Vulnerable and Safe Points in Crisis Situations with a Passive Defense Approach in Tabriz, Iran

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Original Article

Abstract

INTRODUCTION: Sustainable urban development and sustainable cities are the most important challenges faced by humans in the 21st century, as the cities may suffer a lot of damage in times of crisis. Therefore, paying attention to the passive defense subject can significantly reduce the level of damage caused by disasters. The present study is conducted with the aim to provide a passive defense approach to selecting the best shelter for temporary accommodation.

METHODS: This was a descriptive-analytical study in which the required information was collected using library and field methods. In order to analyze the information, the analytic network process (ANP) technique was employed in order to determine the importance coefficients of indicators in a real environment. Finally, by overlapping information layers, the most preferred locations were identified in proportion to the objective, and the system was used to draw the layers and determine the importance weights of the indicators.

FINDINGS: Given the importance weights, the characteristics of a suitable place included areas with sufficient open spaces and at the same time, compatible with the surrounding uses with a relatively higher potential for the establishment of the injured. Therefore, due to the existence of open and suitable spaces as well as proper access, the outskirts of Tabriz, Iran, have a high capacity for accommodating the incident victims.

CONCLUSION: Combining different layers of effective uses, the final map of the optimal spaces for the construction of urban shelters was obtained dividing the areas in five categories of very good to very weak, and eight appropriate locations were specified. The adaptability of uses, distance from densely populated areas, parks and green spaces, and access to main passages obtained the highest scores for temporary accommodation.

Keywords: Network Analysis; Secure Location; Passive Defense; Location

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Introduction

Paying attention to the replacement of uses with a defensive and safety view, emphasizing the principles of passive defense, and using the views of predecessors and the experiences of leading countries in passive defense, especially in the field of urban planning, can contribute to the improvement of urban defense planning and to achieving sustainable urban security and development. Given the progress made in the field of militarily engineering in developed countries, it is necessary to secure cities so that they suffer the least human and financial losses during wars and unexpected events. This study tries to use the principles of passive defense in urban planning with emphasis on installation and vital uses as vulnerable uses and secure urban spaces by providing them with a defensive role, in addition to providing insight into how to protect and defend human beings and their places of residence by enforcing current and future passive defense rules and regulations.

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Moreover, the study aims to provide a platform for the security and sustainability of the cities with the least possible damage during a foreign invasion and even a terrorist operation. The need to adopt a clear strategy to secure areas and reduce their vulnerability to natural and manmade disasters is an inevitable necessity (1). War is one of the fixed elements of human history. Over the past years, Iran has witnessed four important wars: the war between Iran and Iraq, the First Gulf War, the Afghanistan War, and the US-British War against Iraq; given this, the geopolitical goals, containment, and siege are of the strategic goals of global arrogance. In the field of passive defense, unnatural or manmade crises such as wars, technology-induced crises, political crises, explosion, fires, etc. are among the topics of interest. In the unnatural crisis area, the need to defend itself is serious and important for every country. Therefore, the study of location, planning, and passive defense of the city based on its natural location, distribution of uses, security considerations such as camouflage, concealment, and distribution and fortification greatly reduces urban costs in times of crisis (2). In 1997, a group of non-governmental organizations (NGOs) and the International Committee of the Red Cross (ICRC) established the Sphere Project, which included universal rules of minimum standards in the field of humanitarian services. The project aims to set a practical framework for tasks and promotion. The goal of this project is to determine a practical framework for performing the duties and upgrading the quality of humanitarian aid in the face of adverse disasters and disturbances, as well as increasing human responsibility towards the affected people. This project is divided into four sections: water supply, sanitation, and hygiene promotion; food security and nutrition; shelter, settlement, and non-food items; and health action, with shelter and settlement being examined in this study (3). Tabriz, Center of East Azerbaijan Province, is the city under study, which as a mountainous city has experienced many natural disasters so far, the most important of which are earthquakes and floods. In general, in addition to the geological position of the city, several other factors have increased the likelihood of a crisis in Tabriz, including its position in the air corridor, the special military and political situation of this city, ethnicity, the weak land texture, the outskirts of mountains prone to landslides, non-compliance with construction engineering laws and regulations, land instability, lack of reconstruction of damaged areas, lack of proper passageways, lack of studies and infrastructure measures to address the problem of flooding, lack of basic programs to deal with future crises, and hundreds of other problems, which are currently observed in Tabriz, and if they continue will cause blind and unresolved problems in the future. In the event of such a situation, even expending heavy costs and effort of the planners will not be effective to improve the situation. Accommodation in shelters provides temporary accommodation and living for about three to seven days, as well as the maintenance and organization of activities and environmental management, and also the resilience and the preservation of urban life. In this regard, according to the perspective document of the Iranian Ministry of Energy, up to the horizon of 1404 (2025), all water and sewage companies are required to provide access to sufficient safe drinking water and facilities for collecting, transferring, and sanitary wastewater treatment for members of society within national and international standards and participation in the areas such as protection of water including the separation of drinking and non-drinking water, environmental assistance, and providing public health (5). Therefore, the present study is conducted with the main objective of locating suitable urban shelters with a passive defense approach and sub-objectives of identifying and using criteria to select the best shelter for temporary accommodation, helping decision makers and city trustees to prioritize the potential locations, and selecting the optimal location for the shelter using an analytic network process (ANP) model and geographic information system (GIS). Various studies have been accomplished on the subject, including the following. A study by Kar and Hodgson in the state of Florida, USA, to determine the appropriate location for immediate evacuation using GIS, by combining two methods based on weighted linear combination and the technique of showing success or failure in 17 areas of South Florida; 48% of the shelters were placed in inappropriate areas. For 15 shelters in inappropriate areas, there were no shelters or places with suitable high or medium capacity, up to 10 miles away (6). Dabbagh and Ahmadi performed a study on the optimal location of relief centers in Urmia, Iran using GIS and multi-criteria decision-making (MCDM) methods. In

the results, they specified the indicators of the optimal location of relief centers in terms of degree of importance as security, time of use, concentration, area of coverage, and compatibility access, respectively (7). In a study, Hosseinzadeh Dalir et al. examined passive defense and sustainable urban development with emphasis on the threat-ridden uses of Tabriz metropolis from the perspective of wars, in addition to performing the necessary analyses using GIS software on the distribution and deployment of strategic uses in Tabriz metropolis as a historical-cultural city and economic-communication hub in the northwest of the country. Finally, the central areas of the city and the southwestern and northwestern suburbs of the city were identified as unsuitable and critical due to the aggregation of dangerous and threat-ridden uses (8). In a study, Saidpour and Kashefidust investigated the location of urban shelters with a passive defense approach on the case study of the city of Saqqez. The findings suggested that parts of the city with adequate open space and compatible with the surrounding areas had a relatively higher potential for the placement of the incident victims. They proposed nine locations for this purpose, among which the green spaces, unutilized lands, and schools had the highest score for temporary accommodation (9). Haji Kazemi and Abdullah Zadeh in a study on the prioritization of metro stations as underground shelters based on the passive defense principles and criteria investigated the optimal location of underground shelters on Tabriz metro stations. Based on 5 main criteria, i.e. the access, demographic, environmental-natural, physical, and performance criteria to compare the stations as the shelter locations, Station 6 was selected as the optimal station for the establishment of the shelter on Line 2 of Tabriz Metro (10). Salehi and Saeedi studied passive defense requirements in the location of Bushehr airport; in field of airports, specifying the type of threats and the defense approach appropriate to the airports given the type of their operation and structure and taking into account the diverse range of threats, while presenting standard indicators in the location of airports, they addressed the existing problems of Bushehr International Airport and the location of its new site (11). In a study, Shieh et al. explored the factors affecting the location of high-rise buildings with an emphasis on the environmental sustainability in Qazvin using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) model, with the results showing that there is no model in Iran for locating high-rise buildings, including in Qazvin. Based on their findings, the economic, environmental, and physical and land use factors ranked first to third and were more important than other components (12). Ilanlou et al. investigated the location of urban waste recycling site and its conversion industries in Kelardasht city, Iran, and in the first step, they tried to identify the criteria by Delphi method and selected 5 criteria: distance from residential and commercial areas, distance from urban thoroughfares, distance from rivers, distance from hospitals and educational centers, and distance from hotels, banks, and offices. In the next step, they determined allowable distances for these criteria using the method of center of gravity of definite distances, and to determine the weights and their use in raster maps and production of the zoning map, they employed the analytic hierarchy process (AHP) and GIS. Then based on the zoning map, the best places to position the recycling facilities in Kelardasht city were introduced (13).

Methods

Research method: The present study is considered as an applied study carried out with a descriptive-analytical method. The required information was obtained through the library study, documents, field observations, and use of statistics and census tables. In this study, the Fuzzy Analytical Network Process (FANP) model was employed to weigh the criteria and rank the points in the environment of the Super Decisions system. Then, information layers and maps were prepared according to the criteria, and finally, a combination map of the criteria presenting the best location for the construction of shelters in this area was extracted.

ANP: ANP is an inclusive and robust method for accurate decision-making, proposed by Thomas L. Saati in 1996. In the introduction of the article "Principles of Analytic Network Process", he stated that ANP is an essential step in the decision-making process that, due to the negligence of the traditional approach due to its linear structure, has taken into account the reversibility structure, which can be considered a missing step in the decision-making process taking into account all the positive and negative aspects. Therefore, the most important difference

between this method and AHP is in the effect of the criteria on each other. Figure 1 provides a better understanding of the differences between AHP and ANP structures. Given the figure in the AHP structure, first an objective or a node is located, which ends in a node or a destination cluster. Therefore, there is a linear structure, from top to bottom and without returning from lower or higher levels. However, in the ANP mode, a network and its clusters are not distributed regularly. Besides, in a cluster, the cluster is allowed to be affected by itself (internal dependence) or affect another cluster (external dependence), and there is also permission to return directly from the second cluster or to pass through the middle cluster. In an ANP structure, a system may be formed of a hierarchy by a gradual increase in communication, so that a pair of connecting components is arbitrarily interconnected and some of its components are internal loop dependence.

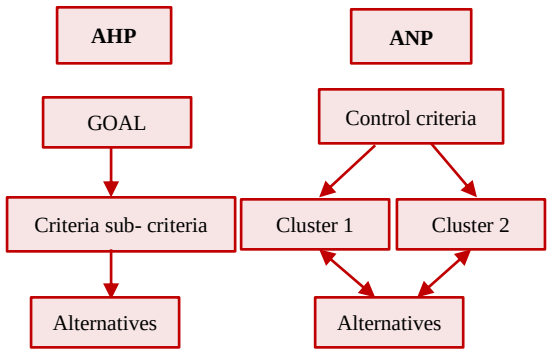

Figure 1. Difference between analytic network process (ANP) and analytic hierarchy process (AHP) diagrams

ANP consists of three basic steps: The first step is to create a model and structure of the topic. The first step in ANP is to build a conceptual model and determine the relationships between clusters and nodes. The subject needs to be clearly expressed and analyzed within a logical system such as a network.

The second step is to form pairwise comparison matrices and extract their preference vector: This step is similar to AHP, in which the degree of importance or preference of the criteria and sub-criteria, based on the control criterion in the range of 1-9 or by count downing by an expert or experts, is questioned and measured, and then the degree of incompatibility of judgments is measured by a factor known as the incompatibility ratio (IR). If this ratio is less than 0.1, the judgment incompatibility is acceptable; otherwise, the judgments must be reconsidered. After making sure of the compatibility of the judgments, the weight coefficients of the criteria are determined. If the calculations of this method are performed using the Super Decision system, a method called Eigen vector method (Relation 1) is used for this purpose to determine the preference vector of the matrices.

$$A*w = \lambda_{max}*w \quad (1)$$

Where A, W, and λ are the pairwise comparison matrix, Eigen vector, and the largest Eigen value, respectively.

The third step in forming a supermatrix: A supermatrix has a similar meaning to the Markov chain. For this purpose, in order to calculate the final preferences of the components in systems with dependent variables, all the primary preference vectors obtained from the pairwise comparison matrices are entered into a column matrix. The four conditions in AHP (reversibility, homogeneity, dependency, and expectations), which are the same as the hierarchical dependency condition, are violated in ANP, as the violation of this condition makes ANP a powerful technic in the construction of more complex environments compared to AHP, because then, this method could consider a variety of interactions and communications. In addition, ANP creates a structure that potentially eliminates errors of judgment by improving "information processing assurance". Although this process does not require a hierarchical structure, like AHP, it benefits from a relative scale with human judgments. Therefore, using the relative scale, all the effects and judgments of individuals are obtained and accurate predictions are made about them with these scales. The ANP algorithm for this study has been extracted as Figure 2:

Findings

East Azarbaijan province, with its center of Tabriz, is one of the most important, densely populated and prosperous provinces of Iran, which is located in the northwestern corner of the country with an area of 250,590 km^2 (Figure 3). In terms of geographical location, it is located in the range of 45°, 7′ to 48°, 20′ east longitude, and 36°, 45′ to 39°, 26′ north latitude. The height of Tabriz city is 1348 to 1561 m above the sea level and it has an average annual rainfall of 310 mm. According to the 2016 census, this city has a population of 1,733,033 people (14).

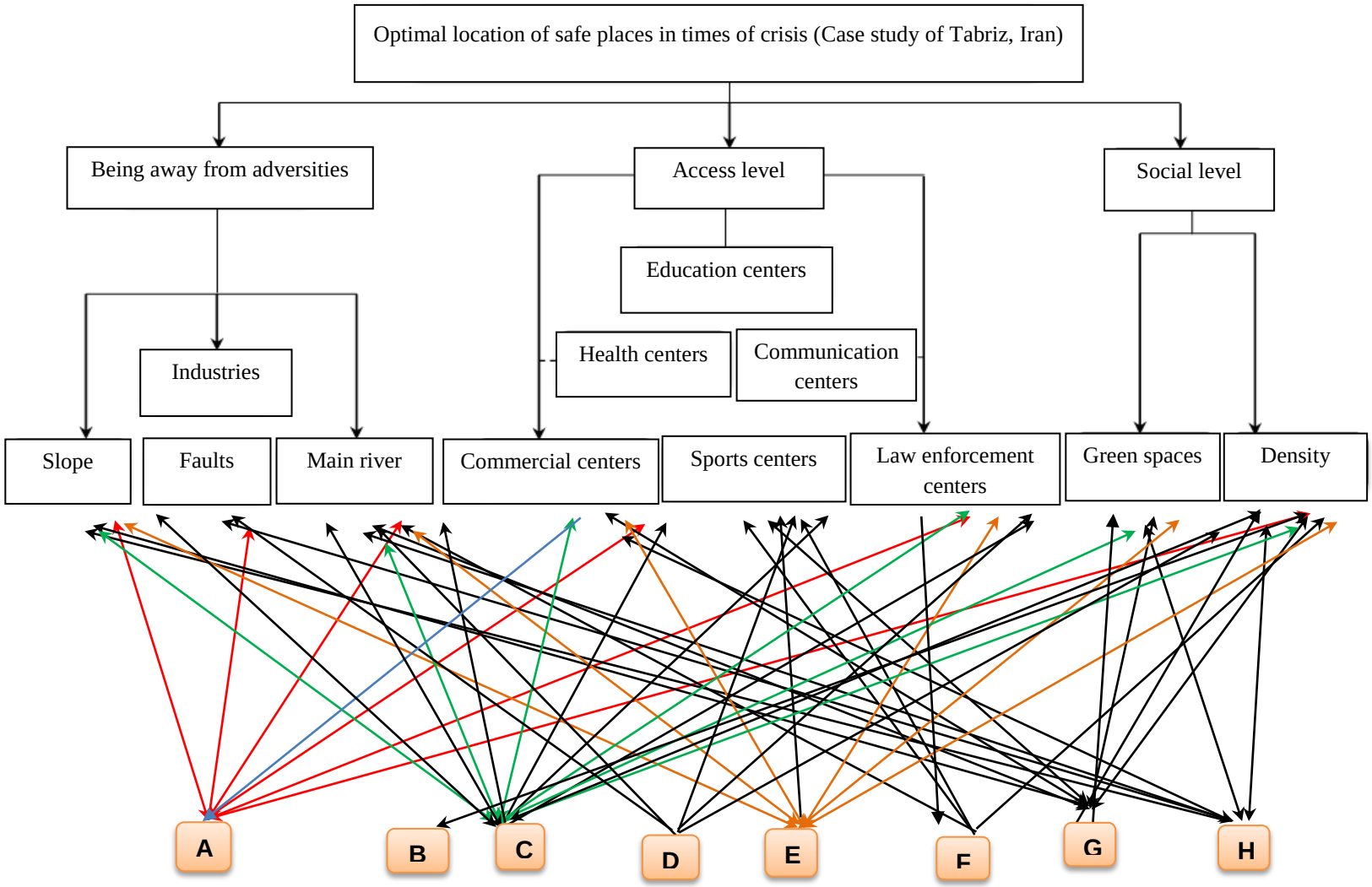

Figure 2. Research analytic network process (ANP) algorithm

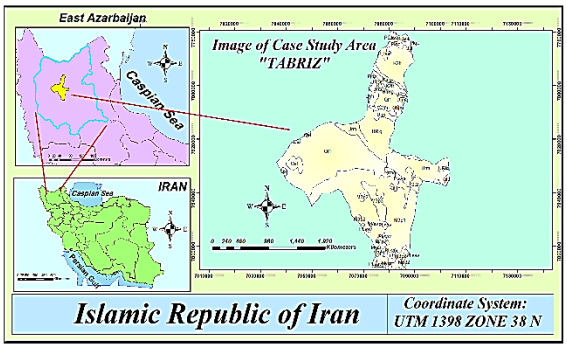

Figure 3. Geographical location of the study area

Failure to properly locate shelters in times of crisis may result in another catastrophe, even far worse than the first disaster. Therefore, in the current study, the location for the construction of shelters after a disaster in Tabriz was conducted using the ANP model, in which the fuzzy data were used due to the uncertainties. The criteria used to locate GIS layers included population density, green space, security centers (law enforcement and military), commercial centers, industries and factories, land slope, education centers, sports and health centers, seasonal and permanent rivers, and communication routes. Accordingly, the layers were created in the GIS system environment as follows:

Compatibility of uses: Compatibility means the consistency, coordination, and non-interference between two types of urban uses, which is one of the stages of spatial evaluation and analysis of urban applications, and in terms of urban planning, the uses that are in each other's sphere of influence should be consistent and do not interfere with each other's performance (15). Therefore, each use in the city is different from some uses and is compatible with others. This compatibility and incompatibility are defined with factors such as noise pollution, air pollution, access, and the like. Regarding the location of urban shelters, urban uses can be divided into two categories: vital uses that help control the crisis and the resulting damage, such as open spaces such as unutilized lands, green spaces, gardens, and farms, second, the uses such as hospitals and health centers, schools and educational centers, and administrative and law enforcement centers, which increase the damage and these uses include industrial uses. Hospitals and health centers are the most important uses of the city at the time of crisis. According to the statistics published by Tabriz University of Medical Sciences, this city has 11 public educational-treatment hospitals, 8 public non-governmental hospitals, with a total of 5,071 clinics, laboratories, and other medical centers, which are potential places to help the injured in times of crisis (16).

Distance from different service stations (fire centers, etc.): The location and establishment of fire stations are one of the decisions that every fire headquarter chief and crisis manager will face; therefore, the proper location of Tabriz metropolitan fire stations, which has 23 stations, can have the following advantages: 1. determining the shortest time of the distance between the fire station and the scene of the disaster. 2. Reducing the overlap of several fire stations in order to make the best use of the facilities and resources of the stations. In this regard, for the general policy of distance from fire stations in Tabriz, according to experts, to create any shelter in urban areas, the most important principle is to find empty unutilized land. As the timely service of fire stations in order to reduce damage and casualties in times of crisis requires their proper location (17).

The increase in population has led to the rapid physical development of the city of Tabriz, which has led to a lack of adequate enjoyment of services and disturbances in public services, including access to fire stations. Global standards predict an area of 5 km for a station operation, and on the other hand, the time to reach the place of fire is considered to be 3-5 minutes. This radius is considered to be 1700 m in terms of space distance; therefore, the location of the stations should be analyzed according to the radial model and distributed in such a way that the whole city is accessible within four minutes. Table 1 indicates the appropriate distance between the temporary accommodation shelters and fire stations in Tabriz metropolis, which is classified into 5 classes, with each class given a weight between 1 and 9 in terms of its preference (9).

Table 1. Classification of suitable distance from a fire station

Layer	Good	Relatively good	Moderate	Relatively poor	Poor
Distance from fire station	0-300	300-500	500-700	700-1000	Above 1000
Weight	9	7	5	3	1

Table 2. Classification of suitable distance from the communication network

Layer	Good	Relatively good	Moderate	Relatively poor	Poor
Distance from communication network	0-100	100-200	200-300	300-400	Above 400
Weight	9	7	5	3	1

Layer of access to communication network: One of the influential factors in locating urban shelters is the access to communication routes. The more access to the communication routes, the more efficient these sites will be. Additionally, factors such as the width of the streets, the quality, and volume of traffic, the one-sidedness of the streets, etc. are effective in the location of the temporary accommodation. Due to the texture of Tabriz metropolis and the location of the two eastern and western ring roads, as well as the special mountainous position of this area, which has prevented the widening of communication routes in the city, and the residence place of people in the vicinity of highways and main streets, especially the main intersections are among the positive factors of location. The location of worn-out and traditional textures, the lack of support from the relevant authorities for the improvement of these textures, mountainous and hilly areas of Tabriz, and the placement of new settlements on the active and large faults of Tabriz are among the factors that require special investigations on this city. Accommodation shelters should be adjacent to passages that provide access to different areas on the one hand, and the possibility of damage and obstruction of these passages should be low on the other hand, so the risk of access obstruction does not stop the accommodation and relief operations. Table 2 represents the proper distance of the shelters from the communication network.

Population density layer: Basically, the objective of creating shelters is to provide services to humans and disaster-affected groups; thus, given the population criterion, wherever the number and density of human beings is higher, the need of residents for relief services will increase. In areas of the city where the population density is high, the probability of injury and damage caused by the crisis is more than the low-density areas. In other words, the lower the population density in the city and the more evenly distributed it is in the city, the less damage there will be. Conversely, high population density in the city means more casualties and damage during a crisis (19). Nowadays, one of the most important and general phenomena worldwide is the rapid population increase and urban growth, which is clearly seen in developing countries. One of the most prominent features of these countries is the high concentration of population in the metropolitan areas, which can cause a catastrophe in case of occurrence of a natural or manmade disaster, even where its initial impacts were not very serious. In times of crisis, these casualties will be higher in densely populated vulnerable areas with a compacted texture (20). On the outskirts of the city, the main purpose of establishing shelters is to provide services to the disaster-affected human groups; therefore, according to population criteria, wherever the number and density of people is higher, the need for providing relief services to residents will increase. In areas of the city where the population density is high, the risk of injury and crisis is greater than in areas with low density. Conversely, high population density in the city means more casualties and damage during the crisis. Therefore, in this study, areas of Tabriz with a higher population were considered to have a higher weight in the analysis (Table 3).

Distance from health centers: In critical situations, the performance of medical centers, especially the emergency department, is more important; hence, one of the main criteria in determining the most suitable safe place for the construction of temporary accommodation shelters is the proximity to medical centers and hospitals. According to the statistics issues by Tabriz University of Medical Sciences, this city has 11 public educational-treatment hospitals, 8 public non-governmental hospitals, with a total of 5,071 clinics, laboratories, and other medical centers (16). The time for the emergency to reach the disaster scene has a global standard of at least 8 minutes, which is 11 minutes in Iran on average.

Table 3. Classification of suitable distance from the population density points

Layer	Good	Relatively good	Moderate	Relatively poor	Poor
Population density (people per hectare)	0-30	30-60	60-90	90-120	Above 120
Weight	1	3	5	7	9

Table 4. Classification of appropriate distance from health centers

Layer	Good	Relatively good	Moderate	Relatively poor	Poor
Distance from health centers	100-150	150-300	300-450	450-700	Above 700
Weight	9	7	5	3	1

However, in crisis situations where there is a possibility of blockage of roads and lack of ability to use vehicles, the criterion for determining the area of access to medical centers must be considered on an on-foot basis. Therefore, to reach the standard arrival time of at least 8 minutes on foot and at an average speed, the distance should be 440 m (20). Therefore, places as shelters are preferred that have the shortest distance to the treatment centers compared to other places. Due to the importance of easy access to such centers, they were classified into five categories (Table 4).

Distance from law enforcement and security centers: Because of the need to maintain public discipline and security of the residents of temporary shelters, access to military and law enforcement centers is an important index. In the police stations, the on-foot distance in times of crisis to reach the incident scene is 400 m, and this distance is considered as 2 km for barracks given their distribution in the city. Since after the crisis, people rush to the scene from far and near cities to help their fellow human beings, in these cases, maintaining discipline and protection of the lives and property of the injured, especially women and children, against aggressive or criminal operations of individuals or aggressive groups (inside and outside the shelters) providing support services to victims, preventing chaos in the crisis situation, preventing theft and abuse of victims, and identifying suspicious individuals, highlights the role of security and law enforcement forces. Given the above, proximity to security and law enforcement centers in Tabriz metropolis with 9 checkpoints and 9 police stations is one of the parameters that should be taken into account in order to create and maintain security in emergency accommodation centers (22). Tables 4 and 5 present the appropriate distances between health centers, military, and police stations in five classes, with weights between 1 and 9 given based on their preference (9).

Distance from parks and green space: Considering the history of natural disasters in the region, the post-incident planning (crisis management) that can, in addition to creating a suitable place in terms of physical, security, social, etc. factors, be a place where human dignity is preserved and is capable of providing the quick return of the earthquake-stricken people to normal life, is necessary. Achieving such a goal requires planning before the crisis and disasters in vulnerable urban areas, in other words, identifying suitable lands for the goal of location. In this regard, the population-attracting centers, including public parks, shopping malls, hotels, etc., where the dynamic population are passing through the city during the day, the designed shelter distance should be minimum (23). The use of indigenous knowledge of local people in the identification of safe and defensible natural areas and the appropriate natural location of the area in the field of crisis management and passive defense are considered among the strengths of external and internal factors to improve safety according to the passive defense principles and indicators (24). Choosing the right places to deploy vital and relief facilities are important issues in passive defense, and increasing the deployment of facilities in places where they are unlikely to be destroyed will help increase safety and defense capability (25). For this purpose, in this study, vacant and unused lands and urban parks were considered suitable for the location of temporary accommodation places according to their conditions.

Final combination of layers: After evaluating the criteria and converting them to the comparable and standard scales, the ANP model was utilized to determine the relative weight of each criterion. Prioritization of the indicators was performed according to the expert opinions and evaluation of the indicators studied. Then the layers were integrated and finally the shelter location map was depicted.

Table 5. Classification of appropriate distance from law enforcement and security centers

Layer	Good	Relatively good	Moderate	Relatively poor	Poor
Distance from law enforcement and security centers	100-150	150-300	300-450	450-700	Above 700
Weight	9	7	5	3	1

In the GIS environment, using the Spatial Analysis function, the weights obtained from the ANP model were assigned to the layers, and the layers were placed on each other, and ultimately the location map of the shelters was drawn. In the map obtained by the combination of the effective layers of the shelter locations, the lands were classified into five levels (good, relatively good, moderate, relatively poor, poor). Areas of the city with compatible uses, high population density, and proximity to major thoroughfares were suitable to accommodate victims. Therefore, relatively suitable and suitable lands were considered for the construction of shelters. Figure 4 demonstrates the proposed locations for the construction of shelters.

Figure 4. Locations proposed to build shelters in times of crisis

Discussion and Conclusion

Due to the importance weight (Table 6), the characteristics of suitable places include parts of the Tabriz that have sufficient open spaces and at the same time are compatible with the surrounding uses, in addition to a relatively better potential for the deployment of the injured. In contrast, areas with mixed and inconsistent uses and insufficient space have the least potential for shelter planning. Therefore, due to the presence of open and suitable spaces as well as proper access, the outskirts of Tabriz have a high capacity for accommodating the victims. Given the study findings, the best places to accommodate more suitable shelters in the city of Tabriz are open spaces and also the eight suitable places proposed (Figure 4).

In conclusion, regarding the appropriate places proposed in the study, it is necessary to take the proposed measures:

Table 6. Final weights of location indicators in the analytic network process (ANP) model and geographic information system (GIS)

Rank	Criteria	GIS output	ANP output
1	Compatibility of uses	0.249	1
2	Distance from population density area	0.184	0.827
3	Parks and green space	0.158	0.628
4	Access to main thoroughfares	0.089	0.571
5	Health centers	0.078	0.441
6	Access to fire station	0.073	0.367
7	Educational centers	0.063	0.201
8	Security and law Enforcement centers	0.059	0.138
9	Commercial centers	0.047	0.089

A. Considering the necessary equipment and services in the selected locations for temporary accommodation, especially parks, including determining the helicopter landing place, bathrooms, water resources, etc., so that in case of a disaster, it is not necessary to spend time to provide them, hence not disturbing the quick relief process.

B. Building open and large spaces such as parks, sports fields, etc. with a minimum area of 2000 m 2 in order to quickly evacuate the victims of the disasters to these areas and temporarily settle them in.

C. Proper and timely information and introduction of safe places for the establishment of the people through the public media and so on.

D. All public and private bodies, parks, military places, sports gyms, administrative places, and relief and other places that have a suitable space in or around the city, using the principles of safety and protection, should use their spaces in a multi-purpose manner in this matter to participate in the relief and accommodation operation.

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Conflict of Interests

Authors have no conflict of interests.

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