Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 4, No. 7, July, 2018

The Evaluation of Temporary Shelter Areas Locations Using Geographic Information System and Analytic Hierarchy Process

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Received 06 February 2018; Accepted 21 June 2018

Abstract

Earthquakes are notorious as devastating natural disasters that can result in tragic fatalities and economic loss. The building of earthquake evacuation shelters is an effective way to reduce earthquake consequences and protect lives. In present study, analytic hierarchy process (AHP) was applied as a multiple criteria of decision making (MCDM) method to investigate different shelter sites that belong to a disaster-prone area of the north of Iran. The principles of vulnerable areas, access to roads, firefighting centers, populated areas, fault lines, and medical centers were considered to determine optimal temporary shelter areas locations. With the support of a geographic information system (GIS), the method comprised three steps, i.e. selecting candidate shelters, analyzing the spatial coverage of the shelters, and determining the shelter locations. Finally, a case study was used to demonstrate the application of the multi-criteria model and the corresponding solution method and their effectiveness in planning urban earthquake evacuation shelters. It was found that the "distance from fault line" criterion of 0.429 could be the most effective factor along the others.

Keywords: Disaster Management; Geographic Information System; Analytic Hierarchy Process; Earthquake; Shelter Site Selection.

1. Introduction

A disaster as a sudden, calamitous event can heavily disrupt the function of a region leading to material, human as well as environmental losses which are more than the their ability in order to cope by means of their resources [1]. Over the past years, the number of disaster hits and their impacts have been increasing noticeably, e.g. there were between 50 and 400 ones from 1950-2010 [2], causing the infrastructure to be destructed intensively. A large number of people become homeless annually due to natural disasters, such as hurricanes and earthquakes. It is inevitable that people prefer living in urban regions. Consequently, according to the rapid development of the global economy, it is a good reason for becoming more vulnerable to natural disasters [3]. An earthquake event can be determined using a high level of uncertainty. Therefore, in advance preparation can be crucially important as a seismic force can be rather life threatening. To decrease the possible damage, many engineering techniques have been employed so as to enhance the building resilience [1]. However, in cases that buildings have not necessary ability to protect people, it is important to ensure that there are adequate shelters to accommodate the victims, located in appropriate that are quickly accessible. To ensure people's safety, the existence of disaster shelters for emergency conditions is one of the most effective techniques. In the other word, evacuation of injured people to the shelters is the first step to resilient methods. At the shelters, immediate accommodation, medical caring as well as foods for affected and injured people should be provided [4]. Shelters need to be designed strategically for efficient recovery. It should be ensured that not only will the regions in which the shelters

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http://dx.doi.org/10.28991/cej-03091104

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are built be located at a safe distance from threat zones, but the people will also be able to easily access them from their homes.

The advent of geographic information system (GIS) has also provided another cost and time effective means of temporary shelter areas locations mapping. GIS is an excellent and useful tool to handle huge amount of spatial data and can be used in the decision making process in a number of engineering fields [1, 4]. It is because of the quick access to data obtained through global positioning systems and RS techniques. In the 1990s, a novel method emerged on maintenance decision. It is arguable that decision theory has defined as useful tool for a number of professions such as engineers and various maintenance challenges which can be modeled as multiple criteria of decision making (MCDM) issues. The MCDM techniques can be used for maintenance decision making [5, 6]. Correct maintenance policy selection is one of these challenges applicable in MCDM.

The main aim of present study is proposing a resilience building technique for communities in disaster-prone geographies. Analytic hierarchy process (AHP) is applied as a MCDM method for investigation of different shelter sites that belong to a disaster-prone area of the north of Iran. The study would hopefully help humanitarian agencies and communities to ready for expediting recovery and reconstruction process well. The rest of this study is organized as follow: Section 2 illustrates the review of existing literature and research background. Section 3 indicates the AHP technique and case study in the north of Iran. Section 4 describes the exploration criteria in selecting emergency shelters. Section 5 includes results and discussion of the study. The last section represents the conclusion and directions for future research work.

2. Literature review

Locating is the process of finding and selecting positions according to some criteria. Each place tends to have different abilities, capabilities as well as activities. Sometimes, indicators and benchmarks of selected places can be different, but they may be united for achieving the best result. Various factors such as quality, quantity and economiy of environmental influences, communication networks, the level and type of urban infrastructure services and level of geographical accessible that are determined on the basis of the control type under locating where all effective parameters are participated [5]. The criteria for selecting different temporary rehabilitation locations relevant to various disasters are generally appointed according to the nature of disaster and the area demographic condition. A vast number of studies have been conducted into proper planning of disaster readiness and mitigation stages. Recently, Different researches has been done about different issues like the suitable positions of emergency medical centers, selection of temporary shelter location, locations of emergency storehouses for aid kits [7-14].

The dynamics of location problems in using the shelter site in Turkey was investigated by Kilci et al. [15]. A mixed integer linear programming mathematical location model was applied, which coupled with the Turkish Red Crescent requirements to enhance their existing system. The minimum weights of open shelter regions were maximized applying the mathematical models while shelter location areas were determined. The assigned population points related to the area of each open shelter should be controlled to evaluate how to use the shelter areas.

The result of mathematical models was evaluated by means of producing a base case scenario based on real data. Givechi et al. [16] showed how to determine temporary housing sites in region six of Shiraz municipality due to the high probable seismic activities in the near future by AHP model. Their findings indicated the tendency of selecting temporary housing close to the victims' destructed accommodation, which meant that they preferred to be near their house. The casualties were also accommodated in safe camps, closed enough to their houses. These benchmarks are employed for the analytical descriptive technique to select the temporary housing site. The accessible data information about the study area, criteria selection and indexes are weighted regarding to the experts views of crisis management, expert-choice software and couple comparing. The output corresponding to this step is weights value table of the studied benchmarks according to the significance in studied area. AHP (Analytic Hierarchy Process) and ArcGIS techniques are used to generate the surface zonation map about the sixth region of the Shiraz Municipality. For each specified weighted benchmark, a layer was generated and the results were combined to produce the surface map of the region completely.

Different guidelines were considered to design a temporary shelter to meet architectural and urban design approaches. The guideline included two major problems. The first one was community participation, which would lead to ownership feeling among victims. Additionally, the possibility of converting the temporary shelters into permanent ones was an issue that needed more creative and innovative architectural and structural designing [17]. However, some of the recent studies have been performed into the temporary shelters, in some of which, urban and architectural designing has been discussed. In this study, the spatial setting sort (central, linear, and hybrid) of shelters, the neighboring textures situation (based on the considerations form and orientation) and available ways are crucial problems which are discussed. Moreover, some of considerable issues is defined as type of materials, the location of open regions, internal setting of spaces using behavioral patterns considering of the stricken communities and the expectations of users [17].

Bolin and Stanford [18] investigated the issue which is related to the temporary housing and emergency shelters for the victims after disasters. The results showed different ways to access shelters and housing aids, demographic factors, the relation between post disaster and housing, and the important role of social support networks in housing. A vast number of studies have shown a multi-criteria/multi-objective location method to evaluate more complicate applications requirements. Nappi and Souza [19] presented 10 criteria in terms of quantitative and qualitative perspectives in temporary shelter locations. The criteria gave a good reference in order to create a multi-criteria location model in wide range of application fields. Hadiguna et al. [20] studied a web-aided multi-criteria decision support system for evaluating the public facilities which can be applied as earthquake and /or tsunami evacuation centers. By proposing the multi-criteria and applying a geographic information system (GIS), Tsai and Yeh [21] indicate a model of optimum disaster prevention evacuation locations. It would aid local governments to determine evacuation shelters. An innovative multidisciplinary technique was introduced by Tamima and Chouinard [22] to estimate shelter requirements and evacuation scenarios in case of a main earthquake, considering road conditions, and the distance between shelters and homes.

3. Materials and Methods

This study used AHP methodology, introduced by Thomas Saaty in the 1980s. Based on previous studies [23, 24], a consistent and ideally objective by help of creating a methodology has been considered so as to determine the desirable temporary shelter regions after earthquake hits, taking into account multi criteria families, multi-attribute methodologies, various options for attributes creation, sub-attributes and decision alternatives. Additionally, in this approach, the attributes involved in the evaluation process had a subjective and appreciative characteristic regarding the evaluator's understanding who facilitated its wide admission, performing an acceptable assessment of when the values of subjectivity were improved.

3.1. Case Study Description

Iran as arid and semi-arid region has a limited area of cultivable land which is mainly scratched in the north. This study was carried out at northern region, Iran (approximately 36° North Latitude, 52° East Longitude) (Figure 1). This town is one of the northern cities in Mazandaran province in the southern coast of the Caspian Sea. The town is located in the middle of agricultural fertile lands and has an area of 446 square kilometres. Since the Babol river passes through the city, both the bank of the river and the beach of the sea form tourist attractions in the city. Also, the population of the town has been steadily growing during the last 50 years.

Figure 1. Map of the studied area

3.2. Analytic Hierarchy Process

The MCDM approach was applied for maintenance decision-making since the theory of decision has been become as helpful tool for various professionals and because of modelling the different maintenance challenges in the form of MCDM problems [5, 6]. Not only did, the analysis and MCDM model focus on decision-making, but they would also provide permissible insights into the decision process. MCDM contributes to analyzing decision-making contexts, organize the processes, rises coherence of the goals and final decisions and cooperation among decision makers, which hence causing a better mutual understanding and debating [1]. In order to analyze complicate decisions including various criteria, analytic hierarchy process (AHP) as a MCDM technique as a mathematical approach implemented by Saaty [23]. Pairwise comparison that is used within AHP scope carries out a criteria comparison applied in decision analysis to estimate values of each of these criteria [12]. In AHP method, a matrix is generated as a calculation result of criteria weights and pairwise comparisons. It was also possible to estimate decisions consistency ratio (CR) in pairwise comparison. CR illustrates random probability values used in a matrix of pairwise comparison.

To ascertain the weights, the following process in AHP model was done in Equation (1). If *n* number criteria are determined for comparison [25]:

(a): Build a pairwise comparison matrix in the form of ($n \times n$) for *n* objectives.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Where a_{ij} presents how much more crucial the *i*th objective is compared to the *j*th ones, while making a reasonable material handling/equipment decision determination. For all of *i* and *j*, it is vital that the values of a_{ij} and a_{ji} are equal to 1. The possible investigation values of a_{ij} in the pairwise comparison matrix, related to their corresponding interpretations have been shown in Table 1.

(b): Divide every value of column *j* by the total values of column *j*. The total values of each column relevant to new matrix Aw (Equation 2) should be one. Therefore, a normalized pairwise comparison matrix is created.

$$Aw = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \cdots & \frac{a_{1n}}{\sum a_{in}} \\ \vdots & \ddots & \vdots \\ \frac{a_{n1}}{\sum a_{i1}} & \cdots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix} \quad (2)$$

(c): In the AHP, the principal eigenvector of matrix A should be found for estimating c_i. This study applied a suitable simplified technique to simply compute the first approximation of the eigenvector using computing the c_i as their average. Calculation of c_i as the average values of row *i* related to matrix *Aw* for yielding the column vector *C* where values of c_i represent the relative importance degree (weight) of the *i* th objective.

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ . \\ c_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{n} & \cdots & \frac{\frac{a_{1n}}{\sum a_{in}}}{n} \\ \vdots & \ddots & \vdots \\ \frac{\frac{a_{n1}}{\sum a_{i1}}}{n} & \cdots & \frac{\frac{a_{nn}}{\sum a_{in}}}{n} \end{bmatrix} \quad (3)$$

(d). Assessment the control of the weight values consistently. This method to be followed for consistency determination as follows: Firstly, calculate the matrix $A \times C$ (consistency vector).

$$A \times C = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \times \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ . \\ c_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ . \\ x_n \end{bmatrix} \quad (4)$$

Secondly, determining x_i by multiplying $A \times C$, which is a second, better, approximation of the eigenvector. After that, λ_{max} can be calculated using the following formula in Equation 5:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{x_i}{c_i} \quad (5)$$

In which, λ_{max} max is defined as the eigenvalue of the pairwise comparison matrix. Then, an approximation of the consistency index (*CI*) was computed.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

Lastly, so as to ensure the consistency of the pairwise comparison matrix, the consistency judgment should be investigated for the best value of *n* by *CR* [26], that is,

$$CR = \frac{CI}{RI} \tag{7}$$

Where RI is the random consistency index for different numbers of n, presented in Table 2. The consistency was satisfactory when $CR \leq 0.10$. Otherwise, there are serious inconsistencies. In this case, the AHP may not yield meaningful results [25].

4. Criteria for Shelter Site Selection

As a noticeable problem, decision-making needs to be supported by systematic decision techniques, which follow benchmarks widely covering environmental, social and economic aspects. Moreover, applying the accurate criteria lead to decrease errors of decision making and save time. In present study, some possible criteria including vulnerable areas, roads accessibilities, fire-fighting centres, populated areas, fault lines, and medical centres were considered. Also, the work flow of present research is shown in Figure 2.

Figure 2.Workflow of present study

4.1. Proximity to Access Paths

The principal aim of evacuation route planning tends to guiding all evacuees to a safe region to avoid many life losses following natural disasters. To this goal, it is important to build an emergency preparation system to locate shelters and their shortest routes. It means that Shelters must be located nearby the evacuation roads and in the suitable region near to health facilities to provide medical aids during an evacuation period. Both proximity and should be reclassified into six intervals on the basis of the distance and area using natural breaks (Figure 3a).

4.2. Proximity to Vulnerable Areas

From recent earthquake experiences, it was found that although much of the damage has been caused by earthquakes, it could also be owing to the absence of urban planning principles and criteria, i.e. lack of accurate estimation of city vulnerability to the effects of possible earthquakes. Figure 3b illustrates the position of the major roads and the proximity to these criteria.

4.3. Proximity to Firefighting Centres

In case of disasters, providing fire protection resources which have been built for a number of refugees is important issue due to helping to strengthen rescue abilities of the sites. Existence of fire centres close to temporary accommodation is considered strong aspect of temporary accommodation planning, and based on the standards, the best distance from fire stations to temporary accommodation might be roughly 1 km (Figure 3c).

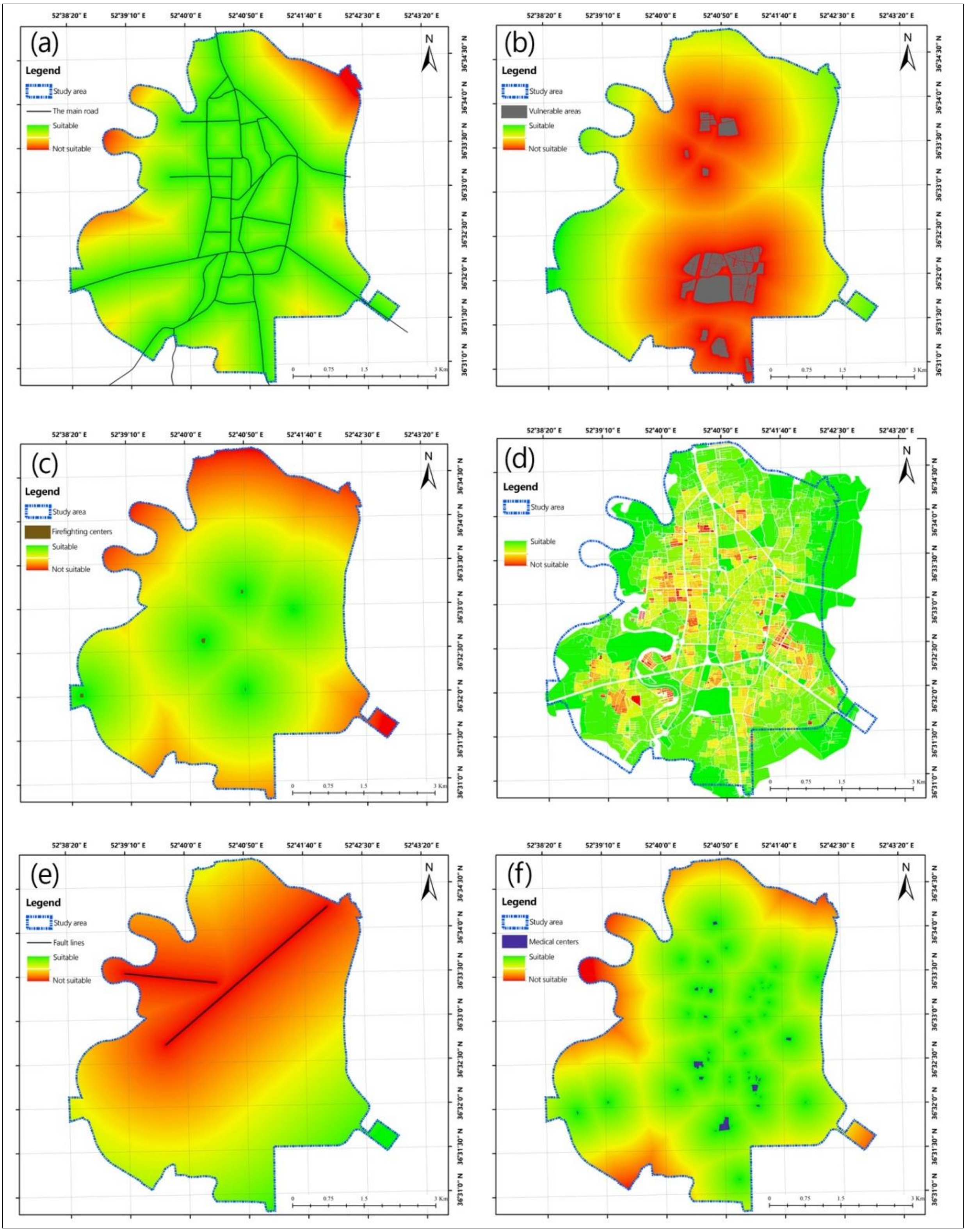

Figure 3.Normalized Criteria maps of the study area. Proximity to a) accessible paths, b) vulnerable areas, c) firefighting centers, d) populated areas, e) fault lines, and f) medical centers.

4.4. Proximity to Populated Areas

One of the factors in this regard is population density. The more populated an area is, the more vulnerable it would be to earthquakes. The minimum space required for every person at temporary accommodation is shown to be about 35 square meters. This space includes health tools, roads, saving installations, offices, water provision systems, markets and shelters. Age-sex population combination: on the basis of the experiences, old people, children and women are more vulnerable against earthquakes than other. In this way, shelters should be located at the places where number of women is more than men. The number of children and elder people should also be compared to other age groups. The adsorbent centre position of the population and its normalized layer are shown in Figure 3d.

4.5. Distance from Fault Line

Earthquakes often happen in the fault lines because of slippage and pressure releasing. On the basis of the requirements, the distance between shelters locations and earthquake faults should be at least 500m [27] (Figure 3e).

4.6. Proximity to Medical Centres

Furthermore, the distance between material reserve warehouses and medical buildings should meet needs walking as basic means of transportations supplemented using motor vehicles and a suitable distance must be 3000 meters or one hour walking. The positions of medical centres are illustrated in Figure 3f.

5. Results and Discussion

5.1. Normalized Weights of Thematic Layers

AHP was used to determine the weights of the thematic layers. Saaty's AHP is a widely used MCDM technique in the field of natural hazard. Interestingly, the GIS-based AHP method has been advanced by the international scientific community as a powerful tool for analysing complex spatial decision problems. The comparison ratings are on Saaty's 1-9 scale [23]. In order to determine the weight of each thematic layer, questionnaires of comparison ratings on the Saaty's scale were prepared and filled in by disaster experts within Iran. Consequently, all the thematic layers were compared to each other on a pairwise comparison matrix (Table 1).

Table 1. AHP evaluation scale

Numerical value of a_{ij}	Definition
1	Equal importance of i and j
3	Moderate importance of i over j
5	Strong importance of i over j
7	Very strong importance of i over j
9	Extreme importance of i over j
2, 4, 6, 8	Intermediate values

The Expert Choice software package (E.C. Inc. 1995) based on the AHP method was used to estimate important weights of the thematic layers and to test consistency ratio (CR). In AHP, the pairwise comparisons of all the thematic layers were taken as the inputs, while the relative weights of the thematic layers were the outputs. The final weightings for the thematic layers are the normalized values of the eigenvectors that are associated with the maximum eigenvalues of the ratio matrix [5, 27] (Table 2).

Table 2. Pairwise comparison matrix for the AHP process

Theme	Theme					
	FL	FC	MC	PA	AP	VA
Distance from fault line (FL)	1	9	8	4	6	2
Proximity to firefighting centers (FC)	0.11	1	05	0.16	0.25	0.12
Proximity to medical centers (MC)	0.12	2	1	0.25	0.5	0.16
Proximity to populated areas (PA)	0.25	6	4	1	2	0.5
Proximity to access paths (AP)	0.16	4	2	0.5	1	0.25
Proximity to vulnerable areas (VA)	0.5	8	6	2	4	1

5.2. Layers Integration to Identify Suitable Sites of Temporary Shelter Areas

After identifying the importance coefficients of criteria, turn it on, select the location of shelters, which to this end, Geographic Information System (GIS), is used. In this regard, the required data were collected and digitized for the database to be established. Then because of the importance of not same information layers in locating temporary accommodation sites, all layers of information were prioritized using the comments of experts in terms of importance and the weight of the layers was determined using Expert Choice software. The site is suitable for localization, data layers, were adjusted in proportion to the existing standards, and according to expert opinions. And then combines maps, were created by overlaying of layers of information, and applying the coefficients of each of the indicators. As a consequent, with integration of all information layers were formed final layer overlapped of temporary accommodation sites (Figure 4). It should be noted that, Information obtained map is, raster, and show a range of places favourable to very suitable.

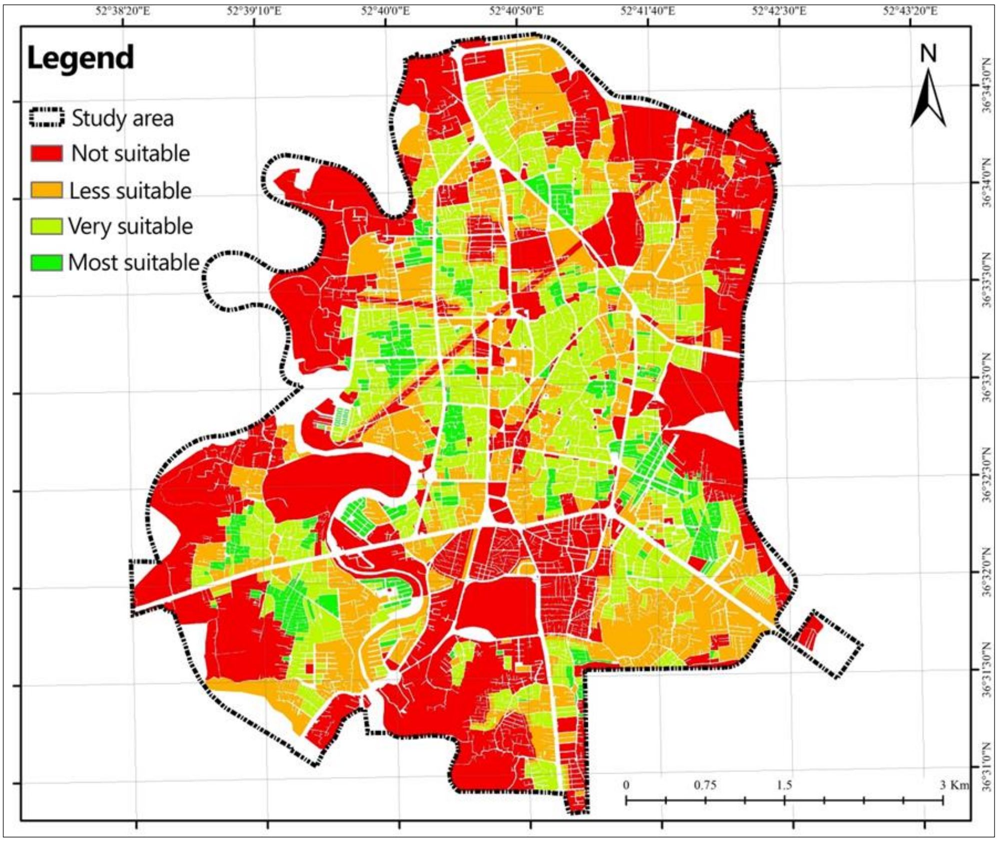

Figure 4.prone zones map for locating sites of temporary shelter areas

According to Table 3, showing the size of classified regions, the most suitable areas with just 0.058 precent (1331220 square meters), reflected the fact that the aforementioned city had a limited region in order to establish temporary shelter areas after the earthquake.

Table 3. AHP weights and priority ranking for shelter site selection

Criteria	Normalized weights	Priority rank
Distance from fault line (FL)	0.429	1
Proximity to firefighting centers (FC)	0.028	6
Proximity to medical centers (MC)	0.044	5
Proximity to populated areas (PA)	0.121	3
Proximity to access paths (AP)	0.109	4
Proximity to vulnerable areas (VA)	0.268	2

Afterward, sensitivity analysis (SA) is used to determine the best region and prioritize the areas based on defined criteria. Sensitivity analyses can help to validate and determine the robustness of the results by demonstrating that small data alterations do not change the ranking of alternatives. Twelve areas proved suitable for easy accessibility of temporary shelter establishment. The proposed regions should be analysing by the criteria that employed in the research process, and each region that is most consistent with the conditions defined in the criteria will be introduced as the best region for the construction of temporary accommodation. Figure 5 illustrates the proposed regions location.

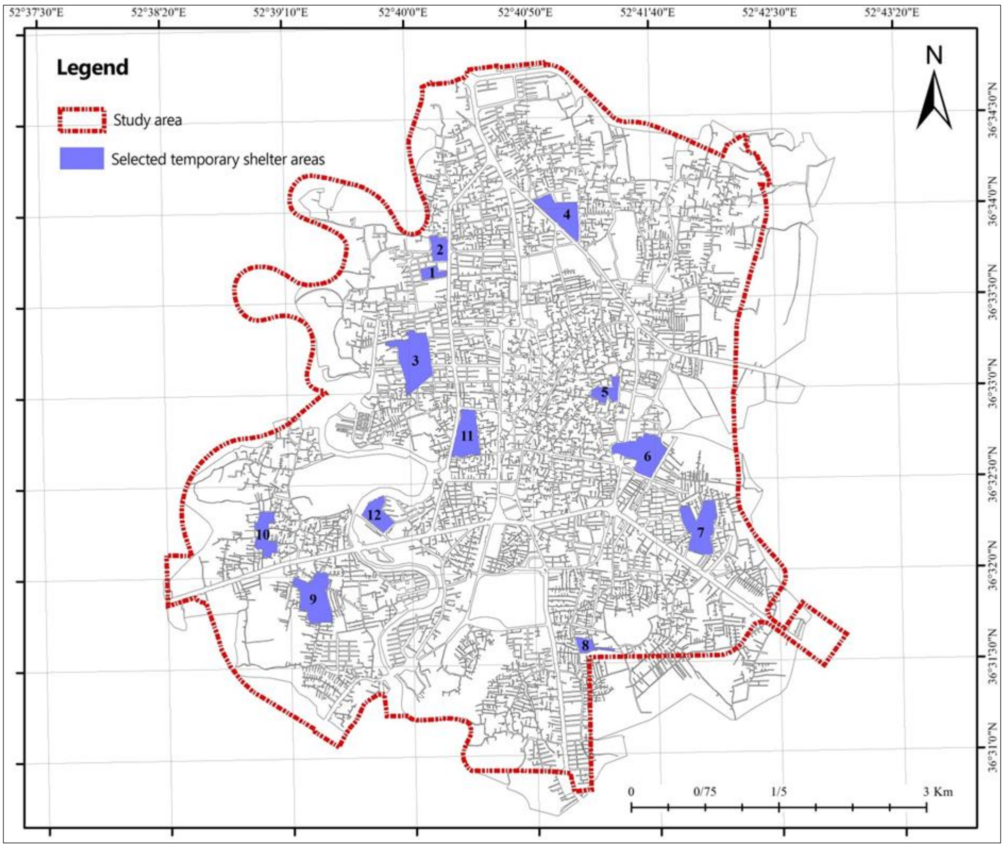

Figure 5. Selected temporary shelter areas based SA

As can be seen in Table 4, region 5 shown in the blueprint (Figure 5) has the highest priority for the construction of a temporary shelter. Subsequently, the number nine is more suitable with the terms defined by the user. On the other hand, the number 11 is introduced with least consistency of the conditions as the least suitable area suggested by the model.

Table 4. Analysing suggested areas to use proposed criteria

Row	Zones ranking	PA (Km)	FL	MC	AP	FC	VA
1	4	294.0	421.4	147.5	139.3	1243.2	450.4
2	5	257.2	679.5	242.8	406.3	1383.9	440.7
3	10	287.3	285.9	535.9	159.2	978.5	535.8
4	8	277.4	496.6	370.3	203.3	1514.7	825.8
5	1	267.8	1167.7	103.0	271.2	242.4	1877.1
6	3	321.5	1878.0	277.0	115.1	580.8	708.0
7	11	271.4	2830.7	395.5	367.7	1487.0	374.0
8	9	270.1	2990.4	479.3	334.9	1005.4	192.8
9	2	371.4	1625.4	380.1	55.8	1251.5	1311.0
10	6	286.2	1364.1	435.9	341.4	803.7	1119.2
11	12	316.4	575.0	374.3	114.5	318.3	723.3
12	7	279.8	699.5	652.0	298.0	832.7	907.8

*Unit of all criteria is Kilometre.

6. Conclusion

Earthquake evacuation is invariably a dynamic process characterized by much uncertainty in an ever-changing environment. The location of earthquake shelters, therefore, becomes an important component in preparation for this unforeseen event. GIS aids in the strategic location of earthquake shelters and other emergency facilities. This study corroborating GIS as a cutting-edge method made an effort to transform the conventional technique of location modelling into more practical system, which would permit a more realistic planning method.

The problem of locating temporary shelter areas after a disaster was addressed and the relevant literature was reviewed. A kind of MCDM procedure for selecting the best shelter locations from among a set of benchmarks was developed. The model finds the location of shelter and matches population regions (districts) with the closest open shelter while taking shelter area usage into account. This research has contributed to the northern district of Iran be more prepared against disasters that might occur in the future. For this purpose, suitability map of shelter areas was obtained using GIS technology. After selecting appropriate locations for temporary Accommodation, the criteria for site selection and the value of each criterion were determined with regard to the literature and experts' recommendations. The analytic hierarchy process was applied and the criteria weights were determined by the analytical hierarchical process to obtain more accuracy results. As a result of paired comparison, the "distance from fault line" criterion with 0.429 value is presented as a most influential factor and "Proximity to medical centres" criterion (0.044) is recognized as a lowest impact factor in establishing of temporary Accommodation. According to the results, 0.48 precent of the areas in the aforementioned site was not suitable, however, just 0.058 precent was most suitable for temporary shelters to be built after an earthquake. According to SA, the specified regions (No. 5 and 9) indicated to be probable alternatives for making the best decision.

7. References

[1] Chen, Zhifen, Xiang Chen, Qiang Li, and Jin Chen. "The Temporal Hierarchy of Shelters: a Hierarchical Location Model for Earthquake-Shelter Planning." International Journal of Geographical Information Science 27, no. 8 (January 30, 2013): 1612–1630. doi:10.1080/13658816.2013.763944.

[2] EM-DAT, 2015. Natural disasters trends. The International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED). http://www.emdat.be/natural-disasters-trends (Accessed on 10 November 2015).

[3] Desouza, Kevin C., and Trevor H. Flanery. "Designing, Planning, and Managing Resilient Cities: A Conceptual Framework." Cities 35 (December 2013): 89–99. doi:10.1016/j.cities.2013.06.003.

[4] Bayram, Vedat, Barbaros Ç. Tansel, and Hande Yaman. "Compromising System and User Interests in Shelter Location and Evacuation Planning." Transportation Research Part B: Methodological 72 (February 2015): 146–163. doi:10.1016/j.trb.2014.11.010.

[5] Triantaphyllou, Evangelos, Boris Kovalerchuk, Lawrence Mann, and Gerald M. Knapp. "Determining the Most Important Criteria in Maintenance Decision Making." Journal of Quality in Maintenance Engineering 3, no. 1 (March 1997): 16–28. doi:10.1108/13552519710161517.

[6] De Almeida, A.T., and G.A. Bohoris. "Decision Theory in Maintenance Decision Making." Journal of Quality in Maintenance Engineering 1, no. 1 (March 1995): 39–45. doi:10.1108/13552519510083138.

[7] Alçada-Almeida, Luís, Lino Tralhão, Luís Santos, and João Coutinho-Rodrigues. "A Multiobjective Approach to Locate Emergency Shelters and Identify Evacuation Routes in Urban Areas." Geographical Analysis 41, no. 1 (January 2009): 9–29. doi:10.1111/j.1538-4632.2009.00745.x.

[8] El-Anwar, Omar, Khaled El-Rayes, and Amr Elnashai. "An Automated System for Optimizing Post-Disaster Temporary Housing Allocation." Automation in Construction 18, no. 7 (November 2009): 983–993. doi:10.1016/j.autcon.2009.05.003.

[9] Sadidi, Javad, Reyhaneh Saeedi, Aliasghar Torahi, and Parviz Zeaiean Firuzabadi. "Determining the Optimal Algorithm to Locate the Best Place for Earthquake Refugee Camps: A Case Study for Tehran, Iran." Positioning 05, no. 04 (2014): 97–106. doi:10.4236/pos.2014.54012.

[10] Chu, Jianyu, and Youpo Su. "The Application of TOPSIS Method in Selecting Fixed Seismic Shelter for Evacuation in Cities." Systems Engineering Procedia 3 (2012): 391–397. doi:10.1016/j.sepro.2011.10.061.

[11] Hosseini, S. M. Amin, Albert de la Fuente, and Oriol Pons. "Multicriteria Decision-Making Method for Sustainable Site Location of Post-Disaster Temporary Housing in Urban Areas." Journal of Construction Engineering and Management 142, no. 9 (September 2016): 04016036. doi:10.1061/(asce)co.1943-7862.0001137.

[12] Trivedi, Ashish, and Amol Singh. "Prioritizing Emergency Shelter Areas Using Hybrid Multi-Criteria Decision Approach: A Case Study." Journal of Multi-Criteria Decision Analysis 24, no. 3–4 (April 21, 2017): 133–145. doi:10.1002/mcda.1611.

[13] Chen, Zhifen, Xiang Chen, Qiang Li, and Jin Chen. "The Temporal Hierarchy of Shelters: a Hierarchical Location Model for Earthquake-Shelter Planning." International Journal of Geographical Information Science 27, no. 8 (January 30, 2013): 1612–1630. doi:10.1080/13658816.2013.763944.

[14] Choi, Jong-Ho, In-Joon Kang, and Sang-Seok King. "Study on the Selection of the Tsunami Shelter Using AHP and GIS Analysis." Korean Journal of Geomatics 30, no. 6_1 (December 31, 2012): 503–509. doi:10.7848/ksgpc.2012.30.6-1.503.

[15] Kılcı, Fırat, Bahar Yetiş Kara, and Burçin Bozkaya. "Locating Temporary Shelter Areas after an Earthquake: A Case for Turkey." European Journal of Operational Research 243, no. 1 (May 2015): 323–332. doi:10.1016/j.ejor.2014.11.035.

[16] Givechi, S., Attar, M. A., Rashidi, A., & Nasbi, N. (2013). Site selection of temporary housing after earthquake by GIS and AHP method Case study: Region 6 of Shiraz. Urban-Regional Studies and Research Journal, 5(17), 29-32.

[17] Forouzandeh, Ali Javan, Mahmood Hosseini, and Maryam Sadeghzadeh. "Guidelines for Design of Temporary Shelters After Earthquakes Based on Community Participation." In14th World Conference on Earthquake Engineering, Beijing, China, Oct, pp. 12-17. 2008.

[18] BOLIN, ROBERT, and LOIS STANFORD. "Shelter, Housing and Recovery: A Comparison of U.S. Disasters." Disasters 15, no. 1 (March 1991): 24–34. doi:10.1111/j.1467-7717.1991.tb00424.x.

[19] Hosseini Nasab H, Tavana M, Yousefi M. A new heuristic algorithm for the planar minimum covering circle problem. Production & Manufacturing Research. 2014 Jan 1;2(1):142-55.

[20] Hadiguna, Rika Ampuh, Insannul Kamil, Azalika Delati, and Richard Reed. "Implementing a Web-Based Decision Support System for Disaster Logistics: A Case Study of an Evacuation Location Assessment for Indonesia." International Journal of Disaster Risk Reduction 9 (September 2014): 38–47. doi:10.1016/j.ijdrr.2014.02.004.

[21] Tsai, Chung-Hung, and Yi-Lung Yeh. "The Study of Integrating Geographic Information with Multi-Objective Decision Making on Allocating the Appropriate Refuge Shelters: Using Kengting National Park as an Example." Natural Hazards 82, no. 3 (March 19, 2016): 2133–2147. doi:10.1007/s11069-016-2298-9.

[22] Tamima, Umma, and Luc Chouinard. "Development of Evacuation Models for Moderate Seismic Zones: A Case Study of Montreal." International Journal of Disaster Risk Reduction 16 (June 2016): 167–179. doi:10.1016/j.ijdrr.2016.02.003.

[23] Saaty TL, The analytic hierarchy process: planning, priority setting, resource allocation. McGraw-Hill, New York (1980).

[24] Saaty, Thomas L. "What Is Relative Measurement? The Ratio Scale Phantom." Mathematical and Computer Modelling 17, no. 4–5 (February 1993): 1–12. doi:10.1016/0895-7177(93)90170-4.

[25] Chakraborty, Shankar, and Debabrata Banik. "Design of a Material Handling Equipment Selection Model Using Analytic Hierarchy Process." The International Journal of Advanced Manufacturing Technology 28, no. 11–12 (June 29, 2005): 1237–1245. doi:10.1007/s00170-004-2467-y.

[26] Zou, X., & Li, D. (2008). A multidisciplinary GIS-based approach for the potential evaluation of land consolidation projects: a model and its application. In WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering (No. 7). World Scientific and Engineering Academy and Society.

[27] Hu, Fuyu, Saini Yang, and Wei Xu. "A Non-Dominated Sorting Genetic Algorithm for the Location and Districting Planning of Earthquake Shelters." International Journal of Geographical Information Science 28, no. 7 (March 14, 2014): 1482–1501. doi:10.1080/13658816.2014.894638.