Optimal Site Selection of Relief Centers Using Geospatial Information System and Multi-Criteria Decision-Making Methods in Urmia

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Abstract

INTRODUCTION: Pre-crisis planning is one of the important issues facing managers and planners, especially in the field of crisis management. In recent years, the world has faced an increasing number of natural and man-made disasters, such as earthquakes. Moreover, the growing effect of disasters on communities has highlighted the need for efficient and effective emergency logistics operations in this field, and some criteria are provided for decision-making and prioritization of relief centers in crisis situations.

METHODS: In the current research, Analytic Network Process (ANP) and PROMETHEE (Preference Ranking Organization Method for Enriching Evaluations) methods were used for analysis and ranking, and construction cost and usage time indicators were considered for the first time. Criteria were also defined and evaluated as layers according to global standards and crisis management criteria in the region. In addition, geographic information systems and experts' opinions were used to evaluate the indicators.

FINDINGS: Due to the higher weight value, safety (0.36), usage time (0.24), as well as concentration and coverage level (0.22) received priority for the selection of the most optimal relief sites in crisis situations. Therefore, centers, such as Amini Stadium and Golestan Park, which had a lower performance status in terms of the mentioned indicators, compared to other options, were placed in a lower rank in the final ranking, in comparison with other centers.

CONCLUSION: The indicators identified in order of importance were security, time of use, concentration and coverage level, and compatible access. In the end, Takhti Stadium, Saat Park, and Rajaei Stadium received priority for the establishment of relief centers in terms of performance and the weight value of the mentioned indicators in time of crisis.

Keywords: Site Selection; Relief Centers; Multi-criteria Decision Making; PROMETHEE Method.

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Introduction

Every year, natural disasters, such as earthquakes, claim the lives of numerous people across the globe. Natural disasters impose heavy financial and human costs on governments and communities. Natural disasters, especially earthquakes, have long been the most destructive factors affecting humans, society, and their settlements. Experience has shown that in Iran, the site selection of temporary housing for injured of disasters is usually performed by relief organizations after the accident without considering the necessary standards.

Nonetheless, there is no doubt that incorrect site selection may lead to another catastrophe, even worse than the initial disaster (1). In every earthquake, numerous people lose their lives, many are injured, plenty of houses are destroyed, and the citizens and victims are confronted with a wide array of problems (2). The risk management of these disasters requires the identification and prioritization of system risks, as well as the

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development of some plans to take preventive measures.

Failure Modes and Effects Analysis (FMEA) has been proposed in a study of common methods for identifying and prioritizing these types of risks. Moreover, it was suggested that the combined fuzzy FMEA and weighted aggregated sum product assessment (WASPAS) decision-making methods be used to fully rank the risks, in comparison with other common methods (3). The provision of shelter and rescue services at the earliest possible moment is recognized as the main need of earthquake-stricken people. After the earthquake, the immediate provision of suitable places is almost impossible.

Therefore, prior to such crises, it is indispensable to provide some suitable locations (in terms of access to urban uses, security, and distance from hazardous areas). This site selection is one of the most important errands of rescue teams to save the lives of the injured during an earthquake. Consequently, making serious predictions for emergency and temporary housing is one of the important tasks of planners in crisis management in any planning and executive system.

Today, post-accident psychological consequences are major concerns of those in charge of crisis management in developed countries. Therefore, the role of site selection and temporary accommodation of victims in the predicted places is of utmost importance in urban design and planning (4). At the same time, the experience of past events demonstrated that the chance of rescuing the injured decreases over time. Therefore, fast and accurate decision-making is of great importance in these circumstances. In order to deal with crises, it is necessary to recognize the main stages of each crisis and their management and make the necessary preparations to confront and control them.

Therefore, if the relief and crisis logistics has a coherent and scientific system, it can be hoped that many crises will be anticipated and contained before they occur, or their consequences will be minimized in case of occurrence. In recent years, numerous studies have been conducted in the field of relief logistics. Many researchers have focused specifically on planning and policymaking. Brucer et al. (2014) presented a three-objective model for site selection and transportation in the post-disaster phase. In this model, site selection depends on the number and location of distribution centers and transportation, as well as the transfer of goods from these centers to demand points.

The objective function of the mentioned model is to minimize transportation time, the number of distribution centers, and dissatisfaction. To this end, they used the Epsilon constraint method and arrived at the answer in a shorter time (5). Yadwali et al. (2015) have proposed an optimization model for transporting perishable goods to earthquake-stricken areas. The objective function of this model was to minimize the total number of facilities during the rescue period (6). In their study, Dabbagh and Nasiri (2019) introduced suitable sites and spaces with relatively better potential in emergencies for the accommodation of the injured in Tabriz. Their determined criteria for the construction of shelters for temporary accommodation included urban land use compatibility, distance from population density, parks and green space, and access to the main passages (7).

Farahani (2016) has prioritized the optimal places for temporary accommodation of earthquakes victims according to the establishment of relief centers in cities. Accordingly, in the framework of the descriptive-analytical research method, after the identification of the effective criteria in locating temporary housing, the mentioned study has weighed the main criteria and indicators. It also used the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) (8).

In their study, Dabbagh and Yousefi (2019) used the FMEA technique to identify hazards and assess disaster risk criteria in the regions. They reported the weight of criteria as 36 based on their causal relationships through the combined learning algorithm. Finally, 28 important factors were recognized, and essential management criteria were introduced for their reduction (9). Babaei and Kamran Shahanaghi (2016) have conducted an integrated and multi-level investigation of site selection of emergency routing in conditions of uncertainty in order to have a stable response and undergo the least changes in various situations (10).

Amini et al. (2019) have identified road accident safety as a global challenge, imposing irreparable financial and human losses in these countries. According to the World Health

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Organization (WHO), if this trend continues, road accidents will become the seventh leading cause of death, and the optimal assessment and site selection of relief centers have been proposed. According to related studies, Iranian provinces located in mountainous and forested areas, such as Gilan, have demonstrated very poor performance, compared to other provinces in desert areas, such as Yazd (11).

In a practical study based on descriptive-analytical design, Rahmani et al. (2015) identified the most suitable places for temporary accommodation of potential earthquake victims in Bojnord using GIS (12). In the conducted studies, the selection of suppliers and order allocation in the process of purchasing relief items in crisis situations has been considered important and necessary. For instance, a study presented a model of multi-criteria decision-making approach and mathematical planning model for supplier selection and order allocation. Bidders are ranked as suppliers of relief items based on effective quantitative and qualitative criteria, using the fuzzy PROMETHEE method. The computational results have confirmed the better performance and efficiency of the robust multi-objective feasibility planning model (13).

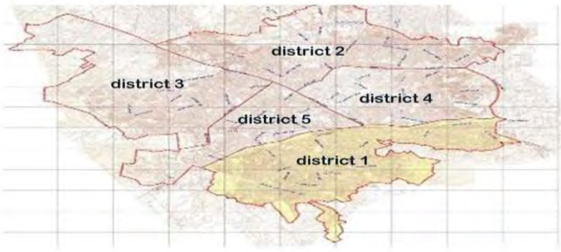

Figure 1. Map of Urmia municipality

Urmia is located in the central part of West Azerbaijan province covering an area of about 5227 square kilometers (Figure 1). It is the most populous city in the province with a relative share of 31.28%. This city is surrounded by Lake Urmia in the east, Turkey in the west, the cities of Mahabad, Naqadeh, and Oshnavieh in the south, as well as Salmas in the north (14). At the 2016 census, it has 736,224 inhabitants (Table 1).

The city is divided into 4 municipal districts, 16 zones, and 81 neighborhoods (15).

Urmia has complex geomorphology and geology. As illustrated in Figure 2, this complexity

Table 1. Urmia housing information (10)

Description	Family	Population	Male	Female
District 1	55456	174900	86953	87947
District 2	60350	207453	105684	101769
District 3	47132	164753	82726	82027
District 4	42989	130262	65303	64959
District 5	19123	58856	28377	30479

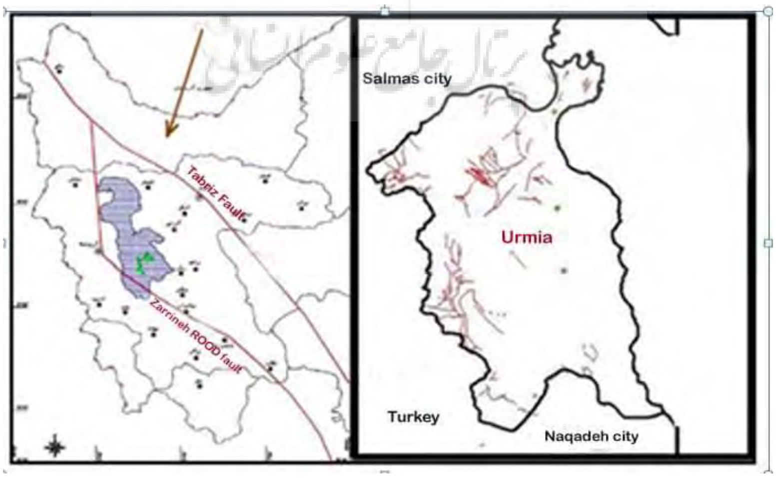

Figure 2. Network of fault systems and fractures in the study area (adapted from 1:100000 geological map of the area) and the main and large faults of Urmia and Tabriz (16)

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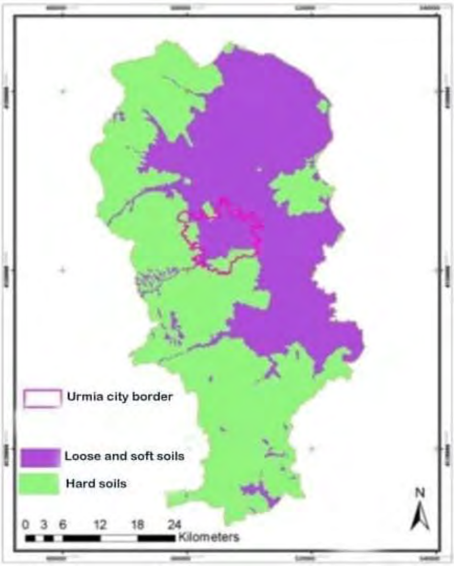

Figure 3. Soil layer of the area

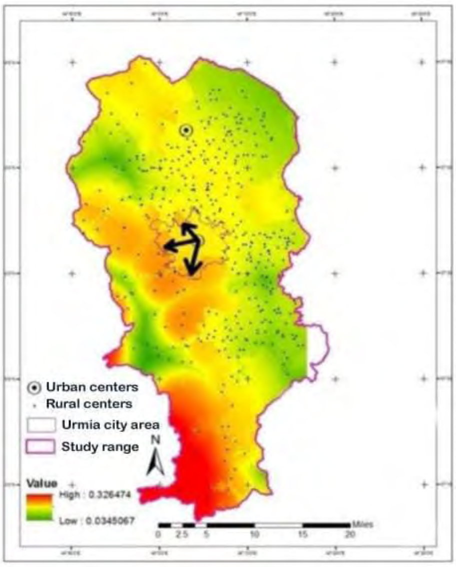

Figure 4. Seismic zoning map of peak ground acceleration of Urmia (18 & 19)

is due to the existence of a network of large northwest-southeast faults (western shore of the lake), as well as a network of parallel lines in the east of the city (mainly in the lake bed). Different patterns are formed by a network of dense faults, folds, and joints in the region. These patterns of fault network and fractures are completely different. This system of the abovementioned faults and joints shapes and controls the morphological structure of the region.

Figure 2. Network of fault systems and fractures in the study area (adapted from 1: 100000 geological map of the area) and the main and large faults of Urmia and Tabriz (16)

The existence of deep and large faults (global and regional), as well as the network system of multiple faults, geological effects, and geomorpho-tectonic indicators, is suggestive of the high potential of the region in terms of tectonic and seismic activities. According to existing by-laws, any place with a design base acceleration of g4/35 is classified as a zone with relatively high risk (17). The location of Urmia urban area on the active Urmia fault, as well as the presence of basanite, leucite, and leukocytes-bearing rocks in the western margin of the lake, are among the pieces of evidence demonstrating the extreme depth of Urmia fault.

Therefore, as presented in Figure (4), the slope of the Urmia Lake basin is inclined to the mentioned fault and increases as it gets closer to it. Such a deep and large fault in the urban area of Urmia is indicative of the high potential of the region in terms of strong earthquakes. In addition, it is adjacent to major active faults, such as Tabriz and Salmas faults, as well as active faults in Turkey, where the occurrence of more than 350 earthquakes indicates the intensity of the activities of these faults.

Figure (3) demonstrates the soil layer of the study area. Based on the lithological characteristics of rock units and the aggravating effects of the soil agent on seismic movements, the soils of the area are divided into two groups: a) loose, soft, and deep soils (Quaternary deposits) and b) shallow and hard soils.

Methods

This practical study was conducted based on a descriptive-analytical method. Criteria and indicators were selected based on library documents and articles, as well as crisis management standards. The required information was obtained using the library, documentation, and field methods, as well as statistics and census tables. A sufficient number of experts in Crisis Prevention and Management Organization of the province weighted the criteria and identified suitable locations (for temporary housing of victims in times of crisis) according to the available criteria and information.

GIS as well as intervals (VL-L-M-H-VH)[1] were used to evaluate and rate quantitative indicators so that VH is the most important, while

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VL is the least important. In this regard, a questionnaire was developed and provided to the relevant experts to determine the weight value of the parameters and compare them in pairs and evaluate the effective parameters in finding the optimal location for the construction of relief centers in the study area.

In the current research, the analytical network process (ANP) model was used to assign a relative weight to each criterion and rank the points in the super decisions software. Simple optimization models are often single-objective, single-criterion. Since different and inhomogeneous criteria will be used for decision making, it is required to use a method that can estimate the specific conditions of this issue. These relief centers are usually chosen from spacious places

To evaluate and select the establishment of relief centers, PROMETHEE multi-criteria decision making was used owing to its advantage in balancing the positive and negative ranking processes of criteria, as well as the clarity and reliability of its results, compared to other multi-criteria decision-making methods. The overview of the article is displayed in Figure 5.

1. Very low, Low, Medium, High

Multi-criteria decision-making method

In the PROMETHEE method, the relief location is selected from among a set of options (A). Assuming that K is the effective criterion for decision making, for each alternative a ∈ A, the value of Fj (a) represents the value of jth criterion in option a. The ranking is performed in three steps:

Step 1: The Pj preference function is assigned to each jth criterion. The value of Pj (a, b) is calculated for each option pair ranging from 0 to 1. If Fj (a)= Fj (b), Pj (a, b) would be 0, and this value increases with increasing Fj (a)= Fj (b). Moreover, when the difference is large enough, Pj$(a،b)$ =1. Different shapes can be assumed for the Pj function, depending on the modeling of jth criterion. The PROMETHEE method proposes six generalized criteria for the preference function to the decision-maker.

Step 2: The total priority π (a, b) for each a option is calculated on b option.

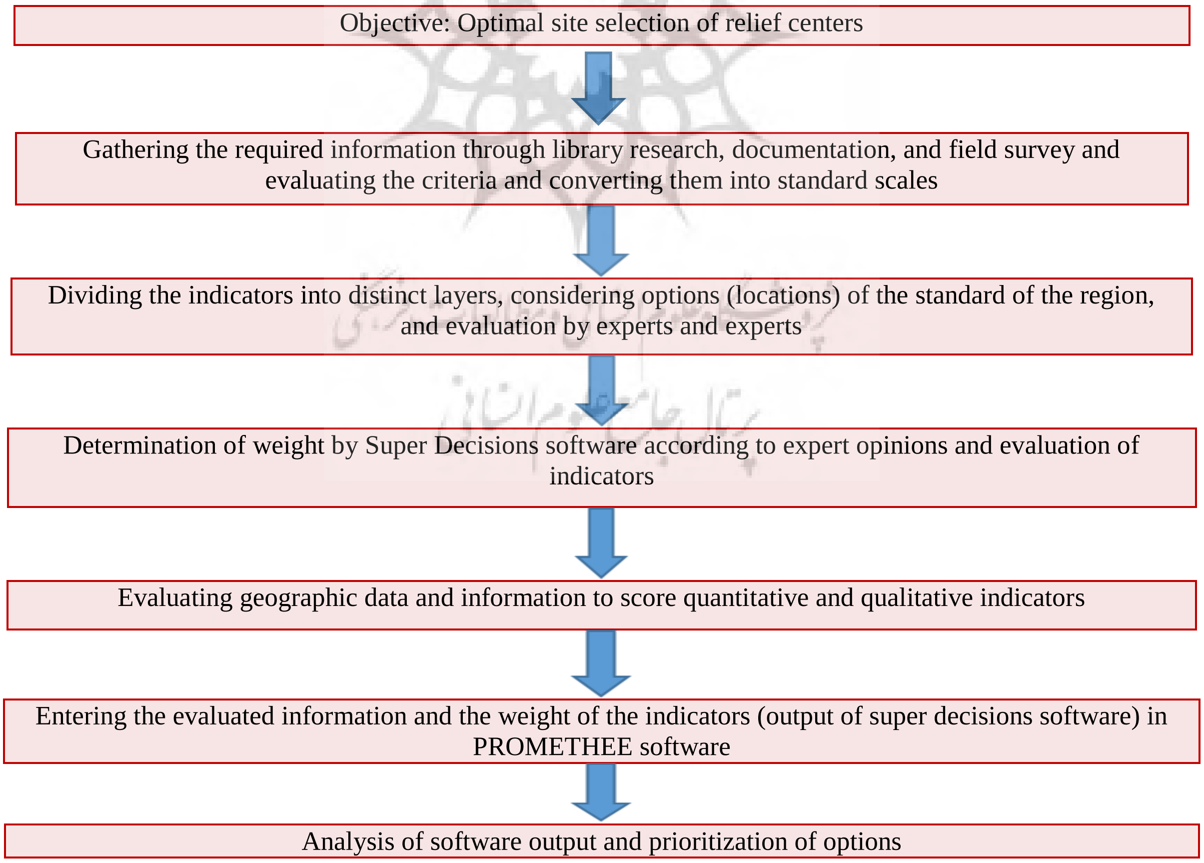

Figure 5. Overview of the research

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Higher π (a, b) indicates that option a is more preferable. Π (a, b) is calculated as follows:

$$\pi(a،b) = \sum_{j=1}^{K} wjpj(a،b)،(\sum_{j=1}^{K} wj = 1) \qquad 1$$

Step 3: π (a, b) indicates the degree of priority of option a over option b. To calculate the total preference power of option a over other options, the output flow is calculated:

Positive rating flow or output flow:

$$\sum_{x=A} \pi(a،x)(a)\,\phi + \frac{1}{n-1} \qquad 2$$

This flow shows how much option a takes precedence over other options. This flow is, in fact, the power of option a. A larger φ + (a) signifies the best option. The preference of other options over option a, called input flow, is the result of the following calculation:

Negative rating flow or input flow:

$$\sum_{x=A} \pi(x،a)\ \varphi - (a)\frac{1}{n-1} \qquad 3$$

This flow demonstrates how much other options have priority over option a. This flow is, in fact, the weakness of option a. The smallest negative current $\varphi^{-}(a)$ represents the best option. Therefore, a partial ranking can be performed (PROMETHEEI ranking) by having access to and examining the two flows of φ^{+} and φ^{-} separately. To fully rank the options, the net ranking flow should be defined for each option (PROMETHEE):

$$\varphi(a) = \varphi^{+}(a) - \varphi^{-}(a) \qquad 4$$

This flow is the result of a balance of positive and negative ranking flows. Higher net flow indicates the superior option. One of the important advantages of the PROMETHEE method is simplicity, clarity, and reliability of results. This method can perform the evaluation process on a limited set of limited alternatives, in a partial or complete ranking. The clear effect of each criterion and their weight on the answers is indicative of the high efficiency of the algorithm in this method with its simplicity and its development based on the importance of the difference in performance between the two solutions (distinguishing it from the hierarchical structure method).

Findings

Some criteria and options were considered in the current study for the establishment of relief centers. These criteria were based on available literature, and some other additional ones, namely construction cost and time of use.

Criteria

1.Construction cost: All expenses incurred in the establishment of the desired relief centers (Min)

2.Time of use: Duration of access to relief centers (min)

3.Compatible access level: proximity to fire stations, hospitals, and main roads (max)

4.Incompatible access level: Relief centers should be as far away as possible from gas stations, CNGs, fault lines, and similar cases (Max).

5. Concentration and level of coverage: How much population does the place cover? (Max)

6.Security: Security means protecting the lives and assets of the victims against aggressive or criminal operations of aggressors (inside and outside the accommodation centers). Centers that are located closer to the first checkpoints and police stations are given priority (max).

Population density

Cities with lower population density and even distribution of population throughout the city have lower vulnerability to earthquakes (min).

Table 2 specifies the number of categories and the value of each category for each criterion.

Options

1.Bakeri Sports Complex 2. Takhti Stadium 3. Isar Park 4. 5 Hour Park. Shahid Rajaei Sports Complex 6. Kargaran Sports Complex 7. Amini Stadium 8. Golestan Park 9. Al-Ghadir Sports Complex, 10. Kowsar Park.

After pairwise comparisons between criteria and preparation of the Pairwise comparison matrix, using the capabilities of Super Decision software, the final weight of each criterion and incompatibility coefficient (0.0058) which indicates the correctness of the comparisons were calculated for each factor. They were automatically normalized by Visual PROMEPTHEE software after logging in (Table 3).

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Table 2. Classification and evaluation of criteria (Source: Authors and No. 10)

Usage time (minutes)	Construction cost (million tomans)	Incompatible access (meters)			Compatible access (meters)			Population density (per 10000 METER)	Security	Surface area (meters)	A C
		Fault lines	Distance from the gas station	Distance from the gas pump	Proximity to the main roads	Near the hospital	Near the fire station				
6-10	0-50	more than 200	250-1100	more than 250	0-100	0-300	0-500	more than 1200	0-100	more than 2000	(VH) very high
10-15		150-200	200-250	200-250		300-500	500-1000	900-1200	100-200	1500-2000	(H) high
15-20	50-100	100-150	150-200	150-200	100-200	500-700	1000-1250	600-900	200-300	1250-1500	(M) medium
20-30		less than 100 meters	100-150	100-150	200-300	700-1000	1250-1500	300-600	300-400	1000-1250	(L) Low
more than 30 minutes	more than 150		0-100	0-100	more than 300	more than 1000	<1500	0-300	more than 400	less than1000	(VL) very low

Table 3. Super Decisions software output

Final	0.00558	---
Title	**Normalized**	**Ideal**
Security	0.36	1.00
Coating surface	0.22	0.62
Population density	0.04	0.12
Compatible access (meters)	0.06	0.18
Incompatible access (meters)	0.04	0.1
Usage time	0.24	0.67
Construction cost	0.04	0.11

After weighting by GIS and Google Earth software and using the Measure tool, such information as the distance of the options from the criteria and the area of the surface was extracted. Considering the classification and evaluation of the criteria (Table 2), these distances were used quantitatively and qualitatively as input information in Visual PROMEPTHEE software. For instance, as illustrated, the distance of Takhti Stadium to the hospital is 168 meters (Figure 6)

Figure 6. A sample of extracted geographic information

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which is regarded as a very good option according to Table 2 (proximity to the hospital less than 300 VH) in Visual Primet software.

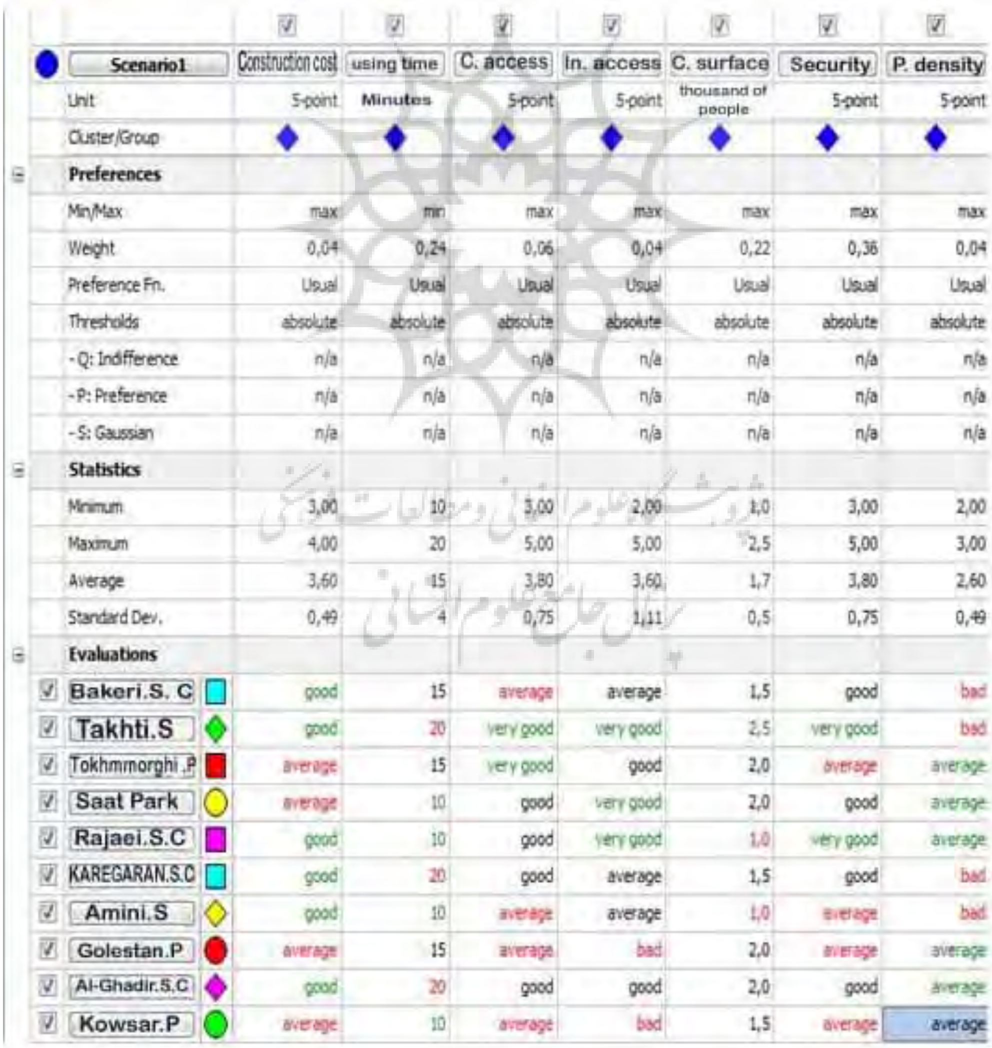
Discussion and Conclusion

Data input to Visual PROMEPTHEE software is displayed in Figure 7. As demonstrated, all other criteria will have a maximum, except for the criterion of construction cost, time of use, and population density. Super Decision software was used to weigh the effective parameters in locating crisis management sites (with an incompatibility coefficient of 0.0058) which were automatically normalized by Visual PROMEPTHEE software after entering. At the bottom of the figure, there is a pairwise comparison matrix for options and criteria.

Based on Figure 7 (weight calculation section), in order of weight value, the indicators for selecting the most optimal relief location in crisis situations are as follows:

1. Security (0.36), 2. Time of use (0.24), 2. Concentration and level of coverage (0.22), 4. Compatible access (0.06), 5. Construction cost, incompatible access, and population density (0.04).

Figure 8 demonstrates the amount of positive and negative flows, as well as the net flow. This flow is the result of the balance of positive and negative rating flows, with a higher net flow representing the superior option. In this method, the transparent effect of each criterion and its weight on the answers is the high efficiency of the algorithm in this method, despite its simplicity and foundation based on the importance of the



			☑	☑	☑	☑	☑	☑	☑
●	Scenario1		Construction cost	using time	C. access	In. access	C. surface	Security	P. density
	Unit		5-point	Minutes	5-point	5-point	thousand of people	5-point	5-point
	Cluster/Group		◆	◆	◆	◆	◆	◆	◆
⊟	**Preferences**								
	Min/Max		max	min	max	max	max	max	max
	Weight		0,04	0,24	0,06	0,04	0,22	0,36	0,04
	Preference Fn.		Usual	Usual	Usual	Usual	Usual	Usual	Usual
	Thresholds		absolute	absolute	absolute	absolute	absolute	absolute	absolute
	- Q: Indifference		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	- P: Preference		n/a	n/a	n/a	n/a	n/a	n/a	n/a
	- S: Gaussian		n/a	n/a	n/a	n/a	n/a	n/a	n/a
⊟	**Statistics**								
	Minimum		3,00	10	3,00	2,00	1,0	3,00	2,00
	Maximum		4,00	20	5,00	5,00	2,5	5,00	3,00
	Average		3,60	15	3,80	3,60	1,7	3,80	2,60
	Standard Dev.		0,49	4	0,75	1,11	0,5	0,75	0,49
⊟	**Evaluations**								
☑	Bakeri.S. C	■	good	15	average	average	1,5	good	bad
☑	Takhti.S	◆	good	20	very good	very good	2,5	very good	bad
☑	Tokhmmorghi .P	■	average	15	very good	good	2,0	average	average
☑	Saat Park	●	average	10	good	very good	2,0	good	average
☑	Rajaei.S.C	■	good	10	good	very good	1,0	very good	average
☑	KAREGARAN.S.C	■	good	20	good	average	1,5	good	bad
☑	Amini.S	◇	good	10	average	average	1,0	average	bad
☑	Golestan.P	●	average	15	average	bad	2,0	average	average
☑	Al-Ghadir.S.C	◆	good	20	good	good	2,0	good	average
☑	Kowsar.P	●	average	10	average	bad	1,5	average	average

Figure 7. Input information

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Rank	action	Phi	Phi+	Phi-
1	Takhti Stadium ◆	0,4289	0,6422	0,2133
2	saat Park ●	0,3733	0,5178	0,1444
3	Rajaei Sports Complex ■	0,3644	0,5733	0,2089
4	Al-Ghadir Sports Complex ◆	0,0489	0,3667	0,3178
5	Bakeri Sports Complex ■	-0,0822	0,3156	0,3978
6	Tokhmmorghi park ■	-0,1156	0,2956	0,4111
7	KAREGARAN sport complex ■	-0,1889	0,2622	0,4511
8	Kowsar Park ●	-0,2378	0,2267	0,4644
9	Golestan Park ●	-0,2533	0,2200	0,4733
10	Amini Stadium ◆	-0,3378	0,1867	0,5244

Figure 8. Calculation of PHI values

difference in performance between the two answers (distinguishing it from the hierarchical structure method).

Figures 8 and 9 show the ranking of places using the PROMEPTHEE method based on their performance indicators and weight.

The left part of the figure displays the +Phi rating (the strength of the options) in which the better options tend to 1, while the worse and negative options tend to 0. Nonetheless, in the right part of the figure which indicates the - Phi-based ranking (the degree of weakness of the options), the better options tend to 0, whereas the worse and negative options tend to 1. For example, the Al-Ghadir Stadium did not perform well in the positive flow and was located towards 1 (red zone), while in the negative flow, it was inclined towards 0 (green zone).

The middle vertical line in the above figure shows the net Phi values. When the line of each option is higher than the lines of the other options, it indicates that this option has outperformed the other options. On the other hand, when two functional lines intersect, it suggests that the two options are incomparable (according to the rules of incomparability in the PROMEPTHEE method (1). For example, Takhti Stadium and Shahid Rajaei Sports Complex and Saat Park are incomparable. Nevertheless, the amount of performance (net Phi) of Takhti Stadium is higher than other options.

In Figure 10, the options are specified from left to right based on the ranking of the PROMEPTHEE method (1. Takhti Stadium, 2. Saat Park,3. Shahid Rajaei Stadium ..., 9. Golestan Park, 10. Amini Stadium). For each option, the rectangular area determines the performance of the criteria for that option, as well as the ph score and the order of the most important properties of each option. At the top of the rectangle, the positive criteria of the options are specified, whereas the negative criteria of those options are specified at the bottom.

For instance, Takhti Stadium which has the first rank and has a pH + has a much better performance in terms of security, population coverage level, compatible access, incompatible access, and construction cost. However, it has poorer performance in terms of population density and usage time, compared to other options.

According to the weight value of indicators, which are all determined in Figure 7, those options that meet those criteria with higher weight value, such as safety (0.36), time of use (such as proximity to medical and fire centers) (0.24), and population coverage level (0.22) achieved higher ranks. Therefore, centers such as Amini Stadium and Golestan Park, which have a lower performance in terms of such indicators as security, and population coverage level are placed in the final ranking for locating relief centers in crisis situations, compared to other centers.

In Gaia presentation (Figure 11), options are demonstrated with points and criteria with

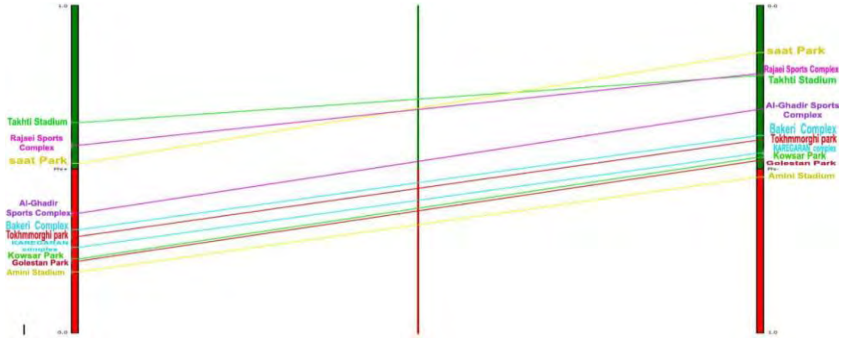

Figure 9. PROMEPTHEE method ranking

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concentric graphs. The length of an axis also indicates the relative strength of that criterion. The longer axis is reflective of a more important criterion. On the other hand, the direction of an axis indicates where the best possible options for this criterion are located. In Gaia display, similar options are closer to each other, and contradictory options are farther apart. Moreover, the criteria with similar preferences are placed in the same direction, whereas the criteria that have conflicting preferences are in different directions.

For instance, Shahid Rajaei Sports Complex and Kargaran Sports Complex performed well in terms of construction cost index and were very close to each other. Nonetheless, in terms of population density index, it had very poor performance (due to being in the opposite direction to population density). Amini Stadium and Bakri Sports Complex did not perform well in terms of concentration and coverage level (population coverage) and compatible access (including outdoor and green space, fire stations, hospitals, residential areas, cultural centers, educational centers, and gyms), and incompatible

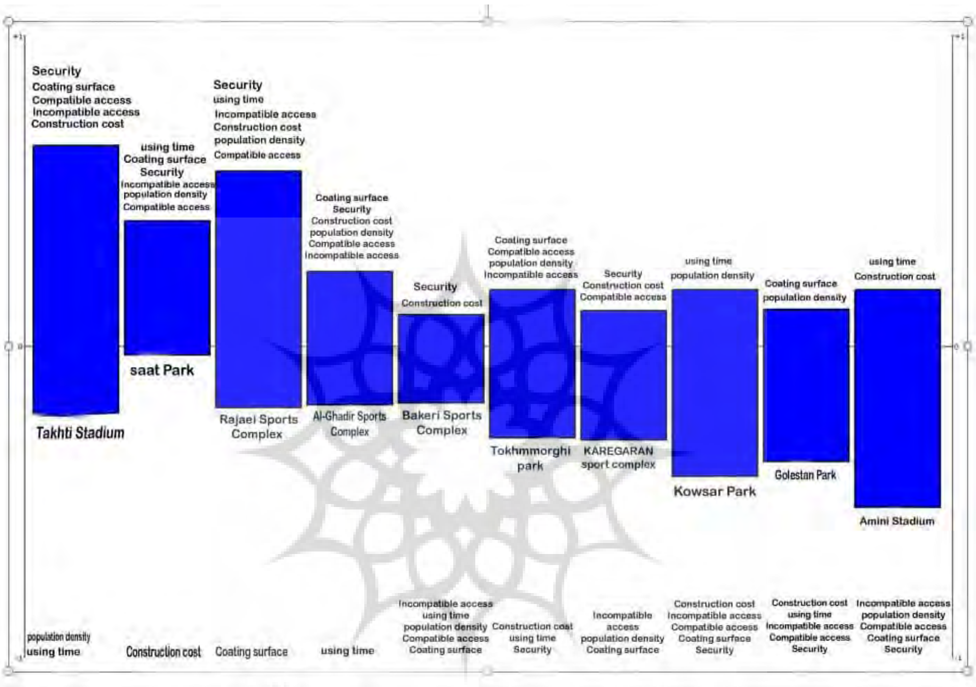

Figure 10. Visual PROMEPTHEE software output

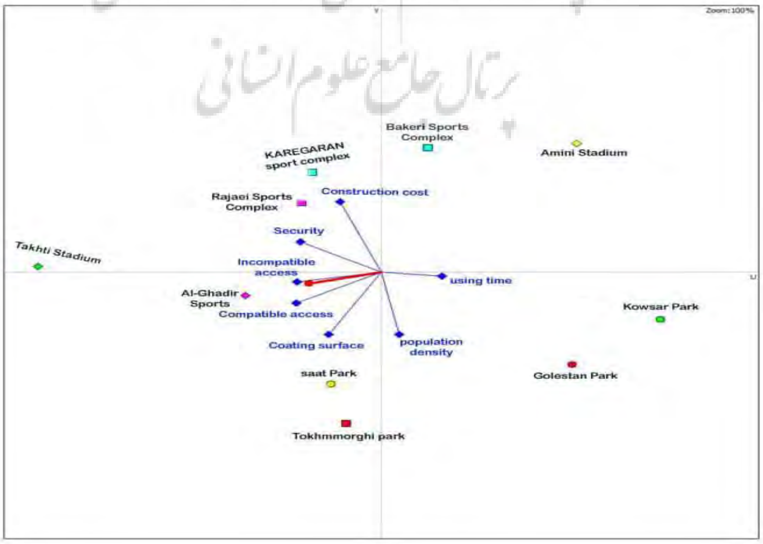

Figure 11. Gaia diagram

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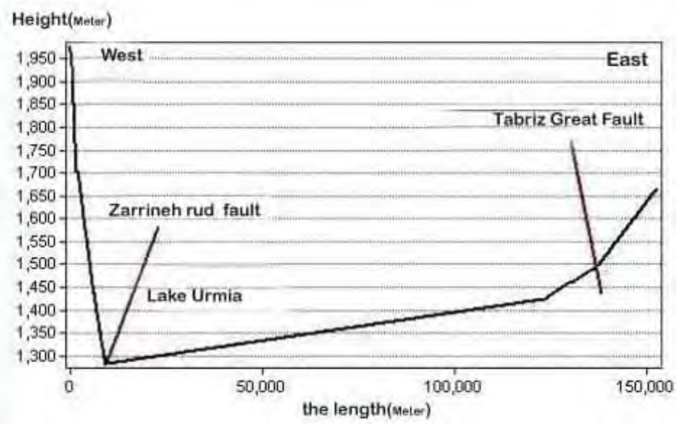

Figure 12. Topographic profile of the region - main faults and subsidence of the lake basin and urban area of Urmia

access (including distance from such centers as gas stations and CNGs).

Therefore, the conditions of the above-mentioned centers should be improved to develop and expand relief centers and sites in crisis situations in Urmia.

Figure 12 shows the recorded layers, seismic, and faults of the study area. It is indicated that the geographical (spatial) hypocenter of earthquakes is located in a radius of 30 km to the west and southeast of Urmia and also to the north, southwest, and south in a radius of 50 km.

Selected methods and criteria were proposed for locating relief sites in crisis conditions in a case study of Urmia with 10 options(1. Bakeri Sports Complex 2. Takhti Stadium 3. Isar Park 4. Saat Park 5. Shahid Rajaei Sports Complex 6. Kargaran Sports Complex 7. Amini Stadium 8. Golestan Park 9. Al-Ghadir Sports Complex 10. Kowsar Park), by the experts of Crisis and Relief Management Organization and the Red Crescent Organization of West Azerbaijan Province.

These criteria included construction cost, usage time, compatible access level, incompatible access level, population coverage level, security, and population density. Thereafter, these criteria were evaluated and applied as layers. After pairwise comparisons between criteria and preparation of pairwise matrix, the final weight of each criterion was determined by Super Decision software (version 2.0.8). In the next step, using the GIS and Google Earth software and the Measure tool, such information as the distance of the centers from the criteria and surface area were extracted.

Considering the classification and evaluation of criteria (Table 2), these intervals were quantitatively and qualitatively used and evaluated as input information in Visual PROMETHEE software.

As evidenced by the evaluations, the best places to establish relief centers in times of crisis based on the net flow are as follows: Takhti Stadium (0.428), Saat Park (0.373), Shahid Rajaei Sports Complex (0.364), Al-Ghadir Sports Complex (0.048), Bakri Sports Complex (-0.82), Isar Park (-0.115), Kargaran Sports Complex (-0.188), Kowsar Park (-0.237), Golestan Park (-0.253), and Amini Stadium (0.337).

Consequently, planning is suggested to improve the status of those centers with unfavorable performance in terms of site selection indicators of relief sites. Moreover, a need exists to plan for the improvement of conditions in these centers to develop and expand relief centers and sites in times of crisis.

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Conflict of Interests

The authors declare that they have no conflict of interest regarding the publication of the current study.

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