A HYBRID APPROACH OF
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AND DEMATEL METHOD TO PRIORITIZE
SELECTION CRITERIA OF BANK
BRANCHES LOCATIONS

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A HYPYDE APPROACH OF INTUITIONISTIC FUZZY SET THEORY
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Abstract
Optimally locating new bank branches is a strategic decision in banking industry in order to stay competitive. The
importance of this issue is primarily due to the fact that locating branches in appropriate sites is one of the main
factors in absorbing and satisfying bank customers. This results in a core benefit for banks, particularly in a vibrant
competition. In addition, without a set of well-chosen selection criteria and their prominence, the goal of locating
suitable sites for bank branches would not be efficiently achieved. In this research, six most widely used criteria for
bank branch location consideration are obtained from the literature review. These criteria include demographic
attributes, access to public facilities, transportation, competition, cost and flexibility. In order to prioritize these
criteria, an integrated methodology of the intuitionistic fuzzy set theory as well as Decision Making Trial and
Evaluation Laboratory Model (DEMATEL) technique (i.e. IFDEMATEL) are utilized. The DEMATEL technique
considers interrelationships between criteria. Furthermore, the intuitionistic fuzzy set theory, which has some
advantages over fuzzy set theory, to include the vagueness and imprecision of subjective judgments of specialists is
applied. As a case study, a well-known Iranian public bank in the city of Rasht, Iran is considered. Consequently,
the obtained ranks from the integrated method provide useful information for bank managers in determining
efficient locations of their new branches.

Keywords
Bank Location, DEMATEL, Intuitionistic fuzzy set theory, Fuzzy set theory, Multi-attribute decision making
(MADM)

Introduction
Recently, banking services have experienced noteworthy developments which lead to changes in the organization of
banks. Competitive environment of banking industry results in a more convoluted location network of bank
branches (Miliotis, 2002). Furthermore, growing information technology and widespread usage of online banking
makes the decision of bank branch locations a more significant and complicated task for banking specialists (Allahi,
Mobin, Vafadarnikjoo & Salmon, 2015; Turetken, 2008).

Deposit amounts and consequently banking profits can be greatly influenced by a bank branch’s location. Han & Dai
(Han & Dai, 2013) cited that physical bank outlet is a vital criterion in the bank marketing. Moreover, the volume of deposits which is closely related to potential target customers and per capita income levels are crucial
components to locate new branches and to assess branch performance (Boufounou, 1995; Han & Dai, 2013). Several
researchers have indicated that loss and profit of banks are considerably connected to the locations and number of bank branches in the area. Geographic reach (having branches in many states and cities) and local branch density (having many branches of a bank in a given region) were introduced as two significant factors for customers (Dick, 2008). Considering the fact that banking has changed significantly with the onset of online banking in developed countries, geographic bank location is still a crucial decision to make in many developing countries. According to a market survey in 2001, nearly 39% of bank customers choose their bank mainly owing to its location (Fung, 2001). Those decision making problems with geographical information are called location decisions, which are a major part of location science. Some application fields of location science include public facilities, private facilities, military environment and business areas (Farahani, Steadiesefi & Asgari, 2010).

A great number of studies have utilized MADM in location selection problems. Here some of them are mentioned: In 2005, the analytic network process (ANP) was employed to select the best location for a shopping mall (Cheng, Li & Yu, 2005). In another study, a hybrid methodology of the analytic hierarchy process (AHP) and VIKOR (Višekriterijumsko KOmpromisno Rangiranje) was introduced to solve the plant location selection problem (Tavakkoli-Moghaddam, Heydar & Mousavi, 2011). Locating an undesirable facility is a complex problem, which was addressed in a research article utilizing ANP (Tuzkaya, Önüt, Tuzkaya & Gilsün, 2008). In another research article, the AHP was applied to rank potential restaurant locations in Taipei, considering 11 criteria within five aspects of transportation, commercial area, economic, competition and environment (Tzeng, Teng, Chen & Opricovic, 2002). More recently, an intuitionistic fuzzy DEMATEL methodology was utilized in order to prioritize the components of SWOT matrix in the Iranian insurance industry (Nikjoo & Saeedpoor, 2014). In another research article, an intuitionistic fuzzy DEMATEL method was applied in the field of green supply chain management (GSCM), so as to develop green practices and performances in GSCM (Govindan, Khodaverdi & Vafadarnikjoo, 2015).

MADM methods in prioritizing criteria for bank branches location selection have not been utilized sufficiently in the literature. Only the study of Han & Dai (2013) was seen where they took the advantage of fuzzy AHP and applied it in China. Thus, the hybrid IFDEMATEL as a multi-attribute group decision making (MAGDM) method is used in this study to fill this lack of study gap and compare the outcomes from an application case in Iran. This method has been applied in the prioritization of criteria for bank branches location selection problem in an Iranian bank case study. In the next part of the article both fuzzy set and intuitionistic fuzzy set theories are explained. Afterwards, the explication of the DEMATEL technique is presented before the IFDEMATEL is introduced. The application of the method in an Iranian bank is elaborated in the next section and ultimately results and concluding remarks are discussed in the final section.

**Fuzzy and Intuitionistic Fuzzy Set Theories**

**Fuzzy Set Theory**

In the practical decision-making environment, it is common that experts or Decision Makers (DMs) express their opinions on a qualitative criterion in linguistic terms rather than crisp values on the basis of their experience. These assessments are opaque and make difficulties to perform further analysis. Thus, Fuzzy Set (FS) theory can be applied to deal with ambiguous concepts of people’s subjective decision. Fuzzy set theory was proposed by Zadeh (1965) to deal with obscure opinions of humans’ subjective decisions in order to solve real-world complex systems (Lai & Hwang, 1995). Each member of a fuzzy set has a degree of membership and a membership function, which is a real number between zero and one. Imprecise reasoning can be accomplished and experts’ opinions from disparate subjects can be acquired easily with the help of fuzzy logic, which is derived from fuzzy set theory. Triangular Fuzzy Number (TFN) is the most popular shapes between the various shapes of fuzzy number. Some important definitions and notations of fuzzy set theory are described as follows (Zadeh, 1965; Zadeh, 1976; Zimmermann, 2001):

Definition 1: A triplet $(a, b, c)$ in which $a \leq b \leq c$ represents a triangular fuzzy number. Each value of $a$, $b$ and $c$, indicates the smallest, the medium and the largest possible value respectively, which defines a fuzzy occurrence. The membership function of the fuzzy number is defined as Equation (1) (see Exhibit 1):

\[
f_A(x) = \begin{cases} 
0 & x < a, x > c \\
\frac{x-a}{b-a} & a \leq x \leq b \\
\frac{c-x}{c-b} & b \leq x \leq c 
\end{cases} \tag{1}
\]
Definition 2: Let $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. Then the main arithmetic operations of them are as Equations (2)-(5) (Vafadarnikjoo, 2014; Lee, 2005):

$$\tilde{A} - \tilde{B} = (a_1 - b_1, a_2 - b_2, a_3 - b_3)$$  \hspace{1cm} (2)

$$\tilde{A} + \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$$  \hspace{1cm} (3)

$$\tilde{A} \times \tilde{B} = (a_1 b_1, a_2 b_2, a_3 b_3)$$  \hspace{1cm} (4)

$$\tilde{A} \div \tilde{B} = (a_1 / b_1, a_2 / b_2, a_3 / b_3)$$  \hspace{1cm} (5)

**Intuitionistic Fuzzy Set Theory**

An extensive number of researches have been conducted in fuzzy related areas since the introduction of fuzzy sets theory by Zadeh in 1965. A significant extension of FS theory is Intuitionistic Fuzzy Sets (IFS) theory which was proposed by Atanassov in 1986. IFS theory is characterized by a membership function and a non-membership function and compared to FS theory has some advantages, which can be utilized in MADM application area in order to achieve more valid results. In IFSs, it can be possible to model unknown information taking advantage of degree of hesitation. In fact, in IFSs, it is possible to consider hesitancy degree of decision makers that is very common in practical decision making problems in which DMs cannot easily express preference for an alternative. IFSs can bring about more comprehensive outcomes as they are able to depict the vagueness of agreement, disagreement and hesitation of a DM (Liu & Wang, 2007; Xu & Liao, 2013; Govindan, Khodaverdi & Vafadarnikjoo, 2015). The basic concepts of IFS theory is elaborated as follows (Nikjoo & Saeedpoor, 2014; Govindan, Khodaverdi & Vafadarnikjoo, 2015):

Definition 3: Given $X$ is a fixed set then an IFS $A$ in $X$ would be shown as Equation (6) (Atanassov, 1986):

$$A = \left\{ (x, \mu_A(x), \nu_A(x)) | x \in X \right\}$$ \hspace{1cm} (6)

The membership degree of the element $x \in X$ to the set $A$ (i.e. $\mu_A(x): X \rightarrow [0,1]$) and non-membership degree of the element $x \in X$ to the set $A$ (i.e. $\nu_A(x): X \rightarrow [0,1]$), considering the condition $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ , $x \in X$ are represented in Equation (6). The hesitancy degree of $x \in X$ to $A$, which is shown as $\pi_A(x)$, where $0 \leq \pi_A(x) \leq 1$, $x \in X$, is defined as Equation (7):

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x), \hspace{1cm} x \in X,$$ \hspace{1cm} (7)

Definition 4: An intuitionistic trapezoidal fuzzy number $A$ with parameters $b_1 \leq a_1 \leq b_2 \leq a_2 \leq a_3 \leq b_3 \leq a_4 \leq b_4$ is represented as $A = ((a_1, a_2, a_3), (b_1, b_2, b_3, b_4))$ in the set of real numbers $\mathbb{R}$. Membership function and non-membership function of the number $A$ are as Equations (8)-(9) (Nehi & Maleki, 2005).

$$\mu_A(x) = \begin{cases} 
0 & x < a_1 \\
\frac{x-a_1}{a_2-a_1} & a_1 \leq x \leq a_2 \\
1 & a_2 \leq x \leq a_3 \\
\frac{x-a_3}{a_4-a_3} & a_3 \leq x \leq a_4 \\
0 & a_4 < x 
\end{cases}$$ \hspace{1cm} (8)

$$\nu_A(x) = \begin{cases} 
1 & x < a_1 \\
\frac{a_2-x}{a_2-a_1} & a_1 \leq x \leq a_2 \\
0 & a_2 \leq x \leq a_3 \\
\frac{a_4-x}{a_4-a_3} & a_3 \leq x \leq a_4 \\
1 & a_4 < x 
\end{cases}$$ \hspace{1cm} (9)
In the case of \( b_2 = b_3 \) and \( a_2 = a_3 \), an intuitionistic trapezoidal fuzzy number \( A \) transforms to an intuitionistic triangular fuzzy number. In Exhibit 1, an intuitionistic trapezoidal fuzzy number is shown. If \( A_1 = ((a_1, a_2, a_3, a_4), (b_1, b_2, b_3, b_4)) \) and \( A_2 = ((c_1, c_2, c_3, c_4), (d_1, d_2, d_3, d_4)) \) are two intuitionistic trapezoidal fuzzy numbers and \( k > 0 \), then the following properties are resulted (Nehi & Maleki, 2005):

\[
A_1 + A_2 = \left((a_1 + c_1, a_2 + c_2, a_3 + c_3, a_4 + c_4), (b_1 + d_1, b_2 + d_2, b_3 + d_3, b_4 + d_4)\right) \tag{10}
\]

\[
kA_1 = \left((ka_1, ka_2, ka_3, ka_4), (kb_1, kb_2, kb_3, kb_4)\right) \tag{11}
\]

Theorem 1: Let \( A = ((a_1, a_2, a_3, a_4), (b_1, b_2, b_3, b_4)) \) be an intuitionistic trapezoidal fuzzy number in the set of real numbers \( R \). Its expected value is calculated by Equation (12) when \( \frac{x-a_1}{a_2-a_1}, \frac{x-a_4}{a_3-a_4}, \frac{x-b_2}{b_1-b_2}, \frac{x-b_4}{b_3-b_4}, b_1 \leq a_1 \leq b_2 \leq a_2 \leq a_3 \leq b_3 \leq a_4 \leq b_4 \in R \) (Grzegorzewski, 2003).

\[
EV(A) = \frac{1}{8} \left(a_1 + a_2 + a_3 + a_4 + b_1 + b_2 + b_3 + b_4\right) \tag{12}
\]

**Exhibit 1. Membership Functions of an Intuitionistic Trapezoidal Fuzzy Number (a) and a TFN (b).**

**DEMATEL Technique**

DEMATEL method is built on a foundation of graph theory specifically directed graph known as digraph, which enables DMs to analyze and resolve problems through visualization method. These graphs are more useful compared to directionless graphs owing to this fact that they are able to represent the directed links of sub-systems. In order to deal with complicated issues, the DEMATEL method was developed between 1972 and 1976. This method puts all factors into two distinct categories called "cause" and "effect" by applying influence values between factors. This categorization leads to a more thorough understanding of system’s elements and as a result finding solutions to resolve complex system’s problems. In DEMATEL, "factors" or "criteria" are defined the same, both are elements that a DM is keen on determining the interrelationships between them by setting up a pair-wise relation matrix. Steps of this method are explained as follows (Wu & Lee, 2007; Nikjoo & Saeedpoor, 2014; Vafadarnikjoo, Mobin, Salmon & Javadian, 2015):

Step 1: The direct relation matrix should be generated. The matrix \( A_{n \times m} \) can be achieved by pair-wise comparisons between criteria that is carried out by an expert team and each element of this matrix \( a_{ij} \) represents the impact value of criterion \( i \) on criterion \( j \). The influence of criterion (factor) \( i \) on a criterion (factor) \( j \) means how increase/decrease in \( i \) can increase/decrease in \( j \).
Step 2: The direct relation matrix should be normalized by using Equations (13) and (14):

\[ X = k \times A \]

\[ k = \frac{1}{\max \sum_{j=1}^{n} a_{ij}} \quad 1 \leq i \leq n \]  

Step 3: The total relation matrix should be produced by Equation (15) in which \( I \) is the identity matrix.

\[ T = X(I - X)^{-1} \]  

Step 4: A causal diagram is generated. By applying Equations (16)-(18), sum of rows \( (D) \) and sum of columns \( (R) \) are calculated according to matrix \( T \). Value of \( D \) of a factor is its influential impact on others. Value of \( R \) is an impact the factor receives from others (Lin, 2013).

\[ T = \begin{bmatrix} t_{ij} \end{bmatrix}_{nxn} \quad i, j = 1,2,\ldots,n \]  

\[ R = \begin{bmatrix} \sum_{i=1}^{n} t_{ij} \end{bmatrix}_{nxn} = \begin{bmatrix} r_{i} \end{bmatrix}_{nx1} \]  

\[ D = \begin{bmatrix} \sum_{j=1}^{n} t_{ij} \end{bmatrix}_{nx1} = \begin{bmatrix} d_{i} \end{bmatrix}_{nx1} \]

Where \( (D+R) \) represents the horizontal axis vector, which is called "prominence", this indicates the relative importance of each criterion. \( (D-R) \) is named "relation". In general, If \( (D-R) > 0 \) the criterion is a member of cause group; and If \( (D-R) < 0 \), the criterion is a member of effect group. Cause factors have impact on the entire system. Their performance can influence on the overall goal. Moreover, criteria in cause group should be paid more attention. Effect factors are tended to be easily impacted by others, which causes factors in effect group inappropriate to be a critical success factor (Lin, 2013).

Step 5: The inner dependence matrix is attained. In total relation matrix, the sum of each column would be equal to 1 by the normalization method after which the inner dependence matrix can be resulted.

The Intuitionistic Fuzzy DEMATEL Technique (IFDEMATEL)

In this section, the IFDEMATEL methodology will be explained that can be applied in a given decision making problem. In Exhibit 2, the framework of the IFDEMATEL is summarized.

**Exhibit 2. The Framework of the IFDEMATEL.**

- Identifying the expert team
- Determining criteria
- Determining interrelations between criteria
- Replacing the linguistic information with IFNs
- Constructing the causal diagram
- Decision Making

Step 1: Setting up an expert team: It is necessary to set up a team of experts in order to make pair-wise comparisons between criteria (factors) taking advantage of their experience and knowledge.

Step 2: Developing decision making criteria: On the basis of literature review and experts' judgements, some decision making criteria can be determined. In every decision making problem, a number of criteria is needed to evaluate alternatives.

Step 3: Determining the interrelation between criteria: In this step, experts will determine the interrelationship between criteria utilizing a five-point linguistic rating scale as shown in Exhibit 3. It reveals the impact value of each criterion on the other criterion.

<table>
<thead>
<tr>
<th>Linguistic phrases</th>
<th>Influence score</th>
<th>Intuitionistic trapezoidal fuzzy numbers</th>
<th>Expected Crisp Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No influence</td>
<td>0</td>
<td>(0,0,0,0), (0,0,0,0)</td>
<td>0</td>
</tr>
<tr>
<td>Very Low influence</td>
<td>1</td>
<td>(0.0.1,0.20.3), (0.0,1.0,20.3)</td>
<td>0.15</td>
</tr>
<tr>
<td>Low influence</td>
<td>2</td>
<td>(0.3,0,4,05.06), (0.2,0,4,05.07)</td>
<td>0.45</td>
</tr>
<tr>
<td>High influence</td>
<td>3</td>
<td>(0.7,0.8,09.1), (0.7,0.8,09.1)</td>
<td>0.85</td>
</tr>
<tr>
<td>Very high influence</td>
<td>4</td>
<td>(1,1,1,1), (1,1,1,1)</td>
<td>1</td>
</tr>
</tbody>
</table>

Step 4: Replacing the linguistic information with intuitionistic fuzzy linguistic scale: Intuitionistic trapezoidal fuzzy numbers are used (as represented in Exhibit 3) to replace the linguistic information in the initial relation matrix after which Equation (12) is utilized to obtain crisp values. In Exhibit 3, the expected crisp value corresponding to each intuitionistic trapezoidal fuzzy number is shown. Due to the fact that each expert has their own fuzzy importance weight ($W_p$) (See Exhibit 4) considering Equations (2)-(5), the fuzzy aggregated impact value of criterion $i$ on criterion $j$ of the n experts ($\tilde{a}_{ij} = (a_1, a_2, a_3)$) can be calculated utilizing Equation (19):

$$\tilde{a}_{ij} = \frac{\sum_{p=1}^{n} W_p Z_{ij}^p}{\sum_{p=1}^{n} W_p}$$  \hspace{1cm} (19)

In Equation (19), $Z_{ij}^p$ is the crisp value of impact of criterion $i$ on criterion $j$ assessed by expert $p$ (according to the chosen intuitionistic trapezoidal fuzzy numbers, it can be 0, 0.15, 0.45, 0.85 or 1; see the last column in Exhibit 3). Finally, using Equation (20) the crisp aggregated impact value of criterion $i$ on criterion $j$ (i.e. $a_{ij}$) will be achieved:

$$a_{ij} = \frac{a_{1} + a_{2} + a_{3}}{3}$$  \hspace{1cm} (20)


<table>
<thead>
<tr>
<th>Linguistic Variable</th>
<th>Triangular Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>(0.0, 0.1, 0.3)</td>
</tr>
<tr>
<td>Low (L)</td>
<td>(0.1, 0.3, 0.5)</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>(0.3, 0.5, 0.7)</td>
</tr>
<tr>
<td>High (H)</td>
<td>(0.5, 0.7, 0.9)</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>(0.7, 0.9, 1.0)</td>
</tr>
</tbody>
</table>

Step 5: Constructing the causal diagram: The total relation matrix will be resulted using Equations (13)-(15). The D value of a criterion is its influential impact on others and can be computed using Equations (16) and (18). The R value is an influence the criterion receives from others and can be calculated utilizing Equations (16)-(17). In order to construct the causal diagram the dataset of ($D + R, D - R$) should be mapped. This diagram puts forward a view into the comprehension of the whole system.

Case Study: Applying the IFDEMATEL Method in an Iranian Public Bank

In order to prioritize the selection criteria of bank branches location, an Iranian public bank has been chosen as an application of the IFDEMATEL method.

Step 1: Setting up an expert team: Some background on our experts are provided, which can set the stage for insights into later steps of our method when assigning importance weights to experts (as shown in Exhibit 5). Expert 1 has 11 years of work experience in banking at top-level management and evaluating construction plans. He earned a master degree in management and his age is between 30-35 years old. Expert 2 has 21 years of work experience in banking at top-level management and evaluating construction plans. He earned a master degree in management and his age is between 30-35 years old. Expert 3 has 16 years of work experience in banking at top-level management and evaluating construction plans. He earned a master degree in management and his age is between 30-35 years old. Expert 4 has 18 years of work experience in banking at top-level management and evaluating construction plans. He earned a master degree in management and his age is between 30-35 years old.
experience in banking at middle-level management with a bachelor's degree in accounting and his age is between 46-50 years old. Expert 3 has 25 years of work experience in banking that nearly 11 years of which he did service as a bank manager. He earned a diploma in Economics and his age is between 46-50 years old. Expert 4 is an accounting specialist in the fields of foreign exchange operations and marketing with 21 years of work experience. He has a bachelor's degree in accounting and his age is between 41-45 years old. The fuzzy importance weight of each expert is defined according to educational background, field of experience, work experience duration, organizational level and age (see Exhibit 5).

**Exhibit 5. Fuzzy Importance Weights of Experts.**

<table>
<thead>
<tr>
<th>Experts</th>
<th>Linguistic Variable</th>
<th>Triangular Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td>H</td>
<td>(0.5, 0.7, 0.9)</td>
</tr>
<tr>
<td>Expert 2</td>
<td>M</td>
<td>(0.3, 0.5, 0.7)</td>
</tr>
<tr>
<td>Expert 3</td>
<td>H</td>
<td>(0.5, 0.7, 0.9)</td>
</tr>
<tr>
<td>Expert 4</td>
<td>VH</td>
<td>(0.7, 0.9, 1.0)</td>
</tr>
</tbody>
</table>

Step 2: Developing decision making criteria: On the basis of prior research works, six most widely used criteria for bank branch location consideration are obtained which are demographic attributes (C1), access to public facilities (C2), transportation (C3), competition (C4), cost (C5) and flexibility (C6). Demographic attributes (C1) includes customers' income and population density of the region. Access to public facilities (C2) includes proximity to public parking, market centers, hospitals, hotels, restaurants, local markets, public/private offices and companies. Transportation (C3) includes proximity to squares, junctions and city center. Competition (C4) includes proximity to branches of competitors. Cost (C5) includes cost of construction/purchase/rent of the site (ground). Flexibility (C6) includes existence of ground and facilities for development (Allahi, Mobin, Vafadarnikjoo & Salmon, 2015; Miliotis, 2002; Bofounou, 1995; Cebi & Zeren, 2008; Min, 1989; Yang & Lee, 1997).

Step 3: Determining interrelation between criteria: Our experts determined the interrelationships between six criteria for bank branch location problem. For instance the opinions of expert 4 is shown in Exhibit 6.

**Exhibit 6. The Expert 4 Opinions of Interrelationship between Criteria.**

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C5</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Step 4: Replacing the linguistic information with intuitionistic fuzzy linguistic scale: In this step the linguistic information of each expert's opinion is replaced with intuitionistic trapezoidal fuzzy numbers and the expected crisp values are obtained. In Exhibit 7, the replaced pair-wise comparison matrix of expert 4 is shown as an instance. Finally, the aggregated opinion of all four experts considering their fuzzy importance weights are calculated and shown in Exhibit 8.

Step 5: Constructing the causal diagram: The total relation matrix is constructed (Exhibit 9). According to Exhibit 9, the \((D + R)\) or prominence vector and \((D - R)\) or relation vector are achieved and shown in Exhibit 10.

By mapping the dataset of \((D + R, D - R)\) the causal diagram is resulted as depicted in Exhibit 11. The vectors show the relation vector \((D - R)\) as it is clear C2 has the highest rank in \((D - R)\) and the vectors are depicted from C2 to the other five criteria.

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.00</td>
<td>0.15</td>
<td>0.00</td>
<td>0.15</td>
<td>0.15</td>
<td>0.45</td>
</tr>
<tr>
<td>C2</td>
<td>0.85</td>
<td>0.00</td>
<td>0.45</td>
<td>0.85</td>
<td>0.45</td>
<td>0.15</td>
</tr>
<tr>
<td>C3</td>
<td>0.85</td>
<td>0.45</td>
<td>0.00</td>
<td>0.45</td>
<td>0.85</td>
<td>0.45</td>
</tr>
<tr>
<td>C4</td>
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<td>0.15</td>
<td>0.15</td>
<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
</tr>
<tr>
<td>C5</td>
<td>0.00</td>
<td>0.85</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>C6</td>
<td>0.15</td>
<td>0.45</td>
<td>0.45</td>
<td>0.85</td>
<td>0.15</td>
<td>0.00</td>
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</tbody>
</table>

Exhibit 8. Average of all Experts' Opinions Considering Their Relative Fuzzy Weights.

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.00</td>
<td>0.6015</td>
<td>0.6938</td>
<td>0.4585</td>
<td>0.4892</td>
<td>0.4763</td>
</tr>
<tr>
<td>C2</td>
<td>1.0139</td>
<td>0</td>
<td>0.8073</td>
<td>0.8399</td>
<td>0.9199</td>
<td>0.7449</td>
</tr>
<tr>
<td>C3</td>
<td>0.7046</td>
<td>0.7654</td>
<td>0</td>
<td>0.7037</td>
<td>0.8399</td>
<td>0.7651</td>
</tr>
<tr>
<td>C4</td>
<td>0.6015</td>
<td>0.3206</td>
<td>0.6130</td>
<td>0</td>
<td>0.2810</td>
<td>0.4892</td>
</tr>
<tr>
<td>C5</td>
<td>0.4550</td>
<td>1.0139</td>
<td>0.5926</td>
<td>0.1686</td>
<td>0</td>
<td>0.4574</td>
</tr>
<tr>
<td>C6</td>
<td>0.3206</td>
<td>0.4139</td>
<td>0.6730</td>
<td>0.6968</td>
<td>0.6632</td>
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</tbody>
</table>

Exhibit 9. The Total Relation Matrix.

<table>
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<tr>
<th></th>
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<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.2938</td>
<td>0.4185</td>
<td>0.4523</td>
<td>0.3688</td>
<td>0.4052</td>
<td>0.3791</td>
</tr>
<tr>
<td>C2</td>
<td>0.6194</td>
<td>0.4334</td>
<td>0.6159</td>
<td>0.5570</td>
<td>0.6152</td>
<td>0.5520</td>
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<tr>
<td>C3</td>
<td>0.5217</td>
<td>0.5390</td>
<td>0.4109</td>
<td>0.4941</td>
<td>0.5585</td>
<td>0.5147</td>
</tr>
<tr>
<td>C4</td>
<td>0.3664</td>
<td>0.3167</td>
<td>0.3876</td>
<td>0.2298</td>
<td>0.3154</td>
<td>0.3359</td>
</tr>
<tr>
<td>C5</td>
<td>0.4048</td>
<td>0.5064</td>
<td>0.4472</td>
<td>0.3279</td>
<td>0.3210</td>
<td>0.3876</td>
</tr>
<tr>
<td>C6</td>
<td>0.3574</td>
<td>0.3807</td>
<td>0.4429</td>
<td>0.4059</td>
<td>0.4291</td>
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</table>

Exhibit 10. The Prominence (D + R) and Relation (D-R) Vectors.

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>R</th>
<th>D+R</th>
<th>D+R rank</th>
<th>D-R</th>
<th>D-R rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>2.3177</td>
<td>2.5634</td>
<td>4.8811</td>
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<td>4</td>
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<tr>
<td>C2</td>
<td>3.3930</td>
<td>2.5946</td>
<td>5.9876</td>
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<td>0.7983</td>
<td>1</td>
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<tr>
<td>C3</td>
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</tr>
<tr>
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<td>2.3835</td>
<td>4.3353</td>
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<td>-0.4317</td>
<td>6</td>
</tr>
<tr>
<td>C5</td>
<td>2.3948</td>
<td>2.6445</td>
<td>5.0394</td>
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<td>-0.2497</td>
<td>5</td>
</tr>
<tr>
<td>C6</td>
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<td>2.4438</td>
<td>4.7342</td>
<td>5</td>
<td>-0.1533</td>
<td>3</td>
</tr>
</tbody>
</table>

Exhibit 11. The Causal Diagram.
Results and Concluding remarks
Taking into consideration Exhibits 10 and 11, only two criteria: access to public facilities (C2) and transportation (C3) belonged to the cause group due to their positive scores in \(D - R\) and the remaining criteria belonged to effect group as their \(D - R\) scores were negative. It was also apparent that access to public facilities (C2) had the first rank, transportation (C3) had the second rank, demographic attributes (C1) had the fourth rank and competition (C4) had the sixth rank in both \(D + R\) and \(D - R\) rankings. As a result, their prioritizations were determined. Ranks of two criteria cost (C5) and flexibility (C6) came into conflict. Cost (C5) stood at third and fifth levels in \(D + R\) and \(D - R\) rankings respectively whereas on the other hand, flexibility (C6) was exactly opposite. To resolve this issue a priority is assigned to \(D + R\) ranking as their \(D - R\) scores were almost the same with subtle difference as can be seen in the causal diagram (Exhibit 12). Ultimately, the final prioritization of the six criteria is as follows: access to public facilities (C2)\(\rightarrow\) transportation (C3)\(\rightarrow\) cost (C5)\(\rightarrow\) demographic attributes (C1)\(\rightarrow\) flexibility (C6)\(\rightarrow\) competition (C4).

The resulted ranks obtained from the integrated IFDEMATEL method provided useful information for bank managers in determining efficient locations of their new branches. It was concluded that access to public facilities (C2) was the most critical criterion, which must be taken into consideration by bank branch locations DMs. The other five criteria that played key roles in finding congenial sites for new bank branches were transportation (C3), cost (C5), demographic attributes (C1), flexibility (C6) and competition (C4) respectively. In the research of Han and Dai (2013) the competitor factors (competitor numbers and type of service products) were defined as the two most significant criteria for the location of bank outlets in China. These results are in line with the results of our study. The outcome of this research was on the basis of four expert opinions of a public Iranian bank, so the result would not be easily generalized to all other banking environments, but the IFDEMATEL methodology has the ability to be a useful decision making tool for banking DMs worldwide to find new bank branches locations efficiently. Furthermore, the proposed approach may be easily applied in other manufacturing and service industries to locate different facilities, e.g. warehouses, distribution centers, stores, etc., considering various set of criteria.

References


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