An Integrated Fuzzy Model for Resilient Supplier Selection

Moslem Alimohammadlou [1], Abbas Bonyani [2]

[1] *Department of Industrial Management, Faculty of Economic, Management and Social Science, Shiraz University, Shiraz, Iran*
mslmaml@shirazu.ac.ir (Corresponding author)

[2] *Department of Industrial Management, Faculty of Management and Accounting, Allameh Tabataba'i University, Tehran, Iran*
Abbas.bonyani@gmail.com

***Abstract*— Nowadays, the business environment has provided causes of emerging a high level of uncertainty and turbulent behavior in supply chains. In most cases, suppliers are considered as the main sources of external risks which provide causes of emerging wide levels of disruptions in supply chains; therefore, choosing the appropriate and also resilient suppliers can greatly reduce purchasing costs and delay times and also increase the ability to maintain business in the case of disruption, competitiveness of the company and satisfaction of customers.**

This study is aimed to identify and investigate the attributes for evaluating the suppliers' resilience from the two aspects, the importance and effectiveness of choosing the resilient suppliers in Iran electronic industries. In this regard, screening, dematel, analytic network process and goal programming have been used that they were performed in the fuzzy environment due to the uncertainty of the nature of all studies. Results showed that some attributes including, human resource management, visibility, and financial strength are the most influential factors. In terms of importance, agility, adaptability, and vulnerability are also the most important factors. At the end, while presenting a case study of the industry and applying goal programming, the ability of the proposed combined model in solving the real-world problems is shown.

Keywords: *Resilient Supplier, DEMATEL, Analytic Network Process, Goal Programming, Fuzzy Logic.*

1. Introduction

The supply chain encompasses all of those activities associated with moving goods from the raw-materials stage through to the end user [1]. Today's business environment has created a high level of uncertainty and turbulent behaviors in supply chains. These turbulent behaviors are the results of some factors such as globalization, an increase in outsourcing level of activities, increased demand fluctuations, a decrease in life cycles of products, a sharp decrease in inventories, and a decrease in the number of suppliers of companies [2]. In addition to the above-mentioned issues, supply chains are facing with major challenges and threats such as natural disasters (floods, earthquakes, storms, fires), cyber-attacks, sanctions, disruptions in supply, production and distribution system, and so on. Supply chains are generally subject to disruptions, and their competitiveness not only depends on the cost reduction, higher quality, delivery time reduction, and higher level of service to customer, but also their ability to prevent and overcome different disruptions endangering their function; therefore, they should be resilient [3].

According to Christopher and Pack, the risk sources of the supply chain are divided into five levels, including, process, control, supply, demand, and environment [4]. In another categorization, the risk sources of the supply chain are categorized into 3 classes including, internal (process) risks, network-related risks (supply and distribution), and external (environmental) risks [5]. Disruptions can be arisen in supply chains in the two forms, internal and external [6]. Meanwhile, suppliers are often considered as the main source of external risks which lead to a wide range of disruptions in the supply chain [7]; because in most industries, costs related to supplying the raw materials, as the main part of production costs, consist of more than70 percent of production costs [8]. Due to the mentioned reasons, choosing the appropriate and also resilient suppliers can greatly reduce the purchasing costs and delay times and also increase the ability to business continuity in case of disruptions (disruptions such as sanction, changing the exchange rate, incompleteness of industry infrastructure, changes in demand and customer expectations, rapid technological changes, poor quality of suppliers' productions, inflexibility of suppliers, and etc.), and consequently,

IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

competitiveness of the company and customer satisfaction. As a result, this study is aimed to identify and investigate the attributes for evaluating the suppliers' resilience from the two aspects, the importance and influence of choosing the resilient suppliers in Iran electronic industries.

To this end, it is first necessary to identify and investigate the attributes for evaluating the suppliers' resilience in this industry. In this study, the important attributes related to the suppliers' resilience evaluation are identified by studying the literature review and then, polled by the industry and academia experts using the fuzzy screening questionnaire; finally, most important and most influential attributes related to the evaluation of suppliers' resilience are identified using the fuzzy decision-making techniques.

2. Literature review

Since 2003, that the resilience concept was proposed, various researchers provided different definitions for it, which in the following most important definitions are referred. Schafi proposed the ability and speed of companies to return to their normal level of performance in production and service after a disruption as the resilience of supply chain [9]. Roberto and Perira et al., called the ability of the supply chain in quick response to unexpected event as the resilience of supply chain, so that the operations could be promoted to a previous or even better new level of performance [10]. Yang and Zhou, have defined the resilience of supply chain as the ability to respond to disruptions resulted from natural disasters which can be analyzed by regarding the resistance of supply chain its recovery speed [11]. Despite numerous studies and rich background in the area of supplier selection, research in the area of supplier selection in resilient supply chain is limited [12]. Some of the most important researches are referred in the following.

Halder et al., selected suppliers in the resilient chain using a hybrid method based on the AHP, TOPSIS, and QFD. The attributes used for this issue include two categories of attributes: technical attributes (resilience), including supply chain density, supply chain complexity, responsiveness, node sensitivity, and reengineering; producer attributes, including, buffer capacity, flexibility of supplier sources, and delay time [13]. Sawick evaluated and selected the suppliers in the case of supply chain disruptions, and allocating orders to the selected suppliers using a mixed-integer programming modeling [14]. Halder et al. provided a strategic and quantitative approach to select the resilient suppliers in a fuzzy environment. Their attributes included quality, product capability, customer satisfaction, and product cost [15].

Azadeh et al. provided a comprehensive approach for selecting the suppliers in the green-resilient supply chain. The examined aspects included finance, quality, service and corporate social responsibility, resilience and environmental. The attributes of resilience aspect were self-organization, reversibility, and flexibility. They used the integrated analytic network process and fuzzy dematel methods to determine the weights and relations among the attributes, and also data envelopment analysis method for ranking the suppliers [16]. Torabi et al. addressed the supplier selection and order allocation in a resilient supply chain using the two-step Probabilistic programming. They focused on strengthening the suppliers, contracting with supportive suppliers, and business continuity programs in order to promote the chain [17].

Kamal Ahmadi and Nahrast provided a two-stage mixed-integer programming model in order to select the supplier and allocate order along with the transportation channel selection and providing the contingency plans to reduce the negative effects of disruptions and also minimizing the total network costs in a resilient supply chain [18]. Sahu et al. evaluated and selected the resilient suppliers in a fuzzy environment using the fuzzy vikor method. In order to evaluate the resilience of suppliers, they used two classes of public and resilience attributes [19]. Attributes of evaluating the suppliers' resilience: In order to identify and validate the evaluation attributes of suppliers' resilience, 27 attributes have been obtained from the review of theoretical foundations as shown in Table1.

Table 1. Attributes considered for resilient supplier selection in resilient supply chains

Attribute	Relevant literature	Remarks
Visibility	[20],[21],[22],[23],[24],[25],[2],[26],[27],[28],[19],[29]	The ability to see through the entire supply chain (all nodes and links), which helps to identify potential threats
Collaboration	[24],[30],[22],[21],[31],[31],[27],[32],[33],[34],[9],[29]	The ability to work effectively with other supply chain entities for mutual benefit, e.g. sharing information and other resources to reduce vulnerability
Flexibility	[24],[23],[22],[21],[26],[2],[20],[27],[28],[3],[32],[33],[35]	The ability of a firm and supply chain to adapt to changing requirements with minimum time and effort
Agility	[21],[2],[26],[28],[36],[32],[34],[29]	The ability to respond quickly to unpredictable changes in demand and/or supply
Velocity	[27],[29]	The pace of flexible adaptations that can determine the recovery speed of the supply chain from a disruption
Vulnerability	[7],[37],[38],[39],[35],[40]	Supplier should not be vulnerable to various sources of risks. There should be a resilient sales and operations planning process for suppliers to identify and react to sources of vulnerabilities
Research and development	[41],[42],[7],[43],[44],[45]	Suppliers should have a strong R&D wing to incorporate innovations in technology and to adapt with the present market turbulences. In addition, suppliers should work in collaboration with the R&D activities of the firm for risk mitigation
Risk awareness	[7],[46],[47],[48],[49],[50]	Supplier should be aware of various levels of risks, such as risks related with assets, process, organizations and environment. Risk awareness helps them to act in cases of emergency, thus increasing resilience capability of suppliers
Technological capability	[7],[51],[52],[53],[17],[54]	Suppliers must be technologically capable to adapt themselves towards innovations. Incorporating advanced product and process technologies enable suppliers to be resilient enough to adjust with technological turbulence
Risk management culture	[27],[26],[2],[25],[40],[31],[21],[24],[34],[32],[3],[28]	Ensuring that all organizational members embrace supply chain risk management, and this involves, e.g. top management support and firm integration/team work
Safety	[7],[54],[55],[56],[57]	Suppliers must provide their employees with a safe and healthy working environment in order to prevent accidents and injury to health occurring in the course of work or as a result of the operation of the supplier
Supply chain network structure	[34],[9],[58],[59]	Constructing the supply chain network for resilience, e.g. balancing redundancy, efficiency, vulnerabilities, etc.
Adaptive capability	[34],[60]	Supply chain resilience focuses on the system's adaptive capability to deal with temporary disruptive events. The dynamic nature of this adaptive capability allows the supply chain to recover after being disrupted, returning to its original state or achieving a more desirable state of supply chain operations
Trust	[34],[36],[25],[22]	Trust is generally seen as a precondition for risk sharing. Supply chain management is built on a foundation of trust
Risk and revenue sharing	[34]	Risk and revenue sharing is important for long-term focus and collaboration among supply chain partners
Sustainability	[34],[61],[24],[62]	Resilience plays a key role in sustaining dynamic capabilities and maintaining the link between dynamically integrated capabilities and sustainable competitive advantage. Sustainability is a key enabler for resilience of supply chain
Financial strength	[32],[27],[21]	Financial strength is one of the most important empowering factors of resilience that directly affects the supply and procurement activities
Knowledge management	[9],[34],[27],[25],[20],[22],[44]	Developing knowledge and understanding of supply chain structures (i.e. physical and informational), and the ability to learn from changes as well as educate other entities
Information sharing	[24],[23],[22],[11],[31],[25],[2],[26],[27],[28],[3],[36],[32],[34],[18]	sharing information helps mitigate risk in the supply chain. A key priority for supply chain risk reduction has to be the creation of a supply chain community to enable the exchange of information between members of that community
Redundancy	[18),[3],[27],[23],[21],[11],[24]	The strategic and selective use of spare capacity and inventory that can be used to cope with disruptions, e.g. spare stocks, multiple suppliers and extra facilities
Complexity	[63],[23],[22],[21],[20],[11],[25],[2],[26],[27],[28],[3],[32],[33]	can be measured as a function of the total number of nodes plus the total number of forward, backward, or within-tier flows in the supply chain
Lead time	[2],[26],[27],[28],[3],[32]	Lead time is the time spent from the order to delivery. As the time is longer, the risk of chain vulnerability is increased due to the disruptions
Distance	[26],[2],[11],[23]	Long distances between companies and suppliers increases the risk of disruptions occurrence
Contingency planning	[21],[25],[64],[65]	Anticipating potential events and specifying the measures to deal with supply chain risks and disruptions before they actually occur, e.g. by forecasting and monitoring early warning signals
Demand management	[66]	Mitigating the impact of disruptions by influencing customer choices through, e.g. dynamic pricing, assortment planning and silent product rollovers
Human resource management	[25],[67],[46]	Training the staffs in dealing with dangerous events and creating the multi-task groups
Appropriate supplier selection	[65]	Using selection criteria that can help to minimize disruptions and their impact, such as political stability in suppliers' territories, quality, capabilities (e.g. technological), financial stability, business continuity, reliability, etc.

3. Methodology

The present study, in terms of the purpose, is an applied research and also in terms of data collection is a descriptive-survey method; because it identifies and describes the attributes related to the suppliers' resilience in electronic industries. On the other hand, a field study method was used to distribute questionnaires among experts in order to fix and evaluate these attributes from the two aspects of importance and effect. To select experts and professional, targeted sampling method was also used; because the judgment of the experts is directly involved in the results of the research, and selection of experts is one of the main steps of the present study. In this regard, the decision group consists of 10 members including 5 experts and managers of the Shiraz Electronic Industries Company and 5 academic members who were the experts in the field of supply chain management.

3.1. Fuzzy screening

Yager introduced a fuzzy screening procedure to select, from a large class of alternatives, a small subset to be further investigated [68]. The fuzzy screening system is a two stage process:

In the first stage, individual experts are asked to provide an evaluation of the alternatives. This evaluation consists of a rating for each alternative on each of the criteria, where each of the criteria may have a different level of importance. The values to be used for the evaluation of the ratings and importance are drawn from a linguistic scale which makes it easier for the evaluator to provide a single value rating for each evaluator for each alternative. This rating is again a linguistic value from the same simple linguistic scale.

In the second stage, a methodology is used to aggregate the individual experts' evaluations to obtain an overall linguistic value for each object. This overall evaluation can then be used by the decision maker as an aid in the selection process. The problem in question consists of three components: (i) a collection of alternative solutions from amongst which we desire to select some subset to be investigated further; (ii) a group of experts whose opinions are solicited in screening the alternatives; (iii) is a collection of criteria which are considered relevant in the choice of the alternatives to be further considered. For each alternative each expert is required to provide his opinion in terms of elements from the following scale S.

Table 2. scale S for the evaluation of criteria and their degree of importance

OU	S_7	Outstanding
VH	S_6	Very High
H	S_5	High
M	S_4	Medium
L	S_3	Low
VL	S_2	Very Low
N	S_1	None

3.2. Fuzzy DEMATEL

Step 1: Select a group of experts: In this step, it is consulted to the experts who have enough knowledge and experience about the problem in order to obtain judgements.

Step 2: Determine factors and construct fuzzy scale: In this part, significant factors are ascertained in order to analyze and evaluate properly. Then, linguistic variable is used in accordance with five fuzzy scales. Thereafter, corresponding triangular fuzzy members are determined (Table 3).

Table 3. Corresponding relationship between linguistic terms and fuzzy numbers

Linguistic terms	Triangular fuzzy numbers
No influence (No)	(0,0,0.25)
Very low influence (VL)	(0,0.25,0.5)
Low influence (L)	(0.25,0.5,0.75)
High influence (H)	(0.5,0.75,1)
Very high influence (VH)	(0.75,1,1)

Step 3: Obtain evaluation of the group decision-makers: The pair wise comparison is obtained in terms of linguistics variables.

Step 4: Establish normalized direct-relation fuzzy matrix: In the presence of the initial direct-relation matrix, a normalized direct-relation fuzzy matrix is built up.

$$\tilde{F} = \begin{matrix} \tilde{F}_{11} & \dots & \tilde{F}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{F}_{n1} & \dots & \tilde{F}_{nn} \end{matrix} \qquad (1)$$

Step 5: Calculate total-relation fuzzy matrix: After having established normalized direct-relation fuzzy matrix, a total relation fuzzy matrix is calculated by ensuring of $\lim_{w\to\infty} F^w = 0$.

Step 6: Analyze the structural model: After having calculated matrix $\tilde{T}$, $\tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$ are determined. In the formula, $\tilde{r}_i$ and $\tilde{c}_j$ denote the sum of the rows and columns of matrix $\tilde{T}$. While $\tilde{r}_i + \tilde{c}_j$ shows the importance of factor *i*, $\tilde{r}_i - \tilde{c}_j$ denotes the net effect of factor *i*.

Step 7: Defuzzified $\tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$: In this step, $\tilde{r}_i + \tilde{c}_j$ and $\tilde{r}_i - \tilde{c}_j$ are defuzzified by using COA (center of area) defuzzification technique in order to determine BNP (best non-fuzzy performance) values.

Step 8: Build up cause-effect relation diagram: In the last step, the cause and effect relation diagram is depicted by mapping the dataset of $r_i + c_j$ and $r_i - c_j$. The calculation can be done according to the step 6 [69].

3.3. Fuzzy ANP

In this approach, pair-wise comparison matrices are formed between various attributes of each level with the help of triangular fuzzy numbers [70]. The FANP can easily accommodate the interrelationships existing among the functional activities. The concept of super matrices is employed to obtain the composite weights that overcome the existing interrelationships. The values of parameters such are transformed into triangular fuzzy numbers and are used to calculate fuzzy values. In the pairwise comparison of attributes, DM can use triangular fuzzy numbers to state their preferences (Table 4).

Table 4. The dominance scale for pairwise comparative judgment

Numerical scale	Linguistic scale	Fuzzy scale (TFN)
1	Just equal	(1,1,1)
2	Equal to moderate	(1,1.5,1.5)
3	Moderate dominance	(1,2,2)
4	Moderate to strong	(3,3.5,4)
5	Strong dominance	(3,4,4.5)
6	Strong to very strong	(3,4.5,5)
7	Very strong dominance	(5,5.5,6)
8	Very strong to absolute	(5,6,7)
9	Absolute dominance	(5,7,9)

To evaluate the DM preferences, pairwise comparison matrices are structured by using triangular fuzzy numbers (*l*, *m*, *u*). The m×n triangular fuzzy matrix can be given as follows:

$$\tilde{\boldsymbol{A}} = \begin{pmatrix} (a_{11}^l . a_{11}^m . a_{11}^u) & (a_{12}^l . a_{12}^m . a_{12}^u) & \cdots & (a_{1n}^l . a_{1n}^m . a_{1n}^u) \\ (a_{21}^l . a_{21}^m . a_{21}^u) & (a_{22}^l . a_{22}^m . a_{22}^u) & \dots & (a_{2n}^l . a_{2n}^m . a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ (a_{m1}^l . a_{m1}^m . a_{m1}^u) & (a_{m2}^l . a_{m2}^m . a_{m2}^u) & \cdots & (a_{mn}^l . a_{mn}^m . a_{mn}^u) \end{pmatrix} \quad (2)$$

The element a_{mn} represents the comparison of component m (row element) with component n (column element). If $\tilde{A}$ is a pairwise comparison matrix, it is assumed that it is reciprocal, and the reciprocal value, i.e.,$1/a_{mn}$, is assigned to the element $\tilde{a}_{mn}$.

$$\tilde{\boldsymbol{A}} = \begin{pmatrix} (1.1.1) & (a_{12}^l . a_{12}^m . a_{12}^u) & \cdots & (a_{1n}^l . a_{1n}^m . a_{1n}^u) \\ \left(\frac{1}{a_{12}^l} . \frac{1}{a_{12}^m} . \frac{1}{a_{12}^u}\right) & (1.1.1) & \cdots & (a_{2n}^l . a_{2n}^m . a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ \left(\frac{1}{a_{1n}^l} . \frac{1}{a_{1n}^m} . \frac{1}{a_{1n}^u}\right) & \left(\frac{1}{a_{2n}^l} . \frac{1}{a_{2n}^m} . \frac{1}{a_{2n}^u}\right) & \cdots & (1.1.1) \end{pmatrix} \quad (3)$$

$\tilde{A}$ is also a triangular fuzzy pairwise comparison matrix. There are several methods for getting estimates for fuzzy priorities $\tilde{w}_i$, where $\tilde{w}_i = (w_i^l . w_i^m . w_i^u)$, *i* = 1, 2, . . ., n, from the judgment matrix $\tilde{A}$ which approximate the fuzzy ratios $\tilde{a}_{ij}$ so that $\tilde{a}_{ij} \approx \tilde{w}_i / \tilde{w}_j$. One of these methods, logarithmic least squares method, is reasonable and effective, and it is used in this study. Hence the triangular fuzzy weights for the relative importance of the criteria, the feedback of the criteria and the alternatives according to the individual criteria can be calculated.

$$W = \begin{pmatrix} 0 & 0 \\ W_{21} & W_{22} \end{pmatrix} \quad (4)$$

The logarithmic least squares method for calculating triangular fuzzy weights can be given as follows:

$$w_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^m\right)^{1/n}}, \quad s \in \{l, m, u\} \quad (5)$$

$$\tilde{w}_k = (w_k^l, w_k^m, w_k^u) \quad k = 1,2,3,\dots,n$$

In order to calculate the final weigh of each level's components (w_i^*), the multiplication of eigenvector matrix of internal relations in eigenvector of that level should be multiplied by the final weight the higher level . If there is no any w_{ii} matrix for a level, then, it is necessary to replace it with a same degree unit matrix.

$$W_i^* = W_{ii} \times W_{i(i-1)} \times W_{i-1}^*$$
$$W_i^* = I \times W_{i(i-1)} \times W_{i-1}^* \quad (6)$$

3.4. Fuzzy goal programming

Fuzzy goal programming is an extension of conventional goal programming to solve decision problems with multiplicity of objectives in an imprecise environment. In this approach, instead of measuring achievement of fuzzy objective values directly, achievement of membership values of objectives to the possible extent to the highest degree (unity) by minimizing under-deviations is taken into account in a solution search process. In this paper, the Zimmerman FGP model is used. Modeling of this method is as follows [71]:

$$\max z = \sum_{j=1}^{Q} wj\lambda j$$

St:

$$\begin{array}{lll} \lambda_j \le \mu_{zj}(x) & j = 1.2.\dots.q & (\text{objective functions}) \\ \gamma_r \le \mu_{gr}(x) & r = 1.2.\dots.h & (\text{fuzzy constraints}) \\ g_p(x) \le b_p & p = h+1.\dots.m & (\text{unfuzzy constraints}) \end{array} \quad (7)$$

Membership function for maximization goals:

$$\mu_{zj}(X) = \begin{cases} 1 & zj \ge zj^+ \\ \dfrac{zj(x) - zj^-}{zj^+ - zj^-} & zj^- \le zj(x) \le zj^+ \\ 0 & zj \le zj^- \end{cases} \quad (8)$$

Membership function for minimization goals:

$$\mu_{zj}(X) = \begin{cases} 1 & zj \le zj^- \\ \dfrac{zj^+ - zj(x)}{zj^+ - zj^-} & zj^- \le zj(x) \le zj^+ \\ 0 & zj \ge zj^+ \end{cases} \quad (9)$$

Membership function for fuzzy constraints:

$$\mu_{gr}(X) = \begin{cases} 1 & g_r(x) \le b_r \\ 1 - (g_r(x) - br)/dr & br \le g_r(x) \le b_r + d_r \\ 0 & g_r(x) \ge b_r + d_r \end{cases} \quad (10)$$

4. Data analysis

4.1 selecting the supplier resilience attributes using the fuzzy screening

In order to select the evaluation attributes of suppliers' resilience, 27 attributes obtained from the review of theoretical foundations (Table 1), were entered into the fuzzy screening questionnaire, and experts were asked answer the questions in accordance with the description of this method. Based on the default determined by the experts, if the total score of a criterion is OU, it is selected. Finally, after analyzing the data, of fuzzy screening questionnaire, 15 attributes were confirmed and selected (Table 5).

- A1 : Agility
- A2 : Redundancy
- A3 : Visibility
- A4 : Information sharing
- A5 : Trust
- A6 : Collaboration
- A7 : Flexibility
- A8: Financial strength
- A9 : Lead time
- A10 : Adaptive capability
- A11: Risk management culture
- A12 : Demand management
- A13 : Sustainability
- A14 : Human resource management
- A15 : Vulnerability

Table 5. Results of fuzzy screening

Result	u_i	OU	VH	H	H	M	M	L	VL	VL	N	Attribute
×	H	H	H	H	H	H	H	H	M	M	L	Contingency planning
		H	H	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	VH	VH	H	H	H	H	M	M	Complexity
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	H	H	H	H	M	Vulnerability
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	H	H	H	H	H	M	M	M	M	M	L	Knowledge management
		H	H	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	OU	OU	OU	OU	VH	VH	VH	H	Agility
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	H	H	H	H	H	M	M	M	M	M	M	Risk awareness
		H	H	H	H	M	M	L	VL	VL	N	MIN
×	H	H	H	H	H	H	H	M	M	M	L	Distance
		H	H	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	VH	VH	VH	VH	VH	H	H	H	H	Information sharing
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	H	H	H	H	M	M	M	M	Velocity
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	H	H	H	H	H	Redundancy
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	VH	VH	VH	H	H	H	H	H	M	Sustainability
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	H	H	H	H	M	Trust
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	OU	VH	VH	VH	H	H	H	M	Financial strength
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	VH	VH	H	H	H	M	M	M	Supply chain structure
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
×	H	H	H	H	H	H	M	M	M	L	L	Safety
		H	H	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	VH	VH	VH	VH	M	M	M	M	M	Visibility
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	VH	VH	VH	H	H	Demand management
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	VH	VH	VH	H	H	H	H	H	Appropriate supplier selection
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	OU	VH	VH	H	H	H	H	M	Lead time
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	VH	VH	VH	H	H	Human resource management
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	H	H	H	H	H	M	M	M	Research and development
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	VH	VH	VH	VH	H	H	H	M	Collaboration
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	H	H	H	H	H	M	M	M	Technological capability
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	VH	VH	VH	H	H	H	H	H	H	Adaptive capability
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
×	VH	VH	VH	VH	VH	VH	H	H	H	H	M	Risk and revenue sharing
		VH	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	VH	VH	VH	VH	H	H	H	H	H	Risk management culture
		OU	VH	H	H	M	M	L	VL	VL	N	MIN
✓	OU	OU	OU	OU	OU	VH	VH	VH	VH	H	H	Flexibility
		OU	VH	H	H	M	M	L	VL	VL	N	MIN

4.2. Determining the most influential attributes using the Fuzzy DEMATEL:

Fuzzy direct-relation matrix: at this step, the direct effect of attributes on each other is determined using the dematel questionnaire, and a fuzzy direct-relation matrix is formed from the average of expert's opinions based on Table 6.

Fuzzy total-relation matrix: After normalizing the fuzzy direct-relation matrix, the Fuzzy total-relation matrix can be obtained (see Table 7).

Table 6. Fuzzy direct-relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}
A_1	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)	(0.000,0.000,0.250)	(0.675,0.925,1.000)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_2	(0.425,0.675,0.925)	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_3	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.000,0.000,0.000)	(0.175,0.425,0.675)	(0.175,0.425,0.675)	(0.175,0.425,0.675)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.675,0.925,1.000)	(0.425,0.675,0.925)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_4	(0.675,0.925,1.000)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.000,0.000,0.000)	(0.175,0.425,0.675)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_5	(0.425,0.675,0.925)	(0.175,0.425,0.675)	(0.425,0.675,0.925)	(0.675,0.925,1.000)	(0.000,0.000,0.000)	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_6	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.425,0.675,0.925)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.000,0.000,0.000)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_7	(0.675,0.925,1.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.675,0.925,1.000)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_8	(0.175,0.425,0.675)	(0.675,0.925,1.000)	(0.175,0.425,0.675)	(0.000,0.175,0.425)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.175,0.425,0.675)	(0.175,0.425,0.675)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.000,0.175,0.425)	(0.175,0.425,0.675)
A_9	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)
A_{10}	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.425,0.675,0.925)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_{11}	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.175,0.425)	(0.000,0.175,0.425)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.425,0.675,0.925)	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)
A_{12}	(0.175,0.425,0.675)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.675,0.925,1.000)	(0.000,0.175,0.425)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)
A_{13}	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.000,0.000,0.250)	(0.425,0.675,0.925)
A_{14}	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.675,0.925,1.000)	(0.675,0.925,1.000)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.675,0.925,1.000)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)	(0.425,0.675,0.925)
A_{15}	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.175,0.425)	(0.000,0.175,0.425)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.425,0.675,0.925)	(0.425,0.675,0.925)	(0.000,0.000,0.250)	(0.175,0.425,0.675)	(0.000,0.000,0.250)	(0.000,0.000,0.250)	(0.000,0.000,0.000)

Table 7. Fuzzy total-relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}
A_1	(0.006 ,0.017, 0.133)	(0.000 ,0.002, 0.103)	(0.001 ,0.003, 0.110)	(0.003 ,0.009, 0.123)	(0.005 ,0.017, 0.147)	(0.005 ,0.017, 0.146)	(0.069 ,0.104, 0.217)	(0.000 ,0.000, 0.076)	(0.072 ,0.110, 0.238)	(0.050 ,0.092, 0.255)	(0.006 ,0.017, 0.158)	(0.005 ,0.018, 0.145)	(0.000 ,0.000, 0.083)	(0.000 ,0.000, 0.077)	(0.076 ,0.120, 0.279)
A_2	(0.044 ,0.083, 0.241)	(0.001 ,0.007, 0.099)	(0.001 ,0.006, 0.129)	(0.005 ,0.016, 0.144)	(0.021 ,0.060, 0.207)	(0.006 ,0.023, 0.170)	(0.008 ,0.025, 0.176)	(0.000 ,0.000, 0.087)	(0.028 ,0.075, 0.242)	(0.075 ,0.126, 0.297)	(0.070 ,0.110, 0.251)	(0.045 ,0.085, 0.228)	(0.000 ,0.000, 0.096)	(0.000 ,0.000, 0.089)	(0.082 ,0.138, 0.319)
A_3	(0.074 ,0.127, 0.305)	(0.018 ,0.051, 0.192)	(0.003 ,0.014, 0.143)	(0.022 ,0.062, 0.221)	(0.024 ,0.075, 0.258)	(0.024 ,0.075, 0.256)	(0.051 ,0.102, 0.285)	(0.000 ,0.000, 0.109)	(0.058 ,0.120, 0.324)	(0.060 ,0.131, 0.361)	(0.074 ,0.128, 0.306)	(0.048 ,0.099, 0.277)	(0.017 ,0.041, 0.158)	(0.000 ,0.000, 0.110)	(0.091 ,0.171, 0.398)
A_4	(0.077 ,0.131, 0.302)	(0.003 ,0.015, 0.154)	(0.043 ,0.077, 0.223)	(0.009 ,0.028, 0.160)	(0.025 ,0.075, 0.252)	(0.048 ,0.097, 0.272)	(0.053 ,0.105, 0.283)	(0.000 ,0.000, 0.107)	(0.038 ,0.101, 0.300)	(0.085 ,0.154, 0.362)	(0.077 ,0.129, 0.302)	(0.072 ,0.122, 0.279)	(0.001 ,0.003, 0.120)	(0.000 ,0.000, 0.108)	(0.095 ,0.173, 0.391)
A_5	(0.058 ,0.116, 0.305)	(0.019 ,0.054, 0.195)	(0.047 ,0.082, 0.230)	(0.074 ,0.116, 0.254)	(0.012 ,0.043, 0.201)	(0.073 ,0.124, 0.286)	(0.031 ,0.087, 0.269)	(0.000 ,0.000, 0.109)	(0.034 ,0.101, 0.306)	(0.089 ,0.164, 0.373)	(0.083 ,0.141, 0.313)	(0.030 ,0.086, 0.261)	(0.001 ,0.003, 0.123)	(0.000 ,0.000, 0.111)	(0.097 ,0.181, 0.401)
A_6	(0.080 ,0.138, 0.312)	(0.019 ,0.054, 0.195)	(0.047 ,0.082, 0.231)	(0.074 ,0.116, 0.255)	(0.072 ,0.124, 0.289)	(0.013 ,0.044, 0.201)	(0.033 ,0.089, 0.271)	(0.000 ,0.000, 0.110)	(0.036 ,0.104, 0.308)	(0.090 ,0.166, 0.374)	(0.083 ,0.141, 0.314)	(0.030 ,0.086, 0.262)	(0.001 ,0.003, 0.123)	(0.000 ,0.000, 0.112)	(0.099 ,0.183, 0.403)
A_7	(0.066 ,0.098, 0.220)	(0.000 ,0.002, 0.103)	(0.001 ,0.003, 0.110)	(0.003 ,0.009, 0.123)	(0.005 ,0.017, 0.147)	(0.005 ,0.017, 0.146)	(0.009 ,0.024, 0.130)	(0.000 ,0.000, 0.076)	(0.072 ,0.110, 0.238)	(0.050 ,0.092, 0.255)	(0.006 ,0.017, 0.158)	(0.005 ,0.018, 0.145)	(0.000 ,0.000, 0.083)	(0.000 ,0.000, 0.077)	(0.076 ,0.120, 0.279)
A_8	(0.021 ,0.063, 0.220)	(0.064 ,0.092, 0.186)	(0.017 ,0.046, 0.166)	(0.002 ,0.029, 0.157)	(0.004 ,0.024, 0.172)	(0.003 ,0.022, 0.169)	(0.004 ,0.023, 0.174)	(0.000 ,0.000, 0.063)	(0.022 ,0.069, 0.237)	(0.026 ,0.079, 0.266)	(0.024 ,0.069, 0.225)	(0.005 ,0.024, 0.169)	(0.017 ,0.042, 0.134)	(0.000 ,0.017, 0.103)	(0.029 ,0.089, 0.288)
A_9	(0.010 ,0.032, 0.199)	(0.002 ,0.011, 0.131)	(0.004 ,0.012, 0.141)	(0.008 ,0.022, 0.157)	(0.046 ,0.086, 0.240)	(0.046 ,0.086, 0.238)	(0.045 ,0.085, 0.242)	(0.000 ,0.000, 0.091)	(0.011 ,0.038, 0.194)	(0.054 ,0.107, 0.305)	(0.050 ,0.092, 0.257)	(0.045 ,0.086, 0.237)	(0.000 ,0.000, 0.100)	(0.000 ,0.000, 0.093)	(0.059 ,0.118, 0.329)
A_{10}	(0.028 ,0.076, 0.244)	(0.002 ,0.010, 0.134)	(0.006 ,0.016, 0.148)	(0.047 ,0.083, 0.219)	(0.045 ,0.086, 0.244)	(0.046 ,0.088, 0.244)	(0.047 ,0.090, 0.251)	(0.000 ,0.000, 0.094)	(0.013 ,0.045, 0.227)	(0.018 ,0.055, 0.234)	(0.051 ,0.095, 0.263)	(0.024 ,0.067, 0.222)	(0.000 ,0.001, 0.103)	(0.000 ,0.000, 0.095)	(0.084 ,0.147, 0.345)
A_{11}	(0.001 ,0.011, 0.145)	(0.000 ,0.003, 0.098)	(0.000 ,0.005, 0.106)	(0.002 ,0.011, 0.118)	(0.003 ,0.031, 0.154)	(0.003 ,0.031, 0.153)	(0.003 ,0.013, 0.140)	(0.000 ,0.000, 0.072)	(0.020 ,0.055, 0.196)	(0.045 ,0.084, 0.241)	(0.003 ,0.016, 0.127)	(0.003 ,0.015, 0.137)	(0.000 ,0.000, 0.079)	(0.000 ,0.000, 0.073)	(0.069 ,0.110, 0.263)
A_{12}	(0.018 ,0.049, 0.183)	(0.017 ,0.042, 0.136)	(0.000 ,0.002, 0.105)	(0.001 ,0.005, 0.114)	(0.004 ,0.014, 0.139)	(0.003 ,0.013, 0.136)	(0.004 ,0.015, 0.141)	(0.000 ,0.000, 0.072)	(0.068 ,0.104, 0.229)	(0.007 ,0.041, 0.201)	(0.005 ,0.016, 0.150)	(0.004 ,0.016, 0.115)	(0.000 ,0.000, 0.079)	(0.000 ,0.000, 0.074)	(0.047 ,0.089, 0.259)
A_{13}	(0.006 ,0.017, 0.150)	(0.002 ,0.007, 0.102)	(0.004 ,0.011, 0.112)	(0.006 ,0.015, 0.121)	(0.044 ,0.077, 0.197)	(0.044 ,0.077, 0.196)	(0.003 ,0.012, 0.139)	(0.000 ,0.000, 0.072)	(0.005 ,0.018, 0.162)	(0.009 ,0.026, 0.185)	(0.007 ,0.019, 0.151)	(0.003 ,0.014, 0.136)	(0.000 ,0.000, 0.056)	(0.000 ,0.000, 0.073)	(0.048 ,0.089, 0.257)
A_{14}	(0.062 ,0.121, 0.314)	(0.003 ,0.015, 0.162)	(0.071 ,0.109, 0.246)	(0.074 ,0.120, 0.264)	(0.051 ,0.105, 0.292)	(0.053 ,0.107, 0.291)	(0.080 ,0.138, 0.309)	(0.000 ,0.000, 0.113)	(0.060 ,0.127, 0.337)	(0.068 ,0.145, 0.379)	(0.061 ,0.121, 0.317)	(0.014 ,0.047, 0.231)	(0.001 ,0.004, 0.127)	(0.000 ,0.000, 0.091)	(0.077 ,0.161, 0.407)
A_{15}	(0.002 ,0.013, 0.147)	(0.000 ,0.005, 0.100)	(0.000 ,0.005, 0.106)	(0.002 ,0.011, 0.118)	(0.004 ,0.031, 0.154)	(0.004 ,0.031, 0.153)	(0.004 ,0.015, 0.141)	(0.000 ,0.000, 0.072)	(0.042 ,0.077, 0.217)	(0.043 ,0.081, 0.239)	(0.004 ,0.017, 0.151)	(0.019 ,0.053, 0.174)	(0.000 ,0.000, 0.079)	(0.000 ,0.000, 0.073)	(0.007 ,0.027, 0.176)

Influential network relations map (INRM): In this step, the sum of fuzzy rows and the sum of fuzzy columns are used to derive vector $\tilde{\boldsymbol{s}}$ and vector $\tilde{\boldsymbol{r}}$ respectively. Then the horizontal axis vector ($\tilde{\boldsymbol{s}} + \tilde{\boldsymbol{r}}$), called Prominence, is formed by adding $\tilde{\boldsymbol{s}}$ to $\tilde{\boldsymbol{r}}$, which indicates the level of importance of the criterion. Similarly, the vertical axis vector ($\tilde{\boldsymbol{s}} - \tilde{\boldsymbol{r}}$), called Relation, is formed by subtracting ***s*** from ***r***, which may divide criteria into a cause group and effect group. When ($\tilde{\boldsymbol{s}} - \tilde{\boldsymbol{r}}$) is positive, the criterion belong to the cause group; otherwise, it belong to the effect group. Therefore, the INRM can be derived by mapping the dataset of ($\tilde{\boldsymbol{s}} + \tilde{\boldsymbol{r}}$, $\tilde{\boldsymbol{s}} - \tilde{\boldsymbol{r}}$), which provides valuable insights for making decisions.

Table 8. Sum of influences given and received on criteria

Fuzzy				Crisp		
	$\tilde{s}_i + \tilde{r}_i$	$\tilde{s}_i - r_i$			$(\tilde{s}_i + \tilde{r}_i)^{def}$	$(\tilde{s}_i - \tilde{r}_i)^{def}$
A1	(0.854,1.619,5.713)	(−3.120,−0.564,1.738)		A1	2.451	−0.628
A2	(0.538,1.124,4.866)	(−1.705,0.384,2.623)		A2	1.913	0.422
A3	(0.809,1.666,6.011)	(−1.741,0.722,3.461)		A3	2.538	0.791
A4	(0.957,1.862,6.165)	(−1.923,0.558,3.285)		A4	2.712	0.619
A5	(1.015,2.165,6.831)	(−2.445,0.431,3.371)		A5	3.044	0.447
A6	(1.055,2.184,6.816)	(−2.379,0.478,3.381)		A6	3.06	0.49
A7	(0.747,1.454,5.461)	(−2.868,−0.400,1.846)		A7	2.279	−0.455
A8	(0.239,0.690,4.054)	(−1.083,0.690,2.732)	⟹	A8	1.418	0.757
A9	(0.961,2.031,6.712)	(−3.375,−0.477,2.376)		A9	2.934	−0.488
A10	(1.182,2.401,7.394)	(−3.916,−0.682,2.297)		A10	3.345	−0.746
A11	(0.756,1.516,5.542)	(−3.291,−0.744,1.495)		A11	2.333	−0.821
A12	(0.531,1.244,5.153)	(−2.842,−0.433,1.780)		A12	2.043	−0.482
A13	(0.216,0.482,3.651)	(−1.364,0.283,2.070)		A13	1.208	0.318
A14	(0.677,1.336,5.240)	(−0.683,1.303,3.880)		A14	2.147	1.451
A15	(1.168,2.280,6.891)	(−4.660,−1.550,1.063)		A15	3.155	−1.674

In order to explain the structural relationship among the factors while keeping the complexity of the system to a manageable level, it is necessary to set a threshold value *p* to filter out the negligible effects in matrix $\tilde{T}$. Only those factors that have an effect in matrix $\tilde{T}$ greater than the threshold value should be chosen and shown in an impact-relations map (see Figure 1). Given the INRM, it can be expressed that attributes including, human resource management, visibility, and financial strength are the most influential factors.

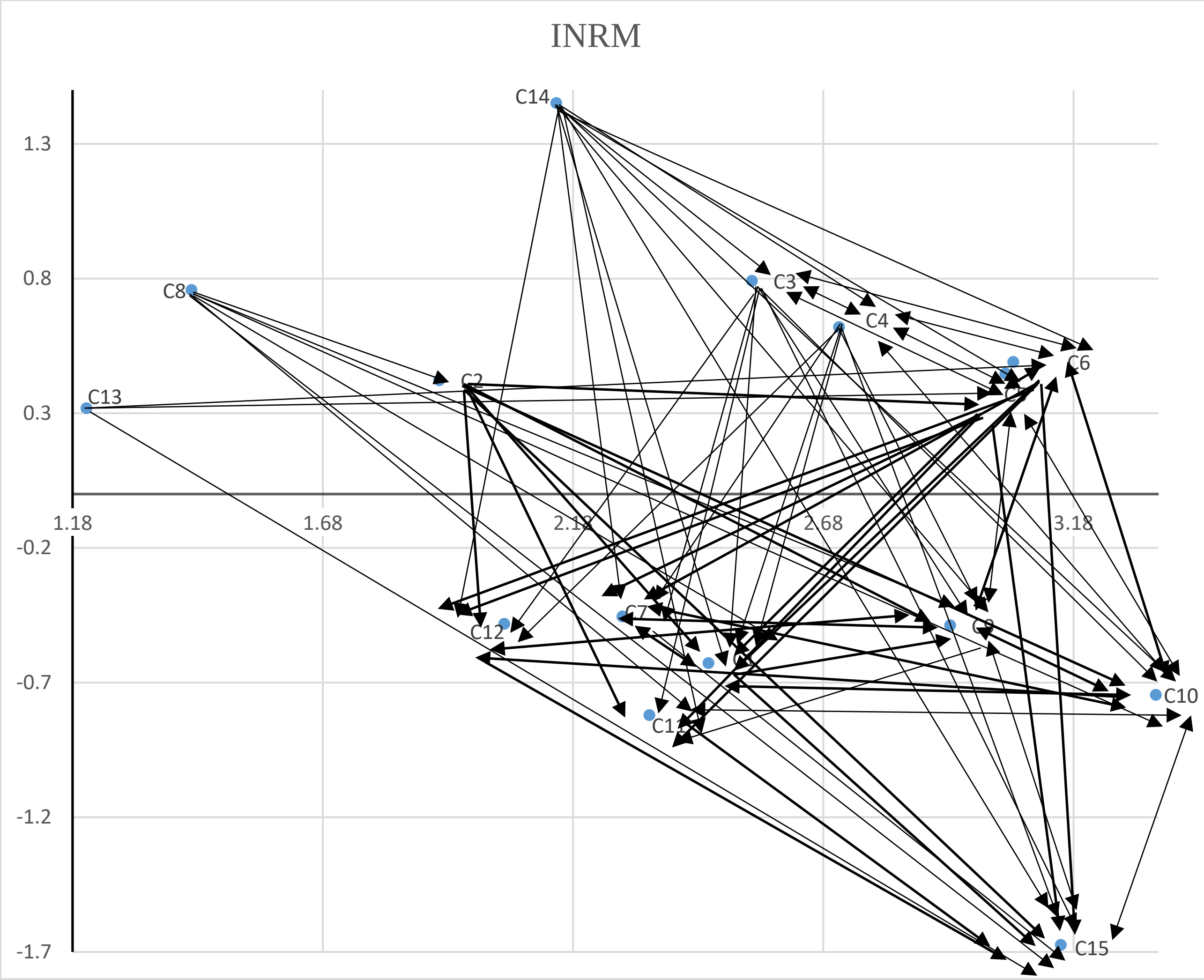

Figure 1. Influential network relations map (INRM)

4.3. Identifying the most important attributes by F-ANP

Pairwise comparison matrix: In this step, the dependency between attributes is defined based on the network relationships map obtained from the DEMATEL, and accordingly, questionnaires of pair-wise comparisons were designed and distributed among experts. In order to integrate the experts' opinions, geometric mean is taken from the pairwise comparisons of respondents. In the end column of the matrix, the eigenvector of fuzzy weights is achieved using the logarithmic leas squares method. Table 9 shows the pairwise comparisons of attributes with regard to the goal. The other pairwise comparisons with regard to each criterion is calculated in the same way. The consistency of all the comparisons was checked using the Gogus and Boucher method.

Eigenvector matrix: These matrices consist of eigenvectors obtained from the previous step (see Table 10-11).

Table 9. Pairwise comparisons of attributes with respect to goal

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	*W*
A 1	(1,1,1)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(1.000 ,1.732, 1.732)	(1.732, 2.646, 2.828)	(1.000 ,1.732, 1.732)	(1.000 ,1.732, 1.732)	(3.000 ,4.243, 4.743)	(3.873, 4.975, 5.477)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(3.873, 4.975, 5.477)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(0.09,0 .129,0. 134)
A 2	(0.816, 0.816, 1.000)	(1,1,1)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(3.000 ,3.742, 4.243)	(3.000 ,4.243, 4.743)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(1.732, 2.646, 2.828)	(3.000 ,4.243, 4.743)	(1.732, 2.646, 2.828)	(1.000 ,1.225, 1.225)	(0.076, 0.096, 0.102)
A 3	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(1,1,1)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.064, 0.079, 0.088)
A 4	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1,1,1)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.000 ,1.225, 1.225)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.063, 0.077, 0.087)
A 5	(0.354, 0.378, 0.577)	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1,1,1)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.732, 1.732)	(1.732, 2.646, 2.828)	(0.354, 0.378, 0.577)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(1.732, 2.646, 2.828)	(1.000 ,1.225, 1.225)	(0.816, 0.816, 1.000)	(0.048, 0.055, 0.066)
A 6	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1,1.22 5,1.22 5)	(1,1,1)	(1.000 ,1.225, 1.225)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.062, 0.075, 0.086)
A 7	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(0.816, 0.816, 1.000)	(1,1,1)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.061, 0.073, 0.085)
A 8	(0.211, 0.236, 0.333)	(0.236, 0.267, 0.333)	(0.354, 0.378, 0.577)	(0.354, 0.378, 0.577)	(0.577, 0.577, 1.000)	(0.354, 0.378, 0.577)	(0.354, 0.378, 0.577)	(1,1,1)	(1.000 ,1.225, 1.225)	(0.211, 0.236, 0.333)	(0.354, 0.378, 0.577)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(0.816, 0.816, 1.000)	(0.354, 0.378, 0.577)	(0.027, 0.029, 0.038)
A 9	(0.183, 0.201, 0.258)	(0.211, 0.236, 0.333)	(0.236, 0.267, 0.333)	(0.236, 0.267, 0.333)	(0.354, 0.378, 0.577)	(0.236, 0.267, 0.333)	(0.236, 0.267, 0.333)	(0.816, 0.816, 1.000)	(1,1,1)	(0.183, 0.201, 0.258)	(0.236, 0.267, 0.333)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(0.577, 0.577, 1.000)	(0.236, 0.267, 0.333)	(0.02, 0.022, 0.028)
A 1 0	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(1.000 ,1.732, 1.732)	(1.732, 2.646, 2.828)	(1.000 ,1.732, 1.732)	(1.000 ,1.732, 1.732)	(3.000 ,4.243, 4.743)	(3.873, 4.975, 5.477)	(1,1,1)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(3.873, 4.975, 5.477)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(0.089, 0.126, 0.133)
A 1 1	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(1,1,1)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.061, 0.071, 0.083)
A 1 2	(0.236, 0.267, 0.333)	(0.354, 0.378, 0.577)	(0.577, 0.577, 1.000)	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.577, 0.577, 1.000)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(0.236, 0.267, 0.333)	(0.577, 0.577, 1.000)	(1,1,1)	(1.000 ,1.732, 1.732)	(1.000 ,1.225, 1.225)	(0.577, 0.577, 1.000)	(0.035, 0.04, 0.053)
A 1 3	(0.183, 0.201, 0.258)	(0.211, 0.236, 0.333)	(0.236, 0.267, 0.333)	(0.236, 0.267, 0.333)	(0.354, 0.378, 0.577)	(0.236, 0.267, 0.333)	(0.236, 0.267, 0.333)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(0.183, 0.201, 0.258)	(0.236, 0.267, 0.333)	(0.577, 0.577, 1.000)	(1,1,1)	(0.577, 0.577, 1.000)	(0.236, 0.267, 0.333)	(0.02, 0.021, 0.028)
A 1 4	(0.236, 0.267, 0.333)	(0.354, 0.378, 0.577)	(0.577, 0.577, 1.000)	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.577, 0.577, 1.000)	(0.577, 0.577, 1.000)	(1.000 ,1.225, 1.225)	(1.000 ,1.732, 1.732)	(0.236, 0.267, 0.333)	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.732, 1.732)	(1,1,1)	(0.577, 0.577, 1.000)	(0.035, 0.039, 0.053)
A 1 5	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.225, 1.225)	(0.816, 0.816, 1.000)	(0.816, 0.816, 1.000)	(1.732, 2.646, 2.828)	(3.000 ,3.742, 4.243)	(0.577, 0.577, 1.000)	(0.816, 0.816, 1.000)	(1.000 ,1.732, 1.732)	(3.000 ,3.742, 4.243)	(1.000 ,1.732, 1.732)	(1,1,1)	(0.06, 0.069, 0.082)
CR^g =0.029 ⟹ Consistent ⟸ CR^m =0.004																

Table 10. Eigenvector matrix of attributes with respect to goal

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
(0.09, 0.129, 0.134)	(0.076, 0.096, 0.102)	(0.064, 0.079, 0.088)	(0.063, 0.077, 0.087)	(0.048, 0.055, 0.066)	(0.062, 0.075, 0.086)	(0.061, 0.073, 0.085)	(0.027, 0.029, 0.038)	(0.02, 0.022, 0.028)	(0.089, 0.126, 0.133)	(0.061, 0.071, 0.083)	(0.035 ,0.04,0 .053)	(0.02, 0.021, 0.028)	(0.035, 0.039, 0.053)	(0.06, 0.069, 0.082)

Table 11. Eigenvector matrix of attributes with respect to each criterion

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
A1	(0.5,0.5,0.5)	(0.092,0.119,0.127)	(0.066,0.096,0.101)	(0.056,0.074,0.077)	(0.04,0.055,0.057)	(0.078,0.102,0.11)	(0.046,0.052,0.059)	(0.074,0.094,0.104)	(0.051,0.071,0.076)	(0.061,0.084,0.089)	(0,0,0)	(0,0,0)	(0,0,0)	(0.074,0.096,0.102)	(0.053,0.07,0.075)
A2	(0.053,0.068,0.072)	(0.5,0.5,0.5)	(0,0,0)	(0,0,0)	(0.056,0.073,0.077)	(0,0,0)	(0,0,0)	(0.107,0.155,0.162)	(0.032,0.038,0.045)	(0.037,0.046,0.052)	(0.055,0.069,0.072)	(0.071,0.091,0.094)	(0,0,0)	(0,0,0)	(0.044,0.055,0.06)
A3	(0.043,0.052,0.056)	(0,0,0)	(0.5,0.5,0.5)	(0.055,0.071,0.075)	(0.032,0.039,0.044)	(0.059,0.079,0.085)	(0.07,0.095,0.098)	(0,0,0)	(0.044,0.055,0.058)	(0.049,0.063,0.067)	(0.053,0.064,0.069)	(0.069,0.087,0.092)	(0,0,0)	(0.055,0.073,0.077)	(0.043,0.054,0.059)
A4	(0.045,0.056,0.059)	(0,0,0)	(0.044,0.058,0.062)	(0.5,0.5,0.5)	(0.041,0.056,0.058)	(0.047,0.062,0.069)	(0.054,0.073,0.075)	(0,0,0)	(0.034,0.043,0.048)	(0.039,0.05,0.055)	(0.056,0.072,0.074)	(0.024,0.026,0.033)	(0,0,0)	(0.04,0.053,0.059)	(0.032,0.042,0.047)
A5	(0.035,0.039,0.047)	(0.067,0.087,0.095)	(0.044,0.056,0.06)	(0.046,0.058,0.062)	(0.5,0.5,0.5)	(0.025,0.032,0.038)	(0.038,0.041,0.052)	(0,0,0)	(0.02,0.022,0.029)	(0.038,0.049,0.054)	(0.054,0.066,0.071)	(0.055,0.068,0.075)	(0.134,0.143,0.172)	(0.026,0.03,0.037)	(0.019,0.022,0.027)
A6	(0.042,0.05,0.055)	(0,0,0)	(0.043,0.054,0.059)	(0.045,0.056,0.061)	(0.04,0.053,0.057)	(0.5,0.5,0.5)	(0.037,0.039,0.051)	(0,0,0)	(0.02,0.022,0.029)	(0.031,0.036,0.042)	(0.045,0.051,0.058)	(0.032,0.037,0.048)	(0.125,0.125,0.161)	(0.026,0.029,0.036)	(0.032,0.04,0.046)
A7	(0.044,0.054,0.058)	(0,0,0)	(0.037,0.041,0.048)	(0.044,0.054,0.06)	(0.027,0.029,0.036)	(0.017,0.018,0.024)	(0.5,0.5,0.5)	(0,0,0)	(0.033,0.041,0.047)	(0.024,0.027,0.035)	(0,0,0)	(0,0,0)	(0,0,0)	(0.025,0.028,0.035)	(0.031,0.039,0.046)
A8	(0.019,0.02,0.028)	(0.03,0.032,0.039)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0.5,0.5,0.5)	(0.015,0.016,0.021)	(0.017,0.019,0.025)	(0.025,0.028,0.039)	(0,0,0)	(0,0,0)	(0,0,0)	(0.015,0.016,0.02)
A9	(0.02,0.021,0.029)	(0.031,0.034,0.04)	(0.012,0.013,0.017)	(0.015,0.016,0.022)	(0.021,0.023,0.029)	(0.017,0.019,0.025)	(0.027,0.029,0.038)	(0.033,0.035,0.047)	(0.5,0.5,0.5)	(0.01,0.011,0.015)	(0.014,0.015,0.021)	(0.019,0.02,0.027)	(0,0,0)	(0.015,0.016,0.023)	(0.012,0.012,0.017)
A10	(0.035,0.041,0.048)	(0.038,0.045,0.054)	(0.042,0.052,0.058)	(0.025,0.029,0.039)	(0.027,0.03,0.037)	(0.026,0.033,0.038)	(0.053,0.069,0.073)	(0.072,0.088,0.1)	(0.033,0.042,0.048)	(0.5,0.5,0.5)	(0.047,0.055,0.061)	(0.056,0.072,0.076)	(0,0,0)	(0.039,0.052,0.058)	(0.054,0.072,0.076)
A11	(0,0,0)	(0.025,0.026,0.035)	(0.02,0.022,0.03)	(0.015,0.016,0.022)	(0.021,0.022,0.028)	(0.017,0.018,0.024)	(0,0,0)	(0.044,0.047,0.064)	(0.015,0.016,0.022)	(0.013,0.014,0.019)	(0.5,0.5,0.5)	(0,0,0)	(0,0,0)	(0.025,0.027,0.035)	(0.019,0.021,0.027)
A12	(0,0,0)	(0.037,0.043,0.052)	(0.028,0.031,0.041)	(0.026,0.03,0.039)	(0.02,0.021,0.028)	(0.025,0.031,0.037)	(0,0,0)	(0,0,0)	(0.032,0.039,0.046)	(0.023,0.026,0.034)	(0,0,0)	(0.5,0.5,0.5)	(0,0,0)	(0.024,0.026,0.034)	(0.018,0.021,0.026)
A13	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0.02,0.021,0.027)	(0.016,0.017,0.024)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0.5,0.5,0.5)	(0,0,0)	(0.015,0.016,0.02)
A14	(0.027,0.029,0.039)	(0,0,0)	(0.028,0.03,0.041)	(0.025,0.028,0.038)	(0.026,0.028,0.036)	(0.024,0.03,0.036)	(0.036,0.037,0.05)	(0,0,0)	(0.02,0.021,0.028)	(0.023,0.026,0.034)	(0.025,0.027,0.038)	(0.032,0.035,0.047)	(0,0,0)	(0.5,0.5,0.5)	(0.018,0.02,0.026)
A15	(0.054,0.071,0.073)	(0.09,0.113,0.124)	(0.041,0.05,0.057)	(0.054,0.069,0.074)	(0.039,0.051,0.056)	(0.046,0.06,0.067)	(0.052,0.066,0.072)	(0.07,0.082,0.097)	(0.052,0.074,0.077)	(0.037,0.047,0.053)	(0.046,0.053,0.06)	(0.054,0.065,0.073)	(0.161,0.232,0.232)	(0.054,0.07,0.076)	(0.5,0.5,0.5)

Final weights: Table 12 shows the final weights of the attributes with respect to goal that accordingly, agility, Adaptive capability, and vulnerability are the most important attributes.

Table 12. final weights of the attributes with respect to goal

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Fuzzy weights	(0.083, 0.127, 0.143)	(0.061, 0.084, 0.096)	(0.064, 0.09, 0.107)	(0.058, 0.082, 0.096)	(0.056, 0.075, 0.094)	(0.057, 0.075, 0.093)	(0.048, 0.062, 0.075)	(0.022, 0.026, 0.036)	(0.024, 0.03, 0.042)	(0.073, 0.105, 0.122)	(0.041, 0.049, 0.063)	(0.031, 0.039 ,0.054)	(0.013, 0.014, 0.019)	(0.034, 0.043, 0.061)	(0.072 ,0.10, 0.123)
Crisp weights	0.122	0.082	0.089	0.08	0.075	0.075	0.062	0.027	0.031	0.103	0.05	0.04	0.015	0.044	0.099

4.4. Resilient supplier selection by FGP

In this section, a real case study is addressed at Shiraz Electronics industries. Shiraz electronic industries Company is considered as one of the professional companies of Iran electronic industries in the fields of research, design and manufacturing in different areas of electronic technology including Radar, electronic warfare, electronics weapons and etc. In this study, 20 suppliers are considered for a piece applied in one of the strategic products of the company, which name of piece, product, and supplier is not mentioned for security reasons.

Decision Matrix: the required information about the suppliers have been obtained by distributing the questionnaire among 5 managers and experts of relevant department in this company (each supplier is assigned score 1-10 based on the obtained resilience attributes from the previous steps) and finally, mean of the opinions is calculated and the decision matrix is formed in accordance with Table 13.

Table 13. Decision Matrix

Attributes	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Weight	0.122	0.082	0.089	0.08	0.075	0.075	0.062	0.027	0.031	0.103	0.05	0.04	0.015	0.044	0.099
Min/Max	max	max	max	max	max	max	max	max	min	max	max	max	max	max	min
S1	5.4	7.4	5.8	6.4	7.6	6.6	5.4	6.8	4.8	6.6	7.4	5.8	6.2	7.4	5.2
S2	3.6	5.2	4.4	5.2	6.2	4.8	3.6	5.4	6.2	5.2	4.8	5.2	4.2	5.4	6.4
S3	7.8	8.2	7.2	7.6	8.2	8.4	7.2	7.4	2.8	7.6	8.2	7.4	7.4	8.2	2.6
S4	2.2	3.4	1.8	2.4	2.2	1.6	1.4	1.8	9.2	2.2	2.2	2.2	1.8	2.2	9.6
S5	9.8	9.2	8.8	8.6	9.4	8.4	9.8	8.4	2.8	9.2	9.2	9.6	9.4	9.4	2.2
S6	2.8	6.6	4.8	4.4	5.6	4.2	3.4	4.4	7.8	4.6	3.6	4.6	3.8	4.4	7.2
S7	2.4	3.8	2.8	3.2	3.6	3.4	2.8	3.2	8.6	2.6	2.2	3.2	2.6	2.6	9.2
S8	8.2	8.4	7.6	8.2	8.2	9.4	8.6	8.4	3.2	9.4	9.6	8.2	8.6	9.2	3.2
S9	1.6	2.6	1.6	3.2	1.8	2.6	2.4	2.4	9.2	1.8	2.4	1.8	2.2	2.4	9.4
S10	3.2	6.4	4.2	4.8	5.8	3.8	3.2	4.4	7.2	4.4	5.2	4.6	5.2	4.8	7.4
S11	7.6	7.2	6.6	6.6	7.8	7.6	7.8	7.4	3.6	8.2	7.2	6.4	7.8	7.2	3.6
S12	8.6	8.8	8.2	9.2	8.8	8.4	8.2	8.2	2.2	8.6	8.4	8.2	8.2	8.2	2.8
S13	4.8	6.2	5.6	7.2	6.6	5.4	5.4	6.2	5.6	5.8	6.6	5.4	6.2	6.6	5.6
S14	6.6	6.4	7.4	5.2	7.2	6.2	6.8	6.4	4.8	7.2	7.4	6.6	6.6	7.6	4.8
S15	2.8	3.2	2.2	2.6	2.4	2.8	2.4	2.6	8.2	2.4	1.8	2.2	2.6	3.2	8.8
S16	4.2	4.4	3.2	4.6	5.2	3.2	4.2	4.8	8.4	3.4	3.8	3.4	4.2	4.4	8.2
S17	9.2	9.6	8.6	8.2	9.8	8.2	9.2	8.6	2.4	9.8	8.8	9.2	9.4	8.6	1.6
S18	4.4	5.6	5.6	6.2	6.2	4.8	4.4	5.2	6.4	5.2	5.4	4.4	5.8	5.6	6.6
S19	3.4	5.2	2.6	4.2	4.2	2.4	3.2	3.6	8.6	3.2	2.4	2.8	3.2	3.8	8.8
S20	9.6	8.2	8.8	9.4	8.2	8.8	8.8	9.6	3.8	8.2	8.4	8.6	8.8	8.2	3.2

Problem modeling: with regard to the experts' opinion in all membership functions, the lower bound was considered equal to the weekly demand of the mentioned item and the upper bound was considered as 500. Therefore, the membership functions for maximum and minimum goals are written in accordance with Eq.11 and Eq.12, respectively.

$$\mu_{Z1}(X) = \begin{cases} 1 & z_1 \geq 500 \\ \dfrac{z_1(x) - 50}{450} & 50 \leq z_1(x) \leq 500 \\ 0 & z_1 \leq 50 \end{cases} \quad (11)$$

$$\mu_{Z9}(X) = \begin{cases} 1 & z_9 \leq 50 \\ \dfrac{500 - z_9(x)}{450} & 50 \leq z_9(x) \leq 500 \\ 0 & z_9 \geq 500 \end{cases} \quad (12)$$

After determining the membership functions, the problem is formulated as follows:

$$\text{MAX } 0.122\,\lambda_1 + 0.082\,\lambda_2 + \ldots + 0.044\,\lambda_{14} + 0.099\,\lambda_{15}$$

s.t.

$$\begin{aligned}
&((5.4\,X_1 + 3.6\,X_2 + \ldots + 3.4\,X_{19} + 9.6\,X_{20} - 50)/450) \geq \lambda_1 \\
&((7.4\,X_1 + 5.2\,X_2 + \ldots + 5.2\,X_{19} + 8.2\,X_{20} - 50)/450) \geq \lambda_2 \\
&((5.8\,X_1 + 4.4\,X_2 + \ldots + 2.6\,X_{19} + 8.8\,X_{20} - 50)/450) \geq \lambda_3 \\
&((6.4\,X_1 + 5.2\,X_2 + \ldots + 4.2\,X_{19} + 9.4\,X_{20} - 50)/450) \geq \lambda_4 \\
&((7.6\,X_1 + 6.2\,X_2 + \ldots + 4.2\,X_{19} + 8.2\,X_{20} - 50)/450) \geq \lambda_5 \\
&((6.6\,X_1 + 4.8\,X_2 + \ldots + 2.4\,X_{19} + 8.8\,X_{20} - 50)/450) \geq \lambda_6 \\
&((5.4\,X_1 + 3.6\,X_2 + \ldots + 3.2\,X_{19} + 8.8\,X_{20} - 50)/450) \geq \lambda_7 \\
&((6.8\,X_1 + 5.4\,X_2 + \ldots + 3.6\,X_{19} + 9.6\,X_{20} - 50)/450) \geq \lambda_8 \\
&((500 - 2.4\,X_1 - 2.8\,X_2 - \ldots - 9.2\,X_{19} - 9.2\,X_{20})/450) \geq \lambda_9 \\
&((6.6\,X_1 + 5.2\,X_2 + \ldots + 3.2\,X_{19} + 8.2\,X_{20} - 50)/450) \geq \lambda_{10} \\
&((7.4\,X_1 + 4.8\,X_2 + \ldots + 2.4\,X_{19} + 8.4\,X_{20} - 50)/450) \geq \lambda_{11} \\
&((5.8\,X_1 + 5.2\,X_2 + \ldots + 2.8\,X_{19} + 8.6\,X_{20} - 50)/450) \geq \lambda_{12} \\
&((6.2\,X_1 + 4.2\,X_2 + \ldots + 3.2\,X_{19} + 8.8\,X_{20} - 50)/450) \geq \lambda_{13} \\
&((7.4\,X_1 + 5.4\,X_2 + \ldots + 3.8\,X_{19} + 8.2\,X_{20} - 50)/450) \geq \lambda_{14} \\
&((500 - 1.6\,X_1 - 2.2\,X_2 - \ldots - 9.4\,X_{19} - 9.6\,X_{20})/450) \geq \lambda_{15}
\end{aligned} \quad (13)$$

$$X_{1,3,8,10,13,14,19,20} \leq 5$$

$$X_{2,6,7,9,15,16,17,18} \leq 10$$

$X_{4,5,11,12} \leq 15$
$X_1 + X_2 + X_3 + \ldots + X_{18} + X_{19} + X_{20} = 50$
$X_i \geq 0 \quad i = 1, 2, 3, \ldots, 20$

X_i is the decision variable and the order value assigned to the i-th supplier. The objective function coefficients are the weights obtained from the F-ANP, which demonstrates the priority degree of each goal. Then, a constraint is considered for each goal given the goal membership function. Therefore, we have 15 goal constraints. In addition to the goal constraints, there are some constraints on suppliers' capacity and also demand.

After modeling the problem, it is solved and the value that should be provided by each supplier is determined. With regard to the results, the order of the selected suppliers is done at their maximum capacity and no order is provided by the other suppliers.

S5=15 S8 = 5 S12 = 15 S17 = 10 S20 = 5

5. Conclusions and suggestions

Since suppliers are one of the main sources of vulnerability in supply chains, the evaluation of suppliers' resilience is one of the most important ways to enter the world of making resilience the supply chain; hence, this study is aimed to identify and investigate the evaluation attributes of suppliers' resilience from the two aspects of importance and effectiveness for choosing the resilient supplier in Iran electronic industries. According to the studies described in the literature review, the studies performed in the area of suppliers' evaluation in a resilient supply chain can be categorized into two general classes: the first category contains the researches performed by the management approach. Some of these studies are those of Halder et al. (2012, 2014), Azadeh et al (2014), Rajesh and Ravi (2015) and Sahue et al (2016). These studies have focused on finding the single sources in resilient chains, and to this end, the attributes related to the suppliers' resilience have been extracted. They have evaluated the suppliers' resilience using the multi attributes decision making methods and introduced the superior supplier. In other side, there are some researches that evaluated the suppliers and allocating orders to them in multiple source-finding using the mathematical modeling. Some of these studies are those of Savick (2013), Torabi et al. (2015), Kamal Ahadi and Mellat Parast (2015). The present study seeks a way to combine the two approaches in this area to have benefits of each approach.

In this regard, firstly by extracting the comprehensive attributes of suppliers' resilience, the weakness of ignoring them by the researchers in the second approach and also the lack of integrity in attributes of first approach, are covered. Results showed that some attributes including, human resource management, visibility, and financial strength are the most influential factors. In terms of importance, agility, adaptability, and vulnerability are also the most important factors. In this study, the efficiency of combining the applied methods (Dematel, analytic network process, goal programming, and fuzzy logic) is well illustrated with a case study.

Research suggestions are as follows:

Considering that the most evaluation attributes of suppliers' resilience are qualitative, in order to reduce the intervention level of experts' subjective judgement in decision making, it is proposed to evaluate and extract the quantitative attributes of evaluating the supplier's resilience.

The issue of evaluating the suppliers in a resilience supply chain, is a part of the design for the resilient supply chain network; therefor it is suggested to perform a study in future on the design of a resilient supply chain network in Iran electronic industries in which the proposed method would be used.

References

[1] Chopra S, Meindl P. Supply chain management. Strategy, planning & operation. Das summa summarum des management. 2007:265-75.
[2] Christopher M, Holweg M. "Supply Chain 2.0": managing supply chains in the era of turbulence. International Journal of Physical Distribution & Logistics Management. 2011;41(1):63-82.
[3] Carvalho H, Barroso AP, Machado VH, Azevedo S, Cruz-Machado V. Supply chain redesign for resilience using simulation. Computers & Industrial Engineering. 2012;62(1):329-41.
[4] Christopher M, Peck H. Building the resilient supply chain. The international journal of logistics management. 2004;15(2):1-14.
[5] Waters D. Supply chain risk management: vulnerability and resilience in logistics: Kogan Page Publishers; 2011.
[6] Vilko J. Approaches to supply chain risk management: identification, analysis and control. Acta Universitatis Lappeenrantaensis. 2012.
[7] Rajesh R, Ravi V. Supplier selection in resilient supply chains: a grey relational analysis approach. Journal of Cleaner Production. 2015;86:343-59.

[8] Nazari-Shirkouhi S, Shakouri H, Javadi B, Keramati A. Supplier selection and order allocation problem using a two-phase fuzzy multi-objective linear programming. Applied Mathematical Modelling. 2013;37(22):9308-23.
[9] Sheffi Y, Rice Jr JB. A supply chain view of the resilient enterprise. MIT Sloan management review. 2005;47(1):41.
[10] Roberta Pereira C, Christopher M, Lago Da Silva A. Achieving supply chain resilience: the role of procurement. Supply Chain Management: an international journal. 2014;19(5/6):626-42.
[11] Yang Y, Xu X. Post-disaster grain supply chain resilience with government aid. Transportation research part E: logistics and transportation review. 2015;76:139-59.
[12] Schiele H, Veldman J, Hüttinger L. Supplier innovativeness and supplier pricing: The role of preferred customer status. International Journal of Innovation Management. 2011;15(01):1-27.
[13] Haldar A, Ray A, Banerjee D, Ghosh S. A hybrid MCDM model for resilient supplier selection. International Journal of Management Science and Engineering Management. 2012;7(4):284-92.
[14] Sawik T. Selection of resilient supply portfolio under disruption risks. Omega. 2013;41(2):259-69.
[15] Haldar A, Ray A, Banerjee D, Ghosh S. Resilient supplier selection under a fuzzy environment. International Journal of Management Science and Engineering Management. 2014;9(2):147-56.
[16] Azadeh A, Abdollahi M, Farahani MH, Soufi HR, editors. Green-Resilient Supplier Selection: An Integrated Approach. International IEEE Conference, Istanbul july 26; 2014.
[17] Torabi S, Baghersad M, Mansouri S. Resilient supplier selection and order allocation under operational and disruption risks. Transportation Research Part E: Logistics and Transportation Review. 2015;79:22-48.
[18] Kamalahmadi M, Mellat-Parast M. Developing a resilient supply chain through supplier flexibility and reliability assessment. International Journal of Production Research. 2016;54(1):302-21.
[19] Sahu AK, Datta S, Mahapatra S. Evaluation and selection of resilient suppliers in fuzzy environment: exploration of fuzzy-VIKOR. Benchmarking: An International Journal. 2016;23(3):651-73.
[20] Colicchia C, Dallari F, Melacini M. Increasing supply chain resilience in a global sourcing context. Production planning & control. 2010;21(7):680-94.
[21] Pettit TJ, Fiksel J, Croxton KL. Ensuring supply chain resilience: development of a conceptual framework. Journal of business logistics. 2010;31(1):1-21.
[22] Lee PK, Yeung AC, Cheng TE. Supplier alliances and environmental uncertainty: An empirical study. International Journal of Production Economics. 2009;120(1):190-204.
[23] Tachizawa EM, Gimenez C. Supply flexibility strategies in Spanish firms: Results from a survey. International Journal of Production Economics. 2010;124(1):214-24.
[24] Ponomarov SY, Holcomb MC. Understanding the concept of supply chain resilience. The international journal of logistics management. 2009;20(1):124-43.
[25] Blackhurst J, Dunn KS, Craighead CW. An empirically derived framework of global supply resiliency. Journal of Business Logistics. 2011;32(4):374-91.
[26] Christopher M, Mena C, Khan O, Yurt O. Approaches to managing global sourcing risk. Supply Chain Management: An International Journal. 2011;16(2):67-81.
[27] Jüttner U, Maklan S. Supply chain resilience in the global financial crisis: an empirical study. Supply Chain Management: An International Journal. 2011;16(4):246-59.
[28] Zhang Y, Lindell MK, Prater CS. Vulnerability of community businesses to environmental disasters. Disasters. 2009;33(1):38-57.
[29] Kamalahmadi M, Parast MM. A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. International Journal of Production Economics. 2016;171:116-33.
[30] Glenn Richey Jr R, Autry CW. Assessing interfirm collaboration/technology investment tradeoffs: The effects of technological readiness and organizational learning. The International Journal of Logistics Management. 2009;20(1):30-56.
[31] Tate WL, Dooley KJ, Ellram LM. Transaction cost and institutional drivers of supplier adoption of environmental practices. Journal of Business Logistics. 2011;32(1):6-16.
[32] Soni U, Jain V, Kumar S. Measuring supply chain resilience using a deterministic modeling approach. Computers & Industrial Engineering. 2014;74:11-25.
[33] Stecke KE, Kumar S. Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies. Journal of Marketing Channels. 2009;16(3):193-226.
[34] Spiegler VL, Naim MM, Wikner J. A control engineering approach to the assessment of supply chain resilience. International Journal of Production Research. 2012;50(21):6162-87.

[35] Zsidisin GA, Wagner SM. Do perceptions become reality? The moderating role of supply chain resiliency on disruption occurrence. Journal of Business Logistics. 2010;31(2):1-20.
[36] Chiang C-Y, Kocabasoglu-Hillmer C, Suresh N. An empirical investigation of the impact of strategic sourcing and flexibility on firm's supply chain agility. International Journal of Operations & Production Management. 2012;32(1):49-78.
[37] Hofmann E. Natural hedging as a risk prophylaxis and supplier financing instrument in automotive supply chains. Supply Chain Management: An International Journal. 2011;16(2):128-41.
[38] Chan S, Larsen GN, editors. A framework for supplier-supply chain risk management: Tradespace factors to achieve risk reduction—return on investment. Technologies for Homeland Security (HST), 2010 IEEE International Conference on; 2010: IEEE.
[39] Wang T-Y, Yang Y-H. A fuzzy model for supplier selection in quantity discount environments. Expert Systems with Applications. 2009;36(10):12179-87.
[40] Yang B, Yang Y. Postponement in supply chain risk management: a complexity perspective. International Journal of Production Research. 2010;48(7):1901-12.
[41] Clegg B, Chandler S, Binder M, Edwards J. Governing inter-organisational R&D supplier collaborations: a study at Jaguar Land Rover. Production Planning & Control. 2013;24(8-9):818-36.
[42] Kloyer M, Scholderer J. Effective incomplete contracts and milestones in market-distant R&D collaboration. Research Policy. 2012;41(2):346-57.
[43] Sáenz MJ, Revilla E. Creating more resilient supply chains. MIT Sloan management review. 2014;55(4):22.
[44] Cousins PD, Lawson B, Petersen KJ, Handfield RB. Breakthrough scanning, supplier knowledge exchange, and new product development performance. Journal of Product Innovation Management. 2011;28(6):930-42.
[45] Whipple JM, Roh J. Agency theory and quality fade in buyer-supplier relationships. The International Journal of Logistics Management. 2010;21(3):338-52.
[46] Kern D, Moser R, Hartmann E, Moder M. Supply risk management: model development and empirical analysis. International Journal of Physical Distribution & Logistics Management. 2012;42(1):60-82.
[47] Lavastre O, Gunasekaran A, Spalanzani A. Supply chain risk management in French companies. Decision Support Systems. 2012;52(4):828-38.
[48] Blome C, Schoenherr T. Supply chain risk management in financial crises—A multiple case-study approach. International journal of production economics. 2011;134(1):43-57.
[49] Foerstl K, Reuter C, Hartmann E, Blome C. Managing supplier sustainability risks in a dynamically changing environment—Sustainable supplier management in the chemical industry. Journal of Purchasing and Supply Management. 2010;16(2):118-30.
[50] Matook S, Lasch R, Tamaschke R. Supplier development with benchmarking as part of a comprehensive supplier risk management framework. International Journal of Operations & Production Management. 2009;29(3):241-67.
[51] Ivarsson I, Alvstam CG. Upgrading in global value-chains: a case study of technology-learning among IKEA-suppliers in China and Southeast Asia. Journal of Economic Geography. 2010;11(4):731-52.
[52] Martínez-Noya A, García-Canal E. Technological capabilities and the decision to outsource/outsource offshore R&D services. International Business Review. 2011;20(3):264-77.
[53] Trkman P, McCormack K. Supply chain risk in turbulent environments—A conceptual model for managing supply chain network risk. International Journal of Production Economics. 2009;119(2):247-58.
[54] Locke RM, Rissing BA, Pal T. Complements or substitutes? Private codes, state regulation and the enforcement of labour standards in global supply chains. British Journal of Industrial Relations. 2013;51(3):519-52.
[55] Punniyamoorthy M, Mathiyalagan P, Parthiban P. A strategic model using structural equation modeling and fuzzy logic in supplier selection. Expert Systems with Applications. 2011;38(1):458-74.
[56] Terziovski M. Innovation practice and its performance implications in small and medium enterprises (SMEs) in the manufacturing sector: a resource-based view. Strategic Management Journal. 2010;31(8):892-902.
[57] Kuo RJ, Wang YC, Tien FC. Integration of artificial neural network and MADA methods for green supplier selection. Journal of cleaner production. 2010;18(12):1161-70.
[58] Leat P, Revoredo-Giha C. Risk and resilience in agri-food supply chains: the case of the ASDA PorkLink supply chain in Scotland. Supply Chain Management: An International Journal. 2013;18(2):219-31.
[59] Tukamuhabwa BR, Stevenson M, Busby J, Zorzini M. Supply chain resilience: definition, review and theoretical foundations for further

study. International Journal of Production Research. 2015;53(18):5592-623.
[60] Briano E, Caballini C, Revetria R, editors. Literature review about supply chain vulnerability and resiliency. Proceedings of the 8th WSEAS international conference on System science and simulation in engineering; 2009: World Scientific and Engineering Academy and Society (WSEAS).
[61] Nishat Faisal M. Sustainable supply chains: a study of interaction among the enablers. Business Process Management Journal. 2010;16(3):508-29.
[62] Brown AS. Conflict on the Green. Mechanical Engineering. 2009;131(3):42.
[63] Rezaei J. Best-worst multi-criteria decision-making method. Omega. 2015;53:49-57.
[64] Park K. Flexible and redundant supply chain practices to build strategic supply chain resilience: contingent and resource-based perspectives: The University of Toledo; 2011.
[65] Urciuoli L, Mohanty S, Hintsa J, Gerine Boekesteijn E. The resilience of energy supply chains: a multiple case study approach on oil and gas supply chains to Europe. Supply Chain Management: An International Journal. 2014;19(1):46-63.
[66] Wagner SM, Neshat N. Assessing the vulnerability of supply chains using graph theory. International Journal of Production Economics. 2010;126(1):121-9.
[67] Hohenstein N-O, Feisel E, Hartmann E, Giunipero L. Research on the phenomenon of supply chain resilience: a systematic review and paths for further investigation. International Journal of Physical Distribution & Logistics Management. 2015;45(1/2):90-117.
[68] Yager RR. Fuzzy screening systems. Fuzzy Logic. 1993:251-61.
[69] Akyuz E, Celik E. A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers. Journal of Loss Prevention in the Process Industries. 2015;38:243-53.
[70] Önüt S, Kara SS, Işik E. Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company. Expert systems with applications. 2009;36(2):3887-95.
[71] Zimmermann H-J. Fuzzy programming and linear programming with several objective functions. Fuzzy sets and systems. 1978;1(1):45-55.