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Spatial analysis and urban land use planning emphasising hospital site selection: a case study of Isfahan city

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Abstract. Providing appropriate and equal healthcare to the various classes of society is among the major issues in social welfare. The spatial distribution and locating of health service centres are significant in addressing the healthcare needs of citizens. This issue needs to be evaluated using quantitative and qualitative approaches throughout those cities with high populations and activity density levels. By taking Isfahan metropolitan area as the case study area, in this study, a combination of Network Analyst tool within Geographic Information System (GIS) and an Analytic Hierarchy Process (AHP) model was used to evaluate the catchment areas of the 26 existing hospitals within the study area. Thus, with effective data collection in the form of layers of information such as transportation network, population density, land use, etc. using (GIS), the authors categorised urban land in seven categories from poor to very good for the construction of hospitals. The result of analysis indicated that existing hospitals covered approximately 24% of active urban areas within a standard access time. The result can be used for policy making and healthcare planning.

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1. Introduction

1.1. Statement of problem

The high concentration of population in urban areas increases the potential of urban crises and risks such as earthquakes, fires, car accidents, work-related incidents, food poisoning and various diseases. In this regard, planners are trying to present an appropriate model for allocating land to urban land uses and appropriate locating of such uses to improve human safety and welfare in the urban area and to provide a better life therein (Valizadeh, 2005: 7). Since aid uses perform vital functions, they are of special importance compared to other urban services (Nazarian and Karimi, 2009: 5). Health and treatment as an aid use are among the most sensitive indicators in relation to sustainable urban and regional development and, given its close relationship with human health, it deserves special attention in urban and regional planning (Bahrami, 2008: 5). Health resources and services should be available to all people equally and fairly (Baghiani Moghadam and Ehrampoush, 2004: 47). However, in terms of the fair spatial distribution and location of healthcare services in order to provide fair and quick access to them in a timely and convenient manner some problems are evident (Ebrahimzade et al., 2010: 40). This is because access to medical services for emergencies and life-threatening conditions is a vital expectation of the public in many communities (Nasiripoor et al., 2009: 140). In particular, in Iran, where due to the specific conditions and natural and other disasters and incidents, many lives are threatened in such emergencies, more attention is required in this regard (Sahibzada and Bagheban, 2006: 104). That is because the speed of service provision in medical service centres, especially in emergency wards, is essential in reducing mortality and disabilities (Zohoor and Pilevarzadeh, 2003: 413). It is vital for patients to reach healthcare centres quickly, which reduces the probability of casualties (Azizi, 2004: 133).

One of the major issues in social welfare is the provision of appropriate and equal healthcare for different classes of society. In addition to its importance, this issue is complex due to the multiplicity of its dimensions and effects, so administrators and managers are faced with major and complex decisions in this regard. Observations suggest that people who have settled in poor urban areas due to their poor financial ability have more limited access to healthcare services as a result of an increase in spatial and social inequalities (Sharifzadegan et al., 2010: 2; Soltani, and Maranadi, 2015: 33). Thus, site selection for hospitals and centres should be based on criteria and standards and existing realities and take into account the urban context and the structure of the transportation network. This way, they can cover all urban areas with respect to standard spatial and temporal distance. This study attempts to use a Geographic Information System (GIS) and network analysis method to evaluate the spatial distribution of and access to the hospitals in Isfahan metropolitan area. A combination of GIS and Analytic Hierarchy Process model (AHP) was used for optimal hospital site selection at the city level and an attempt was made to provide a good model to improve the present situation.

1.2. Research objectives

Several scholars have discussed the issue of healthcare in the global context (Gołata and Kuropka 2018, Ingwe 2012). Based on the 1999 Human Development Report by the United Nations, health status is one of the three criteria for assessing the development of countries around the world. One of the main criteria in the promotion of community health is that of increased citizen access to healthcare services. Hospitals, as a type of healthcare facility, are of especial importance. When acute conditions for patients start, the speed of access to health care is the difference between their survival, serious injury or death. Usually, delay in the transfer of patients to medical centres for reasons such as traffic, poor access network, the unsuitability of many passages for emergency vehicle traffic, and low speed of vehicle traffic on the network cause patients irreparable damages. Therefore, urban planning, especially in the area of transportation network structure, should apply more sensitivity regarding the location of quick and convenient access to emergency centres and hospitals in accordance with standards and criteria, so that these facilities can be used as soon as possible and without facing barriers and limitations in the urban environment. Given the metropolis of Isfahan's population and building density increasing the risk of disease, incidents, and crises, this study aims at a quantitative and qualitative evaluation of hospitals in Isfahan according to the standards and regulations in order to provide an optimum model for their site selection and fair spatial distribution.

1.3. Literature review

Providing healthcare services in urban areas has a long history, but literature is lacking in the area of site selection and distribution of healthcare centres. To the researchers' knowledge, such studies go back to the 1970s. In 1979, the UK Department of Health and Social Security gave attention to the strategic development of healthcare centres, after which, studies began in this area. This line of research was followed in Austria in 1980–1982. The idea of site selection of private hospitals was proposed by Leslie Mayhew of Birkbeck's College in London, who tried to develop a spatial model to predict patient flows to hospitals based on results from changes in supply and demand for non-hospital services (Azizi, 2004: 10–11). A number of studies related to site selection for health centres are reviewed here. Ibrahim and Graham (2003) used the site selection model for maximum coverage of the Saudi Red Crescent in Riyadh. Evance (2004) emphasised the role of GIS in disaster management as related to the operation of emergency centres and stated that not only can GIS reduce damage at the time of accidents, but it can also help with finding optimum locations for effective emergency centres, and this in turn increases high efficiency during a crisis. Cheng and Huang (2007) investigated optimal site selection for Taiwanese hospitals to ensure a competitive advantage using AHP and Sensitivity Analysis. Zarei (2010) studied the spatial analysis and location of urban services in Nurabad using GIS and discussed the location of hospitals as part of the study. Qeisari et al. (2007) tried to identify candidate locations for establishing emergency facilities with minimum cost after specifying demand points on the network. In this regard, they used a genetic algorithm which follows location-allocation and the problem of P-Median. After analysing the factors affecting the placement of EMS centres using GIS and network analysis in the 6th district of Tehran, Shabani (2005) provided recommendations regarding the location of EMS centres. Jamali et al. (2014) evaluated the pattern of hospital locations in Tabriz. Yaghfoory et al. (2014) studied the optimal locations for healthcare centres in the 3rd district of Zahedan using GIS after urban land use planning. The purpose of the present study is to take advantage of the above experience, information and methods to study the spatial distribution and location pattern of hospitals in Isfahan.

1.4. Methodology

Providing appropriate and equal healthcare to various classes of society and optimum spatial distribution and the equitable locating of health services is among the major issues in social welfare. This is because optimum spatial distribution and equitable locating of health services allow users to access health services and improve the spatial distribution of hospitals based on the related standards and regulations. Evaluation of urban land for locating new hospital is necessary. Due to the high population and density in the metropolis of Isfahan, the methodology used in this paper is descriptive-analytical and of an applied kind, and has adopted a systematic approach to the issue based on theoretical information and geographical data (location-space, documents, field investigations, and 1:2,000 maps of Isfahan). The data were collected using the documents, field notes, and the existing maps in the city of Isfahan. First, in designing the passages network of the city of Isfahan, completing it with the required information and digitising in the GIS environment using the network analysis model, the *status quo* of services and performance of each hospital at the city level was analysed. Subsequently, based on that and the Index Overlap model (IO) and AHP, suitable locations for the construction of new hospitals were identified after going through the stages of entering the necessary information layers and managing, analysing, processing, valuating, weighting, and combining them.

1.5. Research area

A. Isfahan has a longitude of 51°39′40″E and a latitude of 32°38′30″N. It is 1,570 metres above sea level. Isfahan is the centre of Isfahan Province with an area of about 512 km² on a plain of Zayandehrud's alluvium on the eastern Zagros Mountains (Omrani, 2005: 31). Map. 1 shows the location of Isfahan in the country, the province, and the city region.

2. Principles and concepts

2.1. Theoretical background

The city has long been not only a symbol of creation, but also a symbol of terror and fear, because irregularities in atmospheric conditions, as well as earthquakes and fires, have occasionally destroyed towns and homes (Shakuie, 2004: 231). The geographical region of Iran is among the world's most vulnerable places to probable disasters, particularly earthquakes. Every year, the occurrence of these events causes great losses of life and property in rural and urban areas (Taghvaei and Azizi, 2008: 19). Therefore, urban planners have sought to develop and explore solutions that secure the health and welfare of citizens. According to Article 29 of the IRI Constitution, improving health status and providing health services with timely and easy access to them, is a universal right of all and is one of the aspects constituting social and economic development (Monfaredian Sarvestani, 2007: 13). Hospitals and healthcare centres are among the utilities that have to meet the emergency needs during and in the aftermath of disasters (Taghvaei and Azizi, 2008: 166). In the system of medical emergency services, two factors should be examined regarding the lack of appropriate performance: (a) the distance between the centre and the incident site; and (b) the time needed to access the incident location (Bahrami, 2009: 67). Thus, experts believe that one of the essential conditions for the success of medical emergency centres is to increase the geographical distribution and the number of hospitals and emergency centres to the extent that such services can reach patients in the shortest time possible (Taghvaei and Azizi,

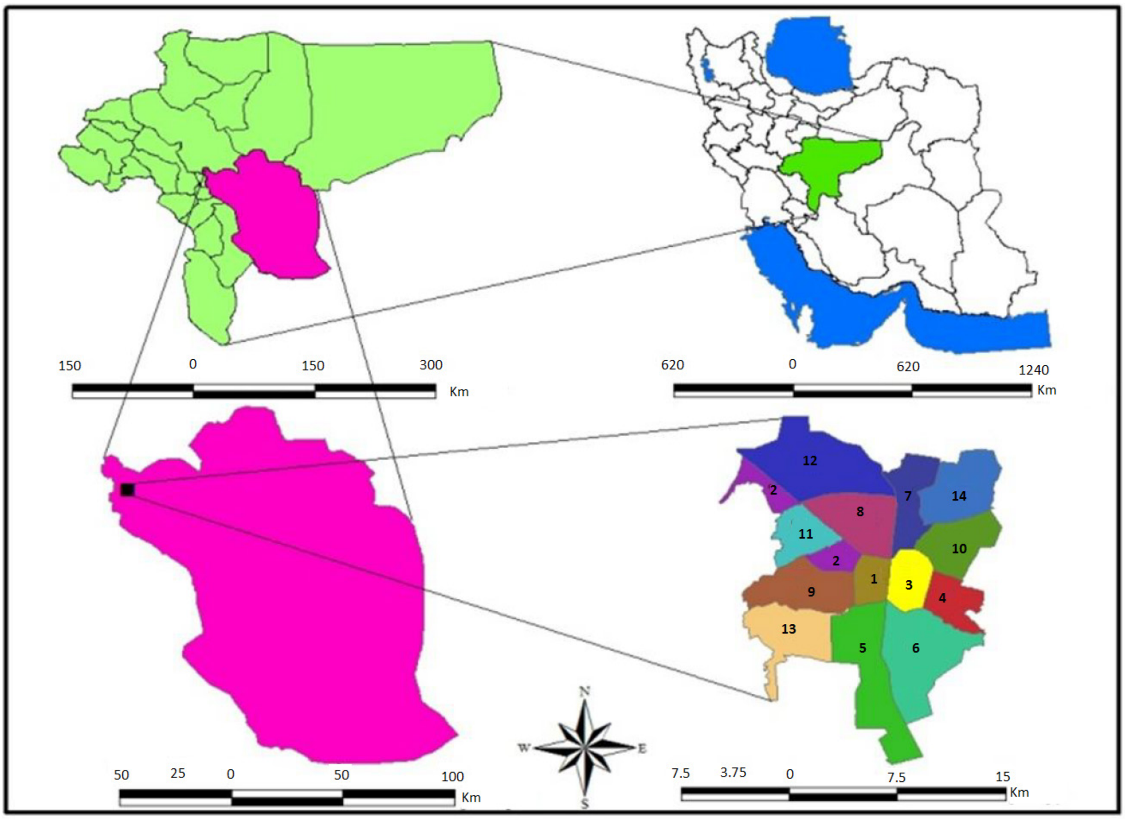

Fig. 1. Location of Isfahan in the country, province and city region
Source: authors

2008: 107). On the other hand, the establishment of an urban element in a specific spatial-physical location is subject to certain principles and mechanisms that, once observed, can increase the performance of the element in the specified location (Roostaei et al., 2011: 46 and Hadiani and Kazeminezhad, 2010: 99–100). In the systems approach from the functionalists' point of view, parts and the whole take their meaning in relation to each other (Latifi, 2006: 24). Thus, since the main purpose of planning is the physical organisation of the city based on social justice, efficiency and quality of environment, proper site selection for activities has particular importance (Taghvaei et al., 2010: 101). Determining proper locations for the establishment of various urban uses depends on many factors (Zebardast and Muhammadi, 2005: 8). Usually, the site selection for urban elements, especially for-profit ones, follows economic mechanisms and free competition rules. However, not-for-profit elements cannot be entirely subject to economic mechanisms, but it is necessary to compensate for market inefficiencies via decisions and policies based on public interest. This applies to public services such as public healthcare units (Yekanifard, 2001: 61). Therefore, in order to ensure human health, which is at the core of sustainable development, it is necessary that all hospitals and healthcare centres be evaluated and revised with respect to location and design (Taghvaei and Azizi, 2008: 22). In this study, to investigate the location of hospitals in Isfahan, due to the sensitivity of the issue and the fact that a large volume of information on spatial-locational aspects has to be collected, combined and analysed for proper evaluation of the contributing factors, a combination of location-based and multi-criteria models can be helpful. GIS, which was created for the purpose of storing, retrieving, changing, analysing and designing data (Richard 2002, 541), is widely used as part of information technology by organisations responsible for health management at global, national, regional and local levels (Zare et al., 2006: 47). The application of this system for site selection and helping accessibility is obvious (Masoomi and Farajzadeh, 2006: 195) and can be used to locate optimal hospital sites.

2.2. Research models

2.2.1. Network Analysis

Connectivity functions are used in GIS analysis and include network analysis and proximity functions. In proximity functions, due attention is not paid to the passages and access network; therefore, buffering analysis results do not have a high degree of confidence (Modiri, 2005: 56). In network analysis, streets and passages that play a vital and fundamental role in transportation within a city are used as linear features; therefore, the results of the analysis have a higher degree of validity compared to those of spatial analysis.

2.2.2. Index Overlap model (IO)

The combination of different information layers in GIS is known as Overlay. In this model, different effects in different classes receive different weightings to create a flexible combination of maps covering a range of numbers. In addition to weighting units in any information layer, each layer is weighted in the site selection according to its importance (Tajik, 2009: 66).

2.2.3. The Analytic Hierarchy Process (AHP)

AHP is one of the most efficient techniques for decision making, and was first developed by Thomas L. Saaty in 1980 (Poorghayoomi, 2010: 39). The method involves a series of two-on-two comparisons in order to make the appropriate matrix. The matrix receives a number of pair-wise comparisons as input and produces the desired weights as output (Malczewski & Ogryczak, 9991: 7). For this reason, in this study, this model is used to evaluate parameters and alternatives and select the appropriate location.

3. Results and Discussion

3.1. Evaluating the *status quo* of Isfahan hospitals and determining their catchment area

There were 26 hospitals in the city of Isfahan, most of which had emergency services wards. Those hospitals have been built in an area of 316,000 m². There are also 23 health clinics in the city. A comparison of the number of hospitals and clinics in the 14 areas showed that area 1 had the highest number of hospitals (eight hospitals). Areas 2, 11, 12, 13 and 14 had no hospital (Table. 1)

Area 3 had the highest number of clinics (six) and areas 2, 8, and 14 had the lowest (no clinics). A comparison of hospital areas shows that with three hospitals, area 5 has the maximum area of hospitals among all city areas. This is even more than that of area 1. That is, the total hospital area in city area 5 is nearly three times that of area 1, which has eight hospitals. As can be seen, there was no balance in the distribution of hospitals and hospital area in the city, so that the highest density of hospitals was around the old town, especially in areas 1 and 3. The catchment area of the hospital across the city is the area that can be covered by its emergency services within a specified standard time. The standard response time for an emergency vehicle (ambulance) is 3 minutes according to international standards (Bahrami, 2008: 75). Based on an average speed of 30 kilometres per hour, this radius is considered to be between 1.5 to 2.5 km (Arse Consulting Engineer, 1996:1). However, this distance depends on factors such as the urban fabric, the structure of a transportation network, and traffic conditions, and can be less or more than the value stated above. Therefore, to determine the catchment area and range of services in international standard time (3 minutes), Find Service Area in network analysis model was used. First, a network of all transportation paths of Isfahan was prepared based on actual traffic directions. Then, after creating topology in Arc Map, other network information such as street type (arterial, collector and distributor and local access), length and width of passages, direction (one-way, two-way, impasse), traffic volume, average

Table 1. Distribution of health facilities in different areas of Isfahan based on the 2001 population

Area	Number of Hospitals	Number of clinics	Hospital beds per capita	Physicians per capita	Nurses per capita	Area of healthcare uses
Area 1	8	3	68.48	234.00	170.08	56,319
Area 2	0	0	-	-	-	41
Area 3	4	6	231.43	630.22	242.50	73,468
Area 4	2	2	191.77	2048.06	721.15	49,614
Area 5	3	1	136.35	796.59	347.78	145,309
Area 6	2	2	623.09	2,644.69	1,190.11	11,330
Area 7	3	3	522.81	2,226.54	1,819.77	14645
Area 8	1	0	1,608.85	13,790.14	3,575.22	11,776
Area 9	1	1	154.34	8,045.13	4,022.56	11,895
Area 10	2	2	1,318.61	5,713.97	6,122.11	15,925
Area 11	0	1	-	-	-	-
Area 12	0	2	-	-	-	-
Area 13	0	1	-	-	-	-
Area 14	0	0	-	-	-	-
Maximum	8	6	1,608.85	13,790.14	6,122.11	145,309
Mean	1.85	2.9	539.5245	4,014.3696	2,023.4758	39,032.24
Minimum	0	0	68.48	234.00	170.08	41

Source: Nastaran (2001: 226) and the authors' calculations

speed, and intersections and limitations were added and the spatial relationship between the network lines was created. Time periods for every passage were calculated based on which the catchment area of every hospital in the city was specified. Figure 2 shows the distribution and catchment area for the hospitals based on the global standard of 3 minutes and 5 minutes. With respect to a catchment area of 3 and 5 minutes, it is observed that a wide range of the west, north west, South, and south west of Isfahan is outside the catchment area covered by existing hospitals. Table 2 shows the area covered by hospitals. The 3-minute service area of Isfahan hospitals was 84,067,249 m², of which 32,864,641 m² is shared between hospitals. Therefore, their useful coverage was 89,834,222 m². Given the area of Isfahan, it can be said that 32.19% of the city area is covered by standard catchment area of existing hospitals (Table. 2). Thiessen Polygon Analysis was used to find the level of performance of existing hospitals (Fig. 3).

3.1.1. Structural and non-structural analysis of Isfahan hospitals and their vulnerability

Analysis of the structural status of hospitals was done in terms of building skeleton, construction date, structural quality, quality of materials used in construction, configuration and access to hospital facilities.

3.1.1.1. Type of building skeleton and the structural quality of hospitals in Isfahan

Type of building materials, resistance, structural properties and architecture of building relate to land type and the seismic properties of the region, and affect the level of vulnerability to natural disasters. The disproportion between regional vulnerability and quality of building materials (in terms of the structural characteristics that provide resistance against natural disasters) significantly increases the extent of damage and vulnerability (Nateq Elahi, 1998: 110). Our evaluation of the 26 hospitals in Isfahan showed that a significant number of those hospitals were made of brick and other materials that were vulnerable to natural disasters (Table. 3).

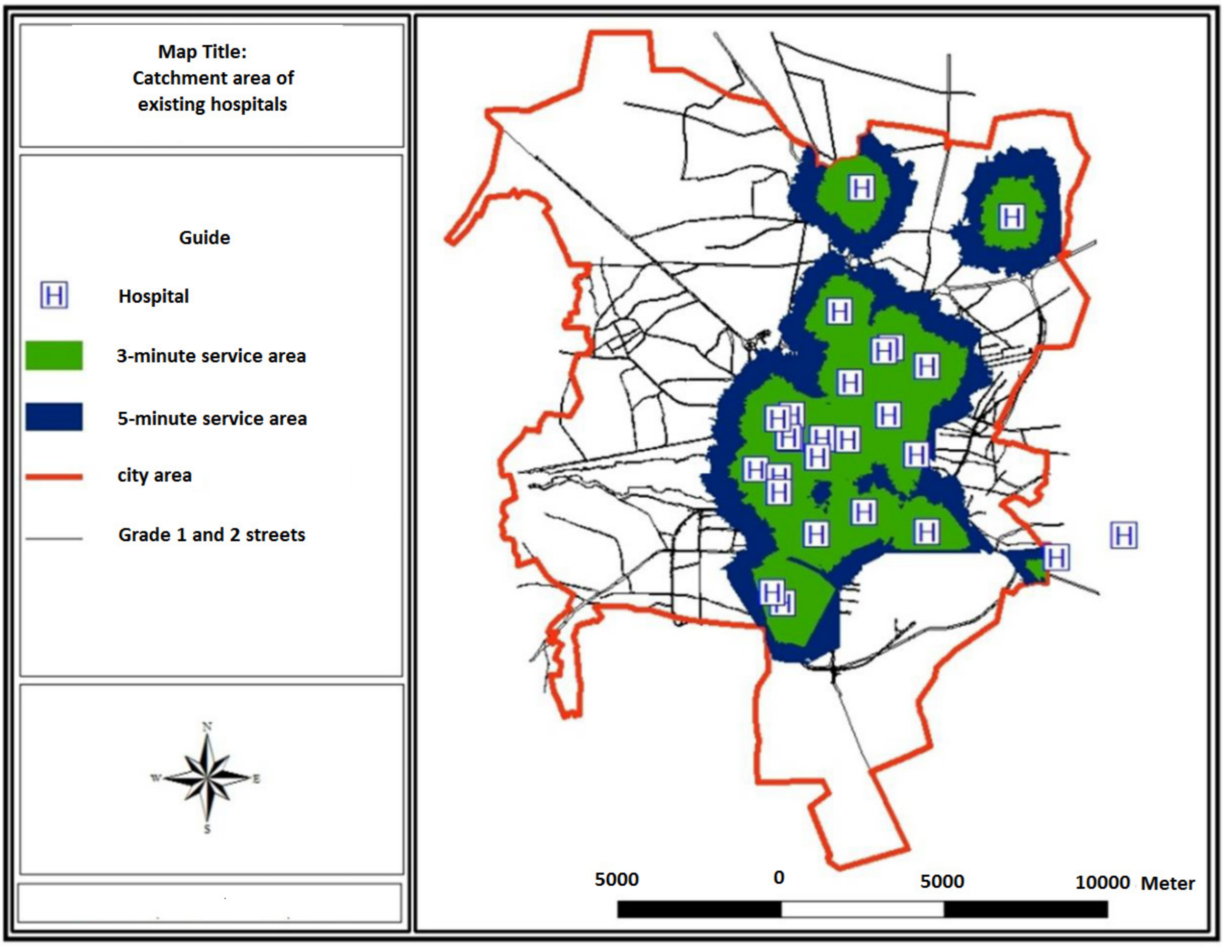

Fig. 2. Distribution and catchment area of hospitals based on the global 3-minute and 5-minute standard

The study of the structural quality in hospital facilities (Nateq Elahi, 1998: 110) shows that 32% of hospitals had poor structure, 40% had average structure and only 28% had good structure (Ismailian, 2011: 191).

3.1.1.2. Quality of materials used in hospitals

Evaluation of the quality of materials used in hospitals (Nateq Elahi, 1998: 111) also indicates that ten hospitals in the city had less strong materials and 16 hospitals had strong materials (ibid).

3.1.1.3. Access to hospitals

The problem of evacuating patients and staff and hospital population from the building in the event of earthquakes and other natural disasters is also important. In fact, due to the failure of the lift after earthquakes, stairs and corridors constitute an emergency exit route. Various events might occur to the stairs, such as the breakdown of walls on both sides, blockage and so on. Experience shows that, in earthquakes, doors become stuck in their frames and cannot be opened. Since hospitals usually have small rooms with doors, it is easy for corridors and hallways to become blocked. The canopy and corridors will easily collapse and block the passage. The destruction of the hospital in addition to its losses creates a legal responsibility towards the victims. The above problems are caused by lack of attention to proper design and earthquake safety measures and stress the importance of principles of safety in hospital design (Ameriuon, 2002: 5). Analyses showed that access to the hospital facilities was weak in ten hospitals of Isfahan (Ismailian, 2011: 193).

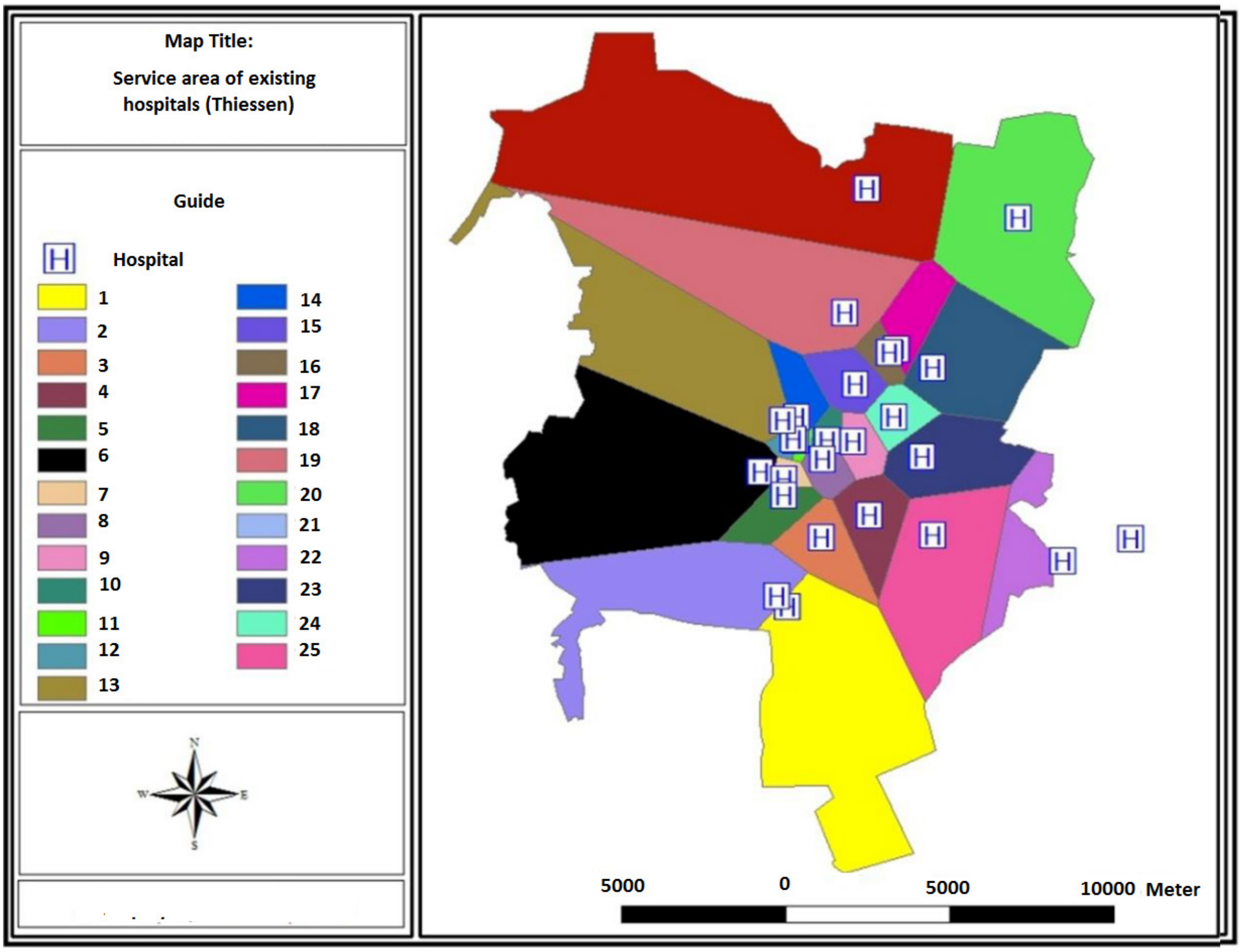

Fig. 3. Distribution and catchment area of hospitals in Isfahan using Thiessen polygons

3.1.1.4. The crisis management system in Isfahan hospitals

Crises caused by natural disasters have significant effects on society. Health centres play an important role in crisis management. The organisation and management of health centres in the event of disasters are of considerable importance. Convenience, comprehensiveness, functionality, and attention to the hospital's main structure are among the main issues necessary for developing a comprehensive crisis management programme for hospitals. Plans for emergency admissions, hospital transportation system design, operational definition of the roles of individuals in each group, training programmes, plans for rapid discharge, physical space for screening and triage, and protection of hospital staff and patients are among the principles of dealing with crises (Nateq Elahi, 1998: 112) (Table. 4).

According to Table 5, the 25 hospitals studied were evaluated as good in terms of internal tasks and development of a plan and average to very poor in terms of other variables. The developed plan of rescue only existed in the form of diagrams in most organisations, and was not clearly defined (Ismailian, 2011: 196).

3.1.1.5. The status of operational information in hospitals

To assess the vulnerability level and to design an emergency plan to prevent and mitigate the effects of natural disasters, it is necessary to recognise and evaluate the operational information of hospitals. This information includes explaining and clarifying the current situation of rescue equipment in the centre and their vulnerability. The existence of screening and triage space in hospitals, and organisational information such as information on the *status quo* of human resources, financial and material resources, objectives, visions and strategies of other organisations and hospitals, legal frameworks, current technical and economic programmes and staff training programmes, were also studied (Nateq Elahi, 1998: 511). The results showed that knowledge of the stock of other hospitals was poor and very poor in the majority of facilities; only nine hospitals had a good presence of screening space; and only seven hospitals had a good condition regarding rescue equipment and vehicles (Ismailian, 2011: 201) (Table. 6).

3.2. Placement of a new hospital

To find the optimal location of new hospitals in Isfahan, it was essential to investigate the various abilities of urban spaces in terms of availability of suitable and sufficient land and its connection with the network of streets and other urban facilities and to identify the areas where such services were needed. Because of the large volume of information required to locate the hospitals, and given the spatial-locational properties of the data, spatial analysis tools such as GIS and multi-criteria decision-making models such as AHP were used. The procedure is as follows.

3.2.1. Identification of factors affecting site selection

Identification and selection of factors that influence site selection is an important stage of research (Faraj Zadeh, 2005: 91); therefore, to find the optimal location for hospitals, an attempt was made to identify different parameters and indicators affecting site selection and to evaluate them in terms of the following layers: (1) transportation network, (2) existing healthcare centres, (3) land use, (4) population density, (5) distance from industrial centres, (6) distance from existing fire stations, and (7) distance from urban green spaces.

3.2.2. Valuation of data layers

Valuation of data layers includes weighting information layers according to their importance and impact on site selection. In this study, the AHP model was used for the valuation of these layers. In this method, the weighting of criteria is done in Expert Choice. The procedure is as follows.

A. Creating a pair-wise matrix: an underlying scale with values from 1 to 9 is made to rate the relative preferences for two items. In this matrix, if alternative A has double preference over B, then B has half priority compared to A. Comparison of each criterion with itself gives a score of 1 (equivalent priority). Therefore, 1 is assigned to all elements on the diagonal of the pair-wise comparison matrix (Mahmoodzadeh, 2010: 92).

B. Calculation of criteria weighting: This stage includes the following operations: a) adding up the values of each column of the pair-wise comparison matrix; b) dividing each element of the matrix by its column total (the resulting matrix is called normalised pair-wise comparison matrix); (c) computing the average of the elements in each row of the normalised matrix. These averages will give an estimate of the relative priorities of the elements being compared. Table 7 shows the matrix created for the selection of emergency centre sites.

C. Assessment of the consistency matrix: At this stage, the consistency of judgments will be determined. This involves the following operations: a) determining the total weighted vector by multiplying the weight of the first scale in the first column of the main binary comparative matrix, then multiplying the second scale in the second column, the third scale in the third column of the main matrix and, finally, finding the sum of these values; and b) determining the consistency vector by dividing the weight vector by the scale weights which were previously specified. Now that the consistency vector has been calculated, we need to calculate the values of λ and consistency index (CI). The value of λ is the average of consistency vector values. IC calculation is based on the fact that λ is always equal to or greater than the number of items under consideration (n). The case of n=λ occurs when the pair-wise comparison matrix is consistent. Therefore, λ – n can be an indicator of a level of consistency determined as follows:

$$CI = \frac{\lambda - n}{n-1} \quad (1)$$

CI is an indicator of deviation from consistency. Consistency Ratio (CR) can be calculated as follows:

Table 2. Hospitals in Isfahan and their service areas

Hospital name	Fixed bed	Address	Field of activity	3-minute service area	5-minute service area	Thiessen service area
Alzahra	950	Soffe Boulevard	General	4,112,972	10,647,937	30,848,052
Baharestan	60	Soffe St., across from Alzahra hospital	General	1,794,349	7,361,975	17,270,667
Shariati	850	Chahar Bagh Bala St.	General	3,499,202	10,182,227	4,852,207
Sepahan	120	Mir St.	General	3,621,909	10,886,285	4,683,304
Sa'di	120	Sa'di's Bustan, Khodaverdi Ave.	General	3,401,362	10,916,883	3,087,524
Seyed Al-Shohada	130	Khayam St., Farshadi Ave.	Hematology and Oncology	2,514,761	8,776,075	32,763,367
Shahid Beheshti	180	Felezi bridge, Motahari St.	Gynecology	3,598,380	11,138,253	835,227
Eisa-Ibn-Maryam	261	Shams Abadi St.	General	3,480,340	10,825,337	1,679,692
Noor and Ali Asghar	275	Ostandari St. next to Shahid Dastgheyb Boulevard	General	3,690,261	11,088,656	2,173,923
Sina		Shamsabadi St., Palace crossroad	General	3,654,686	10,236,632	979,821
Mehregan	40	Sheikh Baha'I St.	General	4,161,655	11,355,794	467,694
Isfahan Clinic	50	Sheikh Baha'I St. Ordibehesgt intersection	General	3,982,806	10,966,584	549,754
Ayatollah Kashani	394	Kashani St.	General	3,730,752	11,353,219	23,212,621
Ahmadiyya	40	Taleghani St. Mirdamad St.	General	3,377,033	10,925,570	2,615,075
Amin	152	Ibn Sina St,	General	3,396,831	10,789,215	3,299,105
Feiz	172	Qods Square – beginning of Modarres St.	Ophthalmology	4,079,281	11,823,130	1,483,678
Jorjani	35	Qods Square – beginning of Zeinabie ST.	General	3,909,511	11,387,355	3,994,624
Askariye	100	Soroosh St. Askariye Ave.	Obstetrics and Gynecology	11,008,510	11,827,493	3,972,047
Imam Musa Kazim (PBUH)	120	Kaveh St.	Burns	3,430,343	10,144,964	24,611,227
Zahra (PBUH)	60	Zeinabieh, Ayatollah Ghaffari St., across from Imam town	General	3,492,963	10,330,373	23,765,831
Gharazi	256	Kaveh highways, after Malekshshr intersection	General	3,691,607	10,787,879	51,420,525
Chamran	192	Bozorgmehr St. , Salman Farsi Ave.	Cardiovascular	289,426	3,340,285	5,604,398
Sadooghi	*	Bozorgmehr St.	General	2,552,570	8,390,243	8,057,848
Imam Ali (PBUH)	100	Ahmadabad St.	General	3,739,296	10,377,678	2,600,908
Hojatie	50	Sajjad St. Sepahsaar St.	General	2,892,897	7,297,710	16,321,510
Farabi	288	Arghavanie	Psychotherapy	*	*	*
Total	4955	*	*	84,067,249	252,338,779	279,006,089
Useful coverage		*	*	51,202,608	89,834,222	*
Shared coverage		*	*	32,864,641	162,504,557	*

Source: Isfahan Municipality & the authors' calculations

Table 3. Structural quality of hospitals

Quality of structures	Frequency	Percent
very poor	0	0
poor	8	32
Average	10	40
good	7	28
Total	25	100

Source: Ismailian (2011: 191)

Table 4. Crisis management status in hospitals of Isfahan

	Very poor	Poor	Average	Good
Developed plan	0	1	8	16
Director of the crisis committee	2	14	8	1
Information committee	3	12	8	2
Trained search	6	15	4	0
Internal tasks	0	0	7	18
Special First Aid teams	2	11	12	0
energy production systems	0	0	10	10
Total	13	58	57	47

Source: Ismailian (2011: 98)

Table 5. Operational information in hospitals of Isfahan

	Very poor	Poor	Average	Good
Available vehicles	0	3	15	7
Rescue equipment	0	3	15	7
Having screening space	6	2	8	7
information on the stock of other hospitals	12	12	1	0
Total	18	20	39	23

Source Ismailian (2011: 201).

Table 6. Pairwise comparison of seven criteria for categorisation of new hospitals

Information layers	Population density	Transportation network	Land use	Health centres	Industrial centres	Green space	Fire stations	Final weight
Population density	1	2	2.5	3	3.5	4	4.2	0.2
Transportation network	0.5	1	1.9	2.4	2.8	3.2	3.4	0.1
Land use	0.4	0.52	1	1.8	2.1	2.4	2.6	0.1
Health centres	0.33	0.41	0.55	1	1.7	1.9	-	0.069
Industrial centres	0.28	0.35	0.47	0.58	1	1.6	1.7	0.043
Green space	0.25	0.31	0.41	0.52	0.62	1	1.5	0.026
Fire stations	0.23	0.29	0.38	0.47	0.58	0.66	1	0.56
Final weight	2.99	4.88	7.21	9.77	12.3	14.76	14.4	1.0

Source: authors

$$CR = \frac{CI}{RI} \quad (2)$$

Where RI is the average consistency index of randomly generated (inconsistent) pair-wise comparison matrices. It can be shown that RI depends on the number of components being compared. CR is designed in such a way that if CR<0.1, there is an acceptable level of consistency in the pair-wise comparisons. But if CR≥0.1, it demonstrates inconsistent judgments. In such cases, the original values of the pair-wise comparison matrix should be revised and modified (Mahmoodzadeh, 2010: 94). Table 8 shows weighting layers in the AHP model for finding the location of hospitals (Table.7).

As is clear from the above table, for layers of distance from green spaces, distance from fire stations and distance from the main transportation network, by increasing the distance the score reduces and *vice versa* (Fig. 4, 5 and 6). For layers of distance from industrial centres and distance from hospitals and health centres, the reverse is true, so that the increase in distance increases the score and *vice versa* (Fig. 7). This is because one of the purposes of locating health centres is for the majority of the population to benefit from these centres. For the population density layer, neighbourhoods with higher density have higher scores and *vice versa*.

The land use layer was based on economic value and suitability of land for building health centres. For example, arid lands received higher scores and commercial uses received lower scores on the basis of the economic value (Fig. 8).

3.2.3. Combining information layers (the final evaluation map)

Combining layers and creating the final map is usually done according to project needs and in a few different ways. If the purpose of placement is to find suitable sites with a high score, the maps are prepared in the form of single-use maps that just display appropriate areas. In these maps, no ranking (various zones) is done for parameters. The other form of final maps, in addition to determining appropriate sites, specifies inappropriate or less appropriate locations, depending on the project. These maps usually show zones separately (by colour, symbol, etc.) (Husseini et al., 2010: 63). In this study, an IO model was used to combine layers. The results are shown in Fig. 9. At this stage, according to the rank, the categories of each layer are weighted and a Raster Calculator is used to add up col-

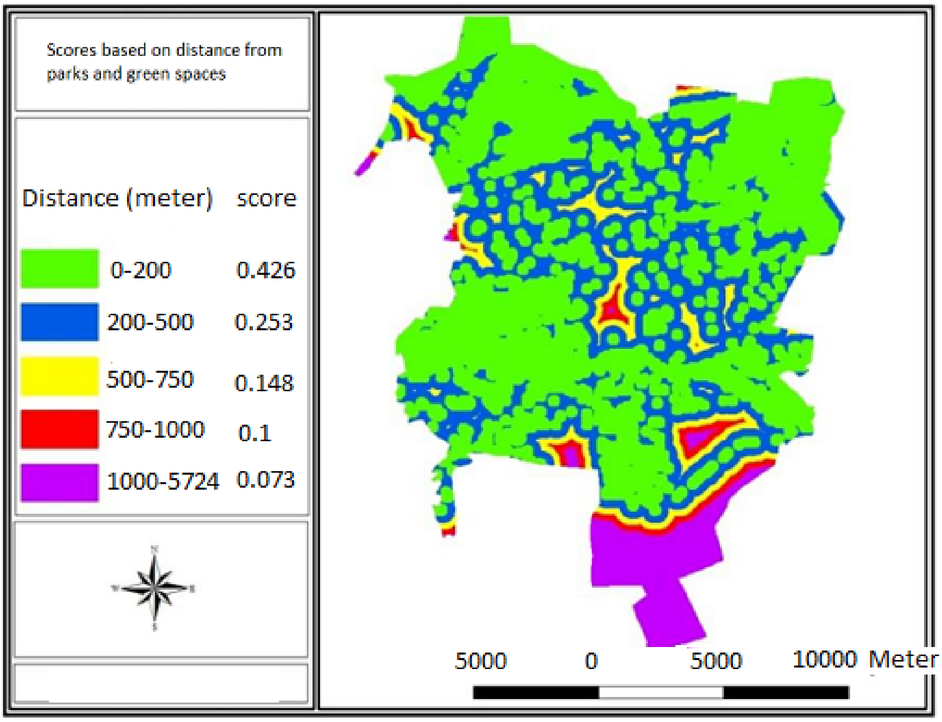

Fig. 4. Scores based on distance from green space

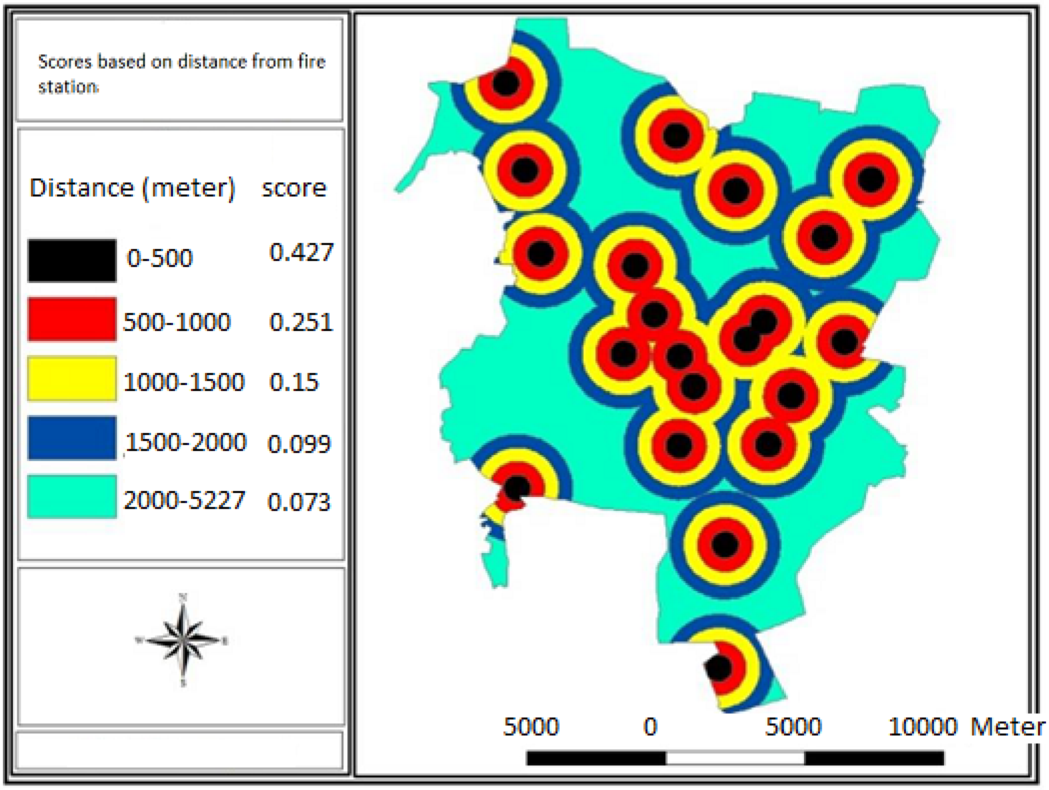

Fig. 5. Scores based on distance from fire station

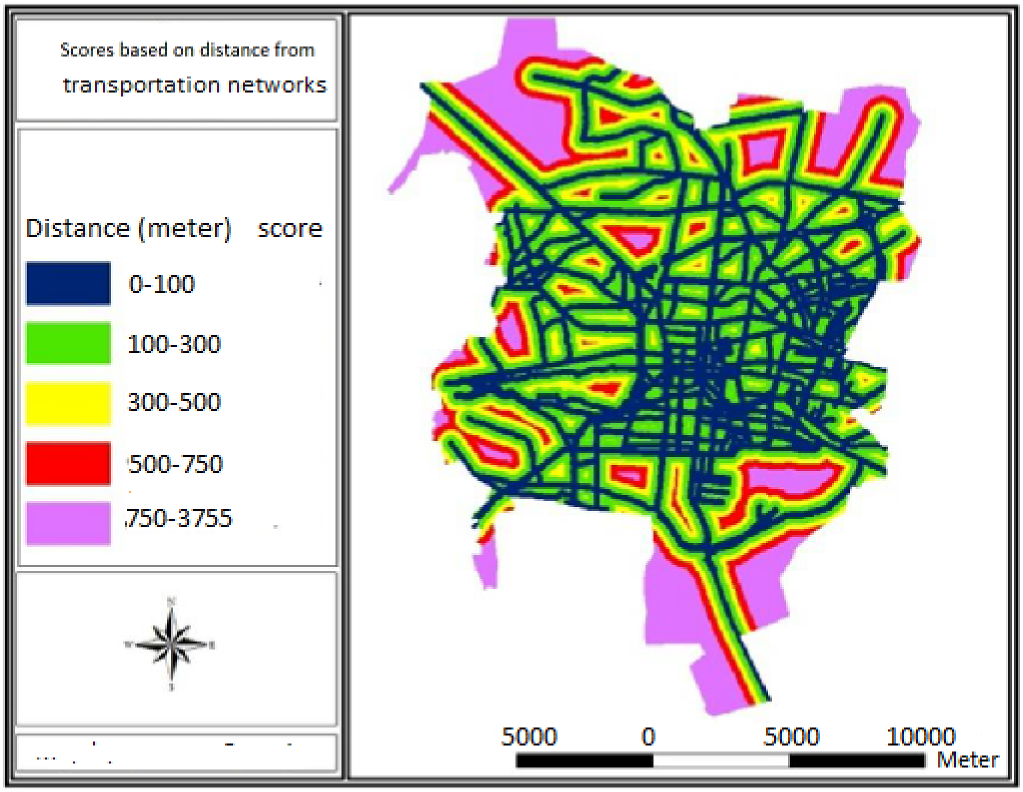

Fig. 6. Scores based on distance from main transportation network

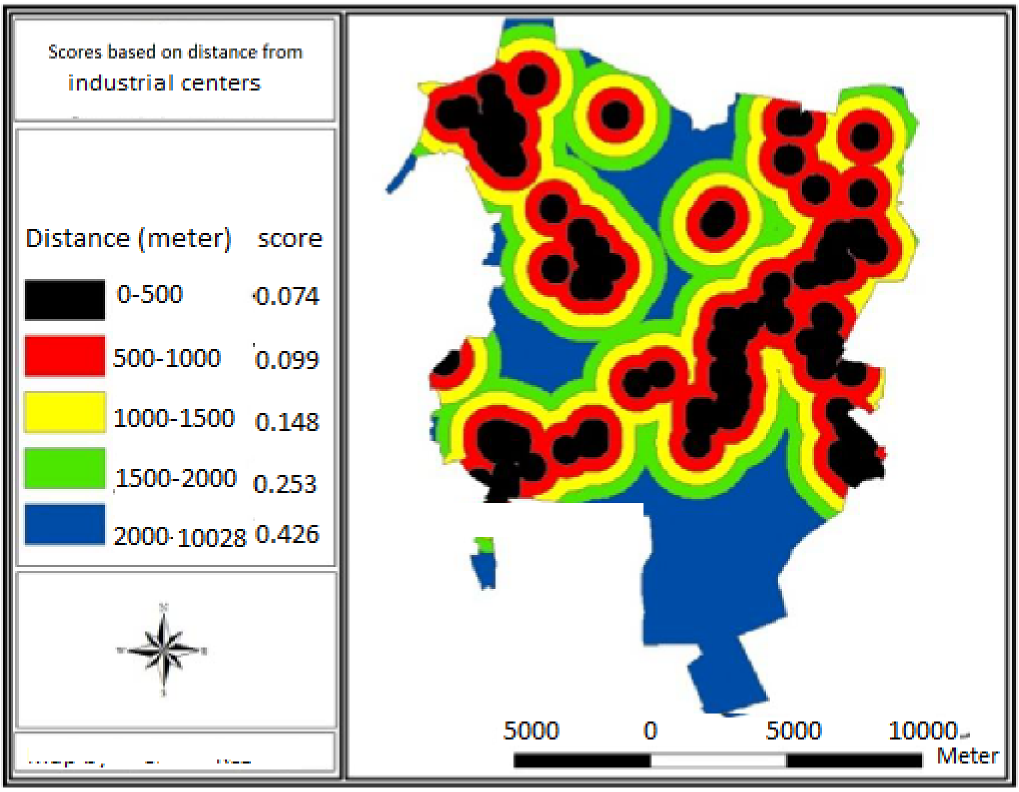

Fig. 7. Scores based on distance from industrial centres

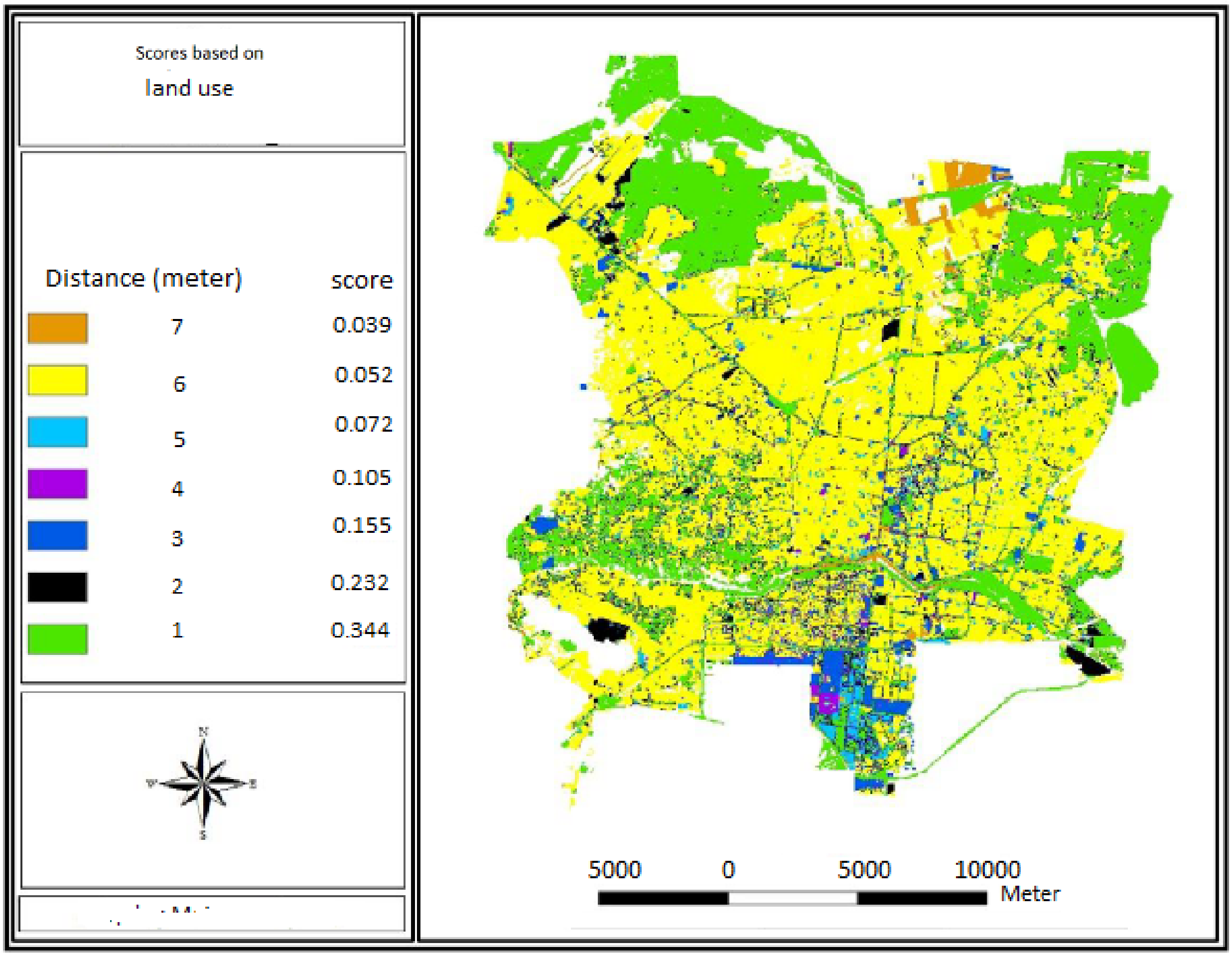

Fig. 8. Scores based on land use

Table 7. Weighting layers in the AHP model for finding the location of hospitals

Criterion	**Weight**	**under criterion**	**Initial weight**	**CR (Consistency ratio)**	**Criterion**	**Weight**	**under criterion**	**Initial weight**	**CR (Consistency ratio)**
distance from communication network	0.219	0-100	0.388	0.01	Distance from fire station	0.056	0-500	0.427	0.00
		100-300	0.253				500-1,000	0.251	
		300-500	0.167				1,000-1,500	0.15	
		500-750	0.113				1,500-2,000	0.099	
		750-3,755	0.078				2,000-5,227	0.073	
distance from health care centers	0.109	0-300	0.067	0.01	Population density	0.316	0-50	0.087	0.01
		200-600	0.099				50.1-75	0.115	
		600-900	0.156				75.1-100	0.164	
		900-1,200	0.256				100.1-140	0.249	
		1,200-8,132	0.423				140.1-250	0.385	
distance from industrial centers	0.083	0-500	0.074		Distance from green space	0.066	0-200	0.426	0.00
		500-1,000	0.099				200-500	0.253	
		1,000-1,500	0.148				500-750	0.148	
		1,500-2,000	0.253				750-1,000	0.1	
		2,000-10,028	0.426				1,000-5,724	0.03	
Land use	0.229	Green space, gardens and arid land						0.344	0.01
		Industrial and transportation						0.232	
		Administrative, law enforcement and sports						0.155	
		Health care						0.105	
		Education and higher education						0.072	
		Market, commercial and residential						0.052	
		Cultural, religious, channels						0.039	

Source: Authors

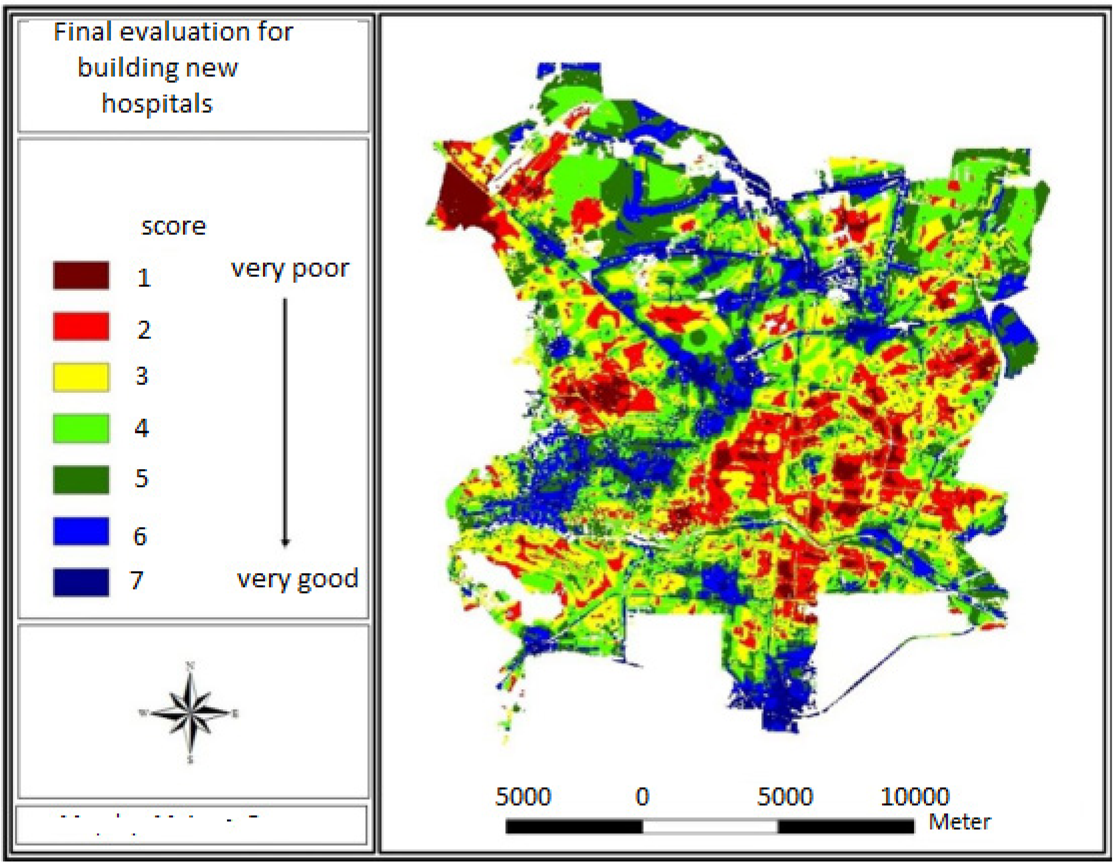

Fig. 9. Final valuation of urban land for building new hospitals

umns of scores of each layer. At this stage, the final map is evaluated, with classification of data in seven distinct categories from 'very inappropriate' to 'very appropriate' for new hospitals. This way, it will be possible to change land use, determine appropriate zones, and locate new sites for building the new hospital in Isfahan.

5.3. Conclusion

Access to health services is one of the most sensitive indicators of sustainable development at urban and regional levels and should be made available to all people equally and fairly. The population and building densities of the metropolitan area of Isfahan increase the possibility of various diseases, accidents and crises. Therefore, spatial distribution and site selection for healthcare facilities across the city according to the standards and regulations seems to be necessary. However, based on the analyses carried out in Isfahan, spatial distribution and site selection of hospitals in the city is inappropriate. In the global standard time (3 minutes), their catchment area is 8,406 hectares, of which 3,286 hectares is overlapping area. Therefore, their effective coverage is 5,120 hectares. Given the total area of Isfahan, it can be concluded that 18.35% of the city area is covered by the catchment area of existing hospital services. The 5-minute service areas of Isfahan is 25,233 hectares, of which 16,250 hectares within the catchment areas of more than one hospital. Therefore, their effective coverage area is 8,983 hectares. Given the total area of Isfahan, it can be said that 32.19% of the city is covered by the standard catchment area of available hospitals. Thus, the need for proper site selection and distribution of the hospitals is scientifically and systematically justified. Thus, effective data were collected in the form of layers of information such as transportation network, land use, etc., using GIS and AHP to specify the sites for construction of new hospitals in seven different categories from 'very poor' to 'very good'. Further studies can investigate the match between the proposed model and ground realities of different spaces and areas. On this basis, new hospitals can be constructed in higher preference sites to provide equitable access for citizens and improve the spatial distribution of hospitals based on standards and regulations in the short, medium and long-term by officials and administrators.

References

Ameriuon, A. (2002). The importance of providing health services in natural disasters and the necessity of attention to safety, health centres and hospitals. The first academic conference on rescue management, Higher Education Institute of Applied Science, Iranian Red Crescent, Tehran, Iran.

Azizi, M. (2004). Using GIS for determining spatial distribution and location of health centers network: the case of Mahabad, A master's thesis. University of Tabriz, Department of Geography and Urban Planning, pp.133.

Baghiani Moghadam, M.H. and Ehrampoush, M.H. (2004) Principles and general issues of health services. Shabnam Publications, Second Edition, Yazd, Page 47.

Bahrami, S. (2008). Analyzing medical emergency services using GIS: the case of Isfahan. Master's thesis, University of Isfahan, Department of Geography and Urban Planning, pp.5

Cheng, R.W. Chin, T.l. Huang, C.C. (2007). "Optimal selection of Location for Taiwanese hospital to ensure a competitive advantage by using the analytic hierarchy process and sensitivity .4441-1341, 3 analysis ". Building and Environment, Vol. 42, Issue.

Ebrahimzadeh, I. Ahadnejad, M. Ibrahimzadeh, H. Shafie, Y. (2010). Locational-spatial planning and organization of health care centres using GIS: the case of Zanjan. Human Geography Research, No. 37 (Fall), pp. 39-58.

Evance, D. (2004). Investigation of active Fire Protection Systems Project 4, building and.research laboratory national institute of standards and technology. U.S department of commerce.

Farajzadeh, M. (2008). GIS and its application in tourism planning, Second edition, SAMT, 91.

Gheisari, K. Qanadpour, F. Asgari Tehrani, M.M. (2007). Placement of Emergency centers in urban transport networks using genetic algorithms, Fifth National Conference on Industrial Engineering, P. 11.

Gołata, E. Kuropka, I. (2018). Mobile Communications, physical distance and access to follow-up healthcare service in Lagos Metropolis, Bulletin of Geography. Socio-Economic Series, The Journal of Nicolaus Copernicus University, Torun, No 42.

Ibrahim, O. Graham, K.R. (2003). "A goal-Programming model applied to the EMS at.771000 / Riyadh City, Saudi Arabia".WWW.Lums.Lancs.ac.uk/publications/viewpdf,2

Ingwe, R. (2012). Physical health facilities in Nigeria's sub-national regions: geodemographic and spatial analyses of health institutions in Nigeria's 36 states and Federal Capital Territory, Bulletin of Geography. Socio-Economic Series, The Journal of Nicolaus Copernicus University, Torun, No 18

Ismailiyan, Z. (2011). The role of integrated management in urban crisis management, Case study of Isfahan city, Doctoral dissertation, Faculty of Humanities and Social Sciences, Department of Geography and Urban and Regional Planning, University of, Tabriz, Iran.

Jamali, F, Mousavi, M. Ishlaqi, M. (2014). Evaluation of the hospital site selection models in Tabriz, Journal of Geography and Planning, 81(74), Spring 2014 , 22-53.

Khosravi, Sh. Sorani, H. Pooryamofrad, E. Shamsipour, M. (2005). The effect of optimization initiatives in providing emergency services. Journal of Shahre Kord University of Medical Sciences, 7(2), pp. 71-80.

Latifi, G. (2006). Crisis management in natural disaster reduction, Sepehr Journal, No. 59, pp. 22-27.

Mahmoodzadeh, H, (2010). Using the ArcGIS in urban planning, First Printing, Elmiran Publications, pp. 120.

Malczewski, J. Ogryczak, W, (1996). The multiple criteria Location Problem. 82, Preference-based techniques and interactive decision support Environment and Planning A.

Modiri, M. (2005). A reference to geographic information systems (GIS), Armed Forces Geographical Organization, Tehran, Iran, pp.56.

Nasiripour, A.A. Bahaduri M. Tofighi, S. Gohari, M.R. (2009). Prehospital emergency functions in Iran, the prospects for comprehensive coverage plan, Journal of Critical Care Nursing, 2(4) (Winter), pp. 139-143.

Nazarian, A. Karimi, B. (2009). Evaluation of spatial distribution and location of fire stations in Shiraz using GIS. Zagros Vision Quarterly, First year, No. 2 (winter), pp. 5-19.

Pour Ghayoumi, H. (2010). Analysis of the spatial distribution and location of urban services in Kazeroun using GIS, Master's thesis, Supervisor: Mohammadi, J, Advisor: Zarabi, A., University of Isfahan, Department of Geography and Urban Planning, pp.7.

Sahibzada, M. Baghban, G. (2006). Comparison of emergency standards approved by the Ministry of Health, with the principles of ISO 9001 version 2000, Health Information Management, third Vol., No. 2 (autumn and winter). pp. 103-111.

Shafiei, M. Mirghafoori, H. (2008). Identifying and ranking factors affecting the quality of educational services- higher education (Case study: School of Management, University of Yazd), Journal of Higher Education, No. 2 (Fall), pp.68.

Sharifzadgan, M.H. Mamdouhi, A.R. Lavi, M. (2010). Spatial inequality in access to public health services for the development of urban health through p-mediam model in Isfahan, Social Welfare, tenth year, No. 2.

Soltani, A. Maranadi, EZ. (2015). Hospital site selection using two-stage fuzzy multi-criteria decision making process, Journal of Urban and environmental engineering 5 (1), pp. 32-43.

Tajik, Z. (2009). Spatial analysis and location of sport centers in Isfahan, Master's Thesis, Supervisor: Zangiabadi, A., Department of Geography and Urban Planning, Isfahan University, pp.66.

Tajik, Z. (2009). Spatial analysis and location of sport centers in Isfahan, Master's Thesis, Supervisor: Zangiabadi, A., Department of Geography and Urban Planning, Isfahan University, pp.66.

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