Iranian Journal of Management Studies (IJMS)
Vol.4, No.2, September 2011
pp: 5-28

The Applying ISM/FANP Approach for Appropriate Location Selection of Health Centers

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(Received: 1 January 2011; Revised: 4 June 2011; Accepted: 9 June 2011)

Abstract

The main purpose of this paper is to present a fuzzy multi-criteria decision making (FMADM) model for appropriate location selection of a health center. Therefore, we identify sixteen criteria and sub-criteria for selecting a health center location. These criteria and sub-criteria have been obtained from literature reviews and practical interviews. This paper proposes a method which combines the methods of the interpretive structural modeling (ISM) and the fuzzy analytic network process (FANP) procedures to deal with the problem of the sub-systems interdependence and feedback. Also the methods of fuzzy set theory, fuzzy analytic hierarchy process and fuzzy analytical network process are used to combine decision-makers' assessments about criteria weightings. Finally, an empirical study for the location selection of a health center in Ramsar is conducted to demonstrate the computational process and effectiveness of FMADM proposed by this paper.

Keywords:

Location Selection, Fuzzy Analytical Network Process, Interpretive Structural Modeling.

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Introduction

Location theory was first introduced by Weber, who considered the problem of locating a single warehouse in order to minimize the total travel distance between the warehouse and a set of spatially distributed costumers. Indeed, he proposed a material index for the selection of the location which if this index is greater than one, the warehouse should be installed in the vicinity of the source of raw material; otherwise it must be near to the market (Brandeau and Chiu, 2001). Isard reconsidered this work with the study of the industrial location, land use, and the related problems (Isard, 2001). Hotelling introduced another early location problem that considered the problem of locating two competing vendors along a straight line (Hotelling, 2003). Hakimi considered the general problem of locating one or more facilities on a network to minimize the sum of the distances and the maximum distance between facilities and points on a network (Hakimi, 2004). Considerable research and theoretical interest in the location problem has been carried out after this seminal paper. Later, a primary facility location model was proposed for a multidimensional location problem based on critical factors, objective factors and subjective factors by Brown and Gibson and Buffa and Sarin (Brown and Gibson 1972, Buffa and Sarin, 1987). Fortenberry and Mitra presented a model for the location-allocation problems considering both qualitative and quantitative factors (Fortenberry and Mitra, 1986). Kahne considered twenty nine attributes and used a weighting model to determine the relative importance with uncertainty in attributes (Kahne, 1975). Charnetski proposed the case of selecting one of the three proposed sites for a modern air terminal with a large number of attributes (Charnetski, 1976). Bahattacharya proposed a holistic method for the facility location selection based on the ones presented by Brown and Gibson (Bhattacharya and et al., 2004).

Location selection is a multi-criteria decision-making (MCDM) problem. To solve this problem, Wu applied FANP to the practical problem of hospital location selection (Wu and et al., 2007). Conceptually, the location selection problem involves interdependencies between elements of the same cluster or different clusters (Fernandez and et al., 2009). The ANP proposed by Saaty can assess multidirectional relationships among decision elements (Saaty, 1980). The ANP is a comprehensive decision-making technique that captures the outcome of dependence and feedback within and between clusters of elements. ANP involves a combination of two parts, where the first comprises a control hierarchy or a network of criteria and sub-criteria that controls the interactions, the second part comprises a network of influences among the elements and clusters. Whereas AHP represents a framework based on a unidirectional hierarchical relationship, ANP permits more complex interrelationships among decision levels and attributes. Not only do the importances of the criteria determine the importance of the alternatives as in a hierarchy, but the importance of the alternatives may also influence the importance of criteria (Saaty, 1980). This study empirically examines the location selection assessment criteria and their relationships for a new health center.

Literature Review

Location selection theory put forth by Weber proposed the position problems of a factory (Brandeau and Chiu, 2001). Later, a primary facility location model by Brown and Gibson and Buffa and Sarin (Brown and Gibson, 1972; Buffa and Sarin, 1987) Mohanty and et al. (2005) suggested that decision-making related to plant location is based on local labor markets, access to customer and supplier markets, availability of development sites, facilities and infrastructure, transportation, education and training opportunities, quality of life, business climate, access to R&D facilities, capital availability, taxes and regulations. Wu and et al. (2007) used the Porter's diamond model and applied AHP to solve the practical problem of hospital location selection in Taichung county of Taiwan. In this regard, the abstarct of literature review is given in Table 1.

Table 1: Abstract of literature review

Title	Reference
An Analytic Network Process Approach for Locating Undesirable Facilities	(Tuzkaya, 2008)
A Fuzzy ANP Approach to Shipyard Location Selection	(Guneri, 2008)
A Fuzzy Simple Additive Weighting System under Group Decision-making for Facility Location Selection with Objective/Subjective Attributes	(Chou, 2008)
Optimal Selection of Location for Taiwanese Hospitals to Ensure a Competitive Advantage by Using the Analytic Hierarchy Process and Sensitivity Analysis	(Cheng, 2007)
Development of an Expert Selection System to Choose Ideal Cities for Medical Service Ventures	(Lin, 2009)
The Capacity and Distance Constrained Plant Location Problem	(Fernandez, 2009)
A Hybrid Fuzzy Integral Decision-making Model for Locating Manufacturing Centers in China: A Case Study	(Feng, 2010)

Methodology

First the criteria for the evaluation of decision-making model were derived from exhaustive literature reviews and practical interviews. After interviewing experts, we constructed the hierarchy based on the evaluation criteria. Then, interpretive structural modeling was applied for identifying the interrelations between criteria and sub-criteria. Finally, we calculate the criteria weights and rank of importance by applying fuzzy ANP method.

Interpretive Structural Modeling

Interpretive structural modeling proposed by Warfield is a computer-assisted methodology to construct and understand the fundamentals of the relationships between the elements in complex systems or situations. The theory of ISM is based on discrete mathematics, graph theory, social sciences, group decision-making, and computer assistance. The procedures of ISM are begun through individual or group mental models to calculate binary matrices, also called relation matrices, to present the relations of the elements.

A relation matrix can be formed by asking the question like ''Does the feature e_i inflect the feature e_j?'' If the answer is ''Yes'' then $p_{ij} = 1$, otherwise $p_{ij} = 0$. The general form of the relation matrix can be presented as follows:

$$D = \begin{bmatrix} 0 & \pi_{12} & . & . & . & \pi_{1n} \\ \pi_{21} & 0 & . & . & . & \pi_{2n} \\ . & . & 0 & . & . & . \\ . & . & . & 0 & . & . \\ . & . & . & . & 0 & . \\ \pi_{n1} & . & . & . & . & 0 \end{bmatrix}$$

D is the relation matrix, where e_i is the ith element in the system, p_{ij} denotes the relation between *i*th and *j*th element. After constructing the relation matrix, we can calculate the reachability matrix using Equation (3) and Equation (4) as follows:

$$M = D + I \qquad (3)$$

$$M^{\bullet} = M^{k} = m^{k+1} \qquad (4)$$

Where *I* is the unit matrix, *k* denotes the powers and M* is the reachability matrix. Note that the reachability matrix is under the operators of the Boolean multiplication and addition. Next we can calculate the reachability set and the priority set based on Equation (5) and Equation (6), respectively listed here:

$$R(t_i) = \{e_i | M^{\bullet}{}_{ji} = 1\} \qquad (5)$$

$$A(t_i) = \{e_i | M^{\bullet}{}_{ij} = 1\} \qquad (6)$$

M_{ij} denotes the value of the *i*th row and the *j*th column. Finally, the levels and relationships between the elements can be determined using Equation (7) and the structure of the elements relationships can also be expressed using the graph (Ning and et al. 2009).

$$R(t_i) \cap A(t_i) = R(t_i) \qquad (7)$$

Fuzzy Set and Fuzzy Number

Zadeh introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data (Wang, 2008). Generally, a fuzzy set is defined by a membership function, which represents the grade of any element *x* of *X* that have the partial membership to *M*. The degree to which an element belongs to a set is defined by the value between zero and one. If an element *x* really belongs to *M*, then $\mu_M(x) = 1$ and if not, then clearly $\mu_M(x) = 0$.

A triangular fuzzy number is defined as (*l*, *m*, *u*); where $l \leq m \leq u$. The parameters *l*, *m* and *u* respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. (*l*, *m*, *u*) has the following triangular membership function (Sung, 2001).

$$\mu_X = \begin{cases} 0 & x < 1 \\ \dfrac{x-l}{m-l} & l \leq x \leq m \\ \dfrac{u-x}{u-m} & m \leq x \leq u \\ 0 & x > u \end{cases}$$

A triangular fuzzy number can be shown in Figure 1.

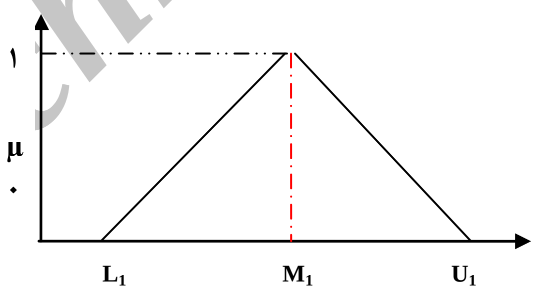

Figure 1: A triangular fuzzy number

Fuzzy Analytic Network Process Methodology

ANP represents relationships hierarchically but does not require them as strictly as hierarchical structure does and therefore allows for more complex interrelationships among the decision levels and attributes. The overall objective is to find out the best concept. The determinants, dimensions and attribute-enablers used for evaluating a set of conceptual design alternatives are determined based on the needs and expectations of both customers and company. That is why they may differ from a company to another or from a product to another. They are also very critical elements at the stage of concept evaluation of a NPD environment because they directly affect to determine the ultimate concept out of the available options.

After constructing structure hierarchy, the decision-maker is asked to compare the elements at a given level on a pairwise basis to estimate their relative importance in relation to the elements at the immediate proceeding level. In conventional ANP, the pairwise comparison is made using a ratio scale. A frequently used scale is the nine-point scale which shows the participants' judgments or preferences. Even though the discrete scale of 1–9 has the advantages of simplicity and easiness for use, it does not take into account the uncertainty associated with the mapping of one's perception or judgment to a number.

Steps of the Proposed Approach

Step I: Model Construction and Problem Structuring

The problem must be stated clearly and decomposed into a rational system, such as a network. The structure can be generated based on decision-maker opinions generated through saying, brainstorming or other methods. Figure 2 presents an example of a network format (Wang, 2008).

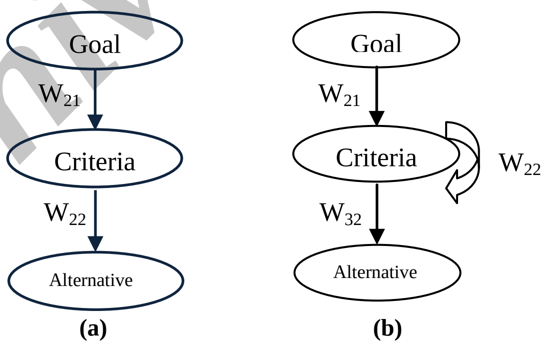

Figure 2: Structural difference between a hierarchy and a network – (a) a hierarchy; (b) a network

Step II. Formation of Fuzzy Matrices

After modeling, paired comparisons under each control criterion are performed. This phase is done by using Delphi method. To make sure the result is more exact and reasonable more experts are expected to participate in pairwise comparison. The elements in a cluster are compared by applying fuzzy scale. The fuzzy scale regarding relative importance to measure the relative weights is given in Table 2 (Bi and Wei, 2008).

Table 2: Linguistic scales for difficulty and importance

Linguistic scales for importance	Triangular fuzzy scale
Just equal	(1,1,1)
Equally important	(1/2,1,3/2)
Weakly more important	(1,3/2,2)
Strongly more important	(3/2,2,5/2)
Very strongly more important	(2,5/2,3)
Absolutely more important	(5/2,3,7/2)

Step III. Establishment of Fuzzy Positive Reciprocal Matrix

$$\tilde{A} = \begin{pmatrix} \tilde{a}_{11} & a_{12} & . & \tilde{a}_{1n} \\ a_{21} & . & . & . \\ . & . & . & . \\ \tilde{a}_{n1} & . & . & \tilde{a}_{nn} \end{pmatrix} = \begin{pmatrix} \tilde{a}_{11} & \tilde{a}_{12} & . & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & . & . & . \\ . & . & . & . \\ 1/\tilde{a}_{1n} & . & . & \tilde{a}_{nn} \end{pmatrix}$$

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

Where $\tilde{A}$ denotes a triangular fuzzy matrix for the relative importance of criteria. Meanwhile $\tilde{a}_{ij}$ represents the triangular fuzzy numbers by the following formulae (Wu and et al., 2007).

$$L_{ij} = \sqrt[n]{\prod_{k=1}^{n} L_{ijk}} \qquad (9)$$

$$M_{ij} = \sqrt[n]{\prod_{k=1}^{n} M_{ijk}} \qquad (10)$$

$$U_{ij} = \sqrt[n]{\prod_{k=1}^{n} U_{ijk}} \qquad (11)$$

Step IV: Weighting Studies

There are many fuzzy AHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and problem justification by using the concepts of fuzzy set theory and hierarchical structure analysis. Decision makers usually find that it is more confident to give interval judgments than fixed value judgments. This is because usually he/she is unable to explicate about his/her preferences due to the fuzzy nature of the comparison process. In this study, we prefer Chang's extent analysis method because the steps of this approach are easier than the other fuzzy AHP approaches. The steps of Chang's extent analysis approach are as follows: Let $X=\{x_1, x_2 \ldots x_n\}$ be an object set, and $U=\{u_1, u_2, \ldots, u_m\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, g_i, is performed respectively. Therefore, *m* extent analysis values for each object can be obtained, with the following signs (Lin and Tsai, 2009).

$$M_{gi}^{1}, M_{gi}^{2}, \quad \ldots \quad , M_{gi}^{m}$$
$$i = 1,,2, \quad \ldots \quad ,n$$

Where all the M_{gi}^{i} ($j=1, 2 \ldots m$) are TFNs.

- The steps of Chang's extent analysis can be given as in the following:

1. The value of fuzzy synthetic extent with respect to the *i*th object is defined as:

$$S_k = \sum_{j=1}^{n} M_{ij} \otimes \left[\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right]^{-1}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{i}$ perform the fuzzy addition operation of *m* extent analysis values for a Particular matrix in such a way that:

$$\sum_{j=1}^{m} M_{gi}^{i} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j \right)$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi} \right]^{-1}$ perform the fuzzy addition operation of M_{gi}^{i} (*j=1, 2,…, m*) Values in such a way that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi} = \left(\sum_{i=1}^{n} l_i , \sum_{i=1}^{n} m_i , \sum_{i=1}^{n} u_i \right)$$

And then compute the inverse of the vector in Equation (6) such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right)$$

The degree of possibility of *M2* = (*l2, m2, u2*) ≥ *M1* = (*l1, m1, u1*) is defined as *V* (*M2*≥ *M1*) =sup $[\min(\mu_{M1}(X), \mu_{M2}(Y))]$ and can be equivalently expressed as the following in Figure 3.

$$V(M2 \geq M1) = hgt(M1 \geq M2) = \begin{cases} 1 & m_1 \geq m_2 \\ \frac{U_1 - L_2}{(U_1 - L_2) + (m_2 - m_1)} & \text{otherwise} \end{cases}$$

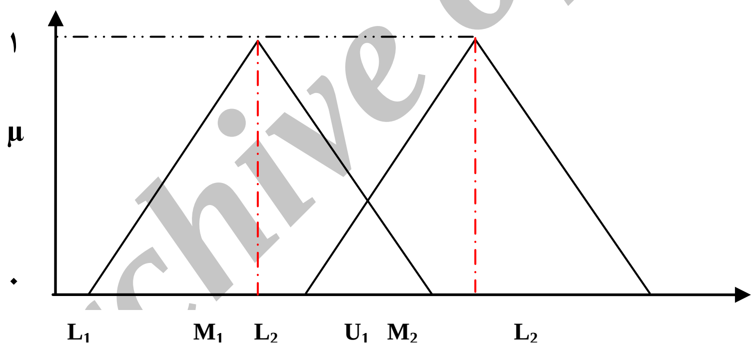

Figure 3: Intersection between M_1 and M_2

The possibility degree for a convex fuzzy number to be greater than *k* convex fuzzy numbers *Mi* (*i*=1,2,…,*k*) can be defined by:

$$V(M_1 \geq M_2, \ ..., M_k) = V(M_1 \geq M_2)$$
$$,..., V(M_1 \geq M_k)$$

Assume that $d'(Ai) = \min V(Si \geq Sk)$ For k = 1,2,…,n; k ≠ i. Then the weight vector is given by $W' = (d'(A1), d'(A2), \ldots, d'(An))^T$, where *Ai* (*i*=1,2,…,*n*) are *n* elements**.** The normalized weight vectors are $W' = (d\,(A1), d(A2), \ldots, d(An))^T$ Where *W* is a nonfuzzy number**.**

Step V. Supermatrix Formation

The supermatrix concept is similar to the Markov chain process. To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix, known as a supermatrix. As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two nodes (components or clusters) in a system (Kahraman et al. 2006). As an example, the supermatrix representation of a hierarchy with three levels as shown in Figure 3 is as follows (Wu and et al., 2007).

$$W_h = \begin{bmatrix} 0 & 0 & 0 \\ w_{21} & 0 & 0 \\ 0 & w_{32} & I \end{bmatrix}$$

Where W_{21} is a vector that represents the impact of the goal on the criteria, W_{32} is a matrix that represents the impact of criteria on each of the alternatives, *I* is the identity matrix, and entries of zeros corresponds to those elements that have no influence. If the criteria are interrelated among themselves, the hierarchy is replaced by a network as shown in figure 3.The (2, 2) entry of W_n given by w_{22} would indicate the interdependency, and the supermatrix would be as follows (Wu and et al., 2007).

$$W_n = \begin{bmatrix} 0 & 0 & 0 \\ w_{21} & w_{22} & 0 \\ 0 & w_{32} & I \end{bmatrix}$$

Note that any zero in the supermatrix can be replaced by a matrix if there is an interrelationship of the elements in a component or between two components. Since there usually is interdependence among clusters in a network, the columns of a supermatrix usually sum to more than one. The supermatrix must be transformed first to make it stochastic, that is, each column of the matrix sums to unity. A recommended approach by Saaty is to determine the relative importance of the clusters in the supermatrix with the column cluster (block) as the controlling component (Saaty, 2000). That is, the row components with non-zero entries for their blocks in that column block are compared according to their impact on the component of that column block (Wu and et al., 2007). With pair-wise comparison matrix of the row components with respect to the column component, an eigenvector can be obtained. This process gives rise to an eigenvector for each column block. For each column block, the first entry of the respective eigenvector is multiplied by all the elements in the first block of that column, the second by all the elements in the second block of that column and so on. In this way, the block in each column of the supermatrix is weighted, and the result is known as the weighted supermatrix, which is stochastic (Zdemir and Ayag, 2009).

Raising a matrix to powers gives the long-term relative influences of the elements on each other. To achieve a convergence on the importance weights, the weighted supermatrix is raised to the power of $2k + 1$, where k is an arbitrarily large number, and this new matrix is called the limit supermatrix (Wu and et al., 2007). The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix are the same. By normalizing each block of this supermatrix, the final priorities of all the elements in the matrix can be obtained.

Step VI. Selection of Best Alternatives

If the supermatrix formed covers the whole network, the priority weights of alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises of components that are interrelated, additional calculation must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be the one selected. In this paper, the first method is applied, and a supermatrix that covers the whole network is formed (Figure 4).

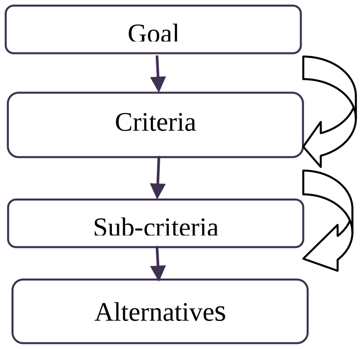

Figure 4: Network form for this paper

According to the aforesaid fuzzy ANP is a multi-attribute decision-making approach based on the reasoning, knowledge and experience of the experts in the field. Fuzzy ANP can act as a valuable aid for decision making involving both tangible as well as intangible attributes that are associated with the model under study. Fuzzy ANP relies on the process of eliciting managerial inputs, thus allowing for a structured communication among decision makers. Thus, it can act as a qualitative tool for strategic decision-making problems. Mohanty and et al. (2005) proposes an application of fuzzy ANP along with fuzzy cost analysis in selecting R&D projects. Kahraman and et al. (2006) use the fuzzy ANP model for QFD planning process, which proposes an application in a Turkish Company producing PVC window and door systems, because fuzzy ANP can produce a comprehensive analytic framework for solving societal, governmental, and corporate decision problems. Yet, there is a lack of published papers in the hospital selection of location demonstrating the method with illustrative examples. In the current paper, it is suggested that fuzzy ANP is appropriate for health center location selection.

Applying fuzzy ANP to Select the Location of Health Center

By reviewing the evaluations of the location selection of health center, this study has constructed indicators to evaluate the location selection. This paper uses the expert opinions in order to construct an evaluation model to assess the location selection of health center. The evaluation of the location selection of health center is based on various factors, e.g., factor conditions, geographical conditions, government, related and supporting industries. Fuzzy ANP is used to illustrate the problems and combine the four factors to establish the hierarchy and network structure for performance evaluation in this study. The proposed fuzzy ANP evaluation model to select the location of a health center in Ramsar with respect to the identified criteria comprises the following steps:

Step 1: Identify Effectiveness Criteria and Establish an ANP Model

To establish a location selection model, this study proposes the following three-step procedure: building initial criteria, modifying criteria and sub-criteria, and building an evaluation model. (Figure 5)

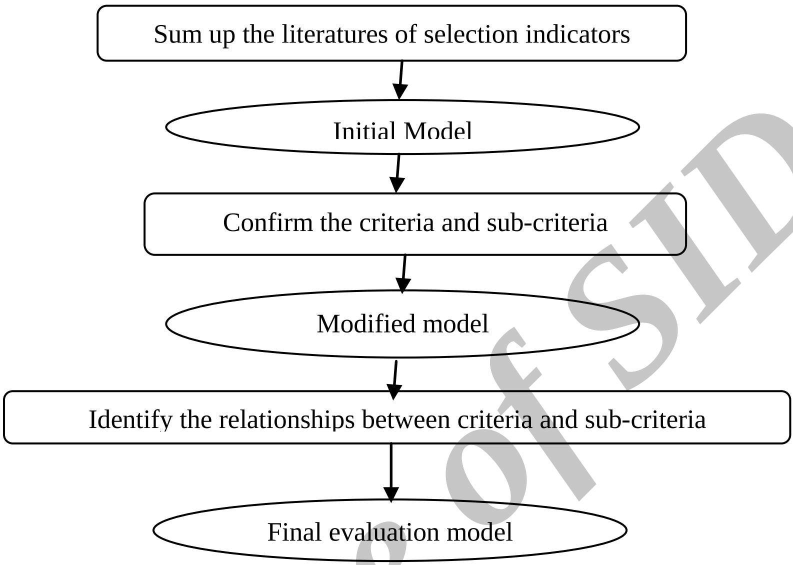

Figure 5: The procedure of building selection model

- Building the Initial Model

In this step, this study uses literature review findings to build an initial model for selecting an appropriate location in service industry by identifying four criteria and thirty sub-criteria.

- Modifying the Initial Model

In this paper thirty experts in health center location selection were invited to identify appropriate criteria and sub-criteria for selecting health center locations. When more than 90% of reviewers evaluating the performance of an upper level criterion judged it as suitable then that is listed in the modified model. When more than 70% and less than 90% of reviewers judge a criterion to be suitable for location selection, the value of that criterion is discussed with reviewers. Finally, four criteria and twelve sub-criteria in the modified model are listed in the proposed evaluation model as showed in Figure 6.

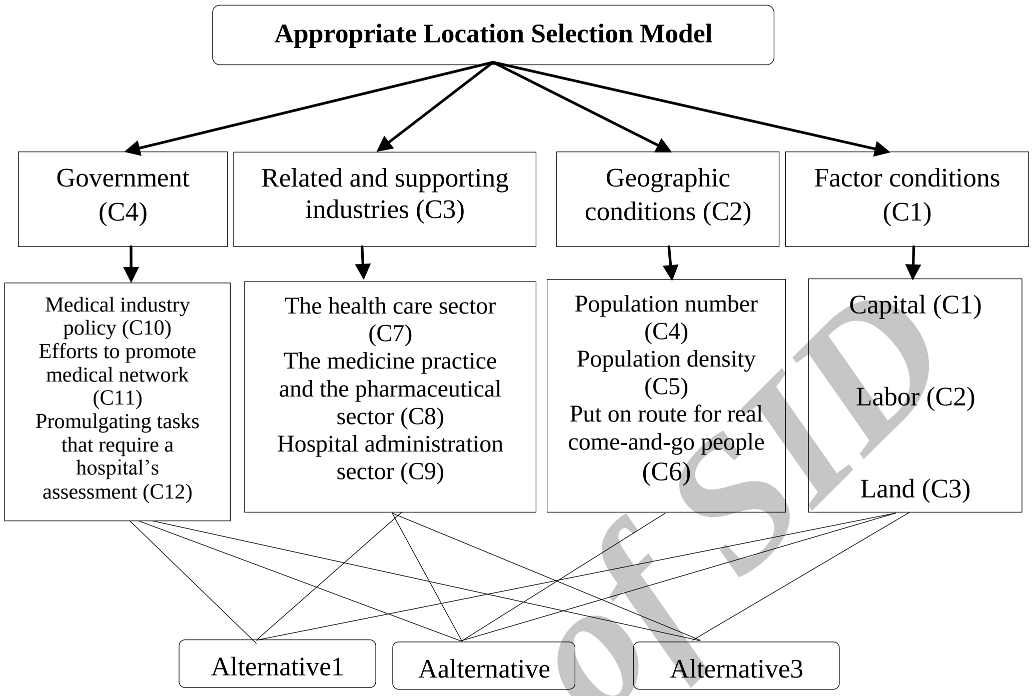

Figure 6: Hierarchy structure

Applying Interpretive Structural Modeling for Identifying the Interrelationships between the Criteria and Sub-criteria

After identifying the criteria for selecting a health center location and the associated criteria, these reviewers identified the interrelationships between the criteria and sub-criteria.

- Establish Relation Matrix

We will judge the relationships between the criteria and sub-criteria using the relation matrix, *D*, as shown in Table 3 which is formed by experts' opinions.

Table 3: relation matrix

	C_1	C_2	C_3	C_4
C_1	0	1	1	1
C_2	1	0	1	1
C_3	0	0	0	1
C_4	0	1	0	0

From the relation matrix, we can calculate the reachability matrix, M^*, based on Equation (3) and (4) and it is shown in Table 4.

Table 4: Reachability matrix

	C_1	C2	C3	C4
C1	1	1	1	1
C2	1	1	1	1
C3	1	1	1	1
C4	1	1	1	1

The reachability matrix presents the relationships of all criteria. These relationships are shown in Figure 7.

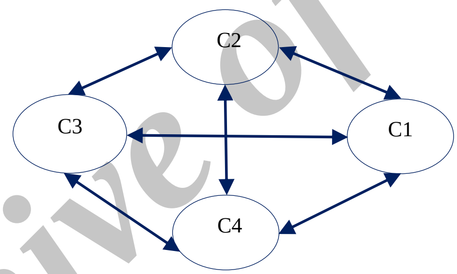

Figure 7: Relationships between criteria

After presenting the reachability matrix for sub-criteria, the relationships between sub-criteria are shown in Figure 8. At last, the network structure problem designs are displayed in Figure 9.

Step 2: Establish the Pair-wise Comparison Matrix

According to Table 1, the questionnaires were handed to a sample group of thirty experts, with each respondent making a pair-wise comparison of the decision elements and then assigning those relative scores. Table 5 shows one of the pair-wise comparison matrixes as an instance.

Table 5: Pair-wise comparison matrix

goal	C1			C2			C3			C4		
C1	1	1	1	0.5	1	1.5	1	1.5	2	2	2.5	3
C2	0.667	1	2	1	1	1	0.5	1	1.5	0.5	1	1.5
C3	0.5	0.667	1	0.667	1	2	1	1	1	0.5	1	1.5
C4	0.333	0.4	0.5	0.667	1	2	0.667	1	2	1	1	1

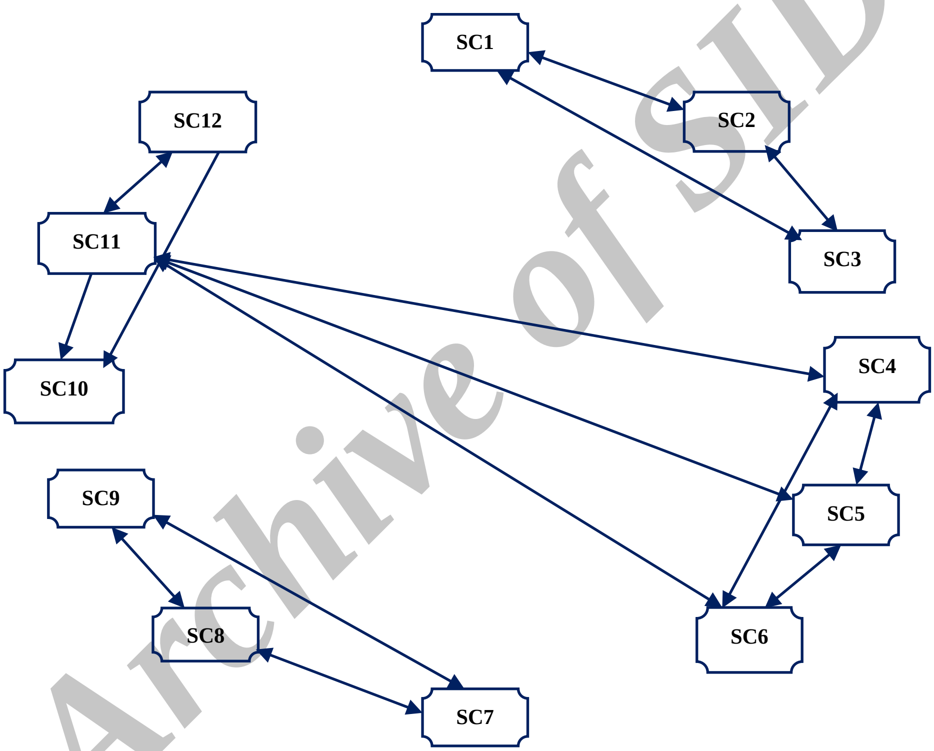

Figure 8: Relationships between criteria

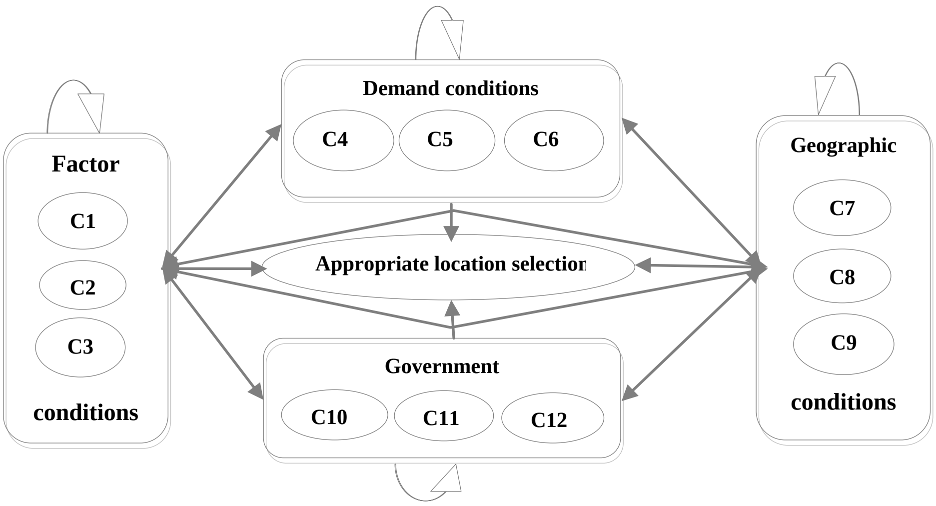

Figure 9: The network structure

Step 3: Establishment of Fuzzy Positive Reciprocal Matrix

After doing all pair-wise comparisons between criteria and sub-criteria and establishing fuzzy pair-wise comparison matrixes, fuzzy positive reciprocal matrix according to Equations (9-11) was formed. Table 6 shows fuzzy positive reciprocal matrix for criteria.

Table 6: Fuzzy positive reciprocal matrix

goal	C1			C2			C3			C4		
C1	1	1	1	0.76	1.3	1.83	1.25	1.76	2.27	2.19	2.69	3.19
C2	0.55	0.77	1.32	1	1	1	0.94	1.5	2.02	0.76	1.08	1.35
C3	0.44	0.57	0.8	0.49	0.67	1.06	1	1	1	0.57	1.08	1.59
C4	0.31	0.37	0.46	0.74	0.92	1.32	0.63	0.92	1.74	1	1	1

Step 4: Weighting Studies

Paired comparison values which were completed with information given by the experts have been transformed into a single value with taking their geometric mean. Then, the values of fuzzy synthetic degrees are calculated considering all alternatives in each line of the comparison values matrix. After this step, fuzzy artificial magnitude value is applied (Table 7) and it is passed to the other process.

Table 7: Fuzzy synthetic degrees

Sum of Rows	L	M	U
R1	5.190313	6.751461	8.283829
R2	3.249863	4.348454	5.69188
R3	2.509983	3.321062	4.450801
R4	2.683007	3.216083	4.517914

After the implementation of fuzzy artificial magnitude, the account values of alternatives are calculated using the values of fuzzy synthetic degrees (Table 8).

Table 8: Fuzzy synthetic degrees

S_i	L	M	U
S_1	0.226212	0.3828	0.607623
S_2	0.141641	0.246552	0.417502
S_3	0.109394	0.1883	0.326469
S_4	0.116935	0.182348	0.331391

Hence, the probabilities of preference for an object are found. The combination of probabilities introduces the weight vector. The normalized version of weight vectors are the values which we are going to use when choosing alternatives.

After the implementation of Chang's secondary step, we will acquire weight vectors. In Table 9, probabilities of preferences are presented.

Table 9: Probabilities of preference

$V(S_j / S_i)$	S_1	S_2	S_3	S_4
S_1	1	0.584	0.340	0.344
S_2	1	1	0.760	0.747
S_3	1	1	1	0.973
S_4	1	1	1	1

The minimum values in every column of Table 9 are used for calculating the weights (Table 10).

Table 10: The minimum values

W_j	Unnormalized weights
W_1	1
W_2	0.584
W_3	0.340
W_4	0.3441

After finding weight vectors we must normalize them as in Chang’s fourth step. In this process, the weights are accumulated and then every weight is divided by the total to become normalized.

Table 11: Normalized values

W_j	Normalized weights
W_1	0.44086
W_2	0.257473
W_3	0.149951
W_4	0.151716

Step 6: Prioritizing and Selecting Alternatives

The values in the limit supermatrix show the priority weights of alternatives. The alternative with the highest overall priority should then be selected (Table 14). Thus, in this paper, location of Alternative 1 is selected.

Step 7: Supermatrix Formation

Unweighted supermatrix, weighted supermatrix and limit supermatrix have been calculated. Weighted supermatrix has been built considering the clusters equally important (Table 13). Raising the weighted supermatrix to an arbitrarily large number, converge of the interdependent relationships has been obtained, or in other words, long-term stable weighted values have been achieved. These values appear in the limit supermatrix, Table 14.

Table 12: Unweighted supermatrix

	G	C1	C2	C3	C4	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	A1	A2	A3
G	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.44	0.25	0.17	0.37	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	0.25	0.41	0.36	0.22	0.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0.15	0.20	0.23	0.15	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0.15	0.12	0.22	0.25	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC1	0	0.45	0	0	0	0.56	0.52	0.41	0	0	0	0	0	0	0	0	0	0	0	0
SC2	0	0.18	0	0	0	0.24	0.31	0.12	0	0	0	0	0	0	0	0	0	0	0	0
SC3	0	0.35	0	0	0	0.18	0.15	0.45	0	0	0	0	0	0	0	0	0	0	0	0
SC4	0	0	0.48	0	0	0	0	0	0.36	0.36	0.217	0	0	0	0	0.161	0	0	0	0
SC5	0	0	0.25	0	0	0	0	0	0.14	0.13	0.239	0	0	0	0	0.173	0	0	0	0
SC6	0	0	0.26	0	0	0	0	0	0.26	0.22	0.372	0	0	0	0	0.195	0	0	0	0
SC7	0	0	0	0.146	0	0	0	0	0	0	0	0.37	0.38	0.343	0	0	0	0	0	0
SC8	0	0	0	0.581	0	0	0	0	0	0	0	0.262	0.26	0.234	0	0	0	0	0	0
SC9	0	0	0	0.273	0	0	0	0	0	0	0	0.361	0.353	0.424	0	0	0	0	0	0
SC10	0	0	0	0	0.443	0	0	0	0	0	0	0	0	0	0.477	0.151	0.417	0	0	0
SC11	0	0	0	0	0.336	0	0	0	0.22	0.274	0.172	0	0	0		0.145	0	0	0	0
SC12	0	0	0	0	0.221	0	0	0	0	0	0	0	0	0	0.523	0.175	0.583	0	0	0
A1	0	0	0	0	0	0.33	0.59	0.58	0.45	0.582	0.253	0.317	0.465	0.395	0.385	0.314	0.241	1	0	0
A2	0	0	0	0	0	0.21	0.17	0.19	0.18	0.107	0.281	0.217	0.235	0.255	0.326	0.266	0.495	0	1	0
A3	0	0	0	0	0	0.45	0.23	0.22	0.35	0.31	0.465	0.466	0.3	0.35	0.289	0.419	0.264	0	0	1

Table 13: Weighted supermatrix

	G	C1	C2	C3	C4	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	A1	A2	A3
G	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.22	0.128	0.089	0.185	0.122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	0.129	0.209	0.183	0.114	0.131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0.075	0.103	0.118	0.076	0.064	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0.076	0.06	0.11	0.125	0.184	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC1	0	0.227	0	0	0	0.284	0.262	0.208	0	0	0	0	0	0	0	0	0	0	0	0
SC2	0	0.094	0	0	0	0.122	0.159	0.063	0	0	0	0	0	0	0	0	0	0	0	0
SC3	0	0.18	0	0	0	0.093	0.079	0.228	0	0	0	0	0	0	0	0	0	0	0	0
SC4	0	0	0.244	0	0	0	0	0	0.183	0.181	0.109	0	0	0	0	0.08	0	0	0	0
SC5	0	0	0.126	0	0	0	0	0	0.075	0.069	0.12	0	0	0	0	0.087	0	0	0	0
SC6	0	0	0.13	0	0	0	0	0	0.13	0.113	0.186	0	0	0	0	0.098	0	0	0	0
SC7	0	0	0	0.073	0	0	0	0	0	0	0	0.188	0.193	0.171	0	0	0	0	0	0
SC8	0	0	0	0.29	0	0	0	0	0	0	0	0.131	0.13	0.117	0	0	0	0	0	0
SC9	0	0	0	0.137	0	0	0	0	0	0	0	0.18	0.177	0.212	0	0	0	0	0	0
SC10	0	0	0	0	0.222	0	0	0	0	0	0	0	0	0	0.238	0.076	0.209	0	0	0
SC11	0	0	0	0	0.168	0	0	0	0.113	0.137	0.086	0	0	0	0	0.073	0	0	0	0
SC12	0	0	0	0	0.111	0	0	0	0	0	0	0	0	0	0.262	0.087	0.292	0	0	0
A1	0	0	0	0	0	0.167	0.296	0.293	0.227	0.291	0.127	0.158	0.233	0.197	0.193	0.157	0.121	1	0	0
A2	0	0	0	0	0	0.105	0.085	0.096	0.094	0.054	0.141	0.108	0.117	0.128	0.163	0.133	0.248	0	1	0
A3	0	0	0	0	0	0.228	0.119	0.111	0.179	0.155	0.233	0.233	0.15	0.175	0.145	0.21	0.132	0	0	1

Table 14: Limit supermatrix

	G	C1	C2	C3	C4	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	A1	A2	A3
G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1	0.41	0.435	0.404	0.404	0.361	0.391	0.523	0.528	0.419	0.483	0.318	0.35	0.424	0.39	0.346	0.338	0.272	1	0	0
A2	0.241	0.219	0.23	0.243	0.309	0.204	0.183	0.195	0.209	0.17	0.255	0.226	0.235	0.246	0.371	0.278	0.459	0	1	0
A3	0.349	0.346	0.366	0.353	0.33	0.405	0.294	0.277	0.372	0.347	0.427	0.423	0.341	0.365	0.283	0.384	0.269	0	0	1

Conclusion

In this paper we propose a fuzzy extension of the analytic network process (ANP) that uses uncertain human preferences as input information in the decision-making process. Instead of the classical Eigenvector prioritization method, employed in the prioritization stage of the ANP, a new fuzzy preference programming method, which obtains crisp priorities from inconsistent interval and fuzzy judgments, is applied. The resulting fuzzy ANP enhances the potential of the ANP for dealing with imprecise and uncertain human comparison judgments. It allows for multiple representations of uncertain human preferences, as crisp, interval, and fuzzy judgments and can find a solution from incomplete sets of pair-wise comparisons.

FANP has been successfully conducted in the selection of an appropriate location for a health center. It has been seen that it was crucial for the decision makers to fully comprehend the desired information in forming mutual comparisons and in appointing the relation levels. It has also been noted that selecting experts on present subject in various experiences, information and education branches is one of the most important issues in ensuring the accuracy during the study and the results. In conclusion, the requirement for us to first build a health center in which area in order to meet the urgent need for a health center in Ramsar was defined with this study. This decision has been made under today's circumstances, so it is quite normal to have different results with the changing conditions in the future. All experts stated that the information they presented could have been quite different 5 years ago. Health center selection process which is a complicated process with many alternatives influencing each other has been completed successfully thanks to FANP method.

In future studies, available financial and technological constraints can be added to the system. In addition, a foundation can also be constructed which would help us decide on the type of health center and would lead us to a more resilient and specific result.

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