

Research Article

A Fuzzy DEMATEL-ANP-Based Approach to Prioritize Activities in Enterprise Architecture

Jamshid Afshani ¹, Abbas Karimi ¹, Nafiseh Osati Eraghi ¹ and Faraneh Zarafshan ²

¹Department of Computer Engineering, Arak Branch, Islamic Azad University, Arak, Iran

²Department of Computer Engineering, Ashtian Branch, Islamic Azad University, Ashtian, Iran

Correspondence should be addressed to Abbas Karimi; akarimi@arak-samacollege.ir

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Prioritization of activities is a multicriteria problem that includes both quantitative and qualitative factors. Moreover, due to the nature of organizations and activities, the impact of activities on each other is fuzzy. Prioritizing activities in real and fuzzy situations will help an organization's decision makers to make the right decisions. In this paper, a new fuzzy hybrid methodology is proposed to describe and prioritize the activities of the organization in fuzzy conditions. First, the activities of the organization are described in a new fuzzy format based on activity model (OV-5) of the C4ISR framework. Furthermore, fuzzy DEMATEL is used to calculate the interdependencies between activities, and then fuzzy ANP is used to calculate the weight of each activity. Finally, by combining the results of the two methods, the priority of activities was calculated. Additionally, an empirical study is presented to illustrate the application of the proposed method.

1. Introduction

Enterprise architecture is currently regarded as one of the best methods of development and efficient utilization of information technology in enterprises. Enterprise architecture is so important that failing to implement it into an enterprise can be a sign of failure in information technology management [1, 2].

Since enterprise architecture is a complex process that covers all parts of an enterprise and requires different people with different expertise, controlling and managing such an extensive process will not be possible without a predefined pattern and a coherent structure. One of the successful methods in such an extensive process would be to use enterprise architecture frameworks [2–5]. In fact, an architect can make use of a framework in order to control the complexity of an enterprise architecture [6–10].

A lot of frameworks have been suggested for enterprise architecture (Zachman, C4ISR, FEAF, TEAF, etc.). Some of them have been new original ideas, whereas some others have been modified versions of a reference model. There has

also been a lot of research in the area of enterprise architecture frameworks.

Although frameworks almost define the policy of an enterprise, enterprise decision makers can affect the course of an enterprise by making two similar enterprises very different following the implementation of an architecture. Therefore, accurate analysis and careful consultation play an important role in enterprise implementation, management, and supervision. One good piece of advice to decision makers of an enterprise would be to identify and prioritize the activities and subactivities according to their importance. In C4ISR framework, the hierarchy of activities and subactivities is described by the activity model (OV-5) [9].

The C4ISR framework uses Unified Modeling Language (UML) to model the enterprise architecture. Applying the UML modeling approach brings a number of advantages: (1) as a standard modeling language, the UML models are understandable for most engineers; (2) it offers multiple viewpoints for different stakeholders to model an integrated architecture; (3) it has an extension mechanism so that the modelers can tailor the modeling language for their specific usage [11–14].

However, a real organization is full of uncertain information and relations which are difficult to model [11, 15, 16] particularly for the effect of each activity on other activities. For example, “activity A has a significant effect on activity B.” This fuzzy relation cannot be described with the standard activity model (OV-5) product of C4ISR.

Much research has been done on enterprise architecture frameworks. Many frameworks have been derived or inspired by reference frameworks. However, none of the proposed frameworks for organizational architecture has a graphical and network format with the ability to describe fuzzy connections between activities.

To solve this problem, this paper presents a new fuzzy format based on activity model (OV-5) product of C4ISR that schematically shows fuzzy and nonfuzzy connections between activities. This new format describes the activities of the organization in a nonlinear structure and shows the activities in a network form.

To prioritize activities, both qualitative and quantitative factors must be considered. Thus, prioritization of activities is a kind of multiple criteria decision-making (MCDM) problem and we need to employ MCDM methods to handle it appropriately.

There are several decision-making methods for different types of problems, such as Analytic Hierarchy Process (AHP), PROMETHEE, ELECTRE, SMART, ANP, multi-granular unbalanced linguistic information, and social network group decision making [17–24]. In generic terms, the common decision-making process follows eight steps [25, 26]. To achieve the goal and objectives, choosing the appropriate decisions making method which fits the specific problem is the first and the most important step in the decision-making process [17].

In this method, we describe enterprise architecture activities in a new fuzzy network format. When the dependency and relationship are mutual and fuzzy, and one element affects the other elements in any order and direction and even has an impact on itself, the issue does not have a hierarchical mode and forms a network or nonlinear system. In this case, fuzzy ANP should be used to calculate the weight of elements [27].

In this study, fuzzy Decision-Making Trial and Evaluation Laboratory (fuzzy DEMATEL) method [28] is also used to extract the mutual relationships of interdependencies within the criteria and the strength of the interdependency.

Finally, the results of both fuzzy ANP and fuzzy DEMATEL methods are combined, and the final result, which is the main priority of the activities, is measured. This hybrid method is applicable to all real organizations. The use of fuzzy concepts in all stages brings final results very close to reality.

The rest of this paper is organized as follows. In Section 2, some of the prior literature related to enterprise architecture, fuzzy DEMATEL, and fuzzy ANP is reviewed. In Section 3, the proposed method is described. In Section 4, the implementation of the method in a real organization is illustrated. Finally, according to the findings of this research, conclusions and suggestions are presented in Section 5.

2. Related Works

Much research has been done in the field of enterprise architecture. In addition, fuzzy DEMATEL and ANP methods were used in extensive research. In both areas, we have studied several articles. Here are some of the most important ones.

An example of research carried out in the enterprise architecture area is a study by Ercan and Kale [29], which examined the role of the current and near future security and defense policy in Turkey, and its purpose was to investigate threats against space-based capabilities. They utilized the emerging technological features to explore space security threats to provide space security.

Ouyang et al. [30] proposed a method to assess the effectiveness of the C4ISR marine combat system based on system dynamics. By analyzing the feedback mechanism of the C4ISR marine system and the causal relationship between the C4ISR and the red and blue sea systems in complex electronic warfare situations, it was found that there is a dynamic model of the system and the equations of the C4ISR marine system in coping with the conditions. The degree of damage from red to blue has been used as a measure of the operational performance of the C4ISR marine system. The simulation results suggest that this method is useful for improving the combat program and improving the performance of the C4ISR combat system. The Air Force Research Laboratory (AFRL)–Sensors Directorate Blue Guardian program shows research development and presentation of sensor integration technologies, which cover integration technologies for not only physical sensors, but also software, communication, and processing elements. Integration technology is called the Blue Guardian Open Adaptable Architecture (OA2) and makes the development and demonstration of new command, control, communications, computer, intelligence, monitoring, and identification (C4ISR) possible by decreasing cost, planning, and integration time. The Blue Guardian has expanded from the flight test training program to lessons learned from problems in integrating sensors and the development of software and hardware OA2 to improve the efficiency and speed of integration of sensors. Shirey et al. [31–33] provide background for this research effort, development approach, and technical details, highlighting OA2 and discussing recent events and future areas to improve OA2 to improve US Air Force potentials.

Kang et al. [9] propose an advanced integrated modeling method for analyzing communication at the NCW Center through its transmission which reduces the runtime of simulation to ensure the accuracy of telecommunication. Proposed proposals mainly address “internal traffic and mobility” that have been developed in the form of forward-looking neural networks to ensure interoperability between the martial system and the network system. Since they are known as discrete events, the proposed models are designed by setting up a discrete event system (DEVS). The experimental results show that the proposed changes lower the error percentage compared to the existing method and reduce the runtime compared to the NCW Center simulation.

Mordecai et al. [34] describe a conceptual modeling framework for model-based interoperability engineering (MoBIE) systems for systems that integrate multilayer interoperability, modeling, designing, and testing. They also implement MoBIE with an integrated modeling language, UML. The suggested model contributes to system-level architecture and decision making and adds significant value to the level of interoperability engineering.

Sabri et al. [35] provide a new architecture for business process by using Knowledge Management Enablers. They use semantic ontologies and SWRL rules in order to link the KMEs and BPA disciplines. Moreover, Haghhighathoseini et al. [2] provided a local enterprise architecture framework for the University Hospital of Iran. Using the two dimensions of implementation and the appropriate specifications, the best framework for companies was selected. Five activities were selected based on expert input. According to these activities, five frameworks with the highest rank were chosen. In the next step, via the AHP method, TOGAF was selected due to the proper features and the ability to run reference formats. The framework for enterprise architecture is also designed by TOGAF in a conceptual model and layers. The results showed that TOGAF is suitable to use in hospitals. Therefore, local hospital modeling of enterprise architecture has been developed through the TOGAF customization for an Iranian hospital in eight levels and 11 episodes.

Due to the nature of organizations, the activities and some data of organizations are fuzzy. None of the previous studies provided a fuzzy format for describing the activities of an organization. To prioritize activities using fuzzy DEMATEL and fuzzy ANP, a network form structure is needed to describe activities that can also describe fuzzy connections between activities. This format is not recommended in any of the previous frameworks.

In other words, fuzzy DEMATEL and ANP methods were used in extensive research. Table 1 shows the number of studies that are closer to the proposed method of this paper. Fuzzy DEMATEL and fuzzy ANP methods have been used in many applications. Based on our studies, no method based on their combination has been proposed to prioritize an organization's activities in fuzzy conditions.

3. Methodology

This study proposes a novel hybrid analytic approach based on the fuzzy DEMATEL, fuzzy ANP, and C4ISR activity model (OV-5) product. In this section, the general phases of the proposed method are explained.

The proposed method includes five general phases:

- (a) Phase I: a new fuzzy format is proposed for activity model (OV-5) product from C4ISR framework.

This new format describes the activities of the organization, in a nonlinear structure and shows activities in a network form. Because of the nature of activities in a real organization, the relationships

between activities and their impact on each other are fuzzy. Instead of the standard C4ISR format, we use this new format to describe the activity model product.

Relationships between activities can be fuzzy for one of the three reasons as follows:

- (1) Data sent between activities is fuzzy
 - (2) The impact of activities on each other is fuzzy. It means how much the success of one activity affects the success of another
 - (3) The subactivities belong to the main activities with a degree of belonging
- (b) Phase II: a matrix of experts' opinions on the importance and effectiveness of activities on one another is prepared; then, the results of the matrix are aggregated and normalized.

In this phase, by using the fuzzy activity model of phase I, we are asking experts for the priority and importance of each activity and subactivity. In the first step, experts' opinions are aggregated. Akzel and Saati (1983) introduced the use of geometric meanings as the best method for combining paired comparisons. Since the number of respondents is more than one person, the final matrix results from the geometric mean of the number of respondents. In order to consider the opinion of all experts, we get an arithmetic mean according to the following equation:

$$\tilde{Z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \dots \oplus \tilde{x}^p}{p}. \quad (1)$$

In (1), p is the number of experts.

The next step is to normalize the pairwise comparison matrix of activities using the following equation:

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r} \right) = \left(l''_{ij}, m''_{ij}, u''_{ij} \right), \quad (2)$$

where r is obtained from the following equation:

$$r = \max_{1 \leq i \leq n} \left(\sum_{j=1}^n u_{ij} \right). \quad (3)$$

- (c) Phase III: the weight of each activity is calculated using the fuzzy ANP method.
- (d) Phase IV: the interdependency between activities is determined using the fuzzy DEMATEL method.

After calculating the normal matrix, the matrix of the total fuzzy relations is obtained according to (4)–(8).

$$\mathbf{T} = \lim_{k \rightarrow \infty} \left(\tilde{H}^1 \oplus \tilde{H}^2 \oplus \dots \oplus \tilde{H}^k \right). \quad (4)$$

TABLE 1: Application of fuzzy DEMATEL and ANP.

Author (s)	Methodology	Objective of the study
Büyüközkan and Çifçi [36]	ANP-DEMATEL (fuzzy)	Evaluation of green suppliers under fuzzy environment
Kabak [37]	ANP-DEMATEL (fuzzy)	Personnel selection
Sadehnezhad et al. [38]	ANP-DEMATEL (fuzzy)	Evaluation of business intelligence performance
Yeh and Huang [39]	ANP-DEMATEL (fuzzy)	Evaluation of wind farm location selection factors
Uygun et al. [40]	ANP-DEMATEL (fuzzy)	Evaluation and selection of outsourcing provider for a telecommunication company
Fazli et al. [41]	ANP-DEMATEL	Crude oil supply chain risk management
Vinodh et al. [42]	ANP-DEMATEL (fuzzy)	A hybrid MCDM approach for agile concept selection
Uygun et al. [43]	ANP-DEMATEL (fuzzy)	Fuzzy MCDM approach to measure institutionalization readiness of SMEs
Najafinasab et al. [44]	ANP-DEMATEL (fuzzy)	Evaluation of land and sea criteria for land use planning in coastal areas
Fetanat and Khorasaninejad [45]	ANP-DEMATEL (fuzzy)	Fuzzy MCDM approach for offshore wind farm site selection in Iran
Karaşan and Kahraman [46]	ANP-DEMATEL (fuzzy)-TOPSIS	A novel intuitionistic fuzzy DEMATEL-ANP-TOPSIS integrated methodology for freight village location selection
Chen et al. [47]	ANT-DEMATEL (fuzzy)	A rough-fuzzy DEMATEL-ANP method for evaluating sustainable value requirement of product service system
Abikova [48]	ANP-DEMATEL (fuzzy)	Application of fuzzy DEMATEL-ANP methods for siting refugee camps
Ocampo et al. [49]	ANP-DEMATEL (fuzzy)-AHP	A novel multiple criteria decision-making approach based on fuzzy DEMATEL, fuzzy ANP, and fuzzy AHP for mapping collection and distribution centers in reverse logistics
Toosi and Samani [50]	ANP (fuzzy)-DEMATEL (fuzzy)-VIKOR (fuzzy)	Prioritizing watersheds using a novel hybrid decision model based on fuzzy DEMATEL, Fuzzy ANP, and fuzzy VIKOR
Sardasht and Rashedi [51]	ANP-DEMATEL (fuzzy)	Identifying influencing factors of audit risk model: a combined fuzzy ANP-DEMATEL approach
Mavi and Standing [52]	ANP-DEMATEL (fuzzy)	Critical success factors of sustainable project management in construction: a fuzzy DEMATEL-ANP approach
Celikbilek and Nur Adıgüzel Tüylü [53]	DEMATEL-ANP (fuzzy)	Prioritizing the components of e-learning systems by using fuzzy DEMATEL and ANP

Each fuzzy number is calculated as follows:

$$[l_{ij}^t] = H_l \times (l - H_l)^{-1}, \quad (5a)$$

$$[m_{ij}^t] = H_m \times (l - H_m)^{-1}, \quad (5b)$$

$$[u_{ij}^t] = H_u \times (l - H_u)^{-1}. \quad (5c)$$

In these formulas, l is a single matrix and H_b , H_m , and H_u each are nn matrices, in which the forms contain the lower number, the middle number, and the upper number of the fuzzy triangular numbers of the matrix H . At this point, the defuzzified matrix is calculated using the matrix of fuzzy total relationships using center of gravity method as follows:

$$C_{i,j} = \frac{l_{i,j} + m_{i,j} * 2 + u_{i,j}}{4}. \quad (6)$$

By use of the defuzzified matrix, internal dependency is calculated by the following equations:

$$\text{threshold} = \frac{\sum_{i=1}^n \sum_{j=1}^n C_{i,j}}{n * n}, \quad (7)$$

$$W_{2,i,j} = \begin{cases} 0, & i(C_{i,j}) < \text{threshold}, \\ 1, & \text{if}(C_{i,j}) < \text{threshold}. \end{cases} \quad (8)$$

(e) Phase V: the final priority of activities is calculated by combining the results of the third and fourth phases.

We firstly mention the base techniques in the following subsections and then, in Section 4 (Application of the Method), present the computation steps of the new method using a case study.

3.1. Activity Model (OV-5). The activity model (OV-5) is one of the 26 products of the C4ISR framework. Descriptive activity model shows the activities related to architecture, data or information that is exchanged between these activities and data or information that is associated with other activities outside the scope (for example, external exchanges). These models are of a hierarchical nature; that is, they begin with a small square indicative of overall activity, and this activity breaks down into smaller activities to the extent that architecture requires. In fact, the activity model describes the activities performed in a business or mission process and ICOMs. The activity model generally includes a chart of the hierarchy of activities covered in the model, activity diagram, facing page text for each diagram that provides any required detail, and a dictionary that defines all activities and terms used in the diagrams (Figure 1). The Integrated Dictionary product serves as this dictionary and contains all terms used in the products constructed for a given architecture, including, but not limited to, the activity model [6].

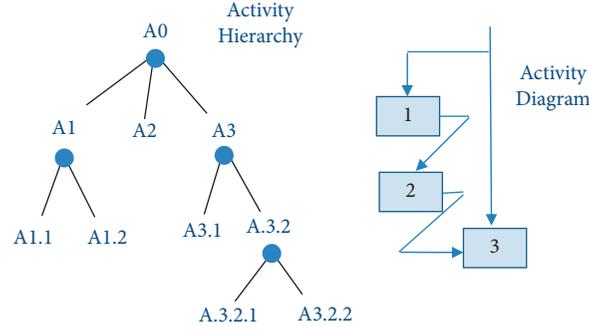


FIGURE 1: Activity hierarchy chart and activity diagram (OV-5) [6].

3.2. Fuzzy DEMATEL Method. DEMATEL is an effective method for analyzing the relationships between system factors by aggregating group knowledge. The most important feature of this approach is in the field of multicriteria decision making and its function in creating a relationship and structure between factors [35]. Due to the ambiguity in the judgment of the experts, the combination of this method with the fuzzy concept will be beneficial. In this paper, the DEMATEL method was used for two purposes: first to calculate the matrix of dependencies between the main factors and then to identify the causative factors. The steps to do this are as follows [8]:

Phase I: provide a matrix of direct relationships between system factors. At this stage, using expert oversight and the language variables in Table 1, they express their view on the direct effect of each of the factors on the others. By converting linguistic estimates into fuzzy numbers, the matrix is obtained by a direct primary relation in which A is an invariant matrix and is a triangular fuzzy matrix representing the direct effect i on the factor j . When $i=j$, the components of the diagonal matrix are zero [8].

$$A = \begin{bmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{i1} & \dots & a_{ij} & \dots & a_{in} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & \dots & a_{nj} & \dots & a_{nn} \end{bmatrix}. \quad (9)$$

Phase II: apply primary direct matrix defuzzification based on the CFCS method.

For primary defuzzification of matrix, the CFCS method which is provided by Opricovic and Tzeng [54] is used. Based on the CFCS method, defuzzification is done in five steps:

Step 1: standardization of fuzzy numbers:

$$xl_{ij}^k = \frac{(l_{ij}^k - \min l_{ij}^k)}{\Delta_{\min}^{\max}}, \quad (10a)$$

$$xm_{ij}^k = \frac{(m_{ij}^k - \min l_{ij}^k)}{\Delta_{\min}^{\max}}, \quad (10b)$$

$$xr_{ij}^k = \frac{(r_{ij}^k - \min l_{ij}^k)}{\Delta_{\min}^{\max}}, \quad (10c)$$

$$\Delta_{\min}^{\max} = \max r_{ij}^k - \min r_{ij}^k. \quad (10d)$$

Step 2: calculation of the normal left and right values:

$$xls_{ij}^k = \frac{xm_{ij}^k}{(1 + xm_{ij}^k - xl_{ij}^k)}, \quad (11a)$$

$$xrs_{ij}^k = \frac{xr_{ij}^k}{(1 + xr_{ij}^k - xm_{ij}^k)}. \quad (11b)$$

Step 3: calculating the totalized normalized value:

$$x_{ij}^k = \frac{[(xls_{ij}^k / (1 - xls_{ij}^k)) + xrs_{ij}^k] + xrs_{ij}^k xrs_{ij}^k}{(1 + xrs_{ij}^k - xls_{ij}^k)}. \quad (12)$$

Step 4: calculation of the crisp number of K 's expert:

$$\text{BNP}_{ij}^k = \min l_{ij}^k - x_{ij}^k \Delta_{\min}^{\max}. \quad (13)$$

Step 5: use of the interpolation of crisp numbers to obtain a cumulative number for all k estimation:

$$a_{ij} = \frac{1}{k} \sum_{k=1}^k \text{BNP}_{ij}^k. \quad (14)$$

After the defuzzification and aggregation of experts' opinions, the matrix of the direct initial relationship is

aggregated, with crisp numbers representing the direct impact of i on the j factor.

Phase III: normalize the direct relationship matrix. At this stage, the initial direct-relation matrix becomes normal. The normalized matrix is obtained directly from the following equation:

$$X = S * A, \quad (15)$$

$$S = \min \left[\frac{1}{\max_i \sum_{j=1}^n |a_{ij}|}, \frac{1}{\max_j \sum_{i=1}^n |a_{ij}|} \right]. \quad (16)$$

$$T = X + X^2 + \dots + X^k = X(I + X + X^2 + \dots + X^{k-1})(1 - X)(1 - X)^{-1} = X(1 - X^k)(1 - X)^{-1}. \quad (17)$$

With the condition that $\lim_{k \rightarrow \infty} X^k = [0]_{n \times n}$, the general relation matrix is obtained from equation the following equation [8]:

$$T = X(1 - X)^{-1}. \quad (18)$$

Phase V: calculate the total rows and matrix pillars of the total relationship T and identify the causes:

$$\begin{aligned} r_j &= \sum_{i=0}^n t_{ij}, \\ c_j &= \sum_{j=0}^n t_{ij}. \end{aligned} \quad (19)$$

3.3. Fuzzy ANP Method. Deciding the process is to find the best position among available options. In almost all decision-making issues, the decision maker is in difficulty due to the multiplicity of criteria. Therefore, for most issues, the decision maker wants to achieve more than one goal in terms of choosing how to implement the activities. In the decision of several classical criteria, the weight of the criteria is well known, but due to the ambiguity and uncertainty in the statements of the decision maker, the data is definitively inappropriate. In recent years, many efforts have been made to resolve such ambiguities and the lack of crisp numbers, which ultimately led to the application of the theory of fuzzy sets in multicriteria evaluation methods. Analytic Network Process (ANP) is a

Phase IV: generate general matrix.

The sum of an unbroken sequence of direct and indirect effects of elements on each other is calculated as a geometric propagation based on the rules of the graphs. The sum of this progression is the matrix of the general relation T , in which I is an $n \times n$ unit matrix.

general version of AHP and is an expanded form of it; therefore, it has all of the AHP's positive attributes such as the simplicity, the flexibility, the use of qualitative and quantitative criteria simultaneously, and the ability to check the compatibility of judgment. Moreover, it can process a complex relationship by considering the elements of the decision using a network structure rather than a hierarchical structure. The Analytic Network Process (ANP) considers each issue as a network of criteria, subcriteria, and options that cluster together. All elements in a network can have a relationship with each other. In other words, in a network, feedback and interconnection between and among clusters are possible. An ANP technique is used to indicate the dependencies of decision-making levels available on the super matrix. At the first level of the network, the goal and the second level are the main factors that have internal affinities and the third level subagents. In the super matrix w , the relative weight of the main factors with respect to the target node is the internal weight between the main factors and the weight of the subfactors relative to their respective principal factors. The matrix T , which is the output of the DEMATEL method, is considered after the normalization as a matrix and used to compute paired comparisons. Qualitative variables and fuzzy numbers used to perform paired comparisons are included in Table 2. To perform pairwise comparisons in group mode, after obtaining the fuzzy pair comparison table for each expert, (20) is used to compute the composition of individual views and obtain the final tables of pair comparisons.

$$Z_{ij}^k = (\sqrt[k]{L_1 \times L_2 \times \dots \times L_k}, \sqrt[k]{m_1 \times m_2 \times \dots \times m_k}, \sqrt[k]{r_1 \times r_2 \times \dots \times r_m}). \quad (20)$$

For defuzzification of integrated paired t-comparison tables, using the CFCS method, using (9)–(13), and taking $k=1$ into account, these relationships are used. k is

considered as one. Only one fuzzy cumulative table becomes nonfuzzy. The final weight is also obtained from the non-fuzzy final table by means of the following equation:

TABLE 2: Variables and corresponding fuzzy numbers.

Quality	Fuzzy number
Effectless	(1, 1, 1)
Very little effect	(2, 3, 4)
Little effect	(4, 5, 6)
High effect	(6, 7, 8)
Very high effect	(8, 9, 9)

$$w_i = \frac{(\prod_{j=1}^n a_{ij})(1/n)}{\sum_{i=1}^n (\prod_{j=1}^n a_{ij})(1/n)}, \quad i, j = 1, 2, \dots, n. \quad (21)$$

Accordingly, it can be argued that the development of criteria and their prioritization for each organization or industry is of great importance and that managers and custodians should make great efforts to implement codified strategies. In addition, due to continuous environmental changes, selecting the most important strategies and implementing them are of great importance in today's world [55–58].

4. Application of the Method

4.1. Iran's Science and Technology Parks. Science and technology parks (STPs) are one of the most important innovation policy initiatives [59]. They are the main mechanisms of public and private initiatives for the promotion of research, development and innovation, and technology transfer. The main goal of these types of institutions is not a purely economic benefit, but also social and cultural benefit, which makes them an appropriate investment from the public institutions' viewpoint. They promote the creation of companies, facilitate agreements with universities and research centers, generate employment, and attract technology-based companies [60].

In Iran, science and technology parks provide the ecosystem for knowledge-based and creative businesses to grow and flourish. The success rate of a science and technology park is the number of successful businesses growing and the products and services they produce. Parks contribute to the growth and prosperity of startups and knowledge-based companies through a series of activities. The most important activities in science and technology parks in Iran include loan payment, branding and advertising, marketing and sales, training and consulting, continuous monitoring and evaluation, office and laboratory (physical establishment) [61–64]. Each of the activities in the science and technology parks, in turn, has an impact on the success of startups and companies. Activities also affect each other. Which activity has the most impact on the success of corporations and science and technology parks? Managers and decision makers in the science and technology parks need to prioritize their activities in order to plan more accurately and to optimally manage their financial and human resources.

4.2. The Computational Steps of the Method.

Phase I: FIRSTLY, the new format of the activity model (fuzzy activity model), for science and technology parks in Iran, is shown in Figure 2. The most important

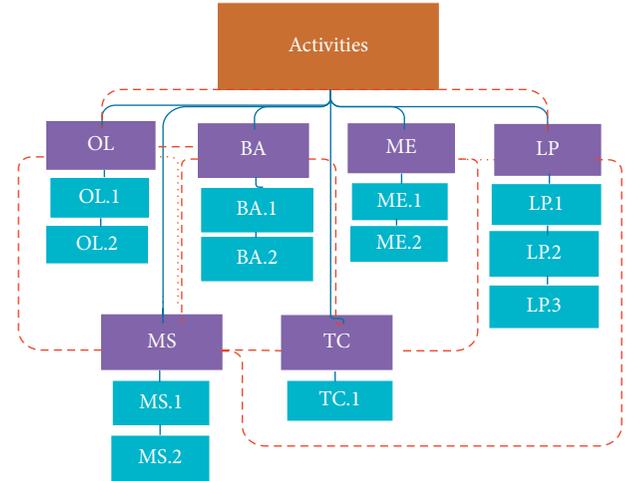


FIGURE 2: Fuzzy activity model: Iran's science and technology parks.

activities in science and technology parks of Iran include loan payment, branding and advertising, marketing and sales, training and consulting, continuous monitoring and evaluation, dedicated office and lab (physical establishment). Instead of the full name of the activity, its acronym is used as follows:

- (i) LP: loan payment
- (ii) BA: branding and advertising
- (iii) MS: marketing and sales
- (iv) TC: training and consulting
- (v) ME: monitoring and evaluation
- (vi) OL: office and lab

The dotted lines in Figure 2 indicate the fuzzy effect of activities on each other. For example, training and consulting (TC) activity affects marketing and sales (MS) and branding and advertising (BA), and vice versa. Additionally, the amount of this impact is fuzzy. In fact, the hierarchical activity diagram has become a network diagram. Therefore, to evaluate priority, a network model should be used.

Phase II: in this phase, taking into account the fuzzy activity model of Figure 2, we are asking experts for the priority and importance of each activity and sub-activity. The table for comparison of the fuzzy activity model (case study) is presented in Table 3. The next step is to normalize the pairwise comparison matrix of activities from Table 3 using (2).

By calculating the inconsistency rate of 0.014 by use of (22), the matrix of compiled paired matrices is consistent and less than 0.1. Table 4 is the normalized comparison matrix of activities using (2).

$$\text{C.R.} = \frac{\text{C.I.}}{\text{I.I.R}} = 0.014. \quad (22)$$

Phase III: the weights matrix is calculated. In fact, the output of the fuzzy ANP method is the weights matrix. To calculate the weight of each activity, we use the normalized matrix from phase II. The matrix of weights W_1 is calculated using (21).

TABLE 3: Comparison matrix of activities (geometric mean of expert opinions).

	OL			MS			BA			TC			ME			LP		
OL	1	1	1	3	4	5	2	3	4	3	4	5	1/5	2	2/5	7	8	8/5
MS	6	7	8	1	1	1	4	5	6	2	3	4	4	5	6	5	6	7
BA	7	8	8/5	6	7	8	1	1	1	4	5	6	2	3	4	8	9	9
TC	2	3	4	2	3	4	4	5	6	1	1	1	4	5	6	6	7	8
ME	7	8	8/5	6	7	8	4	5	6	6	7	8	1	1	1	7	8	8/5
LP	2	3	4	4	5	6	2	3	4	6	7	8	4	5	6	1	1	1

TABLE 4: Normalized matrix.

	OL			MS			BA			TC			ME			LP		
OL	1	1	1	0.07	0.1	0.12	0.05	0.07	0.1	0.07	0.1	0.12	0.04	0.05	0.06	0.17	0.2	0.21
MS	0.15	0.17	0.2	1	1	1	0.1	0.12	0.15	0.05	0.07	0.1	0.1	0.12	0.15	0.12	0.15	0.17
BA	0.17	0.2	0.21	0.15	0.17	0.2	1	1	1	0.1	0.12	0.15	0.05	0.07	0.1	0.2	0.22	0.22
TC	0.05	0.07	0.1	0.05	0.07	0.1	0.1	0.12	0.15	1	1	1	0.1	0.12	0.15	0.15	0.17	0.2
ME	0.17	0.2	0.21	0.15	0.17	0.2	0.1	0.12	0.15	0.15	0.17	0.2	1	1	1	0.17	0.2	0.21
LP	0.05	0.07	0.1	0.1	0.12	0.15	0.05	0.07	0.1	0.15	0.17	0.2	0.1	0.12	0.15	1	1	1

Phase IV: after calculating the normal matrix, the matrix of the total fuzzy relations (Table 5) is obtained according to (4)–(8). In these formulas, l is single matrix and H_l , H_m , and H_u are the lower number, middle number, and upper number of the fuzzy triangular numbers of the matrix H . Their results are presented in Tables 6–8, respectively. Table 9 shows the defuzzified matrix of fuzzy total relationship matrix. By use of the defuzzified matrix, internal dependency is calculated by (7) and (8). W_2 shows the internal dependency of fuzzy activity model of the case study as follows:

$$W_2 = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}. \quad (24)$$

Phase V: in this phase the final activities priorities are calculated by taking into account their interdependencies ($W_2 \times W_1$).

$$W_2 \times W_1 = \begin{pmatrix} 0.468 \\ 0.505 \\ 0.497 \\ 0.524 \\ 0.339 \\ 0.503 \end{pmatrix}. \quad (25)$$

$$w_1 = \begin{bmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \end{bmatrix} = \begin{bmatrix} 0.152464 \\ 0.165414 \\ 0.179198 \\ 0.157895 \\ 0.187135 \\ 0.157592 \end{bmatrix}. \quad (23)$$

According to the result, the priority of each activity is as follows: loan payment = 0.497, branding and advertising = 0.524, marketing and sales = 0.505, training and consulting = 0.524, monitoring and evaluation = 0.339, and office and lab = 0.468. Training and consulting activity has the most priority in the science and technology parks of Iran. Therefore, the decision makers of the organization should formulate their executive policies based on these priorities.

4.3. Discussion. After calculating the weight of the activities in phase III (W_1), we should examine which activities are more related to other activities. In fact, if one activity has the most weight among all activities but has no effect on other activities, it may not be the most important activity of the organization. In addition to the weight of the activity, the number of activities that are affected by this activity is also important. Therefore, in phase IV, we calculated the number of activities that are affected by each activity (W_2). Finally, in phase V, the priority of each activity is calculated by multiplying the internal dependency matrix (W_2) and its weight (W_1).

The proposed method is implemented in a real organization. The comparison matrix (Table 3) has been calculated based on the opinions of 153 business experts and managers of science and technology parks from different parts of Iran.

TABLE 5: Matrix of fuzzy total relationships.

	OL	MS	BA	TC	ME	LP												
OL	5.7	4	4.1	-2.3	-1.9	-1.4	0.8	-1.8	-1.4	-1.9	0.2	-0.3	-4.4	-3	-2.1	1.3	1.4	0.7
MS	2.8	3.2	2.3	7.4	6.6	5.3	-13.1	-1.2	-0.5	-0.7	-5.98	-4.1	6.8	-2.5	-2.8	-2.2	-1.6	-1.4
BA	2	2.4	0.9	1	0.4	0.3	4.8	4.9	4.6	-4.8	-5.0	-2.8	-5.3	-3.5	-4.3	0.1	-2.2	-0.7
TC	-5.4	-5.0	-4.4	-4.1	-3.8	-3.4	8	0.7	-0.5	4.0	-1	4.8	-5.0	0.7	2	-2.8	-2.4	-2.1
ME	1.3	-0.5	-0.4	-1.3	-1.4	-1.0	-1	-2.1	-1.6	-4.5	-1.7	-1.8	3.6	4	3.4	-4.1	-2.5	-2.4
LP	-5.3	-4.8	-3.7	-1.7	-1.7	-1.5	1.3	-1.4	-1.6	0.0	1.5	0.8	-0.7	1	1.2	2.0	2.5	2.1

TABLE 6: Generation of the l matrix of general relationships for activities.

	OL	MS	BA	TC	ME	LP
H_l						
OL	1	0.075	0.05	0.07	0.04	0.17
MS	0.15	1	0.1	0.05	0.1	0.12
BA	0.17	0.15	1	0.1	0.05	0.2
TC	0.05	0.05	0.1	1	0.1	0.15
ME	0.17	0.15	0.1	0.15	1	0.17
LP	0.05	0.1	0.05	0.15	0.1	1
$I-H_l$						
OL	0	-0.07	-0.05	-0.07	-0.04	-0.17
MS	-0.15	0	0.1	-0.05	-0.1	-0.12
BA	-0.17	-0.15	0	-0.1	-0.05	-0.2
TC	-0.05	-0.05	-0.1	0	-0.1	-0.15
ME	-0.17	-0.15	-0.1	-0.15	0	-0.17
LP	-0.05	-0.1	-0.05	-0.15	-0.1	0
$(I-H_l)^{-1}$						
OL	6.7	-2.3	0.84	-1.88	-4.4	1.26
MS	2.42	8.21	-14.31	0.28	7.84	-2.24
BA	2.05	0.98	5.83	-4.76	-5.34	0.1
TC	-5.42	-4.15	7.98	5.03	-5.05	-2.84
ME	1.34	-1.33	-0.99	-4.51	4.6	-4.17
LP	-5.3	-1.74	1.26	0.05	-0.	3.04
$H_l * (I-H_l)^{-1}$						
OL	5.7	-2.3	0.84	-1.88	-4.40	1.26
MS	2.83	7.40	-13.14	-0.67	6.77	-2.22
BA	2.05	0.98	4.83	-4.76	-5.34	0.1
TC	-5.42	-4.15	7.98	4.03	-5.05	-2.84
ME	1.34	-1.33	-0.99	-4.51	3.6	-4.17
LP	-5.3	-1.74	1.26	0.05	-0.66	2.04

TABLE 7: Generation of the m matrix of general relationships for activities.

	OL	MS	BA	TC	ME	LP
H_m						
OL	1	0.1	0.07	0.1	0.05	0.2
MS	0.17	1	0.12	0.07	0.12	0.15
BA	0.2	0.17	1	0.12	0.125	0.17
TC	0.07	0.07	0.12	1	0.12	0.17
ME	0.2	0.17	0.12	0.17	1	0.2
LP	0.07	0.12	0.07	0.17	0.12	1
$I-H_m$						
OL	0	-0.1	-0.07	-0.1	-0.05	-0.2
MS	-0.17	0	-0.12	-0.07	-0.12	-0.15
BA	-0.2	-0.17	0	-0.12	-0.12	-0.17
TC	-0.07	-0.07	-0.12	0	-0.12	-0.17
ME	-0.2	-0.17	-0.12	-0.17	0	-0.2
LP	-0.07	-0.12	-0.07	-0.17	-0.12	0
$(I-H_m)^{-1}$						
OL	4.96	-1.9	-1.78	0.25	-2.19	1.45
MS	3.17	7.6	-1.25	-5.98	-2.54	-1.63
BA	2.44	0.41	5.88	-5.01	-3.51	-2.26
TC	-5.05	-3.77	0.66	7.52	0.71	-2.4
ME	-0.54	-1.44	-2.13	-1.69	4.97	-2.52
LP	-4.84	-1.71	-1.38	1.53	0.99	3.49
$H_m * (I-H_m)^{-1}$						
OL	3.96	-1.9	-1.781	0.25	-2.19	1.45
MS	3.171	6.6	-1.25	-5.98	-2.539	-1.63
BA	2.441	0.41	4.88	-5.01	-3.509	-2.26
TC	-5.05	-3.771	0.66	6.521	0.711	-2.4
ME	-0.54	-1.441	-2.13	-1.691	3.971	-2.52
LP	-4.84	-1.712	-1.38	1.53	0.991	2.491

Implementation of the proposed method on science and technology parks in Iran has shown some facts in knowledge-based businesses in Iran. First, training and consulting in Iran's science and technology parks are top priorities. The reason for this is the lack of enough business education required for college courses. Knowledge-based business managers are generally engineering graduates. These courses do not teach business management skills, or perhaps these types of training are not compatible with market realities. Therefore, they need business skills. Training and consulting

on business skills have the most impact on the success of their businesses. Therefore, business education in universities should be given more attention.

Second, according to the results, marketing and sales activities have become the second priority in Iranian science and technology parks. The reason is clear. Iran's economy is an almost state-run economy. Science and technology parks in Iran are government agencies. A government agency like the science and technology park can better sell knowledge-based companies' products and services to large state-owned corporations.

TABLE 8: Generation of the u matrix of general relationships for activities.

	OL	MS	BA	TC	ME	LP
H_u						
OL	1	0.12	0.1	0.12	0.06	0.21
MS	0.2	1	0.15	0.1	0.15	0.17
BA	0.21	0.2	1	0.15	0.1	0.22
TC	0.1	0.1	0.15	1	0.2	0.21
ME	0.21	0.2	0.15	0.2	1	0.21
LP	0.1	0.15	0.1	0.2	0.15	1
$I-H_u$						
OL	0	-0.12	-0.1	-0.12	-0.06	-0.21
MS	-0.2	0	-0.15	-0.1	-0.15	-0.17
BA	-0.21	-0.2	0	-0.15	-0.1	-0.22
TC	-0.1	-0.1	-0.15	0	-0.2	-0.21
ME	-0.21	-0.2	-0.15	-0.2	0	-0.21
LP	-0.1	-0.15	-0.1	-0.2	-0.15	0
$(I-H_u)^{-1}$						
OL	5.13	-1.4	-1.42	-0.35	-2.12	0.68
MS	2.3	6.3	-0.55	-4.12	-2.78	-1.39
BA	0.9	0.31	5.65	-2.84	-4.29	-0.66
TC	-4.44	-3.4	-0.51	5.79	1.99	-2.13
ME	-0.4	-1.04	-1.59	-1.47	4.41	-2.45
LP	-3.75	-1.55	-1.57	0.79	1.19	3.1
$H_u * (I-H_u)^{-1}$						
OL	4.131	-1.401	-1.421	-0.349	-2.119	0.68
MS	2.301	5.299	-0.551	-4.119	-2.779	-1.391
BA	0.9	0.31	4.65	-2.839	-4.289	-0.661
TC	-4.439	-3.401	-0.511	4.791	1.991	-2.131
ME	-0.4	-1.04	-1.59	-1.469	3.411	-2.45
LP	-3.75	-1.55	-1.57	0.791	1.192	2.1

TABLE 9: Defuzzification of fuzzy total relationships.

	OL	MS	BA	TC	ME	LP
OL	4/44	-1/87	-1/04	-0/43	-2/72	1/21
MS	2/87	6/48	-4/05	-4/19	-0/27	-1/72
BA	1/96	0/53	4/81	-4/40	-4/16	-1/27
TC	-4/99	-3/77	2/20	1/71	-0/41	-2/44
ME	-0/03	-1/31	-1/71	-2/34	3/74	-2/91
LP	-4/68	-1/68	-0/77	0/97	0/63	2/28

5. Conclusion

This study suggests a novel fuzzy approach to evaluate the priority of activities in an organization. The activity model (OV-5) in C4ISR framework describes the activities and the relationship between them in a hierarchical format, and it cannot describe fuzzy relations and impact of activities. In the real world, the impact of activities on each other is fuzzy. Our goal was to prioritize activities in real and fuzzy conditions. Therefore, a new format was needed to describe activities in fuzzy conditions and in a network format.

Thus, a new fuzzy format for describing the activities of the organization is proposed in this paper. The activities described in this new format are then prioritized with the combined approach of fuzzy DEMATEL and fuzzy ANP methods with a little change. The proposed model was implemented in science and technology parks, one of the

new and pioneering organizations in Iran. Implementation of the proposed method on science and technology parks in Iran shows that training and consulting activity has the utmost priority.

The combined fuzzy ANP and fuzzy DEMATEL approaches used in this study offered a more precise and accurate analysis by integrating interdependent relationships within and between a set of activities. The use of fuzzy concepts brings modeling and end results closer to the real nature of organizations.

By use of this methodology in both current and developing organizations, more important activities will be given more attention by the managers and decision makers of the organizations.

To our knowledge, no previous work investigated such a problem by an integrated method with fuzzy DEMATEL and fuzzy ANP and using a new format for describing activities in a fuzzy environment.

Our proposed fuzzy method is comprehensive and applicable to all organizations that require prioritizing their activities in a fuzzy environment. However, the paper still has some limitations. For instance, activity charts of current organizations are described using standard and nonfuzzy formats [2, 35]. Therefore, a new model that can prioritize the activities of the organization without the need to redesign the activity model (OV-5) can be very applicable. The combination of AHP [65] and DEMATEL [28] can be a good solution. Moreover, prioritization of activities is a kind of multiple criteria decision-making (MCDM) problem. Another possible and interesting direction is further research to develop new models for actual group decision-making problems under a social network [18, 20–22] and large-scale group decision-making problems [23, 24] with fuzzy ANP [27] and fuzzy DEMATEL [28].

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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