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## Finding Suitable Locations for Temporary Housing After An Earthquake Using TOPSIS and AHP Methods (Case Study: Rudsar City)

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### Abstract


This research was conducted with the aim of finding suitable locations for temporary housing after an earthquake using Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods (case study: Rudsar city). The statistical population studied in this study included relief and rescue experts as well as various parts of the city of Rudsar for temporary accommodation after the earthquake. The present research method is field-based and descriptive survey-based, and the data collection tool in this study includes a researcher-made questionnaire as well as field measurements. In this study, 4500 plots of land and 9 different blocks for settlement were initially examined using the desired criteria, and the distribution range of each of these blocks was implemented in Geographic Information System (GIS) software. The final criteria identified in this study included the criteria of land use, population, natural, security, and accessibility. Initially, the weight of each of these criteria was calculated using fuzzy AHP analysis, and the results of fuzzy AHP analysis showed that the order of importance of each was as follows: 1) Population criterion, 2) Security criterion, 3) Access criterion, 4) User criterion, and 5) Natural criterion. After identifying the weights of the criteria, the fuzzy TOPSIS method was used to select a suitable location for temporary housing. For this purpose, the opinions of experts were used, and the results of the fuzzy TOPSIS analysis showed that Block 7 was the best location for temporary housing after the earthquake in the city of Rudsar.

**Keywords:** Location, Temporary settlement, Fuzzy analysis, Earthquake.

## 1 | Introduction

During the 20th century, more than 1,100 destructive earthquakes occurred in different parts of the world, resulting in the deaths of more than 1,500,000 people, 90% of which were mainly caused by the collapse of buildings that did not have adequate engineering and safety principles [1].

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As part of the Alpine-Himalayan belt, Iran has always had a high seismicity throughout history, such that various parts of the country have been continuously destroyed by numerous devastating earthquakes, and this phenomenon has so far caused heavy casualties and damage as the country's most important natural disaster. In most parts of Iran, seismicity is directly related to the reactivation of faults, and the highest level of seismicity has occurred along active faults [2].

Rudsar is one of the cities in northern Iran in Gilan Province, where the present research was conducted. Rudsar leads to the Caspian Sea from the north, to the Alborz Mountains from the south, to Ramsar from the east, and to Amlash and Langrud from the west. The mountainous part of Rudsar County has a pleasant and cold climate. The northern part of the county, which is located on the southern edge of the Caspian Sea and is a plain area, is a humid area. Geological evidence shows that throughout its life, the Earth has always been severely threatened by the forces of nature, the most destructive of which is earthquakes. Iran is part of the Alpine-Himalayan orogenic belt, which is the youngest and most tense orogenic region in the world. Therefore, although we have occasionally witnessed devastating earthquakes in this land, studies indicate that during the years 1271 AH to 1368 AH, about 153 destructive earthquakes occurred in the world, claiming thousands of victims, of which Iran had a significant share with 48 earthquakes (17.5%) [3].

Appropriate distribution and balanced layout include determining the location of urban services or uses in such a way that all specific social groups with diverse spatial characteristics benefit from them as much as possible [4]. A look at the history of human life on earth shows that humans have always been exposed to various natural hazards.

Natural disasters are largely beyond human control as part of unavoidable realities. Natural disasters basically refer to changes that occur in environmental conditions in a way that disrupts people's lives and exposes them to dangerous elements and factors that cause environmental destruction [5].

A crisis is an event that occurs suddenly and sometimes escalating, leading to a dangerous and unstable situation for an individual, group, or society. A crisis creates a situation that requires fundamental and extraordinary measures to resolve. Crises vary in type and severity. A crisis is a major and special pressure that causes conventional ideas to collapse and widespread reactions, and creates new harms, threats, dangers, and needs [6].

Given the rapid urbanization and the greater vulnerability of cities to natural disasters, crisis management in cities is of greater importance. In urban areas, the typical adverse effects of natural disasters are a combination of physical safeguards and the dysfunction of urban elements. From the moment a crisis arises, major and important decisions must be made. In facing a crisis, the first necessary and vital task is to categorize the facts and realities [7].

According to recorded reports, out of 40 types of disasters known in the world, 31 have occurred in Iran. Since about 70% of Iran's territory is at risk of earthquakes, earthquakes are considered one of the main hazards. Despite the unknown timing of an earthquake, by understanding how earthquakes work and behave in urban areas and applying appropriate strategies in the field of regional planning and urban design, the risk of earthquakes in urban areas can be minimized. In the present era, one of the most important and common phenomena in the world is the increase in population and, consequently, the rapid growth of urbanization and the physical development of cities.

This issue, generally coupled with reckless human interference in natural environments, including excessive human construction within fault boundaries or disregard for construction regulations and standards, and many other factors, has exacerbated the threat of crises resulting from natural disasters, especially earthquakes, and as a result, a humanitarian crisis or disaster arises.

Therefore, proper management of this crisis is essential to reduce its negative effects on society.

## 2 | Crisis Management

Crisis management involves a series of continuous and dynamic operations and measures and is generally based on the classical management function, which includes planning, organizing, leadership, and control [8].

In fact, crisis management is a set of theoretical concepts and practical measures in the dimensions of planning to deal with disasters before and after the disaster. This term also refers to the way in which a disaster and its consequences are managed. In general, the task of crisis management is to control a crisis in a very short time using the best principles and methods. In short, we can say that the relationship between crisis and crisis management is to optimize the conditions for dealing with the crisis and minimize the losses caused by the crisis.

Locating relief and shelter centers is also part of the post-crisis management process, which is defined as providing shelter for people. Post-disaster shelter is a process of housing homeless people, typically provided in a three-phased process that includes emergency shelter, temporary housing, and permanent housing. In this method of housing, emergency shelters are constructed to provide safe shelters shortly after an incident.

After this stage of settlement is completed, it is time to set up temporary settlement sites. Temporary settlement is a stage of the settlement process that involves housing disaster victims in vacant housing provided by the private sector, or in tents on wasteland or in portable houses, or sheltering people in public places such as schools, etc. It indicates that it is considered immediately after the relief and emergency accommodation phase and in the organization phase.

The duration of this method of resettlement is estimated to be from 6 months to 2 years, depending on the type of crisis and facilities. This method of resettlement can be considered a set of activities, including collecting and identifying disaster-stricken and homeless people, moving them to shelters, and creating safe and healthy living conditions until they return to their original homeland or primary habitat.

After going through the two aforementioned stages and in some cases ignoring the second stage, homeless people can resume their normal lives.

## 3 | The Location Problem

The facility location problem is considered a classic optimization problem that has many applications, especially in the service industries. Examples of these applications can be seen in the location of some places such as gas stations, medical and emergency centers, warehouses, and police stations. The roots and origins of location problems go back to the 19th century in Germany, and the first industrial location problem was presented in this country in 1878.

The governing principle of location is to determine the optimal location based on minimum cost or distance and travel time.

The main goal of assessing a location for a specific land use is to ensure that the development and expansion of human activities there is compatible and in harmony with the natural environment, taking into account the possibilities and limitations. In general, location methods are divided into two categories: discrete location models and continuous location models. In discrete models, the options are specific and limited, and one or more options are selected from the available options.

Therefore, a set of indicators and criteria are selected and then evaluated and combined using special methods, and then the best option is determined from among the options. In this case, it is necessary to create a geographical matrix in which the indicators and criteria are placed in the columns and the options are placed in the rows.

In the continuous method, there is no pre-determined option and the entire space is considered as a whole. A set of criteria is specified to determine appropriate locations.

Using multi-criteria methods, spatial data is mathematically formulated and combined with each other, and spatial decisions are made based on this. There can be a large number of options here.

In this study, the selection of initial locations for emergency shelter using a Geographic Information System (GIS) is a continuous location search, as all locations in the city of Mashhad are evaluated in terms of their suitability for emergency shelter.

## **4 | Criteria for Locating Urban Shelters**

### **4.1 | Natural-Environmental Features**

This criterion is measured by indicators of land surface slope, distance from the fault, liquefaction risk, etc. The shelter must also be safe from secondary hazards such as debris, liquefaction debris, etc. Appropriate vegetation cover allows for reduced temperature changes in different seasons and protects residents from dust. Appropriate slope and permeability, and low groundwater levels facilitate surface water drainage. Also, failure to respect the boundaries of existing streams and rivers increases the risk of flooding in the shelter area [9].

### **4.2 | | Access to the Road**

Roads are one of the important factors in locating a location. Access to open roads of appropriate width is very vital in the event of an accident. Therefore, in terms of locating shelters, locating these centers next to streets with a width of more than 14 meters seems appropriate in terms of providing quick and timely relief. Also, urban access roads are divided into grade 1 roads, grade 2 roads, local roads, and metro stations.

### **4.3 | Compatible Applications**

To measure this criterion, four indicators of medical centers, military and law enforcement centers, access to open space, and fire stations were considered. Easy and quick access to medical centers speeds up relief operations. The greater the distance to these centers, the more time passes between the origin and the treatment centers, and the treatment is jeopardized [9].

### **4.4 | Incompatible Applications**

A set of incompatible uses that must be observed in locating shelters, including distance from them and standards related to construction privacy around them.

This includes main gas lines, electricity, gas pressure reduction stations, gas pumps, CNG stations, tall buildings, flammable materials, chemicals, hazardous chemicals, radioactive materials, polluting industries, and the boundaries of rivers and aqueducts. Damage to facilities such as gas pumps, gas pumps, and gas pressure reduction stations can greatly increase the casualties caused by an earthquake. In this area, there are two types of injuries: injuries resulting from lack of access to vital arteries during the immediate relief period and injuries resulting from secondary accident events such as fire, electric shock, and explosion.

### **4.5 | Demographic Function**

One of the most important factors in locating temporary accommodation centers is the population density criterion, which should be considered as the minimum distance standard from high-density residential areas. The lower the population density of a city and the more balanced its distribution across the city, the lower the city's vulnerability to earthquakes. Conversely, a high population density in a city means more casualties and damages when an earthquake occurs.

## 4.6 | Economic Considerations

This goal is achieved by identifying the most appropriate use of a piece of land that will yield the greatest benefit at the lowest cost. The most important costs include construction, operation, and maintenance costs. Of course, the possibility of land acquisition should also be considered [10].

## 4.7 | Social Aspects

Taking into account the customs, traditions, and practices of population groups, obtaining public input from local residents, and considerations related to cultural heritage can prevent conflicts of interest in the location of shelters.

## 5 | Ranking of Identified Criteria

Each of the important and influential criteria in choosing the best place to stay during an earthquake in the city of Rudsar has been identified.

**Table 1. Identified criteria for selecting a desired location for settlement.**

Criterion	Purpose
Cabri (A)	Temporary accommodation location (G)
Population (B)	
Nature (C)	
Security (D)	
Access (E)	

## 6 | Analytic Hierarchy Process Analysis

Data analysis in this study was carried out using the fuzzy Analytic Hierarchy Process (AHP) method. In the AHP method, preferences between options are determined by pairwise comparisons. The AHP method in a fuzzy environment is a combined and generalized method of the classic AHP method and is very widely used when the complexities of decision-makers' opinions are taken into account.

The following sections describe the processes of both classical and fuzzy AHP in detail. To implement the AHP technique, the first step is to represent the decision problem and objective as a hierarchy of decision elements. This structure usually has one or more clusters.

There are two principles in designing a hierarchical pattern:

- I. According to the principle, each element can only be dependent on one element, and that element must be directly dependent on a higher level than itself.
- II. According to the principle, expectations are that whenever a change occurs in the hierarchical structure, the evaluation process must be repeated [11].

### 6.1 | Cluster Two Decision Elements

The main decision-making criteria are placed in the second cluster, after the research objective. In any problem, there are always main criteria. These criteria can have non-criteria, and non-criteria may be composed of other sub-criteria. Therefore, there is no limit to the decision-making clusters.

### 6.2 | Final Cluster of Decision Options

Decision options are displayed at the lowest level. As mentioned, the goal of the AHP technique is not always to select the best option, and sometimes this technique is used only to rank a set of criteria or sub-criteria, so the target cluster is not present in all AHP studies.

## 7 | The Location Problem

The facility location problem is considered a classic optimization problem that has many applications, especially in the service industries.

Examples of these applications can be seen in locating some places such as gas stations, medical and emergency centers, warehouses, and police stations. The roots and origins of location problems go back to the 19th century in Germany, and the first industrial location problem was presented in this country in 1878. The governing principle of location is to determine the optimal location based on minimum cost or distance and travel time. The main purpose of assessing a location for a specific land use is to ensure that the development and expansion of human activities there is compatible and harmonious with the natural environment, taking into account the possibilities and limitations. In general, location methods are divided into two categories: discrete location models and continuous location models.

In discrete models, the options are specific and limited, and one or more options are selected from the available options. Therefore, a set of indicators and criteria are selected and then evaluated and combined using special methods. And then the best option is determined from among the options. In this case, it is necessary to create a geographical matrix, in which the indicators and criteria are placed in the columns and the options are placed in the rows.

In the continuous method, there is no pre-determined option and the entire space is considered as a whole. A set of criteria is specified to determine appropriate locations. Using multi-criteria methods, spatial data is mathematically formulated and combined with each other, and spatial decisions are made based on this. There can be a large number of options here.

In this study, the selection of initial locations for emergency shelter using a GIS is a continuous location search, as all locations in the city of Mashhad are evaluated in terms of their suitability for emergency shelter.

## 8 | Criteria for Locating Urban Shelters

Identifying and selecting factors affecting location is an important step in the study. The more the identified factors match the ground realities, the more satisfactory the location results will be.

To determine this, it is necessary to fully understand the influencing factors, such as social, cultural, geopolitical, and economic factors. Failure to understand any of these factors may result in the ineffectiveness of the selected location and the emergence of consequences during or after temporary settlement.

In this article, using previous research, factors affecting the location of suitable areas for temporary settlement of the population and the ease of providing services to these areas after an earthquake were selected. Cho and Su used the evaluation index system to locate suitable locations for crisis management [12].

Shoja Araghi and colleagues divided location criteria into three main categories: efficiency compatible with urban land use and incompatibility with urban land use. Soltani et al. divided 27 criteria for locating temporary shelters into 6 main categories: dimensions and location, crisis risk reduction (10), rescue and relief facilities, feasibility of implementation, environmental aspects (13), and social aspects (14).

## 9 | Conclusion

One of the priorities of relief centers and urban management is the location of shelters for emergency housing of people after an earthquake. To this end, managers need appropriate criteria for selecting suitable locations for shelters. The selected articles were categorized and reviewed according to the year of publication and the countries studied. The largest number of articles are related to China, Iran, and Turkey, given that shelter location is usually done on an urban scale.

Optimization algorithms have difficulty reaching an exact answer, so using hierarchical analysis is more popular for urban areas. If the location problem is limited to an urban area and several shelter options are

considered in advance, optimization methods using metaheuristic algorithms such as the genetic algorithm or ant colony algorithm will be useful.

By reviewing articles related to post-earthquake shelter location between 2005 and 2020, the proposed criteria were divided into 7 categories: natural environmental characteristics, considerations, economics, accessibility, compatible uses, incompatible uses, population function, and social aspects. Most of the criteria for the categories of considerations, economic, access to compatible uses, and social aspects for locating shelters related to crises such as floods, storms, etc. are also common, but criteria such as distance from the fault, proximity to the homes of the affected people, and the number of affected people are specific to the location of shelters during an earthquake [9].

The most important criteria for locating articles are, respectively, accessibility, appropriate distance from geographical hazards such as active faults, landslides, debris flows, liquefaction, and proximity to population centers. Also, considering the geography and characteristics of the city under study, it is not mandatory to use all of the criteria provided, and even the weight of each sub-criteria can be updated using the opinions of relevant experts, such as environmental, geotechnical, civil, and urban engineers who have appropriate research or implementation experience.

Tools such as AHP can be used to standardize criteria. In order to apply the mentioned criteria to urban areas and present the results in the form of usable maps for managers, it is necessary to use a tool such as GIS. The GIS environment allows for the standardization of location criteria for assessing disaster management damage in an integrated environment.

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## Author Contributions

Conceptualization, B.B.; Methodology, B.B.; Software, B.B.; Validation, B.B.; Formal analysis, B.B.; Investigation, B.B.; Resources, B.B.; Data curation, B.B.; Writing—original draft preparation, B.B.; Writing—review and editing, B.B.; Visualization, B.B.; Supervision, B.B.; Project administration, B.B. The author has read and agreed to the published version of the manuscript.

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## Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The datasets generated and analyzed during the current study are not publicly available due to research and institutional restrictions but may be provided upon reasonable request.

## Conflicts of Interest

The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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