problems and future challenges. *Resources, conservation and recycling*, *140*, 72-84.
[18] Reefke, H., & Sundaram, D. (2017). Key themes and research opportunities in sustainable supply chain management–identification and evaluation. *Omega*, *66*, 195-211.
[19] Hamdi, F., Ghorbel, A., Masmoudi, F., & Dupont, L. (2018). Optimization of a supply portfolio in the context of supply chain risk management: literature review. *Journal of intelligent manufacturing*, *29*(4), 763-788.
[20] Rad, R. S., & Nahavandi, N. (2018). A novel multi-objective optimization model for integrated problem of green closed loop supply chain network design and quantity discount. *Journal of cleaner production*, 196, 1549-1565.
[21] Kumar, A., Pal, A., Vohra, A., Gupta, S., Manchanda, S., & Dash, M. K. (2018). Construction of capital procurement decision making model to optimize supplier selection using Fuzzy Delphi and AHP-DEMATEL. *Benchmarking: an international journal*, *25*(5), 1528-1547.
[22] Wang, Z., Luo, C., & Luo, T. (2018). Selection optimization of bloom filter-based index services in ubiquitous embedded systems. *International conference on web Services* (pp. 231-245).