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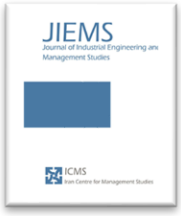

Presenting a model for selecting an innovative supplier from the perspective of co-operation using a fuzzy multi-criteria decision-making approach

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Abstract

The objective of this research is to examine the various elements that influence the choice of an innovative supplier in order to enhance the overall performance of car manufacturers through cooperation. Additionally, a fuzzy multi-criteria decision-making approach is proposed to establish a framework that can enhance the supply chain innovation performance. This study aims to bridge the existing research gap in this particular area by addressing the identified factors and providing practical solutions in Saipa Diesel Company. The current research is a descriptive-survey in terms of its purpose in the field of applied research and based on its nature and method. The statistical population of the research includes 10 experts and managers of Saipa Diesel Company, and the questionnaire was distributed among this number. The methods of collecting information in this research were divided into two categories: library and field. In this research, Delphi, Fuzzy Dimetal and Fuzzy Network Analysis methods have been used. The results of this research showed that the most important indicators of selecting an innovative supplier from the perspective of cooperation are: supplier's ability, supplier's willingness and supply risk. In the first step, the fuzzy Dimetal technique was used to reflect the mutual relationships between the criteria. In this way, at first, the matrix of direct relationship of indicators was formed. According to the results, the willingness of the supplier has the most influence and have the most interaction with other criteria. In the next step, the main criteria of the research were prioritized, and it was found that the ability of the supplier and the willingness of the supplier and the supply risk are the first to third priority respectively. Finally, based on the calculations and the limit supermatrix, it was determined that the geographic proximity index is the first priority. The ability of the supplier with a normal weight of 0.366 has the highest priority, the willingness of the supplier with a normal weight of 0.365 is the second priority, and the supply risk with a normal weight of 0.269 has the lowest priority. Finally, based on the calculations and the limit supermatrix, it was determined that "geographical proximity" with a weight of 0.1739 is the first priority. "Organizational closeness" with a weight of 0.0936 is the second priority. "Commitment to continuous improvement in product and process" with a weight of 0.0833 is the third most important index.

Keywords: supplier selection, supply chain, supplier ability, supplier willingness and supply risk.

Paper Type: Original Research

1. Introduction

The purpose of this research is to identify and leveling innovative supplier selection indicators from the perspective of cooperation in Saipa Diesel Company. The efficiency and effectiveness of any organization is the result of its management performance and its supply chain structure. This is made possible by improving the organization of the supply chain. Supply chain management is a set of approaches that are carried out in order to coordinate between suppliers, manufacturers, warehouses and retailers so that goods are produced and distributed in the right amount at the right time and place and by satisfying a certain level of customer service. , minimize the overall costs of the system (Shin and Chu, 2022).Supplier selection is one of the important components in production and logistics management during which suppliers are examined, evaluated and selected and become a part of the organization's supply chain (Rahimzadegan and Karimi Ghaseraki, 2020). Each supply chain is made up of components and create a competitive advantage, one should look for the selection of components that are more efficient. The problem of choosing a supplier is a decision-making problem with multiple criteria which includes both quantitative and qualitative criteria (Kamali et al., 2019; Hosseini et al. 2022). In fact, one of the important factors of survival

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in today's highly competitive environment is the reduction of product production costs. Also, the innovation of suppliers can significantly reduce purchasing costs and increase the competitiveness of the organization, because in most industries, the cost of raw materials and components of the product includes a major part of the final price of the product (Lindgren and Widen, 2019). Supplier selection and innovation is a complex process that shows how organizations choose strategic suppliers to increase competitive advantages (Nakandala and Lau, 2019). But this process is a problem with several indicators that includes qualitative and quantitative factors. The relative importance of these indicators and sub-indicators is determined by senior management and purchasing managers based on supply chain strategies and can have important effects on supply chain agility (Mandal, 2021; Babaeinesami et al. 2022). In fact, innovation is the transformation of creativity and new ideas into action and results. The main support of innovation in all its dimensions is having and presenting new ideas (Karaman, 2020). Innovations often result from a conscious and purposeful search for new opportunities, and this process begins with the analysis of these opportunities. The word innovation refers to slight changes in thinking, objects, processes or services. (Solaimani and Vander Veen, 2021) Innovation is a social phenomenon and the result of collective learning that can be seen more or less in all societies. However, this phenomenon is more evident in some areas and the economy of the region is formed based on it. In the current era, companies are facing challenges and intense pressures of competitive markets including the globalization of competition and cooperation, diversity of customer needs, and short product life cycles. In today's complex, dynamic and highly variable environment, companies need to design and apply strategies that can help them improve their performance, because in such a competitive environment, companies are able to survive without being left behind by the competition and adapting to changing conditions and synchronize competitive market dynamics (Patrucco et al., 2019; Pourghader Chobar et al. 2021). Today, in the global market, maintaining a competitive position is a constant concern. Supplier innovations and economic uncertainty have changed the face of the competition and the survival of organizations depends on the competitive advantage of their new products. For this reason, organizations should seek to ensure the competitive advantage of their new products by learning and acquiring new knowledge from the environment (Rostami et al., 2017). Currently, companies operate in markets where innovation of suppliers and high-quality products are considered, and products have a short life cycle. Based on this, companies are looking for ways to reduce product development time while simultaneously improving quality and reducing costs. New product development is a strategic and key activity for many companies through which new products will have a significant share in sales and profits. In fact, supplier innovation is an important factor for organizations' success in the market, so managers should improve their new product development performance. This requires greater efficiency and effectiveness of suppliers' innovation development processes especially by preventing resource wastage of peripheral activities. Supplier innovation reduces the cost of activities (Wang et al., 2020). Saipa Diesel Company is one of the active automobile manufacturing companies in Iran. This company is engaged in the production of heavy and semi-heavy vehicles, such as trucks and buses. In today's world, especially in automobile companies, the environment changes much faster than organizations, and this is a challenge that needs to be addressed. On the other hand, the competition in the current market conditions has forced automotive companies to adopt strategies to face this competition so that they can achieve higher performance, which is achieved by choosing innovative suppliers. Therefore, according to the importance of the mentioned materials, the upcoming research seeks to answer the question: What are the most important indicators of selecting an innovative supplier from the point of view of cooperation in Saipa Diesel Company, and how are these indicators prioritized? In the following article, first theoretical foundations and research background is reviewed, then Research methodology is explained and at last the results are discussed and based on the research aims some conclusions are given.

2. Theoretical foundations and research background Selection of suppliers

In today's competitive arenas, in addition to dealing with internal organization and resource issues, manufacturing companies consider themselves to be in need of managing and monitoring related resources and elements outside the organization. The reason for this is actually to achieve competitive advantages with the aim of gaining more market share. According to Porter's theory, competitive advantage is the result of the cooperation and coordination of supply chain members. Based on this, activities such as supply and demand planning, material supply, product production and planning, product storage, inventory control, distribution, delivery and customer service, which were all previously carried out at the company level, have now been transferred to the supply chain level. Considering such conditions, the effective management of the supply chain strives to create and improve efficient and effective relationships with other companies (Schiffer and Gunther, 2005; Daneshvar et al. 2023) .on the other hand; Rapid developments in the world's manufacturing industries have included heavy competition in global markets, technological innovations, and the advancement of computer systems. These developments have caused companies to coordinate their operations with new conditions to become successful global companies that have not been able to leave the competition market. The selection of suppliers is one of the important parts of supply chain management because it is suitable for achieving current and future profitable opportunities and also for making long-term decisions. With the changes in the market, the supply chain has tried to maintain its coherence and consistency in order to improve the methods and systems and seek to create and implement modern and advanced techniques in order to satisfy the competitive needs of the market. In the meantime, with the importance of finding

the position and value of suppliers in market interactions, it seeks to make it possible for organizations and factories to access supplier information. With the increase in the speed and growth of the use of the supply network in recent years, strategies for supplying items and selecting suppliers have become very important, followed by categories such as partnership and business partner and the creation of alliances and development of suppliers which are the communication between the manufacturer and the supplier have expanded and paid attention to long-term perspectives in communication (Jahanfar, 2017; Chobar et al. 2022). Therefore, one of the most important issues in the supply chain for buyers or manufacturers is choosing the right suppliers and determining the optimal amount of order to each of them. In fact, supplier selection as a fundamental issue in the field of supply chain has an impact on the performance of the entire supply chain. (Qajar and Ramsgovian, 2017). The selection of suppliers is one of the tasks of the purchasing unit which must consider many factors. The selection of suppliers consists of complex and diverse facts that should be taken into account in the decision-making process. The conditions created in the market and the new features of international competition have caused organizations and companies to turn to this system (Mohammadi and Ehsani, 2017). Choosing the right suppliers can significantly reduce the purchase costs and increase the competitiveness of the organization. Choosing a supplier especially when the buyers are senior managers and decision makers of large projects requires the use of high precision in decision-making using special methods and tools to analyze various relevant factors. In supply chain management, deciding on supplier selection is one of the main issues facing executives and managers employed in helping organizations to maintain a highly competitive position. Supplier selection and management can be applied to various suppliers throughout the life cycle of a product, from the initial raw materials to the services provided at the end of the life cycle. (Qaraati Kopaei et al., 2013). According to Goffin and his colleagues, the correct management of suppliers is one of the most important issues in the supply chain discussion, because the cost of raw materials and purchases constitute the main cost of a product, and most companies must spend a significant amount of their income on purchasing from suppliers. In other words, the selection of suppliers is a multi-indicator problem that includes qualitative and quantitative factors, and the purpose of evaluating suppliers is to identify the supplier that has the highest potential to meet the needs of the company at an acceptable cost. (Hoffman et al., 2019) Genovese et al. (2010) believe that supplier selection includes analyzing and evaluating the performance of a set of suppliers in order to rank and select them to maintain the efficiency of the supply chain system; Therefore, choosing the right supplier as a critical decision in supply chain management can affect the degree of supply chain stability (Towers et al., 2020). Decision-making and selection of clients and contractors are basically multi-criteria issues. The nature of such decision-making is usually complex and unstructured, which can be helped in the field of decision-making for these issues by using the tools of management science techniques, including multi-criteria decision-making methods (Duta et al., 2022). Also, decisions are made when the available information is incomplete and inaccurate. Another procedural problem in using the official decision-making support procedure is the inconsistent nature of the considered criteria. Also, determining the correct weights for each criterion increases the level of inherent instability in the selection process (Ambkar et al., 2021). Usually, the most important objective of the selector is to identify the suppliers who consistently have the highest potential to meet a company's needs and at acceptable costs. This choice is made through a comparison of provider considerations and based on a set of criteria and capabilities. However, the level of review and evaluation for potential customers may vary depending on the company's needs. The overall goal of selection is to identify customers with high potential. In order to select possible options, each influencer can be placed in the judgment department in terms of continuously determining needs by using appropriate criteria and characteristics (Algard et al., 2022).

2.1. Innovative supplier selection

In fact, innovation is the transformation of creativity and new ideas into action and results. The main support of innovation in all its dimensions is having and presenting new ideas. (Wong, 2004) Innovations often result from a conscious and purposeful search for new opportunities, and this process begins with the analysis of these opportunities. The word innovation refers to slight changes in thinking, objects, processes or services. (Butt et al., 2021) Innovation is a social phenomenon and the result of collective learning that can be seen more or less in all societies. However, this phenomenon is more evident in some areas and the economy of the region is formed based on it. In the current era, companies are facing challenges and intense pressures of competitive markets, including the globalization of competition and cooperation, diversity of customer needs, and short product life cycle. In today's complex, dynamic and highly variable environment, companies need to design and apply strategies that can help them improve their performance, because in such a competitive environment, companies are able to survive without being left behind by the competition and adapting to changing conditions and synchronizing with the dynamics of the competitive market (Rezai Kelidbari et al., 2013).Prior to the evaluation process, it is essential to identify and establish a criteria system. In light of the competitive markets and challenges within the supply chain, the selection of suppliers has become a significant concern, with a focus on innovation and cooperation. Consequently, government agencies and public bodies should not solely concentrate on traditional selection criteria, but also take into account new environmental and sustainable requirements. Typically, scholars prefer to determine supplier

selection criteria based on economic, environmental, and social aspects. Scholars such as Baki (2021), Gören (2018), and Liaqait et al. (2021) have emphasized the importance of considering innovation and environmentally friendly technology in the construction of criteria. Additionally, Saputro et al. (2022) have highlighted the adoption of criteria such as quality, cost, and delivery, while also measuring technology and environment-related factors. Furthermore, Rahman et al. (2022) have stressed the need to enhance collaborative factors in response to the growing awareness of innovation. Today, in the global market, maintaining a competitive position is a constant concern. Supplier innovations and economic uncertainty have changed the face of the competition and the survival of organizations depends on the competitive advantage of their new products. For this reason, organizations should seek to ensure the competitive advantage of their new products by learning and acquiring new knowledge from the environment. Currently, companies operate in markets where innovation of suppliers and high-quality products are considered, and products have a short life cycle. Based on this, companies are looking for ways to reduce product development time while simultaneously improving quality and reducing costs. New product development is a strategic and key activity for many companies, through which new products will have a significant share in sales and profits. In fact, supplier innovation is an important factor for organizations' success in the market, so managers should improve their new product development performance. This requires greater efficiency and effectiveness of suppliers' innovation development processes, especially by preventing resource wastage of peripheral activities. Supplier innovation reduces the cost of activities (Chekameh et al., 2020). In this part, according to the information received from the mentioned sources, regarding the selection of innovative suppliers, it was investigated from the perspective of cooperation. It should be noted that the studied studies are written in two internal and external sections. Aghamiri and Mohseni (2020) in research addressed the issue of "investigating the effect of suppliers' innovation on the agility of the supply chain with regard to the mediating role of sharing information and strategic resources and the moderating role of providing global resources in Iran Khodro Company". The current research is applied research in terms of its purpose and descriptive-survey in terms of its method. The statistical population of this research includes supply chain experts and managers in Iran Khodro Company. Based on the results of the research, it was determined that suppliers' innovation has an effect on the agility of the supply chain due to the mediating role of information sharing and strategic resources in Iran Khodro Company, and also providing global resources is the link between information sharing, strategic resources, supplier innovation and chain agility. It adjusts the supply. In research, Rahimzadegan and Karimi (2020) addressed the issue of "selection of Lars supplier using a developed multi-criteria decision-making method based on MABAC and BWM under conditions of uncertainty". Today, many organizations are facing a lot of competition and an uncertain environment, which has led to a review of business priorities, so designing a lean, agile, resilient and sustainable supply chain model can be effective in providing products and services. One of the most fundamental issues in the supply chain is supplier selection. For this reason, in this paper, a multi-criteria decision-making model is developed to determine the Lars supplier. In fact, the best-worst method is used to determine the weight of the criteria and the MABAC method is used to determine the rank of each supplier. Also, due to the uncertainties of the real world and the ambiguity caused by the opinions of experts in the decision-making process, type-2 fuzzy is used and the proposed model is developed in the type-2 fuzzy environment. In a research, Liu et al. (2021) addressed the topic of "Innovative supplier selection from the perspective of cooperation with MCDM hybrid model: a case study based on NEVs manufacturer". This paper focuses on proposing a new collaborative innovation decision-making framework, which helps NEV manufacturers to choose an innovative supplier that can work hand in hand with them to improve their innovation performance. First, a new Capability-Willing-Risk (C-W-R) evaluation index system developed that considers supply risk from a multi-proximity perspective that is strongly tied to collaborative innovation performance, which is only derived from geographic proximity in previous supplier selection research. Then a hybrid fuzzy-symmetric multi-criteria decision-making model (MCDM) is proposed which integrates fuzzy linguistic ensembles, best-worst method (BWM), prospect theory (PT) and VIKOR. In addition, sensitivity analysis and comparison analysis show the effectiveness and reliability of the proposed decision-making framework and deeply investigate the joint innovation of buyer and supplier. Finally, some management suggestions for supplier selection from the perspective of NEV manufacturers are provided. In a research, Park (2018) addressed the issue of "multi-objective and multi-attribute decision-making approach based on regional information for sustainable supplier selection and order allocation". In order to facilitate the complex decision-making process in global supplier selection issues, this study proposes a coherent approach that consists of two steps and effectively reflects multiple perspectives in global supply chain design for sustainability. In the first step, according to four sustainability indicators for economic and social factors in global trade and logistics, sustainable areas are identified through multi-attribute utility theory to reflect decision makers' views on global trade opportunities. In

the second step, in order to find the optimal suppliers in the regions selected in the first step and their order quantities, an integer linear programming model is used for multiple sourcing and multiple product design. The proposed approach is explained through a case study about bicycle supplier selection. The results show that multi-objective sustainable decision making under multiple sourcing strategy for different product designs achieves a type of supply chain that is significantly different from unstable single-objective decisions. A case study with different decision-making scenarios shows that the decision-maker must have a balanced view in the multi-objective decision-making environment for sustainable supply chain design. So far, there has been a lot of research in the field of supplier selection, and in these researches, the selection of suppliers is often discussed from different points of view, such as agility, greenness, etc. However, by reviewing the research backgrounds, especially domestic ones, we find out that in few researches, the selection of innovative suppliers has been discussed from the perspective of cooperation, which is the most important aspect of newness and innovation in the present research. So far, there has been a lot of research in the field of supplier selection, and in these researches, the selection of suppliers is often discussed from different points of view, such as agility, greenness, etc. For example, in Park's (2018) research, the selection of a sustainable supplier and order allocation has been discussed. The results show that multi-objective sustainable decision making under multiple sourcing strategy for different product designs achieves a type of supply chain that is significantly different from unstable single-objective decisions. Also, in the research of Beik Khakhian et al. (2015), the leveling of the indicators of the selection of agile suppliers and the ranking of suppliers have been discussed. In this research, to increase the efficiency of the results obtained from the fuzzy topsis technique, the weight of the data was determined using the hierarchical analysis method. However, by reviewing the research history, we find that in few researches, the selection of innovative suppliers has been addressed from the perspective of cooperation, which is the most important aspect of newness and the gap in past researches. So far, many methods have been used to select innovative suppliers, and one of the best methods is the combined method of ANP and DEMATEL. Using this combined method, prioritizetion and internal relationships between indicators are discussed. Based on this, the research questions are as follows:

1. What are the most important indicators of choosing an innovative supplier from the point of view of cooperation in Saipa Diesel Company?

2. How is the prioritization of innovative supplier selection indicators from the perspective of cooperation in Saipa Diesel Company?

3. How are the internal relationships between the indicators of innovative supplier selection from the perspective of cooperation in Saipa Diesel Company?

The conceptual model of the research is presented in the form of Figure 1. According to this model presented by Liu et al. (2021), the indicators of innovative supplier selection from the perspective of cooperation are: supplier ability, supplier willingness, supply risk. Also, the internal relationships between the criteria will be identified and will be investigated using pairwise comparisons. Fuzzy DEMATEL technique has also been used to check the relationships between criteria. In fact, this research provides meaningful insights for academics and industries by filling an important gap in the literature and showing managers the positive impact of supplier innovations to facilitate supply chain collaboration

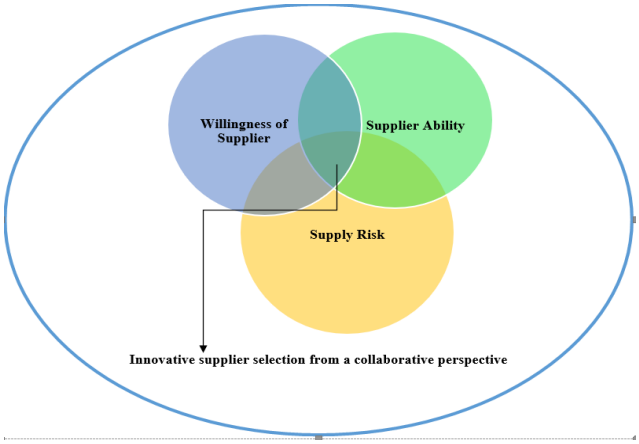

Figure 1. Conceptual model of research, (Liu et al. 2021)

3. Research methodology

Considering that the main purpose of the present research is to present a model for selecting an innovative supplier from the point of view of cooperation using the fuzzy multi-criteria decision-making approach in Saipa Diesel Company, it can be said that the present research is in the field of applied research in terms of its purpose. The basis of the nature and method is descriptive-survey research. In the present study, because research approaches have been used in operations, therefore, the research community consists of experts and senior experts in the field under study. As a result, 10 experts of Saipa Diesel Company, who have at least 10 years of related work experience in the field of supply chain and at least a doctorate degree or a doctorate student, have been used as the study sample. The methods of collecting information in this research are divided into two categories: library and field. Regarding the collection of information related to the literature of the subject and the background of the research, library methods were used, and the field method was used to collect information to answer the research questions. In this research, a questionnaire was used to collect research data. In this research, Saati's paired comparison model is used to design an expert questionnaire (Saati, 2002). Using this model, the relative importance of criteria is estimated using numbers that are the principles of ANP, which are shown in Table 1. For scoring, a nine-hour scale is used as follows:

Table 1. Valuation of indices relative to each other, nine-hour scale (1980)

value	Comparison status of i compared to j	explaination
1	Equally Preferred	Index i has equal importance to j.
3	Moderately Preferred	Option or index i is slightly more important than j.
5	Strongly Preferred	Option or index i is more important than j.
7	Very strongly Preferred	Option i is much more preferable than j.
9	Extremely Preferred	Option i is absolutely more important than j and is not comparable to j.
6-8-4-2	between	It shows intermediate values, for example, 8 indicates a higher importance than 7 and lower than 9 for i.

In this research, Delphi technique and fuzzy DEMATEL and fuzzy network analysis process (ANP) have been used to determine the internal relationships and prioritization of criteria and sub-criteria. For this purpose, the pairwise comparison matrix has been used to determine the weight of the criteria. The current research has been carried out in several stages and using several techniques. The examination reveals that the utilization of the Delphi technique and fuzzy DEMATEL and fuzzy network analysis process methods is appropriate for resolving MCDM problems. Nevertheless, there is a scarcity of research on the application of MCDM methods in the field of supplier selection, specifically in relation to fuzzy network analysis process. Furthermore, there is a lack of detailed analysis on the distinctive characteristics of innovative and collaborative suppliers in the existing research. This aspect contributes to the novelty of this paper in the context of current research. Consequently, this study aims to bridge these gaps and enhance the scope of application by implementing the Delphi technique and fuzzy DEMATEL and fuzzy network analysis process methods in the context of innovative and collaborative supplier selection.

3.1. Fuzzy ANP method

After determining the most important criteria of the subject under study, the priority of each of the identified criteria is addressed. In order to prioritize the criteria, the network analysis process technique has been used. The basis of the network analysis process is based on pairwise comparisons based on the experts' point of view. (Saati, 2002). Although experts use their mental skills and abilities to make comparisons, it should be noted that the conventional hierarchical analysis process cannot fully reflect the human thinking style. In other words, the use of fuzzy sets is more compatible with human linguistic and sometimes ambiguous explanations, and therefore it is better to use fuzzy sets (using fuzzy numbers) to make long-term predictions and decisions in the real world. (Habibi, 1390). Since the numbers used in this method are triangular fuzzy numbers, therefore, the fuzzy scales used in the fuzzy hierarchical analysis process are shown in Table-2 and Figure 2. Usually, for the paired comparison of experts' opinions, the nine-degree spectrum is used, but in many studies, the five-degree spectrum is used for the convenience and familiarity of the respondents.

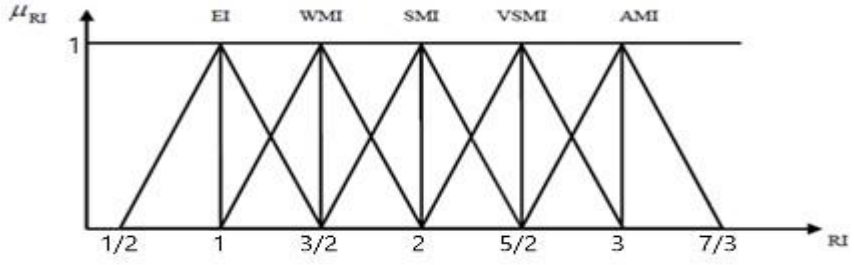

Figure 2. Valuation of indicators relative to each other using triangular fuzzy numbers

Table 2. Valuation of indicators relative to each other

Value	Comparison status of i compared to j	Fuzzy numbers	Inverse of fuzzy numbers
-	Main diameter	(1,1,1)	(1,1,1)
1	Equally Preferred	(1/2,1,3/2)	(2/3,1,2)
3	moderately Preferred	(1,3/2,2)	(1/2,2/3,1)
5	Strongly Preferred	(3/2,2,5/2)	(2/5,1/2,2/3)
7	very strongly Preferred	(2,5/2,3)	(1/3,2/5,1/2)
9	Extremely Preferred	(5/2,3,7/2)	(2/7,1/3,2/5)

Two triangular fuzzy numbers such as F1 and F2 and mathematical operations on these fuzzy numbers can be easily performed as follows:

1.First, enter the opinions of each person in fuzzy form.

2. Calculate the fuzzy mean score of each person's opinions about the visible variables of each hidden variable.

3. Fuzzy average Calculate the fuzzy averages of people's scores.

To calculate the average of the comments of n respondents, the fuzzy average will be calculated as follows:

$$fuzzyaverage = \left[\frac{l_1 + l_2 + \ldots + l_n}{n}, \frac{m_1 + m_2 + \ldots m_n}{n}, \frac{u_1 + u_2 + \ldots + u_n}{n}\right]$$

4. Perform de-fuzzing by calculating the Crisp number. (fuzzification)

There are many methods such as Minkowski method for debuzzing. In this study, Crisp number was used for de-fuzzification (Habibi, 2013).

$$x^1_{\max} = \frac{l + m + u}{3}$$

$$x^3_{\max} = \frac{l + 2m + u}{4}$$

$$x^2_{\max} = \frac{l + 4m + u}{6}$$

Crisp number = Z* = max { $x^1_{\max}, x^2_{\max}, x^3_{\max}$ }

3.2. Fuzzy DEMATEL method

In order to reflect the internal relationships between the main criteria, the fuzzy Dimetal technique has been used. So that experts are able to express their opinions regarding the effects (direction and intensity of effects) among the factors with more mastery. It should be noted that the matrix resulting from the DEMATEL technique (matrix of internal communication) shows both the cause-and-effect relationship between the factors and the influence of the variables. The phase spectrum used is given in Table 3.

Table 3. Fuzzy spectrum in Dimatel technique

Linguistic variable	Quantitative equivalent	Fuzzy quantitative equivalent		
		1	m	u
Effectless	0	0.0	0.1	0.3
Low impact	1	0.1	0.3	9.5
Effective	2	0.3	0.5	0.7
high impact	3	0.5	0.7	0.9
Too much influence	4	0.7	0.9	1

First, the internal relationships between the main criteria have been examined. In this way, the relationship matrix of the main criteria of W22 will be obtained.

3.3. Calculation of direct correlation matrix ($\tilde{X}$)

In the group Dimetal technique, when the viewpoint of several experts is used, the simple arithmetic mean of the opinions is used and we form the direct correlation matrix or ($\tilde{X}$). In this first study, the point of view of each expert has been fuzzy, and by calculating the fuzzy average of the point of view of the experts, the direct correlation matrix or M has been calculated.

- Determining the direct relationship matrix

The CFCS technique has been used to de-fuzzify the direct correlation matrix. The CFCS de-fuzzification method is suitable for the fuzzy aggregation process and presenting better de-fuzzified values. The CFCS method is calculated based on the maximum and minimum values of fuzzy numbers in each range. The CFCS method is a five-step algorithm as follows:

- Normalization of values ($\tilde{N}$)

$$l_{ij}^{n} = \left(l_{ij}^{d} - minl_{ij}^{d}\right)/\Delta_{min}^{max}$$

$$m_{ij}^{n} = \left(m_{ij}^{d} - minl_{ij}^{d}\right)/\Delta_{min}^{max}$$

$$u_{ij}^{n} = \left(u_{ij}^{d} - minl_{ij}^{d}\right)/\Delta_{min}^{max}$$

- Calculation of upper and lower limits of normal values

- Calculation of the total normalized crisp values

$$u_{ij}^{n} = \left(u_{ij}^{d} - minl_{ij}^{d}\right)/\Delta_{min}^{max}$$

- Calculation of crisp values (definitive)

$$where\ \Delta_{min}^{max} = maxu_{ij}^{d} - minl_{ij}^{d}$$

Calculation of normal direct correlation matrix

$$ls_{ij}^{n} = m_{ij}^{n}/\left(1 + m_{ij}^{n} - l_{ij}^{n}\right)$$

$$us_{ij}^{n} = u_{ij}^{n}/\left(1 + u_{ij}^{n} - m_{ij}^{n}\right)$$

First, the sum of all rows and columns is calculated. The inverse of largest number form row and column k.

Calculation of the complete correlation matrix

To calculate the complete correlation matrix, the same matrix (I) is formed first. Then we subtract the same matrix from the normal matrix and invert the resulting matrix. Finally, we multiply the normal matrix by the inverse matrix:

$$T = N \times \left(I - N\right)^{-1}$$

Display the map of network relations

A threshold value must be calculated to determine the Network Relationship Map (NRM). With this method, partial relationships can be ignored and the network of significant relationships can be drawn. Only relations whose values in matrix T are greater than the threshold value will be displayed in NRM. To calculate the threshold value of relationships, it is enough to calculate the average values of the matrix T. After the intensity of the threshold is determined, all the values of the T matrix that are smaller than the threshold are zeroed, that is, the causal relationship is not considered.

The data analysis process in this research is as follows:

1. Identification and screening of research criteria using the Delphi method

2. Identifying the internal relationships between the main criteria with the fuzzy Dimetal technique

3. Identifying the internal relationships between the sub-criteria with the fuzzy Dimetal technique

4. Prioritizing the main criteria based on the objective through the fuzzy ANP technique

5. Prioritizing each sub-criteria in its respective cluster through pairwise comparison

6. Calculation of initial super matrix, balanced super matrix and limit super matrix and final prioritization of research criteria

4. Research findings

Identification and screening of research indicators with Delphi technique

Based on past studies, research literature and conducted interviews, a total of 22 innovative supplier selection indicators were identified from the perspective of cooperation. These criteria were provided to experts in the field of study in the first stage of the Delphi technique, and these experts were asked if they have suggestion to propose a combination of some criteria in the form of a new criterion, and finally no index was added to these sub-criteria. The description of criteria and sub-criteria can be seen in Table 4:

Table 4. Summary of criteria and sub-criteria in the first round of the Delphi technique

Criteria	Sub-criteria	Final criteria
Provider ability	Technological ability	Research and development cost input
		Relative share of research and development staff
		Number of patents applied for
		Design capability
	Intangible ability	Reputation and position in the industry
		Company performance history

The Delphi technique continued in three rounds and was stopped in the third round when the final agreement was reached. After the initial screening and elimination of duplicate items and integration of some items according to

the experts' suggestion, the third questionnaire consisting of 19 final indicators was prepared and presented. Finally, the remaining 19 indicators in the second round have all scored above 3 again. Therefore, the Delphi technique was stopped and the identified indicators were used for the final analysis. Also, the criteria and sub-criteria of the research are named with a numerical index in Table 5- so that they can be easily tracked and studied during the research.

Table 5. criteria, sub-criteria and final indicators of the research

C1	criteria	Sub-criteia	symbol	Final indicators	Symbol
		Technological capability	S11	Research and development cost input	A1
				Design capability	A2
		Intangible ability	S12	Reputation and position in the industry	A3
				Company performance history	A4
	Supplier ability	Quality capability	S13	Product quality	A5
				Product reliability	A6
				Special features of existing products	A7
		Delivery capability	S14	Satisfaction with delivery	A8
				Available production capacity	A9
C2	Willingness of the supplier	Improve performance	S21	Commitment to continuous improvement in product and process	A10
				Supplier efforts to promote "just in time" principles	A11
				Honest and frequent communication	A12
				Closeness of relationships	A14
				Long term commitment	A15
		Information sharing	S22	Mutual respect and honesty	A16
		Long term relationship	S23	Commitment to quality	A17
C3	Supply risk	Objective risk	S31	Geographic proximity	A18
		Mental risk	S32	Organizational proximity	A13
				social closeness	A14

Calculation of internal relationships with the FDEMATEL technique

Based on the research model, the next step is to calculate the internal relationships of the identified indicators. In this way, the relationship matrix of the main criteria of W22 will be obtained. In order to reflect the internal relationships between the main criteria, the fuzzy Dimetal technique has been used. A threshold value must be calculated to determine the Network Relationship Map (NRM). With this method, partial relationships can be ignored and the network of significant relationships can be drawn. Only relations whose values in matrix T are greater than the threshold value will be displayed in NRM. To calculate the threshold value of relationships, it is enough to calculate the average values of the matrix T. After the intensity of the threshold is determined, all the values of the T matrix that are smaller than the threshold are zeroed, that is, the causal relationship is not considered. In this study, the threshold value is 0.940. According to the relationship pattern, a causal diagram can be drawn in Table 6.

Table 6. Pattern of significant relationships of criteria

T matrix	C1	C2	C3
C1	*	0/975	*
C2	1/204	0/995	1/023
C3	1/026	1/065	*

Table 7. Pattern of causal relationships of study indicators

	D	R	D+R	D-R
Supplier ability	2/406	2/998	5/403	-0/592
Willingness of the supplier	3/222	3/018	6/240	0/205
Supply risk	2/830	2/443	5/273	0/387

In Table 7, the sum of the elements of each row (D) indicates the influence of that factor on other factors of the system. Therefore, the willingness of the supplier has the most influence. The sum of the elements of the column (R) for each factor indicates the degree of influence of that factor on other factors of the system. Therefore, the willingness of the supplier has the most influence. The horizontal vector (D+R) is the degree of influence and impression of the desired factor in the system. In other words, the higher the D+R value of an agent, the more interaction that agent has with other system agents. Therefore, the criterion of physical factors has the most interaction with other criteria. The vertical vector (D-R) shows the influence of each factor. In general, if D-R is positive, the variable is considered as causal variable, and if it is negative, it is considered as an effect. Also, according to the pattern of relationships, the causal diagram of the sub-criteria can be drawn as Table 8:

Table 8. Pattern of causal relationships of research sub-criteria

SUBCRITERIA	symbol	D	R	D+R	D-R
Technological capability	S11	0/513	0/499	1/011	0/014
Intangible ability	S12	0/502	0/482	0/985	0/020
Quality capability	S13	0/459	0/504	0/963	-0/046
Delivery capability	S14	0/496	0/498	0/994	-0/003
Improve performance	S21	0/528	0/569	1.097	-0/041
Information sharing	S22	0/531	0/500	1/031	0/031
Long term relationship	S23	0/558	0/496	1/054	0/062
Objective risk	S31	0/473	0/486	0/959	-0/014
Mental risk	S32	0/519	0/544	1/063	-0/025

Therefore, the "long-term relationship" sub-criterion is the most effective. "Performance improvement" sub-criterion has the most influence. The existence sub-criterion of "performance improvement" has the most interaction with other criteria.

Final priority of indicators with FDANP technique

- Calculation of unbalanced supermatrix, balanced supermatrix and limit supermatrix

To determine the final weight, the output of the comparison of the main criteria based on the objective and the internal relationships between the criteria is presented in a supermatrix. This supermatrix is called primary or unbalanced supermatrix. In order to achieve the final priority, the general values in a system with mutual effects, the internal priority vectors (that is, the calculated w's) must be entered in the appropriate columns of a matrix. As a result, a super matrix (actually a partitioned matrix) is obtained, where each part of this matrix shows the relationship between two clusters in a system. (Zobardest, 2019) According to the relationships identified in the present study, the initial super matrix of this study will be as follows:

$$W = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & W_{33} \end{bmatrix}$$

In this supermatrix, the W21 vector shows the importance of each of the main criteria based on the goal. The vector W22 represents the pairwise comparison of the relationships between the main criteria derived from the output of the DEMATEL technique. The W32 vector shows the importance of each sub-criteria in its respective cluster. Zero coefficients also indicate that the factors have no effect on each other at the intersection of rows and columns. The network pattern of the model is designed using ANP technique in Superdesign software. Based on this model, the diagram of the network analysis process (ANP) will be in the form of Figure 3.

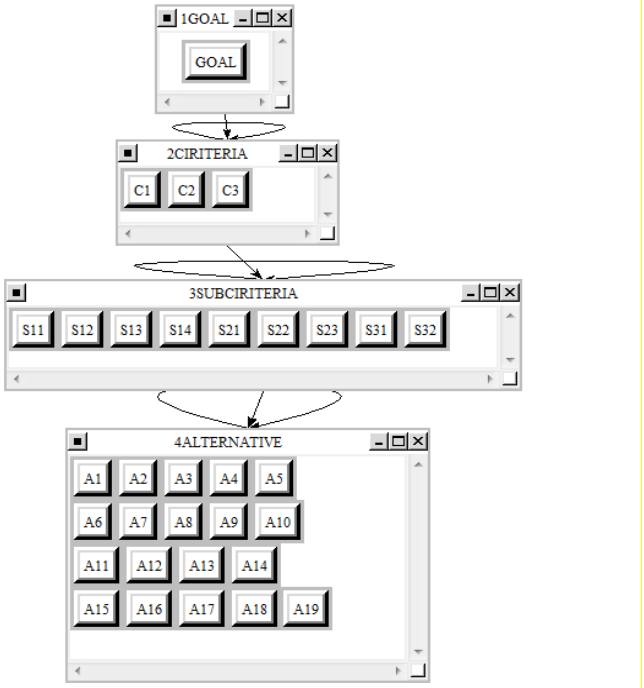

Figure 3. ANP diagram of priority indicators in Superdecision software

According to the calculations performed in the first to fourth steps, the unbalanced (initial) supermatrix has been obtained. In the next step, using the concept of normalization, the unbalanced supermatrix is converted into a balanced (normal) supermatrix. In the balanced supermatrix, the sum of the elements of all the columns is equal to one. The next step is to calculate the limit supermatrix. The limit supermatrix is obtained by exponentiation of all elements of the balanced supermatrix. This operation is repeated until all the elements of the super matrix become similar. In this case, all the registers of the supermatrix will be equal to zero, and only the registers related to the sub-criteria will be a number that will be repeated in all the rows related to that register.

Therefore, the final priority of the criteria will be as shown in Table 9:

Table 9. The final weight of the indicators based on the limit supermatrix

Sub criteria	Final indexes	Symbol	Normal weight
Technological capability	Research and development cost input	A1	0/0439
	Design capability	A2	0/0541
Intangible ability	Reputation and position in the industry	A3	0/0362
	Company performance history	A4	0/0415
Quality capability	Product quality	A5	0/0236
	Product reliability	A6	0/0163
	Special features of existing products	A7	0/0178
Delivery capability	Satisfaction with delivery	A8	0/0308
	Available production capacity	A9	0/026
Improve performance	Commitment to continuous improvement in product and process	A10	0/0833
	Supplier efforts to promote "just in time" principles	A11	0/0665
Information sharing	Honest and frequent communication	A12	0/0683
	Closeness of relationships	A13	0/0484
Long term relationship	Long term commitment	A14	0/0387
	Mutual respect and honesty	A15	0/0347
	Commitment to quality	A16	0/0403
Objective risk	Geographic proximity	A17	0/1739
Mental risk	Organizational closeness	A18	0/0936
	social closeness	A19	0/0656

Based on the calculations and the limit supermatrix, the output of Superdecision software can determine the final priority of criteria and sub-criteria. Therefore, according to the calculations, the final weight of each model index has been calculated with the FDANP technique. Based on the output of the FDANP technique, it can be seen that when the internal relationships of the research variables are also considered, the importance and rank of the study indicators will change. "Geographic proximity" with a weight of 0.1739 is the first priority. "Organizational closeness" with a weight of 0.0936 is the second priority. "Commitment to continuous improvement in product and process" is the third most important indicator with a weight of 0.0833.

5. Discussion and conclusion

This research has been done with the aim of identifying and leveling indicators of innovative supplier selection from the perspective of cooperation in Saipa Diesel Company. Therefore, at the beginning, a deep review of the subject literature and internal and external researches was done to provide the basic foundations for the preparation of the necessary assumptions for evaluating the indicators of innovative supplier selection from the perspective of cooperation. According to the purpose of this research, the current research is in the field of applied research. On the other hand, considering that library study methods and field methods such as questionnaires were used in this research, it can be stated that the current research is a descriptive survey research based on its nature and method. The methods of collecting information in this research were divided into two categories: library and field. Regarding the collection of information related to the literature of the subject and the background of the research, library methods were used, and field methods were used to collect information to answer the research questions. In this research, a questionnaire was used to collect research data. In the present study, because the research approaches were used in operations, therefore, the research community consists of experts and senior experts in the field of study. After ensuring the reliability and validity of the existing questionnaire as the main tool for data collection, the questionnaire was distributed among the experts in the field of study, and in this order the primary raw data was collected for processing, analysis and answering the research questions. It was brought in each phase

of the study, the group of experts has been determined based on the technique used. In the first phase of the study, Delphi technique was used to identify and screen criteria and sub-criteria. In the second phase of the study, the internal relations and the intensity of the relations between the criteria and the sub-criteria have been measured using the fuzzy Dimetal technique. In the final phase, the fuzzy network analysis process technique has been used to prioritize the indicators. The summary of the results of these tests is given below. Answer to the first question of the research: What are the most important indicators of choosing an innovative supplier from the point of view of cooperation in Saipa Diesel Company? Based on the results of the research and the results of the Delphi technique, it was determined that the most important indicators for selecting an innovative supplier from the perspective of cooperation in Saipa Diesel Company are: the supplier's ability criterion (including sub-criteria: technological ability, intangible ability, quality ability and delivery ability); supplier willingness criterion (including sub-criteria: performance improvement, information sharing, long-term relationship); supply risk criterion (including sub-criteria: objective risk and subjective risk). The answer to the second research question: How is the prioritization of innovative supplier selection indicators from the perspective of cooperation in Saipa Diesel Company? In the first step, the main criteria of the research was prioritized and it was found that the ability of the supplier with a normal weight of 0.366 has the highest priority. The willingness of the supplier with a normal weight of 0.365 is in the second priority, and the supply risk with a normal weight of 0.269 has the lowest priority. Finally, to determine the final priority of the main sub-criteria of the model, the initial supermatrix (unbalanced), balanced supermatrix and finally the limit supermatrix were calculated with the ANP technique. Based on the calculations and the limit supermatrix, it was determined that "geographical proximity" with a weight of 0.1739 is the first priority. "Organizational closeness" with a weight of 0.0936 is the second priority. "Commitment to continuous improvement in product and process" is the third most important indicator with a weight of 0.0833. The answer to the third research question: How are the internal relationships between the indicators of innovative supplier selection from the perspective of cooperation in Saipa Diesel Company? In the next step, the fuzzy Dimetal technique was used to reflect the mutual relationships between the criteria. In this way, at first, the matrix of direct relationship of indicators was formed. Based on this, the willingness of the supplier has the most influence and the most interaction with other criteria. Also, the "long-term relationship" sub-criterion has the most influence, the "performance improvement" sub-criterion has the most influence and interaction with other sub-criteria. As can be seen, the results of the research are in line with the researches of Aghamiri and Mohseni (2014), Shahriari and Toghian (2019), Kiaei and Jalali (2018), Liu et al. (2021), Park (2018) and show the important effects of supplier ability. The willingness of the supplier and supply risk in selecting an innovative supplier from the perspective of cooperation. Today, in the global market, maintaining a competitive position is a constant concern. As an example, Aghamiri and Mohseni (2020) in a research addressed the issue of "investigating the effect of suppliers' innovation on the agility of the supply chain with regard to the mediating role of sharing information and strategic resources and the moderating role of providing global resources in Iran Khodro Company". The most important reason for the alignment of the current research with this research is the integration of supplier innovation and supply chain agility, which fills the gap of past research. Also in line with the present research, Liu et al. (2021) sensitivity analysis and comparative analysis show the effectiveness and reliability of the proposed decision-making framework and deeply research into buyer-supplier joint innovation. The obtained results show that the proposed method not only selects the best suppliers, but also clusters all the vendors according to fuzzy similarity degrees, decides on the most critical criteria for supplier valuation, and derives decision rules for the data. he does.

Also, based on the results of this research, the following practical suggestions can be presented:

- Flexibility and timely delivery is a factor that is very important among all indicators and in the cluster of key performance indicators. In order to improve this index, it is suggested to think of measures to reduce the customer's waiting time for the delivery of the necessary and urgent order to the minimum possible. Among these measures, we can maintain a precautionary reserve of materials and parts, increase the number of production line personnel for emergency situations, adopt policies in line with the prediction of social and economic changes and, accordingly, estimate the required amount of materials and parts to meet the immediate needs of customers. He pointed out in emergency and unexpected situations.

- The speed in improving the response to changing market needs is another strategy that is very important according to the experts of the company's logistics unit. It is suggested that by adopting measures such as market segmentation and identifying different customers and then estimating the needs of each market segment, production plans should be adjusted so that the best combination of products required by different market segments is produced.

- In the field of reusing/recycling materials and packaging, choosing the way to transport goods will have a significant effect on the environment, and logistics managers must include this category in their decisions. Rail

transportation is the most desirable option for land transportation due to the use of less energy than other ways of transporting goods, as well as more efficient use of land, air pollution and less noise pollution. The choice of vehicle from the point of view of emissions is another variable that supply chain managers should pay attention to.

- It is suggested that in order to reduce inventory cost, pre-sale policies should be organized in such a way that the customer's order is delivered as soon as the product is produced. In fact, this policy makes the strategy of on-time delivery and reduction of waiting time, which was recognized as the most important strategy in the cluster of options, to be realized.

- The result of this study suggests that managers, at different levels, should emphasize on innovation, cooperation and collaboration in selecting suppliers. As one of the main and strategic challenges in supply chain management is searching for and selecting the appropriate supplier, managers should take full consideration in the process of searching and selecting a cooperative supplier. Moreover, the selected supplier should be innovative and flexible enough to support supply chain managers in the best way. Also, future researchers Considering the limitations of this research, which include the limitation of access to internal organizational information and lack of generalizability to other statistical communities; are suggested to use the fuzzy inference approach and compare its results with this research. It is also suggested that researchers measure research variables based on more accurate models that have specific dimensions for more accurate measurement. Also, future researchers could solve the challenge of sustainable supplier selection by tackling intricate and intricate interdependencies among criteria. This will be achieved through the utilization of diverse multi-criteria decision-making techniques, which will be presented within a neutrosophic logic employing the alpha cut method.

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