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HOSPITAL SITE SELECTION USING TWO-STAGE FUZZY MULTI-CRITERIA DECISION MAKING PROCESS

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Abstract: Site selection for sitting of urban activities/facilities is one of the crucial policy-related decisions taken by urban planners and policy makers. The process of site selection is inherently complicated. A careless site imposes exorbitant costs on city budget and damages the environment inevitably. Nowadays, multi-attributes decision making approaches are suggested to use to improve precision of decision making and reduce surplus side effects. Two well-known techniques, analytical hierarchal process and analytical network process are among multi-criteria decision making systems which can easily be consistent with both quantitative and qualitative criteria. These are also developed to be fuzzy analytical hierarchal process and fuzzy analytical network process systems which are capable of accommodating inherent uncertainty and vagueness in multi-criteria decision-making. This paper reports the process and results of a hospital site selection within the Region 5 of Shiraz metropolitan area, Iran using integrated fuzzy analytical network process systems with Geographic Information System (GIS). The weights of the alternatives were calculated using fuzzy analytical network process. Then a sensitivity analysis was conducted to measure the elasticity of a decision in regards to different criteria. This study contributes to planning practice by suggesting a more comprehensive decision making tool for site selection.

Keywords: Urban Planning; location; multi-criteria decision making; fuzzy logic; GIS; Shiraz.

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INTRODUCTION

The increasing urban population leads to the demand of developing new healthcare and medical service centers especially for remote areas. On the other hand, with improving the overall quality of life and living standards, residents become now more health conscious, explaining the heightened consumer demand in the quality and scope of medical services. Furthermore, the medical service authorities are usually interested to improve organizational structure and encourage hospitals to establish management practices that would enhance their competitiveness (Wu *et al.*, 2007).

The market share captured by a new or existing hospital is sensitive to both facility location and attractiveness. While absence of qualified healthcare practitioner and physician staff is a priority concern to the quality of a hospital, one may argue that having professional staff does not guarantee that the level of medical service of that hospital will be of a quality to success in an intensely competitive atmosphere. Physical access significantly matters. The location selection decision for such centers is an important strategic issue rather than merely tactical one as it is related to the medical service quality (Paul, 1997).

Location decision is probably the most significant decision which will affect its subsequent business to success, since a proper location may attract a large number of potential patients (Kuo *et al.*, 1999). In this way, establishing a hospital in urban districts has its own positive and negative consequences. Positive impacts may include increase in property value in neighboring periphery as well as improving health-related accessibility for the residents of that district. More important are negative side-effects such as environmental contamination and inducing new waves of traffic flow appearing on the network serving the district. In fact, the adjacent community is impacted in forms of increased traffic flow, increased emergency vehicle usage in residential areas, etc. In fact, if the decision reflects a rational decision-making based on proper information and research, then a higher level of community cooperation and participation is expected (Estill & Associates, 2006).

The constituency and multi-criteria nature of the hospital location make the issue as complex as cannot be addressed with conventional managing tools. In fact, hospital location decisions are still based upon personal and subjective criteria rather than any objective analysis (Hanes & McKnight, 1984). Therefore, health planners need more assistance in the development of tools to aid them in the rational selection of location choices. Analytical Hierarchal Process (AHP) and Analytical Network Process (ANP) help capturing both subjective and objective evaluation measures. They provide a useful mechanism for checking the consistency of the evaluations thus reducing bias in decision making. Geo-spatial information system (GIS), fuzzy logic and statistical methods have been often used to improve the capability and quality of AHP/ANP models.

BACKGROUND STUDIES

Methods

The location analysis of medical service centers are often focused on accessibility and activity-based impacts by applying accessibility indicators. Accessibility is defined as "the relative nearness or proximity of one place to another" (Tsou *et al.*, 2005). The concept of accessibility is used to explain the degree to which a product, device, service, or environment is available (Wikipedia, 2011). In a broader term, accessibility means ease of reaching opportunities within a reasonable time, cost and comfort. GIS is the most common tool applied so far to spatial analysis. The capabilities of GIS to handle massive amounts of data over large geographic areas at fine levels of geographic details make it suitable to analyze accessibility to medical service providers (Harea & Barcus, 2007).

The work by Parker and Campbell (1998) explored the potential for GIS technology in examining the utilization of general practitioner and accident and emergency services in Britain (Parker & Campbell, 1998). GIS was successfully employed to examine perceived and predicted accessibility of general practices and spatial distribution of patients using general practitioner services in study period. In a similar study, a GIS application was created in Jeddah City, Saudi Arabia, to cover three main health planning issues which were distribution of health demand, classification of hospital patients and the definition of hospital service area (Murad, 2007).

AHP has been widely applied to important problems in medical and health care decision making. The fields of application can be classified in seven categories: diagnosis, patient participation, therapy/treatment, organ transplantation, project and technology evaluation and selection, human resource planning, and health care evaluation and policy (Liberatore, 2008). However, its application in hospital site selection has not been widely developed.

Vahidnia *et al.* (2009) tried to select the optimum site for a hospital in Tehran using a GIS, while at the same time considering the uncertainty issue. The research quantified local access to existing hospitals throughout a city in terms of travel times. Hospital sites falling outside a particular time threshold were assigned higher priority. The other criteria considered included the site's accessibility from arterial routes, contamination and pollution, land cost, and the capacity to serve a larger population (Vahidnia, Alesheikh, & Alimohammadi, 2009).

The study by Wu *et al.* (2003) applied the Delphi method, the AHP and the sensitivity analysis to develop an evaluation method for selecting the optimal location of a regional hospital in Taiwan and determining its effectiveness. Sensitivity analysis was conducted in detail by varying the objective factor decision weight, the priority weight of subjective factors and the gain factors (Wu, Lin, & Chen, 2007). A similar research conducted to solve the problem of a new hospital location determination in Ankara. Since the evaluations were not presented as quantitative data but included subjective opinions, therefore, fuzzy logic was adapted and FAHP was used (DEU, 2010).

From the literature, it is clear that AHP/ANP and fuzzy AHP/fuzzy ANP methods are not used as competitors with each other. If the users are certain with the information or evaluation, the classical AHP/ANP method is preferred; otherwise, fuzzy AHP/ fuzzy ANP will tend to be the preferred methods. Sipahi and Timor (2010) stated that while the use of the AHP technique has continued to increase exponentially, it is expected that ANP will gain more popularity in the future, as the benefits of ANP become better understood (Sipahi & Timor, 2010). Both AHP and ANP systematically synthesize a variety of goals and objectives to choose an optimal alternative. For this reason, these approaches have been both praised and criticized. Advocates declare that inherent pair-wise comparison in these two models provides a way for the planner to compare items that historically have not been directly included in the decision-making process. On contrast, they can be criticized, based on their views that the pair-wise comparison method has intrinsic inaccuracies since people tend to be inconsistent (Macharis *et al.*, 1999). Before making comparisons, the nature of the problem must be defined exactly. A difficulty with the ANP, in particular, where relationships tend to be more complex, is in designing questions with sufficient accuracy to capture the issue at hand. This can negatively impact the relevance of the following responses (Carter *et al.*, 1999).

As explained earlier while there have been many applications of AHP in the health and medical field, only limited number of cases can be found about including ANP as well. This research attempts to address this gap in the literature by evaluating a number of potential sites for hospital establishment using fuzzy ANP process.

Hospital site selection criteria

Based on hospital size and scale, a broad range of site-selection criteria has been advised by medical authorities or researchers which are partly in use around the world. A summary is provided in **Table 1**.

Table 1. Hospital site selection criteria

Hospital type and scale	Criteria	Suggested by
General	Capture rate of population; Current and projected population density; Proximity to major commuter and public transit routes; Distance from other hospitals; Anticipated impact on exist hospitals	Virginia Hospital Center (VHC), 2009
Children	(a) Technical Issues: Site purchase cost, Existing infrastructure and availability of services, Site gradient, Ground conditions (soils/rock), Access; (b) Site Qualities: Environmental considerations, Heritage considerations, Site area, Site orientation, Site shape; (c) Site Character: Healing environment; (d) Location: Proximity to public transport, Traffic routes, Availability of land for long-term expansion, Future population and prominence,	Queensland State Government, Australia, 2008
Children	Conformity to surrounding region; Incremental operating costs; Travel time; Site ownership; Site shape; Ease of patient flow and staff movement; Perimeter buffer zone	Hospital of Saskatche wan, 2010, U.S.
General	Population density; Travel time; Distance from arterials; Land cost; Contamination	Vahidnia *et al.* (2008)
General	(a) Population number, density and age profile; (b) Firm strategy, structure and rivalry; (c) Related and supporting industries; (d) Governmental policy; (e) Capital, labor and land	Wu *et al.*, 2007
General	Travel time; Population density; socio-demographics of service area	Schuurman *et al.* (2006)
Professional medicine and cure	Proximity to future expansion space; Consistency with city zoning/policies; Compatibility with surrounding uses; Character and scale; Cost of site control; Helicopter access.	UCSF (University of California, San Francisco), 2010
Professiona l medicine and cure	Local community preferences; Accessibility; Centrality; Environment; Land ownership; Size and future	Estill & Associates (2006)

Generally, a hospital site selection is based on two constraints: internal resource allocation and the cost of external resources (Saskatoon Health Region (SHR), 2010). Planners and policy-makers normally do a trade-off between these two to take the final decision. An appropriate located hospital needs not only to be regionally compatible and complimentary but also keeps almost internal advantages of the site. Therefore, the distinctive characteristics of the site such as accessibility, centrality, ownership, and size should be paid enough attention (Estill & Associates, 2006).

RESEARCH METHODOLOGY

Analytic Hierarchy Process (AHP)

The concept of AHP was developed, for the first time in the mid-1970s by Thomas L. Saaty as a quantitative decision-making method for effectively combining the qualitative judgments. By organizing and assessing alternatives in regards to a hierarchy of multifaceted attributes, AHP provides an effective tool to deal with complex decision making and unstructured problems. AHP allows a better, easier, and more efficient framework for identification of selection criteria, calculating their weights and analysis (Bojovic & Milenkovic, 2008). The process of AHP can be simply summarized in four steps: construct the decision hierarchy, determine the relative importance of attributes and sub-attributes, evaluate each alternative and calculate its overall weight in regard to each attribute, and check the consistency of the subjective evaluations (Schoenherr *et al.*, 2008).

In the first step, the decision is decomposed into its independent elements and represented in a hierarchy diagram, which must have at least three levels (goal, attributes, and alternatives). Second, the user is asked to subjectively evaluate pairs of attributes on a nine-point scale. In the third stage, a weight is calculated for each attribute (and sub-attribute), based on the pair-wise comparisons. Because judgments are given subjectively by the user, the logical consistency of these evaluations is tested in the last stage. The ultimate outcome of the AHP is a relative score for each decision alternative.

Analytic Network Process (ANP)

The ANP is a type of AHP which allows groups or individuals to deal with the inter-relations (dependencies and feedbacks) between factors of complex structure in decision making process. Therefore, it can be defined as a multi-criteria decision making (MCDM) method for complicated and unstructured problems or an approach that uses a network model having clusters of elements (criteria sub-criteria and alternatives).

There are three super-matrices associated with each network: the unweighted-supermatrix, the weighted-supermatrix and the limit-supermatrix. Supermatrices are arranged with the clusters (Saaty, 1996). The unweighted-supermatrix contains the local priorities derived from the pairwise comparisons throughout the network. The weighted supermatrix is obtained by multiplying all the elements in a component of the unweighted supermatrix by the corresponding cluster weight. The limit supermatrix is obtained by raising the weighted supermatrix to powers by multiplying it times itself. When every column of supermatrix converged to a same vector , the limit matrix has been reached and the matrix multiplication process is halted. The values of this limit matrix are the desired weights of the elements with respect to the goal.

Fuzzy AHP/ANP

Fuzzy logic provides a language with syntax and semantics to represent the uncertainity of human judgements in reasoning and controling. The fuzzy sets theory, introduced by Zadeh (1968) to deal with vague, imprecise and uncertain problems, has been applied as a modeling tool in many fields (Zadeh, 1986). Because human decision-making is inevitably entails some degree of uncertainty, a combination of analytical methods and fuzzy technique are suggested. For developing AHP/ANP to Fuzzy AHP/ANP, expert's opinion must be represented by a fuzzy number instead of a crisp number. One of the popular shapes of fuzzy number is the triangular fuzzy number (TFN) whose membership is defined by three real numbers (l, m, u) and expressed by Lee (2010) as (**Fig. 1**):

$$\mu_A(x) = \begin{Bmatrix} (x-l)/(m-l), l \le x \le m \\ (u-x)/(u-m), m \le x \le u \\ 0 \qquad\qquad \text{otherwise} \end{Bmatrix} \qquad (1)$$

Given a crisp pairwise comparison matrix (PCM) A, the crisp PCM is fuzzified using the triangular fuzzy number (l, m and u), which fuzzy the original PCM using the conversion number as indicated in **Table 2** (Lee, 2010).

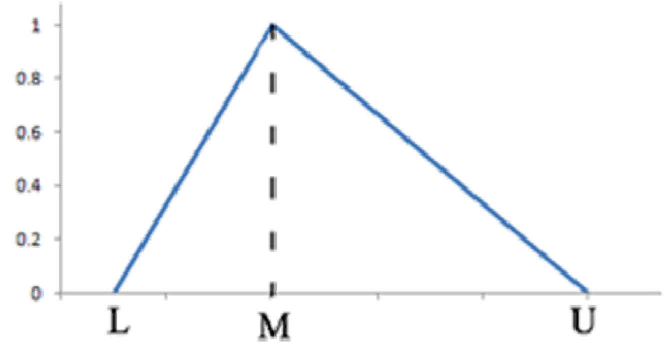

Fig. 1 A triangular fuzzy number.

Table 2. Triangular Fuzzy Scales for fuzzy AHP/ANP

Inverse Scales	Fuzzy Scales	Linguistic Scales
(1,1,1)	(1,1,1)	Equally Preferred
(1/4,1/3,1/2)	(2,3,4)	Moderately Preferred
(1/6,1/5,1/4)	(4,5,6)	Strongly Preferred
(1/8,1/7,1/6)	(6,7,8)	Very Strongly Preferred
(1/9,1/9,1/9)	(9,9,9)	Absolutely Preferred

For making pairwise comparison, a triangular fuzzy comparison matrix can be defined as follows:

$$\tilde{A} = (\tilde{a}_{ij})_{n\times n} = \begin{pmatrix} (111) & (l_{12}m_{12}u_{12})... & (l_{1n}m_{1n}u_{1n}) \\ (l_{21}m_{21}u_{21}) & (111)... & (l_{2n}m_{2n}u_{2n}) \\ (l_{n1}m_{n1}u_{n1}) & (l_{n2}\,m_{n2}u_{n2})... & (111) \end{pmatrix}$$

where $\tilde{a}_{ij}= (l_{ij},m_{ij},u_{ij})$, $\tilde{a}_{ij}^{-1}= (1/u_{ij},1/m_{ij},1/l_{ij})$, for i, j=1,2, …,n and $i\neq j$, and fuzzy weights for this comparison matrix will be calculated as follows (**Eq. 2**):

$$\hat{S}_i = \sum\nolimits_{j}^{n}=`\tilde{a}_{ij} \;/[\sum\nolimits_{k}^{n}=`\tilde{a}_{kj}] = \\ [\sum\nolimits_{j}^{n}=`l_{ij} / \sum\nolimits_{k}^{n}=`u_{kj}, \sum\nolimits_{j}^{n}=`m_{ij} / \\ [\sum\nolimits_{k}^{n}=`\sum\nolimits_{j}^{n}=`m_{kj}, \sum\nolimits_{j}^{n}=`u_{ij} \;/ \sum\nolimits_{k}^{n}=`\sum\nolimits_{j}^{n}=`1_{kj}] \qquad (2)$$

The next step is defuzzification which is a process to evaluate a crisp or point estimate of a fuzzy number. The result of fuzzy synthetic decisions reached by each criterion or alternative is a fuzzy number. Therefore, it is necessary to use the non-fuzzy ranking method for fuzzy numbers for final evaluation. İn previous works, many defuzzification methods has been used. A defuzzified value can be determined using the *centre of area* (CoA) method (Vahidnia *et al.*, 2009).This method was suggested as the most accurate and also practical defuzzification technique. İt is used in this research to determine the weight of each criterion or alternative. For those membership functions in which the precise determination of X^* that does half the area of fuzzy numbers is hardly possible, the following equation **Eq. (3)** is used to obtain the explicit number equivalent to the fuzzy number.

$$X^* = \frac{\int \mu(x)xdx}{\int \mu(x)dx} \qquad (3)$$

However, for TFN with simple membership function, the following equation is suggested by the authors (**Eq. 4**):

$$X = (l,m,u), \text{ If } (m-l) \leq (u-m)$$

$$X^* = 1 + \sqrt{u\frac{m}{2}} \quad \text{else} \quad X^* = u + 1 + \sqrt{u\frac{u-m}{2}} \qquad (4)$$

Research process

The hospital site selection was conducted in two stages: the first was screening stage, which was defined as selecting a limited number of alternative sites based on main criteria among the long list of developable parcels. This has been done using GIS and FAHP. The second stage was evaluation the short list of alternatives based on detailed and local criteria for selecting the optimum site. In this stage, the final option was selected using disaggregate and fine-scale data. The sensitivity analysis was then applied to estimate the degree to which final weight of alternatives change as the values of each criterion is changed. The research process is detailed on **Fig. 2**.

STUDY AREA AND SITE SELECTION CRITERIA

Study area

The case area to considering a hospital site is the Region 5 of Shiraz metropolitan area, Iran. Shiraz is the fifth most populous city of Iran and is the capital of Fars province in south of the country. Because of the existence of well-known Shiraz University of Medical Sciences (SUMS) and its professional medical staff and services, the city has a comparative advantage in health care and medical sector. Specialized medical centers and professional hospitals of Shiraz welcome a large number of patients from southern and western parts of the country as well as from Persian Gulf Arab countries. (Shiraz Medical University, 2011). The metropolitan area consists of nine regions. The reasons of choosing Region 5 include: (a) lack of enough allocation of healthcare and medical centers in the region in regard to its population and (b) policy recommendation of development plans of Shiraz to change the direction of physical development to the south and to empower brown-fields and vacant lands to have an in-ward and infill development instead of urban sprawl.

Screening

Some of conventional criteria for hospital site selection were mentioned earlier. Four criteria are considered in the screening phase (preparation of the short list of alternatives) and include: (a) distance to arterials and major roads; (b) distance to other medical centers; (c) population density and (d) parcel size.

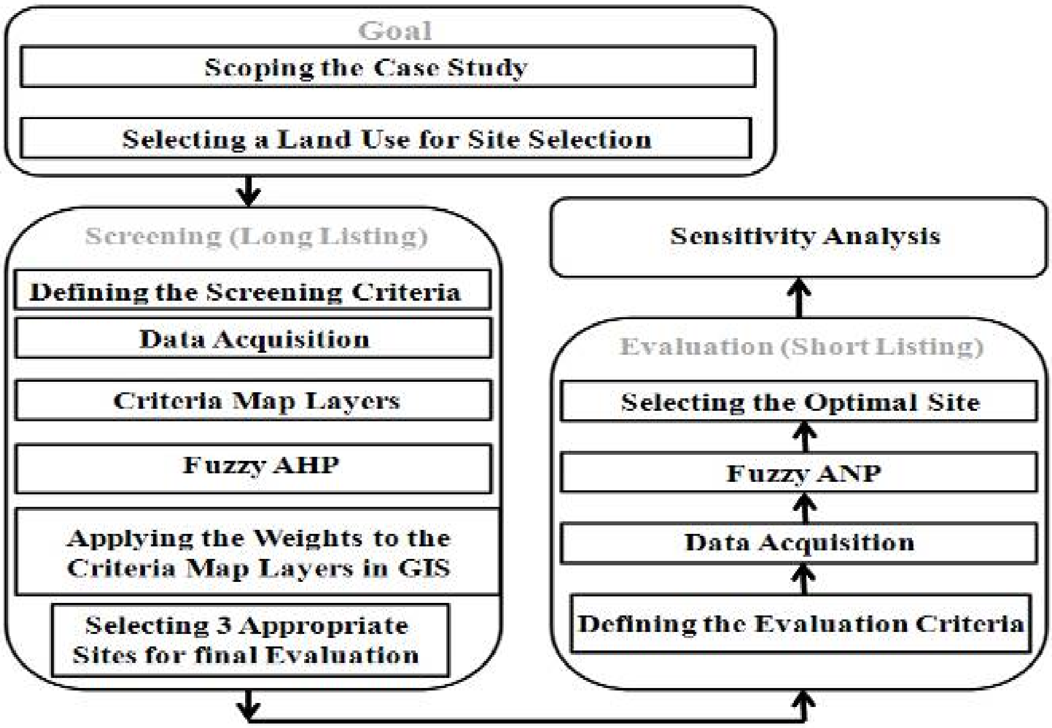

Fig. 2 The methodology used in this study.

(a) Distance to arterials and major roads

Because of the need for quick access by car and emergency service, proximity to arterials is being considered as one of the most important criteria in hospital site selection. Furthermore, having appropriate access is a key criterion taken into account by patients to choose a hospital to go.

(b) Distance to other medical service centers

Service area of a hostipal represents its potential demand. Distribution of hospitals throughout the study area is another important point need to be considered. A balanced distribution of service centers provides community with a higher level of social equity. Being more away from other medical centers can be a positive factor for an alternative site. The data layer for this criteriaon is generated using *Network Analyst* of *ArcGIS* version 9.3.

()()k**(d) Population density**

Population density is associated with potential demand and performance effectiveness of a hospital. The population density is calculated using 2006 census data on a census tract base as the spatial unit of analysis (ICB, 2006). The higher the density, the higher the score is for an alternative.

The weights obtained from FAHP calculations are applied in GIS to the criteria map layers to generate a screening map. Then, considering the available parcels within the region and threshold analysis by reclassification the screening map, three sites are selected for the final stage of evaluation (**Fig. 3**).

SITE SELECTION

Layer combination applying FAHP model

After generating criteria maps, it is time to introduce FAHP model (**Fig. 4**). The results of pairwise comparisons and the weight obtained for each criterion are detailed in **Table 3**.

(c) Parcel size

The potential sites can be ranked based on parcel size. In this study, very small and very large parcels are received negative scores in the evaluation. Meanwhile, it is avoided to select alternatives with irregular forms.

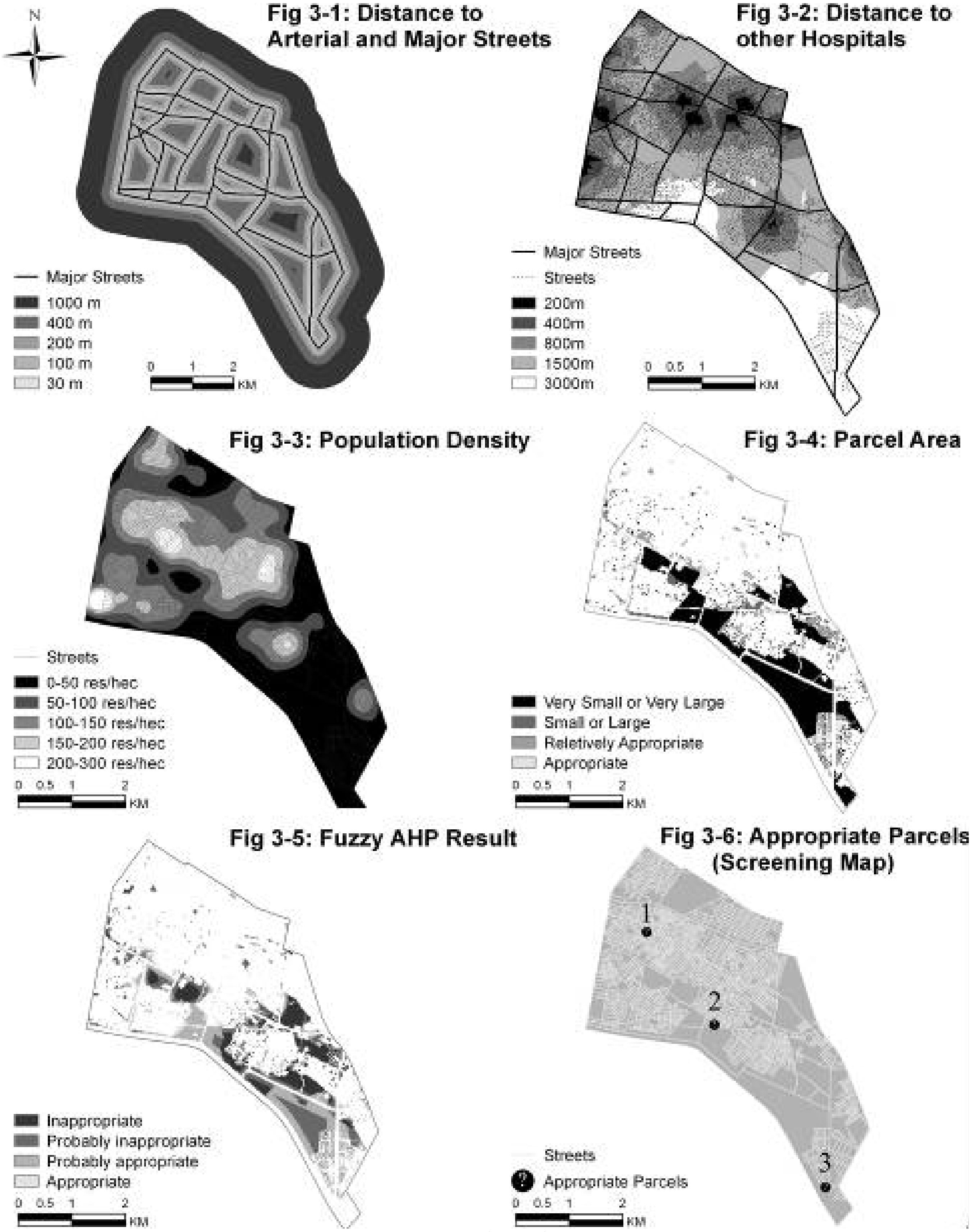

Fig. 3 Screening results.

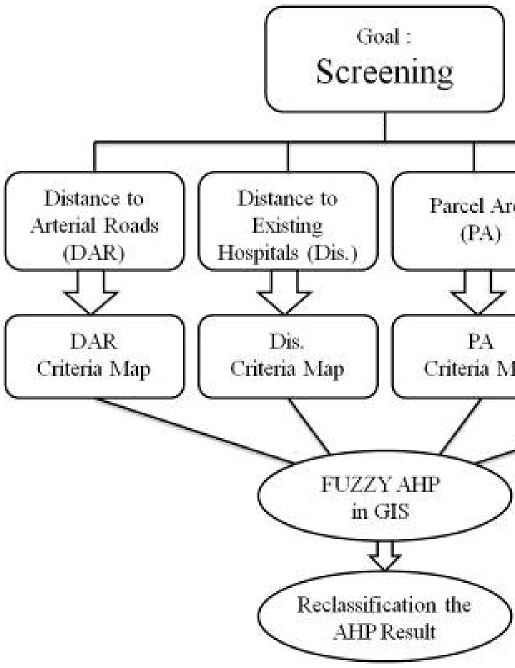

Fig. 4 FAHP model integrated with GIS.

Table 3. FAHP results

	DAR			DOC			PA			PD			WEIGHTS
DAR	1	1	1	0.2	0.25	0.33333	2	3	4	0.25	0.33333	0.5	0.1757
DOC	3	4	5	1	1	1	4	5	6	1	2	3	0.4535
PA	0.25	0.33333	0.5	0.16667	0.2	0.25	1	1	1	0.25	0.33333	0.5	0.0563
PD	2	3	4	0.33333	0.5	1	2	3	4	1	1	1	0.3145

DISTANCE TO ARTERIAL ROADS:	DAR
DISTANCE TO OTHER CENTERS:	DOC
PARCEL AREA:	PA
POPULATION DENSITY:	PD

λmax =	4.1383
CI =	0.0461
RI =	0.9
CR =	0.0512

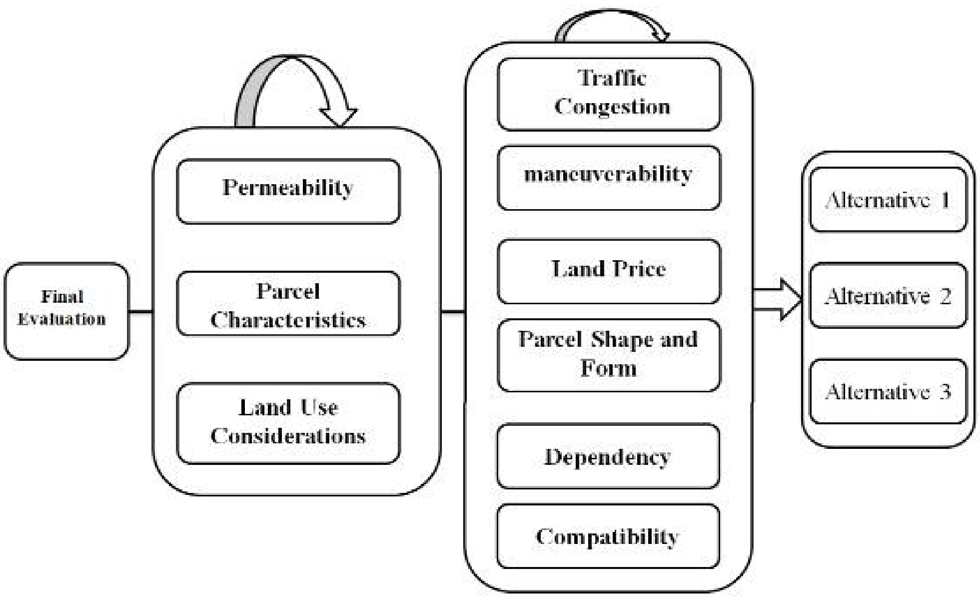

Fig. 5 FANP model.

Among the sites selected in the previous stage, one of them should be chosen as the final option. According to the specifications of each parcel and its neighboring area (by a radius of 400 m), the parcels are compared and then un-weighted super-matrix of the network is calculated (**Table 4**). With super-matrix multiplication in the cluster-matrix, weighted-matrix is obtained (**Table 5**). Then the limit supermatrix is obtained by raising the weighted supermatrix to powers by multiplying in itself until convergence occurs. For the weighted supermatrix, in this study, convergence occurs at 55 times (**Table 6**). This limit matrix is a column stochastic and represents the final criteria weights. After calculating the Alternatives scores in regards to criteria and their weights, the option with the biggest score should be the one selected which is alternative number 2 (**Table 7**).

Table 4. Un-weighted super-matrix

	G	P	L	LU	TC	M.	LP	PF	DEP.	COMP.
GOAL	0	0	0	0	0	0	0	0	0	0
PERMEABILITY	0.075	0	0.823	0.823	0	0	0	0	0	0
LAND CHARACTERISTICS	0.609	0.102	0	0.177	0	0	0	0	0	0
LAND USE CONSIDERATION	0.316	0.898	0.177	0	0	0	0	0	0	0
TC	0	0.102	0	0	0	0.672	0.058	0	0	0
M.	0	0.897	0	0	0.898	0	0.201	0.587	0	0
LP	0	0	0.822	0	0.177	0.267	0	0.367	0	0.177
PF	0	0	0.176	0	0	0.061	0.442	0	0.9	0
DEP.	0	0	0	0.284	0	0	0	0.046	0	0.823
COMP.	0	0	0	0.716	0	0	0.298	0	0.1	0

Table 5. Weighted super-matrix

	G	P	L	LU	TC	M.	LP	PF	DEP.	COMP.
GOAL	0	0	0	0	0	0	0	0	0	0
PERMEABILITY	0.075	0	0.412	0.411	0	0	0	0	0	0
LAND CHARACTERISTICS	0.608	0.051	0	0.088	0	0	0	0	0	0
LAND USE CONSIDERATION	0.316	0.8978	0.088	0	0	0	0	0	0	0
TC	0	0.051	0	0	0	0.672	0.058	0	0	0
M.	0	0.449	0	0	0.898	0	0.201	0.587	0	0
LP	0	0	0.411	0	0.177	0.267	0	0.367	0	0.177
PF	0	0	0.088	0	0	0.061	0.441	0	0.9	0
DEP.	0	0	0	0.142	0	0	0	0.046	0	0.823
COMP.	0	0	0	0.358	0	0	0.298	0	0.1	0

Table 6. Limit super-matrix

	G	P	L	LU	TC	M.	LP	PF	DEP.	COMP.
GOAL	0	0	0	0	0	0	0	0	0	0
PERMEABILITY	0	0	0	0	0	0	0	0	0	0
LAND CHARACTERISTICS	0	0	0	0	0	0	0	0	0	0
LAND USE CONSIDERATION	0	0	0	0	0	0	0	0	0	0
TC	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223	0.223
M.	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.321	0.322
LP	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
PF	0.150	0.151	0.150	0.151	0.151	0.151	0.151	0.151	0.151	0.151
DEP.	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
COMP.	0.060	0.061	0.060	0.061	0.061	0.061	0.061	0.061	0.061	0.061

Table 7. FANP evaluation results

Criteria	Sub-Criteria	Eij			Wj	Wj.Eij		
		A1	A2	A3		A1	A2	A3
Traffic	TC	0.122	0.319	0.558	0.223	0.027	0.071	0.124
	PERM.	0.611	0.279	0.109	0.321	0.196	0.089	0.035
Parcel	LP	0.122	0.319	0.558	0.188	0.023	0.060	0.105
	PF	0.102	0.605	0.292	0.150	0.015	0.091	0.044
Land Use	DEP.	0.610	0.279	0.109	0.056	0.034	0.015	0.006
	COMP.	0.101	0.584	0.314	0.060	0.006	0.035	0.019
		$D_i = \sum_j W_j.E_{ij}$				0.302	0.364	0.334

Sensitivity analysis

To investigate the influence of the tolerance on the obtained Alternatives scores, a sensitivity analysis is recommended. A detailed sensitivity analysis was carried out by changing the weights of two decision criteria and recalculating the scores of alternatives, while the weights of other criteria remained constant. By monitoring the scores changes per displacement of criteria weights, sensitivity of decision to selected criteria was obtained. Because the number of evaluation criteria is 6, so the number of displacements is equal to 15. The results indicated that the obtained weights were highly sensitive to change in traffic congestion level and land price values (**Fig. 7**).

CONCLUSION

AHP and ANP can deal with both quantitative and qualitative attributes. They are useful decision-analysis techniques especially in cases dealing with strategic planning, including site selection. They are also compatible with expert participation methods to integrate their experiences and opinions in planning process. FAHP and FANP are suggested to reflect better the human thinking style and solve the hierarchical fuzzy problems. İn fact, in FAHP and FANP, the pair-wise comparisons in the judgment matrix are fuzzy numbers that are modified by the designer’s emphasis (Kahraman *et al.*, 2003).

In this study, a two-step decision-making framework was used for determining the optimum site for hospital deployment in Region 5 of Metropolitan Shiraz. First, the screening and selection of three appropriate options out of all developable parcels were conducted using a combination of FAHP and GIS. Secondly, with regard to local circumstances, the final evaluation analysis was performed by FANP in which feedbacks and interactions between criteria were also considered.

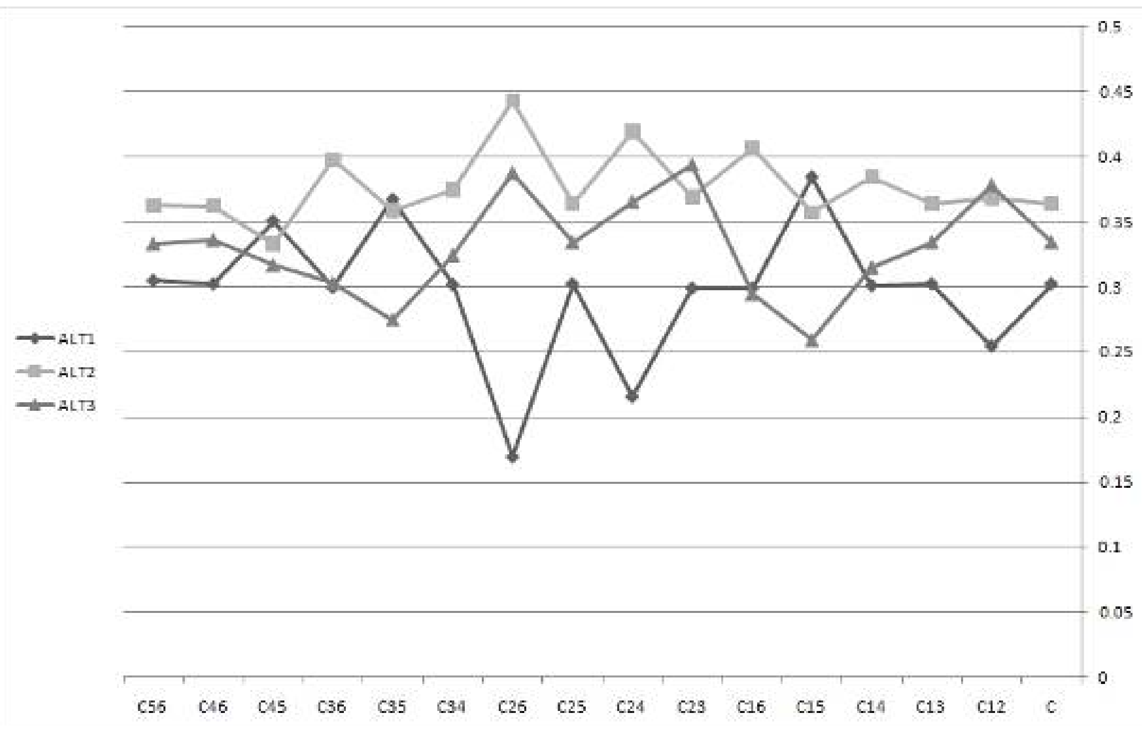

Fig.7 Results of sensitivity analysis.

The optimal alternative is site 2. The sensitivity to selection criteria was also examined. The proposed evaluation method can be used as a reference for medical service administrators to select the optimal location for a new hospital to ensure that it as a competitive advantage once established. This can be considered as a valuable prototype and reference for hospital administrators and academics in establishing a standardized means of selecting location for medical care facilities. This study contributes to planning practice by suggesting a more comprehensive decision making tool for site selection.

Through taking a two-step selection approach, urban land use characteristics at both regional and local levels are considered. This study can be criticized in terms of using a limited number of criteria and potential alternatives. Some of potentially significant factors such as land ownership and environmental pollution affecting a hospital site selection were absent in the analysis. There are several recommendations to improve and develop this research. Some critical site features such as local pollution level, land tenure and ownership and regional infrastructure should be included in the analysis. Also small parcels can be combined together through land readjustment (LR) and transfer of development rights (TDR) policies, thus their priority would be changed. A higher precise can be achieved by extending the range of expert opinions involved and using structured methods like Delphi. The weights obtained for the criteria should be revised in different locations and calculated again.

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