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Optimal site selection for temporary housing after an earthquake in urban areas using multiple criteria decision making methods and GIS (a case study of municipal district 6, Tehran metropolis)

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Abstract

Choosing an appropriate site for temporary housing of the population affected by natural disasters has always been among the issues that have been brought to the attention of organization and authorities responsible for crisis management. In Iran, finding a location for temporary accommodation of citizens is usually conducted by aid agencies regardless of the standards and in an experimental manner after the events. It is clear that inappropriate site selection might end in a disaster even worse than the initial one. Having explored the site-selection criteria for temporary housing after a probable earthquake in district 6 of Tehran, in the present study we try to review the crisis management steps in an earthquake stricken area, and provide some guidelines for choosing suitable locations for temporary housing of people affected by earthquake in Tehran metropolis. In general, site selection and placement of temporary housing areas is a complex subject that is a function of multiple criteria and variables. Therefore, given the technical features of multi-criteria decision making (MCDM) we acknowledge that making use of such methods to determine and measure the importance coefficients of criteria and indices effective in location of activities is regarded as one of the appropriate methods. Given the high construction and population density in the Tehran, particularly Municipal District No.6 of Tehran, it is necessary to conduct accurate studies and planning to minimize the damage and injuries caused by natural disasters and cataclysmic events. Using some indices (including accessibility, proximity to service centers, land use area, proximity to faults, etc.), and TOPSIS method, the present paper has discussed the optimal site selection method for temporary housing areas in Municipal DistrictNo.6 of Tehran. The research findings show that despite inadequate areas suitable for temporary housing, subway stations and land uses such as parks and green spaces are of high priority for accommodation of the victims after a cataclysmic event in District No.6 of Tehran.

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Introduction

In terms of natural position, especially geological features, Iran is situated on a primary folded belt and lies in the middle part of the belt between the Alps and Himalaya rugged areas (Hariri an, 1990: 8). Located in arid and semi-arid climatic conditions, Iran and particularly the cities in the area have become the most important focal point for occurrence of natural hazards. According to UN statistics, the center for unexpected events in the world, due to Iran's special geographical conditions, of more than 40 natural hazards, 31 of them are known to occur in Iran. According to statistics, over the past 90 years in Iran, 120,000 people lost their lives due to natural hazards. Accordingly, Iran is seen as one of the top 10 disaster-prone countries in the world. Events that can become critical in urban areas are: floods, earthquakes, sea-quake, etc., in general, natural hazards, technological crisis, political and ecological crisis (Abhari, 2007, 5-7). Located on Alpine-Himalayan seismic belt, Iran has experienced 130 earthquakes which measured 7.5 or higher on the Richter scale (Ghafory-Ashtiany, 1999:4). Given the geographical conditions, Iran is constantly under threat by events such as earthquake. Man's efforts to deal with earthquakes have opened a door called "crisis management". Crisis management includes some measures following an earthquake, which largely limits the crisis range and makes it manageable. On the other hand, preparedness, crisis management and the way Tehran would deal with natural hazards and events are always among the major concern of officials, experts and researchers. Therefore, planning for prevention, preparedness and urban crisis management are located at the focus of these communities. Municipal District No.6 of Tehran with an area of 20 Km^2 having almost 220,000 inhabitants in 2006 is one of the major districts of Tehran. Concentration ofinstitutions like ministries, embassies, higher education institutions, health care centers and public hospitals, large incorporations, etc., well implies the particular importance of the area from urban and state perspectives. This, in its turn, involves paying due attention to issues of crisis management. In the past few years, a significant number of studies related to temporary housing of people affected by earthquakes have appeared in the literature. NassimFakhim Haji Aqhai (Haji Aqhai: 2006) in her study with the title of "earthquake crisis management in urban areas, a case study of district No.10 of Tehran" pointed out the particular situation of Tehran and believed that efficient crisis management is the only way to prevent disasters after events like an earthquake. She also believes that urban planners have an important task to do. Furthermore, for crisis management using comprehensive municipal information system, she provided and examined different layers of information with decision-making capabilities. In another study (Abdol Halal Airy: 1998) *earthquake risk mitigation plans in urban areas (a case study of district NO. 20, Tehran)* Abdol Halal Airy identified the vulnerabilities in economic, demographic and structural areas and divided them into zones and suggested some criteria and land use regulations for each of them. SaeedKamyabi (Kamyabi *et al.*, 2008:142) using Information Systems and Passive Defense Management attempted to locate places for temporary housing of the populations affected by the earthquake (A case study of districts 2, 5, 22, Tehran). Using Geographic Information System (GIS) he developed a conceptual model and spatial data bases. He went on data analysis and integration to weigh the criteria and indices relevant to selecting a location suitable for emergency accommodation of earthquake victims, and consequently the best locations are open green space of some parks in the urban areas which are far from major pipelines such as power lines, gas lines, etc. In that study, the required space per person was 2 m^2. GhaforyAshtiany *et al.* (2000) in a study with the title of "*risk mitigation in Tehran*" evaluating the current status of Tehran, suggested some practical and executive guidelinesto avoid the risks and reduce the adverse effects of an earthquake in Tehran.

Theoretical foundations

Any earthquake victimizes thousands of people, and given the lack of adequate preparation for adverse effects resulting from earthquakes, this problem is more severe in our country. Although Iran's population comprises only 1% of the world's population, Iranian earthquake victims comprise about 6% of the losses in the world (Ablaqi, 2005:2). In the literature of natural disasters, providing shelter and accommodation for the victims includes a continues flow of emergency shelter up to construction of permanent housing, which is usually introduced by three groups of emergency housing, temporary housing and permanent housing; and sometimes it is introduced by 4 groups: emergency shelter, temporary shelter, temporary housing and permanent housing (Nigg *et al*. 2006:120). Regardless of the characteristics of each type of shelters after the events, two approaches are discussed:

a) Two stage housing perspective: the advocates of two stage process believed that elimination of temporary housing expenses from accommodation process of the homeless can save the costs of temporary housing for rebuilding of permanent houses. Despite their emphasis on rule-governed rebuilding process, the advocate of this view believed that as such houses are likely to be permanent ones; they should be left as the last choice. In addition, in some countries, the construction costs of temporary housing is usually more than that for a permanent house, particularly if the victims are themselves able to rebuild their houses with local materials (Dadash-pour *et al*. 2012:112).

B) Three stage housing perspective: the advocate of this perspective believes that in most cases, where the damage is too sever and widespread and there are no adequate facilities for rule-governed and rapid renovation, it is a disregard for technical level of the plan to ignore temporary housing. In such cases, the planners' view to temporary housing must be considered in a more accurate way. Burby *et al*., in an article with the title of *"creating reversible community against natural disasters through land-use planning"* explaining the measures required for reduction of vulnerabilities and the method of establishing a reversible community, emphasized that local communities must regard disaster as an opportunity (Burby *et al*., 2000:105); An opportunity for further land development and elimination of failures and issues of distressed areas. Therefore, an important parameter "time and expansion of reconstruction period" mediates in making use of the created opportunity. Because it appears that rule-governed reconstruction process that could immediately seize the opportunity created (after the occurrence of an event) for land redevelopment is rare if not impossible. Therefore, the lack of accountability or to delay in meeting the needs of homeless people for shelter would make them think of residing in urban areas and developing and expanding other forms of informal settlements. This is the subject that not only might raise the urban issues but also could spark off urban rebellion which is the most important reason behind this social phenomenon in cities of Iran (Dadash-pour *et al*. 2012:113). In this study, optimal site selection for temporary accommodation of earthquake victims is implemented according to various criteria (including access to hospitals, fire stations, main roads, open spaces, etc.) that each of them can somehow make a quiet and safe place, away from dangerous spots. Given the variety of criteria used in this study, using TOPSIS model, one of the most credible models for site selection, the criteria of the study were integrated and the most appropriate locations for temporary housing of the earthquake victims were identified. The present study trying to consider the crisis management of an earthquake stricken city, made us examine site selection for temporary housing after an earthquake in district No. 6 of Tehran, and provide some guidelines for choosing suitable locations for temporary housing of earthquake victims in Tehran. Tehran, as the first choice for any investigation in urban planning and management,

particularly in terms of natural disasters is very important for scientific studies. Accordingly, this study is a necessity because of following reasons:
- Situated in an active seismic zone, Tehran has a high proportion of buildings vulnerable to earthquake (in this respect, Tehran is one of the most dangerous cities of the world).

The likelihood of a devastating and impending earthquake;

Amplification of earthquake damage due to geotechnical instabilities (landslides and liquefaction)

Mismatch in Tehran's facilities for crisis management, rescue operations, relief measures and immediate response with regard to the extent of losses and damage predicted in a severe earthquake;

Higher risk of floods due to changes in pattern of surface water and natural conditions of aquifer, and violating the riparian of the rivers and streams (Tehran Comprehensive Plan: 2006).

Considering the above discussions, this study seeks to answer the following question: "What are the optimal sites for temporary housing after cataclysmic events in district No. 6 of Tehran?"

Based on the investigation of the topic and the features of the study area, the research hypothesis is: compared to other locations, green spaces and parks would score higher than areas for temporary housing.

Geographical location of the study area

Tehran metropolitan area is situated in the foothills of the Alborz Mountains, part of the Alpine-Himalayan orogenic zone. Along with numerous active faults, the study area has high seismicity potentials. Tehran urban area has developed on alluvial layers (which are accumulated on hard rock by complex geological formations). Based on accelerogram data, Tehran has incurred several severe earthquakes with return periods of 150 years. Manjil, located 220 kilometers northwest of Tehran, suffered a devastating earthquake in 1990 that killed about 15,000 people. Seismologists believe that it is likely that a severe earthquake would happen in Tehran in the near future; since 1830 the city has not experienced any devastating earthquakes (JICA, 2001:1).

JICA (The Japan International Cooperation Agency) has scored different districts of Tehran based on floating model, fault model of northern Tehran and fault model of Ray. In all three models, in terms of risk type, district No.6 is located in the areas with relatively low risk.(Table 1.0).

District No.6 has an area of 2144 hectares that comprises 3% of the total area of Tehran. Considering the areas of the 22 districts of Tehran, district 6 was ranked ninth. District No.6 of Tehran with a population of about 217 thousand people (about 6/3% of Tehran's population) and 20 square kilometers (equivalent to 3% of the city's area), is regarded as one of the most important areas of Tehran (Statistical Center of Iran, 2006).(Figure 1.0).

Materials and methods

This study was conducted in a descriptive-analytical method. Field works, library research, interview with experts, and distribution of questionnaires Between relevant experts were all used for data collection and gathering the primary data. The population of the study included municipal district No.6of Tehran. For this study, TOPSIS model was used for detailed analysis and has been selected as a multi criteria decision-making procedure. This method was introduced in 1992 by Chen and Huang. (Mousavi and Hekmat-nia, 2011:362). Chart 1.0 shows the research process. In this study, to avoid bias in determining the significance level, the effective criteria in site selection and homogenizing the criteria were adjusted through Shannon entropy technique, and we took advantage of the population through distribution of questionnaires between the experts. The population included all experts of crisis management

who were familiar with municipal district No.6. A synthetic method including Shannon entropy technique and TOPSIS model was used for data analysis. Therefore, after selecting the appropriate places for temporary accommodation and with regard to experiences and records of the research and recommendations made by the experts, the relevant criteria necessary for site selection and the value of each criterion for any of the selected places were provided. Having calculated the values of the criteria in site selection stage, based on expert recommendations in crisis management, the scoring of these criteria was adjusted by Shannon entropy technique. Then, using TOPSIS Model and MS Excel, the potential places for temporary housing of the earthquake victims, would be ranked in terms of priority.

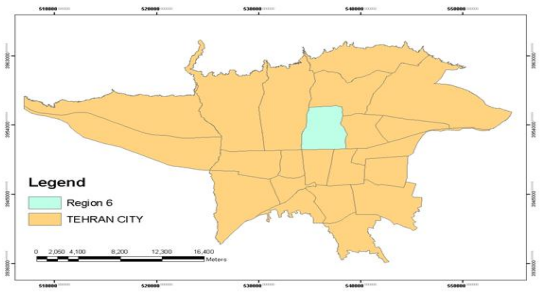

Fig. 1. Tehran and situation of municipal district 6.

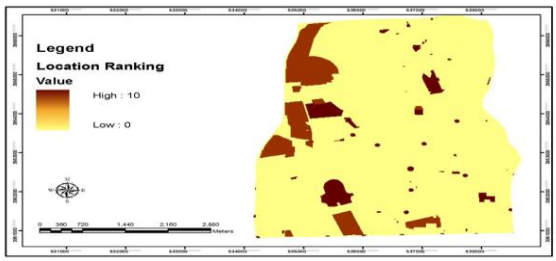

Fig. 2. optimal site selection maps for temporary housing of earthquake victims.

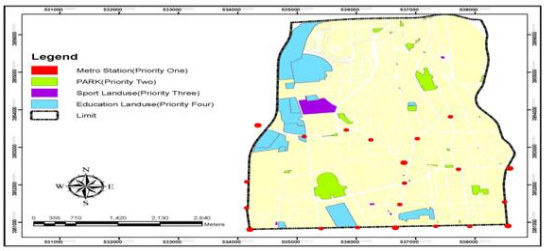

Fig. 3. Optimal site selection map for temporary housing based on TOPSIS prioritization model.

Discussion and data analysis

Large cities like Tehran which are facing overpopulation can never deal with the crisis and hazards without a plan. Urban planners and mangers should make preparations for the periods before and after the crises so that they can minimize the losses and provide the victims with relief and security. In this way, it is necessary to predict some places for emergency housing so that survivors can access primary care in their temporary camp. Consequently, the most important requirement for planning and urban management is to find sites and areas which are the best place to provide shelter, support and effective relief for the victims. Various criteria and factors should be met to identify and select the most suitable emergency housing for earthquake victims in critical conditions. In this study, locations like university campus with an area larger than 10,000 square meters, large parks and green spaces, large sport complex, subway station have been studied for temporary housing of the victims. Accordingly, the criteria and standards used for finding appropriate places included land use area, distance from the fire stations, the age of buildings, distance from fault line and main roads). The table of data matrix and weighting of the criteria are provided for this study. In addition, due to page limits we could not include all tables and statistics relevant to the model. (Table 2.0)&(Table 3.0)&(Table 4.0)&(Figure 2.0)&(Figure 3.0).

Conclusions

Tehran is the most important city in Iran, as it is the capital and enjoys a strategic position. However, given the relative earthquake risk, Tehran is located on one of the most dangerous areas of Iran. Located in such a dangerous position, Tehran needs definite planning for crisis management. Appropriate site selection for temporary accommodation is part of such a plan. The purpose of this study was to suggest a scientific and accurate framework in planning and site selection system for providing the victims with safe shelter. Making use of theoretical foundation and experiences of temporary housing, this study has

tried to compile the relevant indices and apply an appropriate method in multi criteria decision making for site selection of temporary housing in district No.6 of Tehran. In this study, TOPSIS model as a multi criteria decision-making procedure was used for detailed analysis. After selecting appropriate locations for temporary Acc ommodation, the criteria for site selection and the value of each criterion were determined with regard to the literature and experts' recommendations. Due to the physical and spatial characteristics of the municipal district No.6 of Tehran, including presence of distinguished buildings such as ministries, embassies, outstanding institutes of higher education, health centers, public hospitals, large corporations, etc., which are well indicating the importance of this district in urban and national level, after studies and interviews with experts and stakeholders, university campus larger than 10,000 square meters, large parks and green spaces, large sport complex, subway station were suggested and studied for temporary housing of the earthquake victims. More important and effective criteria for temporary housing in times of crisis, and specific physical characteristics of district No.6 were selected and evaluated qualitatively and quantitatively. Finally, subway stations got the first priority, parks and green spaces got the second priority, sport fields and grounds got the third priority and university campus, and higher education institutes got the fourth priority for temporary housing for victims of earthquake and other crises.

Table 1. Results of risk assessment for 22 districts of Tehran.

Areas with relatively low risk	Medium risk areas	Medium risk areas	Areas with high risk	Type of Risk Model
22 ،21 ،6 ،5 ،4 ،3 ،2 ،1	13 ،8 ، 7	20 ،19 ،18 ،15	17 ،16 ،14 ،12 ،11 ،10 ،9	Ray fault model
19 ،18 ،15 ،6 ،5 ،4 ،2	13 ،12 ،11 ،10 ،9 ،8 ،7	3 ،1	-	North Tehran Fault Model
22 ،21 ،20	17 ،16 ،14			
19 ،18 ،15 ،6 ،5 ،4 ،2 ،1	14 ،13 ،9 ،8 ،7	3	17 ،16 ،12 ،11 ،10	Floating models
22 ،21 ،20				

Source: (JICA, 2001: 264).

Table 2. Data matrix and weighting of the criteria.

Criteria place of housing	Land use area (square meters)	inverted distance from fire stations (minutes)	inverted age of buildings (years)	Distance from fault lines	inverted distance from main roads (m)
university campus	400000	0.2	0.02	4000	0.025
parks and open spaces	250000	0.33	0.05	1000	0.017
sport grounds	121,000	0.014	0.033	2000	0.037
subway stations	5000	0.1	0.1	5000	0.025

(Source: authors).

Table 3. Homogenization and calculating the standard deviation and weighing of the indices using Shannon entropy model.

Entropy	0.742	0.929	0.878	0.892	0.973
SD	0.258	0.0707	0.122	0.108	0.207
Weighing	0.441	0.121	0.208	0.184	0.046

(Source: authors).

Table 4. Positive and negative distances, relative distance, ranking and TOPSIS value for each item.

housing locations	rank	TOPSIS value	D^-	D^+
university campus	4	0.36883	0.0867	0.148
parks and open spaces	2	0.37432	0.084/0	0.141
sport grounds	3	0.37145	0.121	0.205
subway stations	1	0.51021	0.142	0.136

(Source: authors).

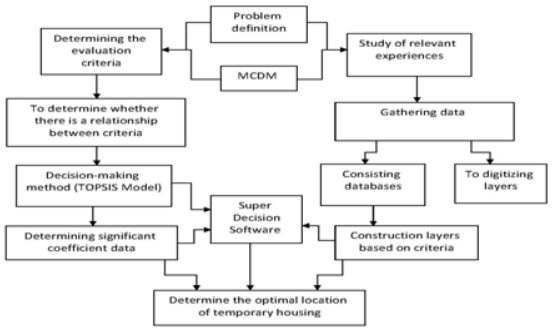

Chart 1. Research process.

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