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Identification and Prioritization of Optimal Places for Locating Urban Hospitals by Combining the F-ANP, F-WASPAS Methods, and GIS Output in the ArcGIS Environment: Case Study: Arak City

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ABSTRACT

Health-medical facilities are among the applications that, if incorrectly located, in addition to the economic and financial necessities that come with it, may lead to irreparable loss of life. Geographical location is a critical component of access to medical services. Therefore, the significance of the optimal and convenient location of this type of usage is multiplied. This study aimed to determine the hospital's optimal locations and provide easy access, better service, customer and patient satisfaction, and public welfare to all segments of society in Iran, the Markazi province, and Arak city. For this purpose, a combination of Geographic Information System (GIS) output and integrated Analytic Network Process-Weighted Aggregated Sum Product Assessment (ANP-WASPAS) model in a fuzzy environment was used. First, effective criteria for locating the hospital were selected based on the literature, national standards and regulations, expert opinion, and the location and geographical conditions of the area. The criteria were then weighted by experts using the Fuzzy ANP (F-ANP) method. Then, according to the criteria and final weights, the desired maps were created in the ArcGIS software environment. The results were then combined using fie fuzzy operators. As a result, optimal and suitable locations for the hospital were introduced. Finally, using the Fuzzy WASPAS (F-WASPAS) method, the identified locations were prioritized.

1 Introduction

In recent years, with the expansion of urban areas and population growth, the demand for construction of service and infrastructure facilities, especially hospitals, fire stations, parking

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lots, and the like, has increased significantly. In our country, the rapid growth of urban areas in recent decades has been so that cities' urban space and infrastructure have not been equipped accordingly. The main effects of the rapid growth of cities are the disruption of the service distribution system and the inadequacy of service distribution. Since health is one of the necessities of life in the city, the issue of social justice and achieving sustainable development is raised; and this concept of justice is justice in opportunities, so equal access to health-treatment services in the framework of social justice is one of the necessities of life[1]. According to the principle of social justice, fair distribution of health services is one of the main goals of urban planners. Satisfying this principle leads to the realization of two other principles: the principle of availability and accessibility of services [2]. Among these, one of the most important institutions that can affect society's health in the current era is hospitals. The hospital is a medical institution that provides diagnostic, therapeutic, health, educational, and research facilities to treat and improve the health conditions of inpatients and outpatients [3]. It should be noted that the establishment of new service centers requires high costs, and it is important to determine the optimal location of these centers so that all citizens can benefit from them. Geographical location is a key component of access to medical services that researchers have studied with diverse and broad perspectives and various techniques [4]. Health uses are the types of uses that, if incorrectly located, in addition to the economic and financial losses that may occur, may result in irreparable loss of life.

Therefore, the importance of this type of usage's optimal and convenient location is multiplied [5]. Proper location of new hospitals increases the speed and ease of access; the hospital is closer to a larger population and reduces construction costs [6]. Location is an activity that analyzes the capabilities and abilities of an area in terms of the existence of suitable and sufficient land, and assesses the area in terms of other uses and urban facilities, and selects a suitable location for a particular application [7]. The location theory identifies the appropriate place or locations for activities or services. This theory has been proposed by several scholars, including Format, Pottage, and Steiner. The study of the location theory was officially started and introduced by Alfred Weber in 1909 [8]. Following the introduction of studies in the field, many studies were conducted between 1909 to 1964, considering several factors. Although the provision of health services in cities has a long history, locating healthcare centers is quite new and dates to the 1970s. In 1979, the UK Department of Health and Social Welfare addressed the strategic development of healthcare centers. Since then, studies in this area have begun and were followed in Austria during 1980-1982. The idea of locating hospital centers was apprehended by Leslie Mayhew from the Birkbeck College in London. His main task was to develop a spatial model for predicting the flow of patients to the hospital, which resulted from changes in the supply and demand of non-hospital services. Rezaei Sabzevar et al. used a multi-criteria decision-making model to select the location of a landfill[9]. Also, Fan et al. used a novel combinational Analytic Network Process (F-ANP) and Fuzzy Quality Function Deployment (F-QFD) approaches to select their design optimally [10]. In an article, Hosseinzadeh et al. discussed the location of urban hospitals by combining the Analytic Hierarchy Process (AHP) and fuzzy model in the Geographic Information System (GIS) environment to provide better service and comfort to citizens [11]. Sharif et al. (2012) also studied the Location-Allocation (LA) problem for medical facilities' planning [12]. Then, Reisi and Afzali used ANP and AHP applications to select locations for industrial use [13]. Also, Mobarghei Dinan et al. used F-ANP and ANP total weight to locate an incinerator plant [14]. In a study in 2015, using the combined Weighted Linear Combination (WLC) and GIS methods, Weissnab et al. identified the best locations for a hospital in Ardabil [15]. In 2020, Maghsoud Rezaei located a hospital in Malaysia using GIS and multi-criteria decision-making [16]. Another example is the use of a combination of multi-criteria decision-making models and GIS in selecting waste disposal sites, which has been done separately by Danesh et al. [17] and Barzehkar et al. [18].

Also, Parsa Moghadam et al. identified the optimal location for urban hospitals [19]. In 2013, Mitropoulos et al. combined the Data Envelopment Analysis (DEA) model and location to develop a more effective model to combine health services [20]. In 2019, Badalpour and Noorbakhsh conducted a qualitative risk analysis in a road construction project using the Weighted Aggregated Sum Produt Assessment (WASPAS) method [21]. Bagocius et al. offered a combinational WASPAS and entropy method for selecting a deep-water port in Europe for economic purposes [22]. Turkis et al. proposed a Fuzzy WASPAS (F-WASPAS) and Fuzzy AHP (F-AHP) hybrid model for choosing a shopping center construction site [23]. Decision-making is an issue human beings have faced since creation. Everyone has different issues to decide. These issues may arise in daily life and personal matters or major decisions. Decision-making is the process of setting goals, gathering relevant information, and selecting the optimal and desirable option [24]. In recent years, in studies, the subject of location has been considered using decision-making models. However, limited studies have been done in the case of urban hospital locations. In the present study, we investigated the optimal location of the hospital Multiple Criteria Decision Making (MCDM) and GIS models in a fuzzy environment [25-30]. The reasons for using each method are presented in the following.

Multi-criteria decision-making models are a set of methods that allow the decision-maker or decision-makers to select, rank, order, or describe a set of options in the decision-making process by considering criteria that are often conflicting. Multi-criteria -decision-making has excellent potential to reduce cost and time and increase spatial decision-making accuracy. Then we used the GIS system because it is an efficient tool in managing and applying different layers of information in the location stage and assessing the current situation. Efficient and appropriate information management dramatically improves the quality of planning. It is not easy to produce the right kind of information using manual methods. GIS provides many essential tools for efficient and appropriate ground information management. GIS necessarily performs the tasks of supporting, collecting, maintaining, analyzing, and displaying location-dependent data. GIS data allows different perspectives to be considered and provides the ability to dynamically query and display information and, in principle, to present more meaningful data. On the other hand, access to digital data may lead to incorrect use or misuse, and thus, may create severe problems regarding data security, reliability, and responsibility. The entire stages of research were conducted in a fuzzy environment, and since an actual sample is examined. Considering natural phenomena are somewhat vague and inaccurate, fuzzy theory, based on uncertainty, aims to model the comparative ambiguities, providing more flexible, realistic, and accurate results. The primary contributions of this research are described as follows:

- A F-ANP model is further developed to determine the weights for the objective criteria.
- A F-WASPAS method is used to prioritize the criteria.
- A novel integrated F-ANP and WASPAS method is proposed.
- The new integrated approach is utilized to assess and prioritize the alternative optimal locations.
- The results are compared, and sensitivity analysis confirms the validity of the results provided by our novel approach.

2 Methodology

This descriptive research utilizes mathematical modeling. Descriptive research includes a set of methods that aim to describe the conditions and phenomena under study and is applied in terms of the objective because the purpose of the research is the scientific application of knowledge. This section defines and explains fuzzy numbers, fuzzy theory, and the ANP, GIS, WASPAS methods in the fuzzy environment and their capabilities and applications.

2.1 Numbers and fuzzy logic

Zadeh [31] proposed the fuzzy set theory to address the uncertainty caused by ambiguity. The most important feature of a fuzzy set is its ability to display obscure data. An interesting feature of the fuzzy set is that it considers the membership function in which each member is assigned a membership grade between zero and one.

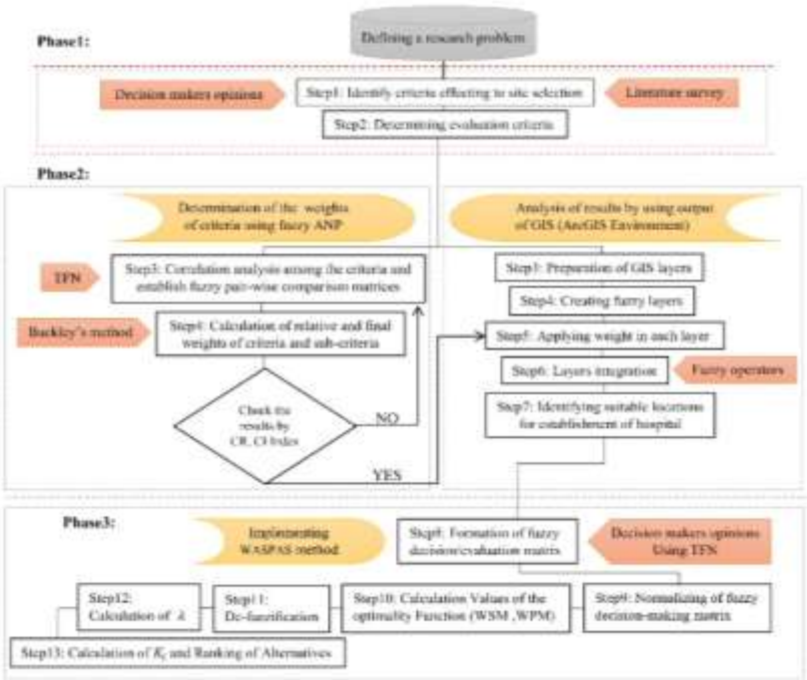

Fig. 1. The schematic diagram of proposed solution methodology.

Showing human judgment about preferences is often indistinct; meanwhile, accurate estimates are obtained by accurate numerical values. The accuracy of people's opinions is low because they are asked to assign a correct ratio based on their understanding of phenomena to their pairwise comparison. In contrast, the individual's perception of the phenomenon cannot be expressed in a definite numerical form. Here, a range of numbers can be better than a definite number in reflecting a person's understanding of the importance of one phenomenon compared to another. Hence, utilizing fuzzy logic to solve such problems, characterized by ambiguity and inaccuracy, is necessary [32, 33]. A fuzzy set is defined as an object class with a range of membership degrees. It is is specified by a membership function, which allocates a membership degree to each of the objects ranging between zero and one [9]. The fuzzy set A is defined as a set of pairs in the space X as follows:

$$A = \{(x, \mu_A(x)), x \in X\}, \quad (1)$$

The membership function $\mu_A : X \to [0; 1]$ characterizes the fuzzy set A, in which each element $x \in X$, is a real number $\mu_A(x) \in [0; 1]$. The value $\mu_A(x)$ at x denotes the degree of membership , which x belongs to A. A closed value of $\mu_A(x)$ to 1 is interpreted as x's higher degree of membership to A.

A crisp subset A of X can also be expressed as a fuzzy set in X, with the membership function as its distinctive function:

$$\mu_{A\,(x)} = \begin{cases} 1 & x \in A; \\ 0 & x \notin A. \end{cases} \quad (2)$$

The set X is "a universe of discourse" and is expressed as $\subseteq X$. The fuzzy set A in X can also be represented by $(x, \mu_A(x))$, in which the zero-degree elements are normally omitted. Hence, we can describe the fuzzy set A in X as $A = \{(x, \mu_A\,(x))\}$, where $x \in X$. Assuming a discrete and finite universe of discourse with the cardinality, n, we have $X = \{x_1, x_2, \ldots, x_n\}$. Therefore, the resulting fuzzy set A is expressed as the following:

$$A = \sum_{i=1}^{n} \frac{\mu_A\,(x_i)}{x_i} = \frac{\mu_A\,(x_1)}{x_1} + \frac{\mu_A\,(x_2)}{x_2} + \cdots + \frac{\mu_A\,(x_n)}{x_n}. \quad (3)$$

Assuming an interval of real numbers for the universe of discourse, X, the resulting fuzzy set, A, is described as:

$$A = \int_X \frac{\mu_A\,(x)}{x} \quad (4)$$

Several types of membership functions exist. The most frequently used membership functions include triangular, trapezoidal, linear, sigmoidal, π-type, and Gaussian. By definition, a fuzzy number is primarily subjective data provided by an expert or a group of experts upon consensus. The triangular fuzzy set membership function is the most commonly applied.

A is considered a fuzzy triangular number, with α (lower), β (modal), and γ (upper) values, if $\mu_A: X \to [0;1]$ is defined as follows:

$$\mu_A(x) = \begin{cases} \frac{x-\alpha}{\beta-\alpha} & if \;\; x \in [\alpha . \beta] \\ \frac{x-\alpha}{\beta-\gamma} & if \;\; x \in [\beta . \gamma] \\ 0 & otherwise \end{cases} \quad \alpha \le \beta \le \gamma \tag{5}$$

The weight values $0 < \widetilde{w}_j < 1$, $\sum_{j=1}^{n} \widetilde{w_j} = 1$ are generally defined by the experts. Various methods exist for determining weights. Some data may not be designated using numbers. Hence, decision-makers usually quantify such using measurement scales divided into the nominal, ordinal, interval, and ratio scales.

2.2 F-ANP Method

In this research, the F-ANP is used to determine the weight of the criteria. The ANP is one of the multi-criteria decision-making techniques found in a set of compensatory models. This model is based on the AHP and replaces the network with a hierarchy represented in a hypermatrix. AHP assumes a one-way, top-down hierarchical relationship, but ANP considers complex interactions between decision levels (interdependence and feedback) between and among decision elements using a network structure instead of a hierarchical structure. To create a conceptual model and a better understanding, we need to transform the subject clearly and explicitly into a logical system such as a network structure. All elements in a network can be related to each other in any way. In other words, in a network, feedback and interaction between clusters are possible [34]. Using the ANP method requires the decision-maker to possess sufficient knowledge of the decision goal, decision environment, and all decision elements to determine the effective criteria in the decision, their impact on each other, thereby enabling the decision-maker to depict the most realistic state of the network.

Paired comparisons should show the absolute priority of the elements over each other. However, because such knowledge about the system is not always available and since the decision-maker generally cannot judge with confidence in the paired comparisons, so to fix this problem, we must develop the network analysis model [35]. By integrating fuzzy logic into the pairwise process of logical comparison of the elements, the ANP method offers more flexible and more realistic, and accurate results in the absence of uncertainty and ambiguity [36].

2.3 F-ANP Method Framework

Step 1: After analyzing the problem, identifying the influential factors, and examining the interactions between them, a matrix of pairwise comparison of the main criteria and sub-criteria of the research (assuming no relationship and existence of relationship) has been formed to construct the model and transform the problem into a network structure.

Step 2: Formation of pairwise comparison matrix and fuzzification of the criteria

The pairwise comparison matrix, denoted by A = [aij], is shown as follows:

$$\tilde{A} = \begin{bmatrix} (\mathbf{1.1.1}) & (p_{12}^{\alpha}.p_{12}^{\beta}.p_{12}^{\gamma}) & \cdots & (p_{1n}^{\alpha}.p_{1n}^{\beta}.p_{1n}^{\gamma}) \\ \left(\frac{1}{p_{12}^{\alpha}}.\frac{1}{p_{12}^{\beta}}.\frac{1}{p_{12}^{\gamma}}\right) & (\mathbf{1.1.1}) & \cdots & (p_{2n}^{\alpha}.p_{2n}^{\beta}.p_{2n}^{\gamma}) \\ \vdots & \vdots & \vdots & \vdots \\ \left(\frac{1}{p_{1n}^{\alpha}}.\frac{1}{p_{1n}^{\beta}}.\frac{1}{p_{1n}^{\gamma}}\right) & \left(\frac{1}{p_{2n}^{\alpha}}.\frac{1}{p_{2n}^{\beta}}.\frac{1}{p_{2n}^{\gamma}}\right) & \cdots & (\mathbf{1.1.1}) \end{bmatrix}$$

In this step, triangular fuzzy numbers (TFN) marked D = (α.β.γ) are used to complete the pairwise comparison matrix according to the fuzzy spectrum.

Step 3: Weighing the criteria using the F-ANP method

Step 3-1: Calculating the weight of criteria and sub-criteria using the Buckley method.

The steps of calculating the weight of the criteria and sub-criteria are described in the following. After collecting the questionnaire, it is noteworthy that the opinions of various experts are combined with geometric meanings. However, since an incompatible matrix can lead to confusing results, it is necessary to check compatibility before solving the problem, measured on a scale of 0.1 and should be less than that. For matrix A = [aij], to use the fuzzy geometric mean in calculating the W_i fuzzy weights, equations 6-9 are presented:

$$r_i = \left(\prod_{j=1}^{n} p_{ij}\right)^{1/n} \qquad i = 1.2.3.\ldots.n \tag{6}$$

$$a_i = \left\{\prod_{j=1}^{n} a_{ij}^{\frac{1}{n}}\right\}.\quad b_i = \left\{\prod_{j=1}^{n} b_{ij}^{\frac{1}{n}}\right\}.\quad c_i = \left\{\prod_{j=1}^{n} c_{ij}^{\frac{1}{n}}\right\} \tag{7}$$

$$a = \sum_{i=1}^{m} a_i \quad . \quad b = \sum_{i=1}^{m} b_i \quad . \quad c = \sum_{i=1}^{m} c_i \tag{8}$$

$$Cw_i = \left(\frac{a_i}{c} . \frac{b_i}{b} . \frac{c_i}{i}\right) \tag{9}$$

Step 3-2: Fuzzy Weighting:

Then the fuzzy weight of the ith index is represented by a triangular fuzzy number according to Eq. (10):

$$Cw_i = r_i(r_1 . r_2 . \dots . r_m)^{-1} \tag{10}$$

Step 3-3: Weight Defuzzification

A defuzzification process is required to achieve a clear output. Defuzzification is producing quantitative results from fuzzy logic considering the fuzzy sets and the corresponding degrees of membership. The output of the defuzzification process is a single number obtained from Eq. (11) (Center of Gravity (COG) method):

$$w_{crisp\ i} = \frac{\alpha + \beta + \gamma}{3} = \frac{Cwi}{3} \tag{11}$$

Step 3-4: Weight Normalization:

Now, the obtained weights must be normalized. We use the sum-normalization method according to Eq.s (12) and (13) to normalize the weights:

$$S = \sum_{i=1}^{n} w_{crisp\ i} \tag{12}$$

$$W_{\mathrm{i}} = \frac{w_{crisp\ i}}{S} \tag{13}$$

Step 3-5: Pairwise comparison of criteria to internal relationships:

As mentioned, the ANP method deals with the criteria's internal relationships. In this section, the interdependencies of the criteria are shown to determine the relationships between the criteria. Expert opinions have been used to obtain this table and determine the interdependencies between the criteria. This table shows each criterion's intersection with the number 0, and the relationship between the row criterion and the column criterion is shown with the number 1.

Step 3-6: Internal relations of the criteria:

According to the results obtained from Step 3-5, we form pairwise comparisons of each of the criteria, calculate the weights, and multiply the criteria by the final weight. The obtained weight is the final weight of the criteria.

2.4 F-WASPAS Method

The MCDM approach is one of the most frequently used techniques in complex decision-making. Among MCDM methods, the WASPAS approach is a highly accurate method that enhances the ranking accuracy of alternatives. WASPAS is a combinational method comprising Weighted Product Model (WPM) and Weighted Sum Model (WSM). In 2012, Zavadskas et al. proposed the MADM method, later labeled as WASPAS [37]. They established that WASPAS is superior to WSM and WPM with higher accuracy compared to other methods. WSM is straightforward and easy to understand, and thus, it is one of the most used methods. It calculates the total score of an alternative by determining the weighted sum of the attribute values [38]. On the other hand, WPM was established to sidestep the alternatives that return weak or invalid attribute values. WPM computes every alternative's score as "a product of the scale rating of each attribute to a power equal to the weight significance of the attribute" [39, 40].

Several studies have emphasized the WASPAS method's capabilities in various areas. In this section, we will extend the WASPAS approach to the fuzzy environment. The fuzzy method allocates relative importance to each attribute with a fuzzy number as an alternative to exact numbers. The WASPAS method is widely used in site selection, shopping center location allocation, and evaluating candidate sites for implementing wind turbine and solar projects. It is also used in building construction, industrial, business, and scientific journal evaluation and ranking.

According to the presented fuzzy theory description, the F-WASPAS steps are summarized as follows:

Step 1. Establish a Fuzzy Decision-Making Matrix (F-DMM). $\tilde{x}_{ij}$ are performance values and $\widetilde{w}_{ij}$ are attributes weights, which are both elements of the Decision-Making Matrix (DMM). Select the linguistic ratings.

Experts determine the system of attributes and the values and initial weights of the attributes. The discrete optimization problem is characterized by preference for m rational alternatives (rows) valued based on n attributes (columns):

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1j} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{i1} & \cdots & \tilde{x}_{ij} & \cdots & \tilde{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mj} & \cdots & \tilde{x}_{mn} \end{bmatrix}; \quad i = \overline{1.m} \ , \ j = \overline{1.n} \tag{14}$$

where $\tilde{x}_{ij}$ is the fuzzy value signifying the performance value of the ith alternative based on the jth attribute. A fuzzy set is represented by a tilde ˜ on top of the set's symbol. We determine the priorities for the alternatives in subsequent steps.

Step 2. All initial $\tilde{x}_{ij}$ attribute values are normalized – returns $\tilde{\tilde{x}}_{ij}$ for the normalized decision-making matrix $\tilde{\tilde{X}}= [\tilde{x}_{ij}]_{m\times n}$.

- For useful criteria $\tilde{\tilde{X}}=\frac{\tilde{x}_{ij}}{max_i \tilde{x}_{ij}}$ (15)
- For non-useful criteria $\tilde{\tilde{X}}=\frac{min_i \tilde{x}_{ij}}{\tilde{x}_{ij}}$ (16)

Step 3. Compute the optimality function's values:

a) Based on the WSM for each alternative, we have:

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{\tilde{x}}_{ij} . \ i = \overline{1.m.} \tag{17}$$

b) Based on the WPM for each alternative, we have:

$$\tilde{P}_i = \prod_{j=1}^{n} \tilde{\tilde{x}}_{ij} . \ i = \overline{1.m.} \tag{18}$$

The fuzzy performance valuation for each alternative gives the fuzzy numbers, $\tilde{\tilde{Q}}_i$, and $\tilde{P}_i$. In order to defuzzify the values, the center of area method is the most straightforward method:

$$Q_i = \frac{1}{3}\left(Q_{i\alpha} + Q_{i\beta} + Q_{i\gamma}\right) \tag{19}$$

$$P_i = \frac{1}{3}\left(P_{i\alpha} + P_{i\beta} + P_{i\gamma}\right). \tag{20}$$

Step 4. Using the WASPAS-F technique, the integrated utility function value for an alternative is defined according to the following Eq. (21):

$$K_i = \lambda \sum_{j=1}^{m} Q_i + (1-\lambda) \sum_{j=1}^{m} P_i . \quad \lambda = 0.\cdots.1 \ . \quad 0 \le K_i \le 1. \tag{21}$$

is obtained assuming that the total WSM score of all the alternatives is equal to their total WPM scores:

$$\lambda = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} Q_i + \sum_{i=1}^{m} P_i} \quad (22)$$

Step 5. Rank the order of preferences. Pick an alternative with the highest $K_i$value.

3 Case Study

The city of Arak is located at 34 degrees and 5 minutes and 30 seconds in the northern hemisphere. It is also located at 49 degrees 41 minutes and 30 seconds east of the Greenwich meridian. Arak is one of the metropolises of Iran and one of the largest cities in central Iran, and the capital of the Markazi (Central) province. The population of Arak (2016 census) was 520,944. The city has a population density of more than 10,000 people per square kilometer, which in this regard, is considered the population center of the Markazi province and the 18th most populous city in Iran.

is one of the industrial cities of Iran, which is the first in terms of diversity of industrial products, the second in terms of the existence of parent industries, and in general, is one of the four industrial hubs of the country and is known as the industrial capital of Iran. Considering its situation between the Caspian Sea and the Persian Gulf and its location between the west and south transit routes, the city is one of the most critical superhighways of the country.

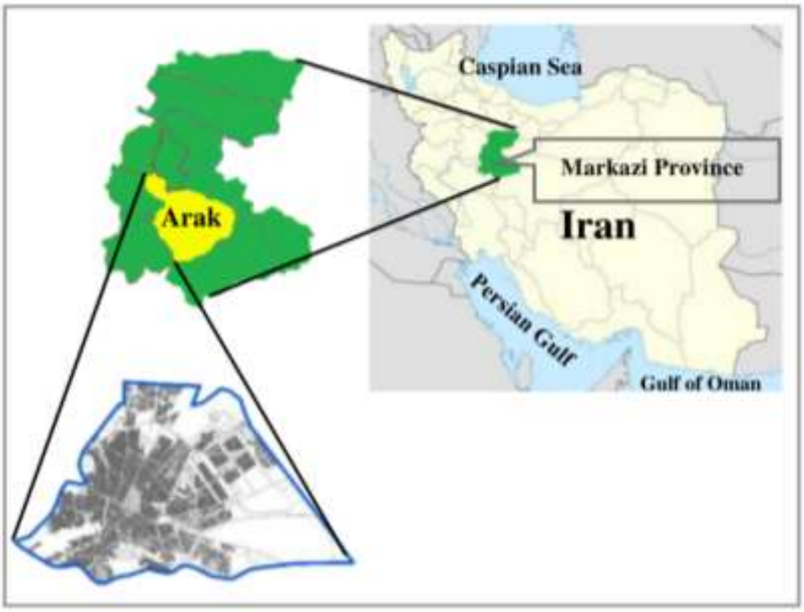

Fig. 2. Map of the Markazi Province and Arak City

Phase 1:

Table 1. Evaluation of Decision making

Criteria code	Evaluation Criteria
C1	Distance from residential neighborhoods
C2	Distance from access
C3	Distance from environmental landscape (green areas)
C4	Distance from a fire station
C5	Distance from the city center
C6	Distance from commercial centers
C7	Distance from factories and industrial workshops
C8	Distance from medical centers
C9	Distance from urban facilities and utilities
C10	Distance from parking and main transport terminals
C11	Distance from military and law enforcement centers
C12	Distance from faults
C13	Distance from educational centers

Because of the increase in the population of Arak and the tendency to urbanization in recent years, the need for an optimal location to increase the number of medical and hospital locations and easy and fast access to these places is one of the primary and basic needs of citizens. The proposed method was implemented in Arak to understand better the method, followed by the implementation of the steps presented step-by-step in Section 2 of the study.

Table 2. Fuzzy weight criteria

Criteria code	Fuzzy weight	Criteria code	Fuzzy weight
C1	(0.075,0.128,0.212)	C8	(0.055,0.097,0.166)
C2	(0.097,0.176,0.296)	C9	(0.021,0.037,0.074)
C3	(0.072,0.130,0.224)	C10	(0.022,0.035,0.061)
C4	(0.027,0.048,0.088)	C11	(0.022,0.034,0.058)
C5	(0.079,0.122,0.188)	C12	(0.031,0.051,0.089)
C6	(0.043,0.079,0.142)	C13	(0.013,0.022,0.043)
C7	(0.025,0.042,0.076)		

Table 3. Normal and definite and final weight criteria

Criteria code	Difinite weight	Normal weight	Final weight
C1	0.136	0.126	0.124
C2	0.186	0.173	0.155
C3	0.139	0.129	0.116
C4	0.053	0.049	0.071
C5	0.128	0.119	0.090
C6	0.085	0.079	0.065
C7	0.046	0.043	0.042
C8	0.104	0.096	0.076
C9	0.042	0.039	0.058
C10	0.039	0.036	0.055
C11	0.037	0.034	0.025
C12	0.056	0.052	0.023
C13	0.025	0.039	0.060

Phase 2:

After determining the final weight of the criteria in the previous step, the information layers are prepared from the current condition in the ArcGIS environment. Then, in the next step, the raster layers are converted into fuzzy layers, and finally, the maps resulting from the combination of the fuzzy layers are obtained by the five fuzzy operators. After reviewing the results, the final map obtained from the combination of layers was determined using a fuzzy gamma operator, and the appropriate points for the construction of the hospital were specified. Then, five areas (A1-A5) were identified in Fig. 3 using expert opinion to prioritize and determine the hospital's optimal and more appropriate location among the areas marked in green as suitable areas.

Phase 3:

Finally, we prioritize the candidate locations using the F-WASPAS method.

In the first step, we form the decision matrix of the technique. The decision matrix consists of rows and columns whose columns are the same criteria for location evaluation, and the rows are the study options (i.e., five candidate locations). Each cell evaluates each option based on each criterion based on a triangular fuzzy spectrum completed by three experts and subsequently integrated by the arithmetic mean method. The merged matrix is shown in Table 4.

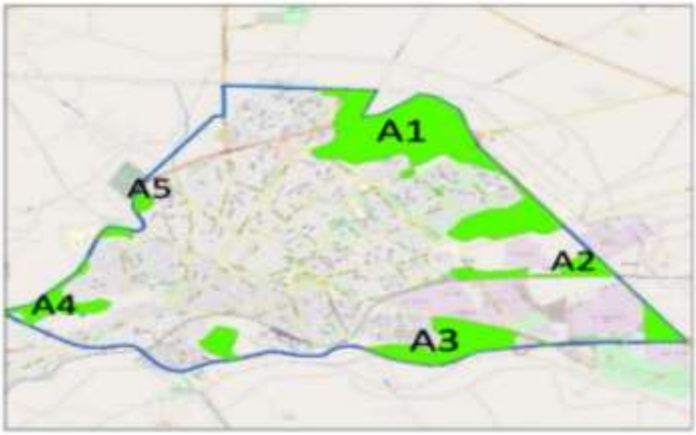

Fig. 3. Candidate areas for prioritization

Table 4. F-WASPAS decision matrix

Criteria code	A1	A2	A3	A4	A5
C1	(4,5,6)	(5,6,7)	(7,8,9)	(7,8,9)	(5,6,7)
C2	(8,9,10)	(5,6,7)	(7,8,9)	(8,9,10)	(4,5,6)
C3	(5,6,7)	(1,2,3)	(3,4,5)	(8,9,10)	(8,9,10)
C4	(7,8,9)	(7,8,9)	(4,5,6)	(1,2,3)	(3,4,5)
C5	(5,6,7)	(5,6,7)	(4,5,6)	(2,3,4)	(2,3,4)
C6	(5,6,7)	(7,8,9)	(6,7,8)	(5,6,7)	(1,2,3)
C7	(5,6,7)	(1,2,3)	(1,2,3)	(5,6,7)	(4,5,6)
C8	(4,5,6)	(5,6,7)	(5,6,7)	(4,5,6)	(3,4,5)
C9	(4,5,6)	(3,4,5)	(2,3,4)	(3,4,5)	(6,7,8)
C10	(4,5,6)	(3,4,5)	(3,4,5)	(5,6,7)	(5,6,7)
C11	(3,4,5)	(4,5,6)	(5,6,7)	(5,6,7)	(2,3,4)
C12	(4,5,6)	(4,5,6)	(4,5,6)	(3,4,5)	(3,4,5)
C13	(3,4,5)	(1,2,3)	(4,5,6)	(2,3,4)	(2,3,4)

In the second step, we normalize the decision matrix based on equations 15 and 16, the results of which are shown in Table 5:

Table 5. Normalized F-WASPAS matrix

Criteria	A1	A2	A3	A4	A5
C1	(0.57,0.63,0.67)	(0.71,0.75,0.78)	(1.00,1.00,1.00)	(1.00,1.00,1.00)	(0.71,0.75,0.78)
C2	(1.00,1.00,1.00)	(0.63,0.67,0.70)	(0.88,0.89,0.90)	(1.00,1.00,1.00)	(0.50,0.56,0.60)
C3	(0.63,0.67,0.70)	(0.13,0.22,0.30)	(0.38,0.44,0.50)	(1.00,1.00,1.00)	(1.00,1.00,1.00)
C4	(0.14,0.25,0.33)	(0.14,0.25,0.33)	(0.25,0.40,0.50)	(1.00,1.00,1.00)	(0.33,0.50,0.60)
C5	(0.40,0.50,0.57)	(0.40,0.50,0.57)	(0.50,0.60,0.67)	(1.00,1.00,1.00)	(1.00,1.00,1.00)
C6	(0.20,0.33,0.43)	(0.14,0.25,0.33)	(0.17,0.29,0.38)	(0.20,0.33,0.43)	(1.00,1.00,1.00)
C7	(0.20,0.33,0.43)	(1.00,1.00,1.00)	(1.00,1.00,1.00)	(0.20,0.33,0.43)	(0.25,0.40,0.50)
C8	(0.75,0.80,0.83)	(0.60,0.67,0.71)	(0.60,0.67,0.71)	(0.75,0.80,0.83)	(1.00,1.00,1.00)
C9	(0.50,0.60,0.67)	(0.67,0.75,0.80)	(1.00,1.00,1.00)	(0.67,0.75,0.80)	(0.33,0.43,0.50)
C10	(0.75,0.80,0.83)	(1.00,1.00,1.00)	(1.00,1.00,1.00)	(0.60,0.67,0.71)	(0.60,0.67,0.71)
C11	(0.67,0.75,0.80)	(0.50,0.60,0.67)	(0.40,0.50,0.57)	(0.40,0.50,0.57)	(1.00,1.00,1.00)
C12	(0.75,0.80,0.83)	(0.75,0.80,0.83)	(0.75,0.80,0.83)	(1.00,1.00,1.00)	(1.00,1.00,1.00)
C13	(0.33,0.43,0.50)	(1.00,1.00,1.00)	(0.25,0.40,0.50)	(0.50,0.60,0.67)	(0.50,0.60,0.67)

In the third step, using equations 17 and 18, we calculate the values of WSM (weighted sum) (Q) and the WPM model (weighted multiplication) (P); finally, using equations 19 and 20, we defuzzify the values, the results of which are shown in Table 6.

Table 6. WSM and WPM values

Alternative	Q	P	Difinite Q	Difinite P
A1	(0.575,0.646,0.695)	(0.501,0.602,0.666)	0.639	0.590
A2	(0.550,0.613,0.659)	(0.445,0.546,0.612)	0.608	0.534
A3	(0.641,0.700,0.741)	(0.554,0.648,0.706)	0.694	0.636
A4	(0.795,0.836,0.863)	(0.717,0.793,0.835)	0.831	0.782
A5	(0.718,0.768,0.801)	(0.658,0.733,0.777)	0.762	0.723

In the fourth step, first, using Eq. 22, $\lambda = 0.480$ was obtained. Then, using Eq. 21, the K-values were calculated, and based on that, the alternative locations were ranked. The results are shown in Table 7. According to Fig. 5, based on λ value-dependent errors, the estimation accuracy in the WASPAS method is higher than the WSM and WPM methods. Also, to increase the accuracy of the calculations, different values of λ were used, the results of which are shown in

Table 8. However, the exact result is when λ holds the optimal value according to Eq. 22.

Table 7. Scoring and ranking of alternatives

Alternative	K_i	Normalized K_i	Rank
A1	0.613	0.181	4
A2	0.569	0.168	5
A3	0.664	0.196	3
A4	0.806	0.237	1
A5	0.742	0.219	2

Table 8. Ranking of locations when λ= 0,...,**1**

	Alternatives				
Values of λ	A1	A2	A3	A4	A5
0=WPM	0.590	0.534	0.636	0.782	0.723
0.1	0.595	0.541	0.642	0.787	0.727
0.2	0.599	0.549	0.648	0.792	0.731
0.3	0.604	0.556	0.654	0.797	0.735
0.4	0.609	0.564	0.659	0.802	0.739
0.5	0.614	0.571	0.665	0.806	0.743
0.6	0.619	0.578	0.671	0.811	0.747
0.7	0.624	0.586	0.677	0.816	0.750
0.8	0.629	0.593	0.682	0.821	0.754
0.9	0.634	0.600	0.688	0.826	0.758
1=WSM	0.639	0.608	0.694	0.831	0.762
Optimal	0.613	0.568	0.664	0.806	0.742
Rank	4	5	3	1	2

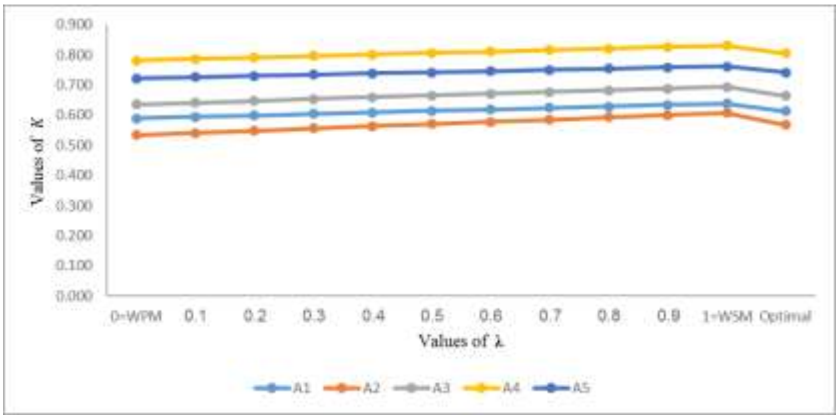

Fig. 4: Ranking accuracy chart

4 Discussion and Conclusion

The primary consequence of the rapid growth of cities is disruption of the service distribution system and the inadequacy of service distribution. Since health care is one of the necessities of life in the city, social justice and sustainable development are proposed. This concept of justice is justice in opportunities, so equal access to health services in the social justice framework is one of the necessities of life. Demand for new hospitals has increased because of the growing urban population. It should be noted that the establishment of new service centers requires high costs, and it is crucial to determine the optimal location of these centers so that all citizens can benefit from them.

In this study, we used the combination of GIS capabilities and ANP and WASPAS models in a fuzzy environment to determine the optimal locations and select the best location for the hospital. First, effective criteria for locating the hospital were selected according to the geographical location of Arak, hospital resources, experts, and books and articles. Then, the criteria were weighed in fuzzy mode, and finally, the results obtained from the GIS method in the fuzzy mode were combined by fuzzy operators in the ArcGIS environment. Finally, the optimal locations were identified, of which the experts determined five locations. Then, using the WASPAS-F method, five locations were identified, prioritized, and the most appropriate locations were specified. In future research, effective indicators and costs in the location are considered along with the effective criteria. The present study was performed in a fuzzy environment using triangular fuzzy numbers. It is suggested that a study be performed using other fuzzy numbers, and the result be examined and compared with our results. It is also suggested that in future studies, the location of specialized and sub-specialized hospitals in Arak be examined.

References

[1] Ziari, Y. and R. Khodadadi, *Locating Semnan's hygienic and health potential places using AHP method in GIS environment centers*. Environmental Based Territoral Planning (AMAYESH), 2013. **6**: p. 177-193.

[2] Taghvai, M. and D. Azizi, *Planning and management urban crisis by emphasising on the facilities, services and site selection of health centers*. Isfahan: Kankash Publication, 2009.

[3] Dunne, G., *How is the hospital organization and how it works*. 3 ed. 2018, Tehran: Jahad University Press, University of Medical Sciences, Islamic Republic of Iran Army.

[4] Hare, T.S. and H.R. Barcus, *Geographical accessibility and Kentucky's heart-related hospital services*. Applied Geography, 2007. **27**(3-4): p. 181-205.

[5] Raazani, A. and A. Asgari, *Urban land use Planning, Using what-if Planning Support System (case-study: Dorud city)*. Urban management, 2008. **6**(20): p. 76-85.

[6] Mesgari, M., M. Teymori, and H. Shorvarzi, *Hospitals Site Selection using Fuzzy GIS*. Bimonthly Shhrngar, 2011. **12**(54): p. 30-40.

[7] Mohammadi, J., H. Poorghayoomi, and M. Ghanbari, *Spatial Analysis and Site Selection fueling stations in Kazeroon*. Research and Urban Planning, 2016. **7**(24): p. 105-120.

[8] Drezner, Z., et al., *The weber problem*. Facility location: Applications and theory, 2002: p. 1-36.

[9] Rezaeisabzevar, Y., A. Bazargan, and B. Zohourian, *Landfill site selection using multi criteria decision making: focus on influential factors for comparing locations*. Journal of Environmental Sciences, 2020. **93**: p. 170-184.

[10] Fan, J., et al., *Optimal selection of design scheme in cloud environment: A novel hybrid approach of multi-criteria decision-making based on F-ANP and F-QFD*. Journal of Intelligent & Fuzzy Systems, 2020. **38**(3): p. 3371-3388.

[11] Hossein Zadeh, N., et al., *Suitable location city hospitals through the hierarchical modulation method (AHP) and model (Fuzzy) in GIS (Case Study: Region 19 of Tehran)*. . GIS and RS Application in Planning, 2017. **8**(4): p. 21-38.

[12] Shariff, S.R., N.H. Moin, and M. Omar, *Location allocation modeling for healthcare facility planning in Malaysia*. Computers & Industrial Engineering, 2012. **62**(4): p. 1000-1010.

[13] Reisi, M., A. Afzali, and L. Aye, *Applications of analytical hierarchy process (AHP) and analytical network process (ANP) for industrial site selections in Isfahan, Iran*. Environmental earth sciences, 2018. 77(14): p. 1-13.

[14] Dinan, N.M., M. Keshtkar, and Z. Mokhtari, *Site selection of a waste incineration plant using integrated fuzzy-ANP and weighted sum-ANP in Qazvin Province, Iran*. International Journal of Environment and Waste Management, 2020. **25**(3): p. 381-394.

[15] Veysi Nab, F., et al., *Locating hospitals using weighted linear combination model in GIS environment in Ardabil City*. Journal of Health, 2015. **6**(1): p. 43-56.

[16] Rezayee, M., *Hospital Site Selection in Iskandar Malaysia using GIS-Multi Criteria Analysis*. International Journal of Basic Sciences and Applied Computing (IJBSAC), 2020. **10**(2).

[17] Danesh, G., et al., *Compilation of a model for hazardous waste disposal site selection using GIS-based multi-purpose decision-making models*. Environmental monitoring and assessment, 2019. **191**(2): p. 1-14.

[18] Barzehkar, M., et al., *Landfill site selection using GIS-based multi-criteria evaluation (case study: SaharKhiz Region located in Gilan Province in Iran)*. SN Applied Sciences, 2019. **1**(9): p. 1-11.

[19] Parsa Moghadam, M., et al., *Optimal site selection of urban hospitals using GIS software in Ardabil City*. Journal of Ardabil University of Medical Sciences, 2017. **16**(4): p. 374-388.

[20] Mitropoulos, P., I. Mitropoulos, and I. Giannikos, *Combining DEA with location analysis for the effective consolidation of services in the health sector*. Computers & Operations Research, 2013. **40**(9): p. 2241-2250.

[21] Badalpur, M. and E. Nurbakhsh, *An application of WASPAS method in risk qualitative analysis: a case study of a road construction project in Iran*. International Journal of Construction Management, 2019: p. 1-9.

[22] Bagočius, V., K.E. Zavadskas, and Z. Turskis, *Multi-criteria selection of a deep-water port in Klaipeda*. Procedia Engineering, 2013. **57**: p. 144-148.

[23] Turskis, Z., et al., *A hybrid model based on fuzzy AHP and fuzzy WASPAS for construction site selection*. International Journal of Computers communications & control, 2015. **10**(6): p. 113-128.

[24] Pourtaheri, M., et al., *Explanation of the Advantages of Using WASPAS Technique on the Positioning of Tourism-Target Villages (Case Study of Tourism Targeted Villages of Lorestan Province)*. Space Planning and Planning, 2016. **20**(2): p. 114-137.

[25] Izadikhah, M., *Deriving Weights of Criteria from Inconsistent Fuzzy Comparison Matrices by Using the Nearest Weighted Interval Approximation*. Advances in Operations Research, 2012. **2012**: p. 574710.

[26] Izadikhah, M., *A fuzzy goal programming based procedure for Machine Tool Selection*. Journal of Intelligent & Fuzzy Systems, 2015. **28**(1): p. 361-372.

[27] Izadikhah, M., Z. Aliakbarpoor, and H. Sharafi, *Ranking DMUs by ideal points in the presence of fuzzy and ordinal data*. Theory of Approximation and Applications, 2015. **9**(2): p. 13-36.

[28] Izadikhah, M., R. Roostaee, and A. Emrouznejad, *Fuzzy Data Envelopment Analysis with Ordinal and Interval Data*. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 2021. **29**(03): p. 385-410.

[29] Izadikhah, M., et al., *Sustainably resilient supply chains evaluation in public transport: A fuzzy chance-constrained two-stage DEA approach*. Applied Soft Computing, 2021. **113**: p. 107879.

[30] Izadikhah, M., *A fuzzy stochastic slacks-based data envelopment analysis model with application to healthcare efficiency*. Healthcare Analytics, 2022. **2**: p. 100038.

[31] Ehsanifar, M. and F. Hossein Zadeh Lotfi, *Utility of Ranking Warehouse Candidates in Workshop Locations Using UTAStar*. Journal of New Researches in Mathematics, 2018. **3**(12): p. 5-14.

[32] Leung, L.C. and D. Cao, *On consistency and ranking of alternatives in fuzzy AHP*. European journal of operational research, 2000. **124**(1): p. 102-113.

[33] Büyüközkan, G. and G. Çifçi, *A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers*. Expert Systems with Applications, 2012. **39**(3): p. 3000-3011.

[34] García-Melón, M., et al., *Farmland appraisal based on the analytic network process*. Journal of Global Optimization, 2008. **42**(2): p. 143-155.

[35] Nejati, M., *Ranking of companies participating in the tenders of Imam Khomeini Oil Refining Company Shazand using multi-objective decision-making techniques (MODM)*, in *Faculty of Engineering-Department of Industrial Engineering*. 2018, Islamic Azad University, Arak Branc.

[36] Ayağ, Z. and R.G. Özdemir, *Evaluating machine tool alternatives through modified TOPSIS and alpha-cut based fuzzy ANP*. International Journal of Production Economics, 2012. **140**(2): p. 630-636.

[37] Zavadskas, E.K., et al., *Optimization of weighted aggregated sum product assessment*. Elektronika ir elektrotechnika, 2012. **122**(6): p. 3-6.

[38] MacCrimmon, K.R., *Decisionmaking among multiple-attribute alternatives: a survey and consolidated approach*. 1968, Rand Corp Santa Monica Ca.

[39] Easton, A., *One-of-a-kind decisions involving weighted multiple objectives and disparate alternatives*. Multiple criteria decision making, 1973: p. 657-667.

[40] Alvand, A., et al., *Identification and assessment of risk in construction projects using the integrated FMEA-SWARA-WASPAS model under fuzzy environment: a case study of a construction project in Iran*. International journal of construction management, 2021: p. 1-23.