



# Suppliers Selection In Resilient Supply Chain By Using Fuzzy DEMATEL Approach (Case Study In SAPCO Supply Chain)

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Article	Abstract
<p>Article history: Received: 1<sup>th</sup> July 2021 Received in revised form: 9<sup>th</sup> July 2021 Accepted: 10<sup>th</sup> July 2021</p> <p>Keywords: Supply Chain Management, Resilient Supply Chain, Resilient suppliers' selection, Fuzzy DEMATEL, SAPCO</p>	<p>Today, one of the approaches to supply chain management is the resilience approach that survives organizations in the current turbulent environment. Managers of the supply chain have found that today competition inter supply chains has been replaced with inter companies. Therefore they are looking for a Competitive Advantage by own supply chain more than past. The resilience supply chain is an essential Competitive Advantage in the present risk-complete environment. One of the resilient of the supply chains is resilient supplier selection. It has features such as flexibility, the counter of risk, and responsiveness to complete delivery orders taken. Accordingly, this study used fuzzy DEMATEL based on Analytical Network Process to determine effective criteria for resilient supplier selection. Experts of SAPCO Company participated in the format of two groups in this study. One group was formed by 15 experts that screened the criteria model, and another group was formed by seven experts that determined the relationship between criteria and classification suppliers. The study shows that supplier risk is an essential factor and after it is flexibility and responsiveness suppliers. As much weighting relate to technological dimension and inter criteria relate to Technology capable. Finally, according to the results of this study, a suggestion is offered to managers of SAPCO Company.</p>

## 1. Introduction

With the emergence and expansion of the supply chain management debate, the attention of many organizations has shifted from within (internal processes of the organization) to the outside and the participating members upstream and downstream of the supply chain. Today, competition between supply chains has replaced companies, and proper supply chain management has led to the survival and profitability of the organization. Selecting suppliers is one of the essential parts and tasks in supply chain management. Given the current world conditions and globalization and increasing competition and increasing willingness to outsource for various reasons and thus increase risk and uncertainty throughout the supply chain, resilience and selection of resilient suppliers are one of the supply chain management operations to deal with It is equal to the occurrence of anticipated and unforeseen risks and disorders. In general, the current situation has forced managers to think of new approaches to supply chain management and comprehensive and multifaceted evaluations in selecting suppliers [1].

SAPCO Company is one of Iran KHODRO, responsible for supplying the necessary parts and manufacturing and designing all components of Iran KHODRO products. The company works to develop and provide auto parts for domestic and foreign automakers, identify sources of parts supply and evaluate their capabilities, select parts manufacturers [2], and conclude supply and guidance contracts for manufacturers in terms of management and quality [3]. The present study aims to identify the factors affecting the selection of the appropriate supplier in the resilient supply chain and determine the causal relationship map of the identified effective factors and determine their degree of importance.

## **2. Research Background**

### **Supply Chain Management**

The supply chain is consecutive networks of business partners who participate in production processes and transform raw materials or the final product to respond to consumer demand [4]. Today, the success of trade has more and more depends on the ability to manage the companies in complex networks of business relations [5].

The supply chain is the extension of the companies that provide services or products to the market [6]. The supply chain is composed of all parts that are directly or indirectly affected by customer demand. The supply chains are factories and suppliers and the hunters, warehouses, retailers, and their customers [7]. The network supply chain is from different launchers and distributors that play their role in supplying materials, changing and converting materials into a semi-prepared product or the final product and distribution of products to customers [8]. The supply chain defines the network of companies involved with each other, which is worthwhile through upstream communications in various processes and activities that the final customers deliver through delivering goods or services to the last customers [9].

A comprehensive definition of supply chain at a particular time, a unique layout of supply chain participants, and communication between them and other supply chains, information and materials, control management, and delivery time with a Special performance level have been defined [9]. Three decision-making factors, strategies and tactics are essential in supply chain management. Decision-making involves planning, operations and design, including strategic supply chain management and tactics, including supply chain technical management [10]. Resilience is an interdisciplinary concept that scientific researchers consider in different disciplines such as physiology, ecology, and economics. Resilience is also seen in single strands such as crisis management, sustainability development, and risk management. The analysis can adapt the supply chain for readiness against unpredictable events, the reaction to its disorders and recovery through maintaining continuous operation at the surface—desirable communication and control of all structures and tasks [11].

The possibility of disorders in each section of the network and in each process exists for broad and varied reasons such as transport delays, natural disasters and human disasters. The supply chain is a system that has the ability to recover fast after the disorder and ensures that customers get the lowest impact from this disorder [12]. Participants in the supply chain are diverse and linked to each other by streaming materials or products.

Table1 Criteria affecting the selection of irradiated suppliers, along with abbreviations

<b>Variables</b>	<b>Abbreviation signs</b>
Transport cost	$C_{11}$
The cost of the order	$C_{12}$
competitive price	$C_{13}$
Flexibility in volume	$C_{21}$
Flexibility in the mixed product (variation)	$C_{22}$
Flexibility in the production system	$C_{23}$
Quality-related certificates, such as ISO 9000	$C_{31}$
Total Quality Management	$C_{32}$
The return rate of quality control	$C_{33}$
Visibility in the supply chain	$C_{41}$
Delivery speed	$C_{42}$
Speed in the supply chain	$C_{43}$
Continuous (integrated) supply chain	$C_{51}$
Vulnerability of risk	$C_{52}$
Level of suppliers of suppliers	$C_{53}$
Risk awareness	$C_{54}$
Technological Ability	$C_{61}$
The ability to design	$C_{62}$
Ability to research unit development	$C_{63}$
ISO 14001 environmental certificate	$C_{71}$
Safety and health exercises	$C_{72}$
Environmental design (green)	$C_{73}$

### 3- Methodology

#### Delphi Method

The Delphi methodology may be an ancient prediction approach that does not need massive samples. It is often used to come up with a knowledgeable agreement for complicated topics. The Delphi methodology suffers from low convergence professional opinions and execution value [12-14].

#### Fuzzy DEMATEL

DEMATEL, was founded at the War Memorial Institute in Geneva, Switzerland. DEMATEL is a comprehensive method for creating a structural model, including causal relationships between complex factors. The measurement of relationships between variables in some cases requires the view of the experts and the experts of the elected experts, whose number is minor, in which case the technique can best reflect the relationship between variables. It should be noted that the matrix derived from the tax technique (domestic relationship matrix) shows both causal and disabled relationships between factors and displays the influence and impact of variables [15].

#### Fuzzy DEMATEL Steps

Step 1: Define an appropriate language scale to gather expert opinions based on fuzzy triangular numbers and create a matrix of direct fuzzy relationships by determining the effect of the i-j characteristics on the experts.

Fuzzy direct connection matrix with dimensions  $n \times n$ ,  $\tilde{A}$  and  $\tilde{a}_{ij} = (L_{ij}, M_{ij}, U_{ij})$  It is the degree of impact of the i-th index on the j-th index from the point of view of each expert.

Step 2: Normalize the fuzzy direct connection matrix through Equations 1 and 2:

$$\tilde{a}_{ij} = (L_{ij}, M_{ij}, u_{ij})$$

$$S = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n u_{ij}} \quad (1)$$

$$\tilde{X} = S \cdot \tilde{A} \quad (2)$$

Step 3: Calculate the total fuzzy correlation matrix as soon as the normalized direct correlation matrix  $\tilde{x}$ . Is obtained. The total fuzzy relation matrix  $\tilde{T}$ . The following formulas can get it.

If  $\tilde{X}_{ij} = (L_{ij}, M_{ij}, U_{ij})$  Define the three definite matrices whose elements are extracted from the fuzzy matrix  $\tilde{X}_{ij}$  as follows. Will have:

$$X_L = \begin{bmatrix} 0 & L_{12} & \dots & L_{1n} \\ L_{21} & 0 & \dots & L_{2n} \\ \vdots & \vdots & \dots & \vdots \\ L_{n1} & L_{n2} & \dots & 0 \end{bmatrix} \quad X_M = \begin{bmatrix} 0 & M_{12} & \dots & M_{1n} \\ M_{21} & 0 & \dots & M_{2n} \\ \vdots & \vdots & \dots & \vdots \\ M_{n1} & M_{n2} & \dots & 0 \end{bmatrix}$$

$$X_u = \begin{bmatrix} 0 & u_{12} & \dots & u_{1n} \\ u_{21} & 0 & \dots & u_{2n} \\ \vdots & \vdots & \dots & \vdots \\ u_{n1} & u_{n2} & \dots & 0 \end{bmatrix}$$

Based on the above definite matrices, we calculate the total fuzzy relation matrix using equations 3 to 6.

$$\text{If } \tilde{t}_{ij} = (L'_{ij}, M'_{ij}, u'_{ij})$$

$$\text{Matrix } [L'_{ij}] = X_L(I - X_L)^{-1} \quad (3)$$

$$\text{Matrix } [M'_{ij}] = X_M(I - X_M)^{-1} \quad (4)$$

$$\text{Matrix } [u'_{ij}] = X_u(I - X_u)^{-1} \quad (5)$$

$$\tilde{T} = \tilde{X}(1 - \tilde{X})^{-1} \quad (6)$$

By calculating these formulas, the matrix was obtained.

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \dots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \dots & \tilde{t}_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \dots & \tilde{t}_{nn} \end{bmatrix}$$

Step 4: Obtain the definite total correlation matrix by de-fuzzy the entire fuzzy correlation matrix. The following formula can be used to defuzzy.

$$\text{Crisp}(\tilde{T}) = \frac{L + 2M + u}{4}$$

Step 5: Calculate the sum of the rows and columns of the total fuzzy connection matrix, denoted by D and R, respectively. To do this, we use relationships 7 and 8.

$$\text{If } T = t_{ij} \quad i, j = 1, 2, \dots, n$$

$$D = \sum_{j=1}^n t_{ij} \quad (7)$$

$$R = \sum_{i=1}^n t_{ij} \quad (8)$$

• Step 6: Draw Ali-Disabled Chart, Ali-Disabled Chart can be drawn through the information set (D + R, D-R). The horizontal axis of the graph is composed of D and R (D + R) and the vertical axis of subtraction D and R (D-R). This graph presents a general schema of how different factors in the model and their importance in the model. (D + R) indicates the importance of each factor in the system. The resulting number for each character indicates the entire

interactions with other characteristics or the total effectiveness and effectiveness of the character directly and indirectly. (D-R) indicates the net effect of each factor. Indicators based on this number are divided into reason and disabled. If the resulting number is positive, that factor belongs to the category of causes, and if negative, the factor belongs to the handle of the people.

Impact defines. • Step 7: Calculate the interior relationship matrix and map the network map (NRM) to illustrate their important relationships and relationships from less important relationships and prevent the crowd of network mapping, a threshold value to show or not. The value of the threshold value is usually the average matrix of the total relationship or is determined by experts.

### **Industry Specifications**

The experts of this research are from the SAPCO supply chain staff. These experts are divided into two groups. The first group of experts and experts of SAPCO in different sectors are 15 people who have been used to localize the model and investigate the resilience characteristics of the research literature. They have been used for paired comparative comparisons in the diploma technique and evaluating options (suppliers) in the fuzzy VICORE technique. The second group is 7 of the company's supply chain experts. These people have undergraduate, master and doctoral education, and their work experience is more than ten years old.

### **Data Collection tools**

In this study, due to the nature of the subject and its techniques, a questionnaire was used to collect data through field surveys and surveys of experts. During the research, three questionnaires were used as follows:

Questionnaire (1) was used to localize the identified factors and determine their importance in the study.

Questionnaire (2) has been used for pairwise comparisons of essential factors in supply chain resilience in influencing each other.

### **How to extract dimensions and criteria**

To identify the influential factors in selecting suppliers in the resilient supply chain, research conducted in scientific articles, similar studies, and interviews with experts identified in the previous stages have been used. The criteria and sub-criteria for selecting resilient suppliers are given in table (2-9).

#### **Group consensus in DEMETEL technique**

To obtain the maximum opinions of experts on various criteria, the following equation has been used. This relationship indicates the group consensus of experts regarding the impact of each indicator on other indicators. If its value is less than 1%, the group consensus of experts is desirable.

$$\text{Average Gaps} = \frac{1}{n(n-1)} \sum_i \sum_j (|\bar{a}_{ij}^m - \bar{a}_{ij}^{m-1}| / \bar{a}_{ij}^m) \times 100$$

Examples of group consensus and the average gap in expert opinions number one are given in table2.

Table2 A group consensus for the first expert

$( \bar{d}_{ij}^7 - \bar{d}_{ij}^6 /\bar{d}_{ij}^7) \times 100\%$	C11	C12		C72	C73
$C_{11}$		0/018	..	0/028	0/093
$C_{12}$	0/056		..	0/028	0/125
$C_{13}$	0/036	0/067	...	0/167	0
$C_{21}$	0/018	0/008	...	0/067	0/052
$C_{22}$	0/008	0/167	...	0/052	0/045
$C_{23}$	0/028	0/052	...	0/028	0
$C_{31}$	0/008	0/036	...	0/021	0/125
$C_{32}$	0/028	0/028	...	0/271	0/069
$C_{33}$	0/039	0/018	...	0/067	0/067
$C_{41}$	0/045	0	...	0/167	0/021
$C_{42}$	0/021	0/093	...	0/125	0/013
$C_{43}$	0/083	0/028	...	0/222	0/222
$C_{51}$	0/044	0	...	0/052	0/067
$C_{52}$	0/018	0/083	...	0/037	0/011
$C_{53}$	0/011	0/028	...	0/103	0/037
$C_{54}$	0/029	0/008	...	0/044	0/039
$C_{61}$	0/093	0/052	....	0/152	0/013
$C_{62}$	0/028	0/167	...	0/093	0/103
$C_{63}$	0/067	0/167	....	0/045	0/125
$C_{71}$	0/125	0/067	....	0/056	0
$C_{72}$	0/167	0/167	....		0/036
$C_{73}$	0/013	0/05	....	0/036	
Average Gaps	0.06%<1%				

$$\text{Average Gaps} = 1/n(n-1) \sum_i \sum_j (|d_{ij}^7 - \bar{d}_{ij}^6|/\bar{d}_{ij}^7) \times 100 = 0.06\%$$

In this research, to perform pairwise comparisons of model factors, verbal expressions and their corresponding fuzzy numbers have been used to consider mental issues and uncertainties in decision making. In the present study, while defining and identifying the critical success factors in the resilient supply chain, to analyze the data collected from the questionnaire, to determine the relationships and how the elements affect and the intensity of their effect, the fuzzy DEMATEL method (F-DEMATEL) was used and to assess Degree of importance (weight) of different factors of the model The combined technique of fuzzy dimethyl based on network analysis (FDANP) has been used.

#### 4- Results

In the present study, while defining and identifying the effective criteria in the supply chain with a resilient approach, to analyze the data and obtain the expected results from the fuzzy DEMATEL method to determine the relationships and how the criteria affect each other, the fuzzy dimtel method based on network analysis (FDANP) To determine the weight or degree of importance of the requirements, fuzzy VICOR is used to prioritize and rank suppliers to answer research questions. EXCEL and MATLAB software are used to perform calculations.

## Identify and evaluate effective criteria

To identify the effective criteria in selecting resilient suppliers, various articles were used, and the requirements were extracted, which is mentioned in the second chapter of the research. Due to many identified criteria, to localize the criteria and determine the essential criteria for the current study, a weight limit will be applied in the model. To do this, the fuzzy Delphi technique was used, in which first a questionnaire with 71 questions (each criterion represents one question) was designed, and 15 questionnaires, which is the number of respondents, were given to them. These questionnaires are qualitative and based on a 7-point range from completely insignificant to completely important. After distributing and collecting the questionnaire, the fuzzy Delphi technique was used to screen and determine essential measures. The calculations were performed using EXCEL software. After calculations and data output from EXCEL software, the characteristics that had a higher value of threshold value of 0.7 after fuzzy aggregation of experts' views and de-fuzzy were selected with the guidance of the tutor. The results of screening and determining the degree of importance of the indicators were re-examined by experts. Finally, 22 sub-criteria were selected as essential and foremost criteria for the final solution of the model. Now the first question of the research was answered.

*Table 3 Dimensions of resilient supplier selection with acronyms*

<b>Main Factor</b>	<b>Symbol</b>
<b>Price / cost</b>	D1
<b>flexibility</b>	D2
<b>Quality</b>	D3
<b>Responsiveness</b>	D4
<b>Risk</b>	D5
<b>Technology</b>	D6
<b>Stability</b>	D7

Table 4 Criteria for selecting resilient suppliers, with acronyms

<b>Factors</b>	<b>Symbol</b>
<b>Transport cost</b>	C11
<b>Order cost</b>	C12
<b>Competitive price</b>	C13
<b>Flexibility in volume</b>	C21
<b>Flexibility in product mix (variety)</b>	C22
<b>Flexibility in the production system</b>	C23
<b>Quality related certification, such as ISO 9000</b>	C31



<b>Total quality management</b>	C32
<b>Rate of return from quality control</b>	C33
<b>Vision in the supply chain</b>	C41
<b>Delivery speed</b>	C42
<b>Speed in the supply chain</b>	C43
<b>Continuous (integrated) supply chain management</b>	C51
<b>Vulnerability to risk</b>	C52
<b>Level of cooperation of suppliers</b>	C53
<b>Risk awareness</b>	C54
<b>Technological ability</b>	C61
<b>Ability to design</b>	C62
<b>The ability of development research unit</b>	C63
<b>ISO 14001 environmental certificate</b>	C71
<b>Safety and health exercises</b>	C72
<b>Environmental design (green)</b>	C73

## **Determining structural relationships of dimensions and criteria**

### **Calculate the direct and total correlation matrix**

After selecting the dimensions and criteria influencing the selection of a resilient supplier, seven experts are now asked to examine the internal relationships between the requirements and how each affects each other. Experts' opinions on the effect of each feature on the others are obtained based on the verbal variables and their corresponding triangular fuzzy positive numbers. The end result of these pairwise comparisons between 7 dimensions and 22 criteria is the fuzzy direct relation matrix for the main dimensions and the criteria related to them. The mean fuzzy direct correlation matrix based on the opinion of seven experts. Through coding, the main dimensions and criteria related to each dimension are introduced. The main dimensions are denoted by the Latin letter D and the index, and the criteria are denoted by the letter C and the index, so that D stands for Dimension and C stands for Criteria. Table 5 shows the total correlation matrix corresponding to the central dimensions TD, in terms of the index i in the row on the index j in the column.

Table 5 Definite total correlation matrix corresponding to the main dimensions  $T_D$

$T_D$	$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	$D_6$	$D_7$
$D_1$	0/35	0/551	0/388	0/494	0/7	0/48	0/585
$D_2$	0/418	0/584	0/328	0/354	0/562	0/41	0/541
$D_3$	0/494	0/678	0/453	0/527	0/701	0/417	0/478
$D_4$	0/43	0/626	0/401	0/473	0/685	0/458	0/56
$D_5$	0/399	0/578	0/352	0/416	0/632	0/446	0/551
$D_6$	0/302	0/449	0/276	0/331	0/508	0/362	0/446
$D_7$	0/261	0/414	0/255	0/313	0/475	0/303	0/377

Table 6 also shows the direct fuzzy relationship matrix between the criteria. In this table, the requirements are specified as coding. For example, code  $C_{11}$  represents the first criterion from the first dimension, i.e. transportation cost.

Table 6 Fuzzy direct relation matrix related to criteria

$\tilde{A}$	$C_{11}$			$C_{12}$			$C$	$C_{73}$		
	L	M	U	L	M	U	.....	L	M	U
$C_{11}$	0	0	0	0/429	0/679	0/893	...	0/143	0/321	0/571
$C_{12}$	0/5	0/75	0/929	0	0	0	.....	0/179	0/429	0/679
$C_{13}$	0/571	0/821	0/964	0/464	0/714	0/929	.....	0/036	0/25	0/5
$C_{21}$	0/429	0/679	0/893	0/464	0/714	0/929	.....	0/321	0/571	0/821
$C_{22}$	0/536	0/786	0/964	0/071	0/25	0/5	.....	0/143	0/393	0/643
$C_{23}$	0/393	0/643	0/893	0/321	0/571	0/821	.....	0/25	0/5	0/75
$C_{31}$	0/464	0/714	0/929	0/571	0/821	0/964	.....	0/071	0/286	0/536
$C_{32}$	0/607	0/857	0/964	0/607	0/857	1	.....	0/179	0/429	0/679
$C_{33}$	0/357	0/607	0/857	0/429	0/679	0/893	.....	0/107	0/357	0/607
$C_{41}$	0/179	0/393	0/643	0/25	0/5	0/75	.....	0/036	0/286	0/536
$C_{42}$	0/107	0/286	0/536	0/107	0/321	0/571	.....	0/214	0/464	0/714
$C_{43}$	0/286	0/5	0/75	0/179	0/429	0/679	.....	0	0/107	0/357
$C_{51}$	0/429	0/679	0/929	0/5	0/75	0/964	.....	0/143	0/357	0/607
$C_{52}$	0/429	0/679	0/929	0/25	0/5	0/75	.....	0/286	0/536	0/786
$C_{53}$	0/286	0/536	0/786	0/179	0/429	0/679	.....	0/107	0/321	0/571
$C_{54}$	0/35	0/607	0/857	0/464	0/714	0/964	.....	0/357	0/607	0/857
$C_{61}$	0/107	0/321	0/571	0/321	0/571	0/821	.....	0/214	0/464	0/714
$C_{62}$	0/036	0/214	0/464	0/036	0/179	0/429	.....	0/214	0/464	0/714
$C_{63}$	0/107	0/357	0/607	0	0/036	0/286	.....	0/179	0/429	0/679
$C_{71}$	0/071	0/286	0/536	0/107	0/357	0/607	.....	0/75	1	1
$C_{72}$	0/036	0/25	0/5	0/036	0/25	0/5	.....	0/571	0/821	1
$C_{73}$	0/214	0/464	0/714	0/107	0/357	0/607	.....	0	0	0

In the following, the total relation matrix related to the criteria is given in a fuzzy and definite form. Also, Table 7 shows the fuzzy total correlation matrix related to criteria and Table 8 shows the factual total correlation matrix associated with  $T_C$  criteria.

Table 7 Fuzzy total correlation matrix related to criteria.

$\tilde{T}$	$C_{11}$			$C_{12}$			C	$C_{73}$		
	L	M	U	L	M	U	.....	L	M	U
$C_{11}$	0/007	0/034	0/167	0/029	0/067	0/206	...	0/011	0/043	0/174
$C_{12}$	0/033	0/072	0/208	0/007	0/032	0/155	...	0/013	0/047	0/174
$C_{13}$	0/036	0/073	0/206	0/03	0/066	0/198	...	0/005	0/037	0/162
$C_{21}$	0/031	0/074	0/225	0/032	0/073	0/22	...	0/022	0/059	0/198
$C_{22}$	0/035	0/075	0/217	0/011	0/046	0/188	...	0/012	0/048	0/179
$C_{23}$	0/031	0/076	0/236	0/026	0/07	0/225	...	0/019	0/06	0/204
$C_{31}$	0/033	0/074	0/221	0/038	0/078	0/216	.....	0/008	0/043	0/178
$C_{32}$	0/04	0/082	0/224	0/039	0/08	0/219	...	0/014	0/05	0/186
$C_{33}$	0/029	0/073	0/229	0/031	0/074	0/224	.....	0/011	0/05	0/192
$C_{41}$	0/015	0/05	0/187	0/018	0/054	0/187	...	0/005	0/037	0/161
$C_{42}$	0/013	0/05	0/197	0/013	0/051	0/193	...	0/015	0/051	0/183
$C_{43}$	0/02	0/056	0/193	0/015	0/051	0/184	.....	0/003	0/029	0/153
$C_{51}$	0/034	0/084	0/256	0/037	0/085	0/25	.....	0/015	0/058	0/213
$C_{52}$	0/032	0/077	0/237	0/022	0/066	0/222	.....	0/02	0/06	0/206
$C_{53}$	0/023	0/067	0/221	0/017	0/06	0/209	.....	0/011	0/047	0/186
$C_{54}$	0/03	0/081	0/252	0/035	0/083	0/249	...	0/026	0/07	0/225
$C_{61}$	0/012	0/051	0/199	0/022	0/061	0/204	...	0/015	0/051	0/184
$C_{62}$	0/005	0/036	0/166	0/005	0/033	0/159	.....	0/014	0/044	0/16
$C_{63}$	0/011	0/048	0/185	0/005	0/03	0/164	...	0/013	0/046	0/17
$C_{71}$	0/008	0/044	0/18	0/009	0/045	0/177	.....	0/043	0/076	0/185
$C_{72}$	0/006	0/04	0/175	0/005	0/039	0/169	.....	0/033	0/065	0/181
$C_{73}$	0/015	0/053	0/19	0/01	0/046	0/179	.....	0/004	0/025	0/136

Table 8 Definite total correlation matrix related to  $T_C$  criteria

$T_C$	$C_{11}$	$C_{12}$	$C_{13}$	$C_{21}$	$C_{22}$	C	$C_{63}$	$C_{71}$	$C_{72}$	$C_{73}$
$C_{11}$	0/06	0/099	0/073	0/092	0/126	.....	0/092	0/126	0/076	0/083
$C_{12}$	0/096	0/123	0/063	0/056	0/093	...	0/089	0/125	0/082	0/091
$C_{13}$	0/097	0/129	0/083	0/09	0/117	...	0/078	0/114	0/073	0/082
$C_{21}$	0/101	0/139	0/09	0/099	0/138	...	0/087	0/124	0/072	0/08
$C_{22}$	0/101	0/13	0/071	0/073	0/114	...	0/084	0/121	0/075	0/085
$C_{23}$	0/105	0/143	0/089	0/098	0/139	...	0/099	0/138	0/084	0/093
$C_{31}$	0/1	0/138	0/093	0/102	0/134	...	0/064	0/106	0/082	0/103
$C_{32}$	0/107	0/142	0/096	0/104	0/138	.....	0/101	0/132	0/069	0/063
$C_{33}$	0/101	0/141	0/092	0/101	0/141	...	0/11	0/147	0/097	0/106
$C_{41}$	0/076	0/111	0/07	0/078	0/112	.....	0/083	0/119	0/08	0/089
$C_{42}$	0/078	0/114	0/068	0/077	0/114	...	0/093	0/127	0/074	0/081
$C_{43}$	0/081	0/114	0/068	0/075	0/109	...	0/092	0/124	0/078	0/085
$C_{51}$	0/115	0/158	0/104	0/114	0/154	.....	0/12	0/16	0/101	0/11
$C_{52}$	0/106	0/143	0/087	0/094	0/135	.....	0/109	0/148	0/096	0/105
$C_{53}$	0/094	0/131	0/079	0/086	0/123	.....	0/101	0/14	0/091	0/1
$C_{54}$	0/111	0/155	0/101	0/113	0/152	.....	0/12	0/161	0/104	0/114
$C_{61}$	0/078	0/118	0/076	0/087	0/121	...	0/088	0/124	0/076	0/085
$C_{62}$	0/061	0/093	0/052	0/057	0/089	...	0/067	0/099	0/057	0/063
$C_{63}$	0/073	0/106	0/056	0/057	0/092	.....	0/082	0/112	0/062	0/065
$C_{71}$	0/069	0/103	0/061	0/069	0/102	...	0/071	0/105	0/063	0/072
$C_{72}$	0/065	0/099	0/056	0/063	0/096	.....	0/071	0/104	0/06	0/066
$C_{73}$	0/078	0/111	0/064	0/07	0/104	.....	0/07	0/105	0/062	0/071

Table 9 Definite total correlation matrix related to  $T_C$  criteria

$T_C$	$C_{11}$	$C_{12}$	$C_{13}$	$C_{21}$	$C_{22}$	C	$C_{63}$	$C_{71}$	$C_{72}$	$C_{73}$
$C_{11}$	0/06	0/099	0/073	0/092	0/126	.....	0/092	0/126	0/076	0/083
$C_{12}$	0/096	0/123	0/063	0/056	0/093	...	0/089	0/125	0/082	0/091
$C_{13}$	0/097	0/129	0/083	0/09	0/117	....	0/078	0/114	0/073	0/082
$C_{21}$	0/101	0/139	0/09	0/099	0/138	....	0/087	0/124	0/072	0/08
$C_{22}$	0/101	0/13	0/071	0/073	0/114	....	0/084	0/121	0/075	0/085
$C_{23}$	0/105	0/143	0/089	0/098	0/139	....	0/099	0/138	0/084	0/093
$C_{31}$	0/1	0/138	0/093	0/102	0/134	....	0/064	0/106	0/082	0/103
$C_{32}$	0/107	0/142	0/096	0/104	0/138	.....	0/101	0/132	0/069	0/063
$C_{33}$	0/101	0/141	0/092	0/101	0/141	....	0/11	0/147	0/097	0/106
$C_{41}$	0/076	0/111	0/07	0/078	0/112	.....	0/083	0/119	0/08	0/089
$C_{42}$	0/078	0/114	0/068	0/077	0/114	....	0/093	0/127	0/074	0/081
$C_{43}$	0/081	0/114	0/068	0/075	0/109	....	0/092	0/124	0/078	0/085
$C_{51}$	0/115	0/158	0/104	0/114	0/154	.....	0/12	0/16	0/101	0/11
$C_{52}$	0/106	0/143	0/087	0/094	0/135	.....	0/109	0/148	0/096	0/105
$C_{53}$	0/094	0/131	0/079	0/086	0/123	.....	0/101	0/14	0/091	0/1
$C_{54}$	0/111	0/155	0/101	0/113	0/152	.....	0/12	0/161	0/104	0/114
$C_{61}$	0/078	0/118	0/076	0/087	0/121	....	0/088	0/124	0/076	0/085
$C_{62}$	0/061	0/093	0/052	0/057	0/089	....	0/067	0/099	0/057	0/063
$C_{63}$	0/073	0/106	0/056	0/057	0/092	.....	0/082	0/112	0/062	0/065
$C_{71}$	0/069	0/103	0/061	0/069	0/102	....	0/071	0/105	0/063	0/072
$C_{72}$	0/065	0/099	0/056	0/063	0/096	.....	0/071	0/104	0/06	0/066
$C_{73}$	0/078	0/111	0/064	0/07	0/104	.....	0/07	0/105	0/062	0/071

**Develop a map of structural relationships**

After de-fuzzy, the total correlation matrix related to the dimensions and criteria of the model, the sum of the rows and columns of the elements of the total correlation matrix associated with the main dimensions and criteria, denoted by D and R, respectively, is calculated. Elements are used. These calculations are given in Table 9. D indicates the effectiveness, and R demonstrates the effectiveness of each factor

Table 10 The sum of rows and columns between the main dimensions and the criteria

Main and Sub Factors	D	R	D+R	D-R
Price / cost	3.548	2.654	6.202	0.894
Transport cost	2.053	1.953	4.005	0.1
Order cost	1.94	2.741	4.681	-0.801
Competitive price	1.877	1.693	3.57	0.185
flexibility	3.197	3.881	7.078	-0.684
Flexibility in volume	2.203	1.858	4.061	0.344
Flexibility in product mix (variety)	2.049	2.646	4.695	-0.597
Flexibility in the production system	2.35	1.691	4.041	0.695
Quality	3.748	2.454	6.202	1.295

Quality related certification, such as ISO 9000	2.164	1.942	4.106	0.222
Total quality management	2.229	2.711	4.939	-0.482
Rate of return from quality control	2.451	1.644	4.096	0.807
Responsiveness	3.633	2.907	6.54	0.726
Vision in the supply chain	1.839	1.788	3.618	0.061
Delivery speed	1.995	2.52	4.515	-0.525
Speed in the supply chain	1.86	1.518	3.378	0.342
Risk	3.374	4.263	7.637	-0.889
Continuous (integrated) supply chain management	2.697	1.661	4.358	1.035
Vulnerability to risk	2.363	2.43	4.792	-0.067
Level of cooperation of suppliers	2.155	1.067	3.761	0.548
Risk awareness	2.636	1.965	4.6	0.671
Technology	2.675	2.877	5.551	-0.202
Technological ability	1.986	2.772	4.758	-0.786
Ability to design	1.514	1.753	3.267	-0.239
Ability of development research unit	1.764	1.971	3.735	-0.207
Stability	2.397	3.537	5.934	-1.14
ISO 14001 environmental certificate	1.727	2.759	4.486	-1.033
Safety and health exercises	1.614	1.712	3.326	-0.098
Environmental design (green)	1.755	1.862	3.648	-0.137

As Table 9 shows, the maximum value of D is for the main dimensions of "quality", which indicates the high impact of this dimension along with the "price" dimension on other main dimensions. The highest R among the main dimensions belongs to "risk" and indicates the intensity of the impact of this dimension compared to different dimensions. Flexibility is the most influential dimension after risk.

According to the results according to Table 9, the most extensive D + R (importance) among the main dimensions is related to the "risk" dimension, which has a lot of interaction with other dimensions, and the lowest D + R is connected to the "technology" dimension, which is the lowest. It has interaction with different dimensions.

Dimensions that have a positive D-R according to Table 9 are among the causal factors and make them effective. Among the main dimensions, "quality" is the most influential dimension. In general, a positive D-R indicates the causality of the agent, and a negative D-R indicates the cause of the agent.

Supplier risk is the most influential dimension in supplier evaluation. In other words, this dimension is the essential and problematic dimension and bottleneck of the supply chain resilience of the company under study. Therefore, we conclude that resilient suppliers should reduce the risk in their company to be selected as reliable suppliers by the company under investigation. Among the essential criteria of this dimension, risk vulnerability was introduced, which is influenced by the three standards of continuous supply chain management, risk awareness, and suppliers' level of cooperation. Therefore, suppliers should try to strengthen the above three criteria so that different sources of riskless harm them.

The flexibility of suppliers is of secondary importance after the risk of suppliers, and this dimension is also one of the categories of disability criteria influenced by other measurements. Price, quality, responsiveness are among the dimensions affecting this dimension. Among the criteria of this dimension, the criterion of flexibility in the product mix (diversity) is the most critical dimension. It is influenced by two criteria of flexibility in volume and flexibility in the production system.

Supplier responsiveness is the third essential dimension in selecting resilient suppliers. Despite the risk and flexibility of suppliers, it is one of the causal factors and affects the first two dimensions. Delivery speed criterion is essential in supplier response and is influenced by two criteria of speed and visibility in the supply chain.

Quality and price are two-dimensional, determined based on the results of the fuzzy dimethyl technique, which are of equal importance and are after the first three dimensions in terms of the degree of importance. In terms of price, order cost is an important criterion affected by competitive price and transportation price criteria. In the quality dimension, total quality management is a more critical criterion affected by return rate criteria of quality control and quality-related certificates.

Sustainability and Technology are the last two dimensions of the degree of importance, both of which are disabled. Stability is more affected by other dimensions than technological capability. ISO 14001 certification is an essential criterion of suppliers' sustainability dimension, which is affected by green design criteria and safety and health practices. Technical capability is the essential criterion of suppliers' technology dimension affected by R&D unit and design capability criteria.

Price dimension: Based on the results, it is determined that the cost of the order is the most crucial criterion and is influenced by the competitive price and shipping price. A competitive price is the second most important criterion in this dimension and impacts the other two measures.

Flexibility dimension: The network relations map in this dimension shows that flexibility in the product mix (diversity) is of great importance, influenced by flexibility in volume and flexibility in the production system.

Quality dimension: The quality dimension itself is one of the most influential dimensions of the model. Among the related criteria, the comprehensive quality management criterion is an essential and disabled criterion. The rate of return on quality control is a reduction criterion and affects quality-related certificates and total quality management requirements.

Accountability dimension: This dimension affects the dimensions of supplier risk reduction and flexibility. Since supplier flexibility and risk are very important in supplier resilience, the criteria of accountability dimension are also critical. The network relationship map of this dimension shows that the criterion of speed and visibility in the supply chain is one of the causal criteria that affect the delivery speed criterion as a more important criterion.

Risk dimension: The criteria of this dimension are among the critical criteria in injecting resilience into the supplier. The criteria of continuous management in the supply chain, risk awareness, and suppliers' level of cooperation are among the causal criteria. The criterion of continuous management of the supply chain is more effective than the other two criteria. The criterion of risk awareness and vulnerability to risk is one of the crucial criteria for the criterion of risk vulnerability affected by the other three criteria.

Technology dimension: According to the network relations map related to this dimension, strong research and development unit and design ability criteria affect technological capability. Given the changing conditions, today can design and technical knowledge be essential to pay attention to the R&D department.

Supplier Sustainability Dimension: The criteria of this sustainability dimension are examined from the perspective of environmental and employee safety. Based on the bit structural relationships of these criteria, it is determined that ISO 14001 is one of the most critical criteria in supplier sustainability, and safety training criteria influence this criterion. And there is a healthy and green design.

### **Determining the degree of importance of dimensions and criteria**

At this stage, the degree of importance of each criterion is obtained using the combined FDANP technique. To escape the inherent problems of the ANP technique and avoid pairwise comparisons between different factors, the DANP technique uses a definite total correlation matrix related to the criteria to form a balanced and unbalanced supermatrix. The total relationship matrix related to dimensions is shown with  $T_D$ , and the total relationship matrix related to standards is shown with  $T_C$ . The total correlation matrix corresponding to the criteria is calculated in Table 9.

Table 11 Weights of factors

CODE	Dimensions And Criteria	Weight Abnormal (Based On DANP)	Weight Normal (Based On DANP)
D1	Price / cost	0.147(2)	
C11	transport cost	0.305(2)	0.045(8)
C12	Order cost	0.431(1)	0.063(3)
C13	competitive price	0.264(3)	0.039(17)
D2	flexibility	0.143(5)	
C21	Flexibility in volume	0.299(2)	0.043(11)
C22	Flexibility in the product mix	0.429(1)	0.061(5)
C23	Flexibility in the production system	0.273(3)	0.039(16)
D3	Quality	0.145(4)	
C31	Quality related certification, such as ISO 9000	0.307(2)	0.045(9)
C32	Total Quality Management	0.432(1)	0.063(4)
C33	Rate of return from quality control	0.261(3)	0.038(18)
D4	responsiveness	0.135(6)	
C41	Vision in the supply chain	0.305(2)	0.041(13)
C42	Delivery speed	0.434(1)	0.058(6)
C43	Speed in the supply chain	0.261(3)	0.035(19)
D5	Risk	0.133(7)	
D51	Continuous supply chain management	0.216(3)	0.029(21)
C52	Vulnerability to risk	0.318(1)	0.042(12)
C53	Level of cooperation of suppliers	0.209(4)	0.028(22)
C54	Risk awareness	0.257(2)	0.034(20)
D6	Technology	0.150(1)	
C61	Technological ability	0.428(1)	0.064(1)
C62	Ability to design	0.269(3)	0.040(14)
C63	The ability of development research unit	0.302(2)	0.045(7)
D7	Stability	0.147(2)	
C71	ISO 14001 environmental certificate	0.435(1)	0.064(2)
C72	Safety and health exercises	0.268(3)	0.039(15)
C73	Environmental design (green)	0.297(2)	0.044(10)

Note 1: The numbers in parentheses are the rank between the dimensions and the normal and abnormal weights between the criteria.

Note 2: In cases where normal and abnormal weights are equal, their rounded numbers are referred to for ranking.

According to Table 11, the importance of dimensions and criteria related to each dimension was determined. Among these, the dimensions of Technology, sustainability and price of suppliers are the most important. The requirements of technological capability and environmental certification of ISO 14001 have the highest weight among the criteria. It should be noted that local weight means abnormal weight, and global weight means average weight.

## 5- Discussion

According to the results of fuzzy dimtel, the risk dimension of suppliers is the most influential dimension in evaluating and selecting suppliers, which should try to affect the selection of suppliers with suggestions positively and thus make the company under study efficient. Because the success and failure of the company in choosing a resilient supplier and its nature supply chain resilience depend on this dimension (the most effective), we should try to use the intensity of permeability of this dimension to strengthen the resilient system. Therefore it is suggested:



A) Development and observance of the necessary standards in selecting the supplier so that the risk components are included.

B) Observing the following criteria to reduce the risk of suppliers, such as increasing the level of cooperation, continuous management of the supply chain and raising risk awareness with current and future suppliers.

Also, according to the results, the flexibility and responsiveness of the supplier are of great importance in the supply of suppliers, and the criteria of each dimension should be considered. In terms of flexibility, the criterion of transport flexibility is essential that should be considered, and in the dimension of responsiveness, the criterion of delivery speed is necessary. According to the results of FDANP in Table 11, the dimensions of Technology, price and stability of suppliers had the highest rankings in terms of weight and the criteria of technology capability, ISO 14001 environmental certification, and order cost had the highest weight. Because of the above, it is suggested that SAPCO pay more attention to the above criteria in selecting resilient suppliers.

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