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# A combination risk-based approach to post-earthquake temporary accommodation site selection: A case study in Iran

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**Abstract**

One of the most important problems after natural disasters in every country is the preparation of temporary accommodations for victims. The developers of preventive plans are also faced with numerous uncertainties in this crisis management topic. Furthermore, uncertainty is not defined in classical mathematical sets. Therefore, the use of intuitionistic fuzzy sets, which include considerations for uncertainty, can be useful in prospective planning in order to counteract possible risks. The main aim of this study is to propose a combined method using risk management and Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) for locating and prioritizing the post-earthquake temporary accommodation sites. To this end, the city of Sanandaj in Iran was selected as the case study of this method. First, brainstorming sessions with 9 crisis management experts from various organizations of Kurdistan province were used to determine 6 decision-making criteria. These criteria were based on identified risks in temporary accommodation process after an earthquake in the region, and criteria extracted from previous studies regarding temporary accommodation locations. The possible alternatives for temporary accommodation sites in this study were 13 different urban public spaces. The pairwise comparison of criteria based on the aim and pairwise comparison of alternative temporary accommodation options based on each criterion was carried out by experts and using intuitionistic fuzzy sets. Finally, the IF-AHP process was used to determine the priority of each alternative.

*Keywords:* Temporary accommodation, risk management, intuitionistic fuzzy sets, AHP, Iran.

## 1 Introduction

In recent decades, the effects of disasters have raised rapidly around the world, and have affected all sectors, in both rich and poor countries. Millions of people are affected annually by disasters, and losses were recorded at 371 billion in 2012. This average has increased in recent years according to the United Nations International Strategy for Disaster Reduction (UNISDR). These Natural disasters consist of floods, earthquakes, etc. [3]. The number of natural disasters has increased sharply and has caused a great deal of damage to buildings. Many homes have been damaged and are unusable, which threatens a large number of homeless people. Housing reconstruction programs play a determinative role in disaster recovery, and providing temporary accommodation is an important step in these programs. This allows the victims to have a private and safe place to return to their normal lives during the reconstruction of permanent accommodations [13]. Temporary accommodation has always remained a major issue for the injured families after any natural or man-made disaster [16]. Managing disaster risks can be improved by investing in methods for dealing with changeable fundamental determinants [27]. Pervious experiences have shown that post-earthquake temporary accommodation process is one of the topics which always preoccupies managers in the field of crisis management. In this

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regard, decision-making based on proven scientific theories and equations can improve the certainty and credibility of the decisions. Therefore, the main goal of this study is to provide a combined method using risk management and Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) for predicting suitable post-earthquake temporary accommodation sites. The model proposed in this study attempts to combine current theories in the field of crisis management and risk management, decision-making management and intuitionistic fuzzy sets in order to fill the gap in the literature and previous studies. The use of these theories in the proposed combined model is due to several reasons; including: (i) Providing temporary accomendations after earthquakes is one of the important processes in crisis management and is always accompanied with a great deal of uncertainty. Therefore, in order to remove or reduce the risks of temporary accommodation process, it is necessary to use a preventive risk management plan. Identifying and evaluation of risks and their effects in various temporary accomendation programs is one of the stages of crisis management after earthquake disasters since most of these risks can be reduced to a controlled level through use of suitable strategies [1], (ii) Due to the existence of numerous criteria for selection of proper location for temporary accomendation sites, use of multivariable decision-making methods is necessary. During the process of multi-variable decision-making, pairwise comparison of options based on decision-making criteria and determination of relative priorities of these variables requires the use of experts opinions. In this regard, use of methods such as Delphi approach or brainstorming can be useful, (iii) The use intuitionistic fuzzy sets seem necessary in multi-criteria decision making in which, in addition to the degree of membership and non-membership, the degree of uncertainty is another factor also considered. This is due to the fact that a factor called hesitation or uncertainty is not defined in classical sets and even fuzzy sets. The intuitionistic fuzzy set has shown certain advantages over fuzzy sets in managing of ambiguity and uncertainty [40]. Interval Valued Intuitionistic Fuzzy Set theory (IVIFS) is an effective and simple tool for creation of MultiAttribute Group DecisionMaking (MAGDM) models. Furthermore, this method is useful for dealing with uncertainty in the complex decision-making support systems [22]. In the current study, a combined model was applied for identification and prioritization of post-earthquake temporary accomendation sites in the Sanandaj-Iran. The participants in the Delphi panel included crisis management experts employed in 18 organizations of Kurdistan province. Some of the identified risks in this stage included: Lack of desire among people for living in determined temporary accommodation sites outside of the city limits; challenges related to hot and cold weather; challenge of waste disposal, snow and rain challenge; trash disposal challenge; blocking of roads due to snow and rain and subsequent disruption in services during winter; the outbreak of infectious diseases; challenges of wind and storm; unsittable positioning of the temporary accommodation site and lack of attention to required criteria (including access to services, distance from fault lines and flood paths, access to gas lines, etc.); and challenges related to provision of drinking water and health products. In the current study, the risks were identified through comprehensive literature reviews and conducting a brainstorming session with crisis management experts of Kurdistan province. As a result, Six criteria were selected as decision criteria for post-earthquake temporary accommodation site selection. These criteria were then used to prioritize various locations in the Sanandaj city using IF-AHP approach.

# 2 Literature review and research background

## 2.1 Literature review on temporary accommodation after the disaster

Temporary accommodation plays a key role in the disaster process. The creation and use of temporary sites at the location of a disaster are used to accommodate victims during an emergency situation, and reconstruction and renovation after disaster occurrence, until permanent accommodation is provided [18]. Temporary accommodation is a vital but controversial part of disaster recovery. Disaster-stricken families who have lost their homes need a private and safe place to do their daily activities as soon as possible after the disaster [23]. Typically, three types of accommodations are required after a destructive earthquake in a crowded region: (i) Emergency accommodations that often include tent, (ii) Temporary accommodations which are usually used for 1 to 2 years, (iii) Permanent accommodations or permanent living spaces[15]. It is generally accepted that provision of emergency and temporary accommodations after an earthquake uses a vast amount of resources in a short time[37]. The temporary accommodation problem, medium-term accommodations and finally permanent accommodations of victims after earthquakes is one of the largest challenges during disaster recovery and reconstruction [25]. According to disaster relief act of Japan, the maximum allowed duration for use of temporary accommodations is 2 years. However, some victims use these accommodations for more than 7 years, especially after the large earthquake of 2012 on Eastern Japan [37]. Design of temporary accommodation sites should consider various factors to ensure than these accommodations can meet the needs of the victims. Architecture and design must be part of the solution and not part of the problem and the process must start years before the disaster, by using sufficient time and a multidisciplinary team including technical and humanities experts (various engineers), production companies, etc. and not during the disaster itself [9]. In the study of post-disaster temporary accommodation, Principles of Presentation, Design and Construction are used for design, construction, and preparation of temporary accommodations with suitable characteristics including Quick availability, Using of local resources and considering local standards in terms of location and service facilities, design of Temporary accommodations for long-term housing needs, the ability to easily remove the site and maintain the environment after the duration of temporary accommodations, preventive planning before the event, and aadopting a developed strategy for recovery and reconstruction. Research findings on the decline in physical performance of residents of temporary accommodation after the Great East Japan earthquake have shown that a poor living environment in temporary accommodations may have a negative impact on the physical performance of individuals, especially the elderly [20]. In the article "Towards Effective Crisis Management in Egypt," five suggestions were proposed as key steps for setting better disaster management routes in Egypt [17] including Risk management; Damage management; Event control; Resource management; and Reducing the impact of the crisis. A survey research on the selection of post-disaster temporary accommodation was carried out by Anand et al. in 2015. This study examined various models for selecting post-disaster temporary rehabilitations. Each of these methods provides selection criteria and minimum standards for handling the needs of the victims. The result of this study shows that availability of basic services such as health centers, transportation, and livelihoods are major concerns when site is chosen for temporary accommodations [4]. In a research entitled "Temporary accommodation site in earthquake crisis using AHP and Geographic Information System", the criteria for temporary accommodation are divided into three categories of the physical, social and environmental criteria, and have been used in the process of finding temporary accommodation sites, using AHP and GIS, according to the weight and importance of the criteria mentioned [12]. Another article titled "The role of temporary accommodation buildings for post-disaster housing reconstruction" investigated the cultural and environmental challenges of the temporary accommodation settlements, and mentioned that the key to reducing the vulnerability of the victims is the prediction of temporary accommodation before the occurrence of the crisis. To this end, using existing places with permanent infrastructure near the initial location of victims has been suggested [14]. Site selection criteria for temporary accommodations after the earthquake was carried out using Delphi Panel by Soltani et al. in 2015 to provide a list of appropriate criteria for deciding on the choice of a temporary accommodation site. To determine the criteria, three methods were used including examining previous studies, conducting interviews with the experts and performing a Delphi Panel. Finally, the main criteria to select a temporary accommodation site were categorized in four sections consisting of land suitability, social and cultural considerations, availability to services and disaster risk reduction [38]. The previous studies on crisis management and temporary accommodation, and how they are carried out, are presented in Table 2.

## 2.2 Research background

### 2.2.1 Crisis management

Crisis management is a set of pre-designed processes which are implemented and applied to prevent or reduce the effects, during pre-occurrence, occurrence and post-occurrence of disasters [26]. Crisis management consists of three stages of Pre-crisis step (prevention and preparation), crisis step (reaction) and post-crisis step (learning and revision) [10]. Crisis Management is a multidisciplinary subject that includes many sciences including social sciences, foreign sciences, medicine, engineering, and many other disciplines which are used for investigation of major unpredictable events [7].

### 2.2.2 Risk management

Risk management in a project consists of the risk management planning processes, identification, analysis, response planning, and risk control in a project. Increasing the likelihood and impact of positive events and reducing the likelihood and impact of negative events is one of the objectives of the risk management in a project [35].

The process of risk management in projects is a logical chain of methods, planned and implemented by decision makers, which control the results to maintain project implementation under certain conditions (Time, cost, and quality parameters) [32].

Risk management is about identification of risks that are imminent. Identifying and designing measures for reducing risk consists of identifying possible risks, determining the occurrence probability of each risk, and estimating the extent of risk effects in communities. One of the risk management processes is Implementation of these measures and reducing the threats [17].

Table 1: Studies conducted related to the topic of research

| No | Author/s | Issue | Method |
|---|---|---|---|
| 1 | [38] | provide a list of appropriate criteria for deciding on the choice of a temporary accommodation site | (i) Extracting 27 criteria to select accomendation site provided by reviewing issued articles, (ii) Identification of 12 other criteria during the interview process with experts, (iii) Approval of 21 criteria during the Delphi process, (iv) Categorizing criteria for selecting temporary accommodation in four sections: Land suitability, Social and cultural considerations, availability to services and reduce disaster risk |
| 2 | [17] | Post-disaster temporary accommodation site: Principles of presentation, design and constructing, the review of a set of guidelines for designing and construction a successful and high quality, and at the same time, sensitivity to controversial issues in addition to saving the costs and time | (i) Analyzing and reviewing the briefs, (ii) Matching the executed cases with briefs, (iii) Providing the necessary suggestions for designing and constructing of a temporary accommodation site |
| 3 | [24] | Temporary accommodation site locating after earthquake: one case for Turkey | (i) Reviewing some cases of past actions in temporary accommodation, (ii) determinating of the locating metrics, (iii) Compilation of a linear program for optimal location, (iv) Testing the compiled program |
| 4 | [31] | Urban vulnerability assessment using AHP in 19 Qazvin areas | (i) Determination of three main criteria and 20 subcriteria, (ii) Using questionnaire, (iii) Using AHP method for prioritization of urban vulnerability factors |
| 5 | [5] | Proposing a model for the post-disaster design in temporary accommodation based on the needs of the victims with the post-implementation evaluation approach (Case study: Seismic villages in Harris, East Azarbaijan) | (i) Different methods of documentary and library, (ii) Field studies through interviews and questionnaires |
| 6 | [12] | Presenting a Method Using AHP and Geographic Information System (Case Study: Damavand Area) | (i) Using Geographic Information System (GIS) , (ii) Using ARCMAP software, (iii) Propagating maps with three factors: faults, earthquakes and soil resistance, (iv) Using the AHP model, (v) Data was collected by library methods and field studies. |
| 7 | [19] | Providing a multi-criteria decision-making method for locating post-disaster temporary accommodation in urban areas | (i) Documentary studies, (ii) Logical studies, (iii) Knowledge of Experts Participating in the Seminar, (iv) SWOT approach, (v) AHP model, (vi) Design and application (medal app) |
| 8 | [18] | Exploring ways to better manage natural disasters in Egypt | (i) Identifying the various types of natural disasters that Egypt is vulnerable to them, (ii) A general picture of the crisis management problems in Egypt, (iii) Providing a set of briefs, a solution to the crisis management problem in Egypt, (iv) investigating a set of considerations to ensure the correct implementation of the briefs. |
| 9 | [20] | Investigating the Length of Physical Operation of Residents in Temporary accommodation sites, after earthquake in Great East Japan | (i) Implementation of physical performance tests on residents in site and temporary accommodation control group by physiotherapists, (ii) Comparing the results of the tests performed on these two groups |
| 10 | [29] | Searching the best practices for post-disaster sustainable temporary accommodation that have features such as: being cheap, fast built, maintaining environmental and social issues, paying attention to the weather conditions of the place and paying attention to all needs of the victims. | (i) Documentary study of natural disasters occurring in the world and the extraction of the statistics of the refugees and casualties caused by the incident, (ii) Extracting the various social and economic damages of each of these events, (iii) Investigating the type of structure used in previous natural disasters, and the advantages and disadvantages each one, (iv) Investigating the challenges that have occurred accommodation process in the past |

Table 2: Relative risk ranking of the earthquake in the Kurdistan Provincial Demographic Centers according to Iran's 2800 Code

| No. | Demographic Center | Relative earthquake risk | | | |
|---|---|---|---|---|---|
| | | Low | Medium | High | Very High |
| 1 | Baneh | | | | * |
| 2 | Bijar | | * | | |
| 3 | Dehglan | | | * | |
| 4 | Divandareh | | * | | |
| 5 | Saghez | | | * | |
| 6 | Sav aabad | | | | * |
| 7 | Sanandaj | | | * | |
| 8 | Gharaveh | | * | | |
| 9 | Kamyaran | | | | * |
| 10 | Marivan | | | | * |

#### 2.2.3 Multi-criteria decision making

Description of criteria and gathering of descriptive information are two important uses of MCGDM for prioritizing various considered options [30]. Multi-Criteria Decision Making (MCDM) is a process which allows decision-making using numerous and sometimes contradicting criteria. MCDM topics can be divided into two main categories: (i) Multi-Attribute Decision Making (MADM): This method is focused on selecting the best option among the predetermined options, (ii) Multi-Objective Decision Making (MODM): This method includes design of alternative options for optimization of multiple decision-making objectives.

#### 2.2.4 Area of the study

The city studied in this study was Sanandaj, the capital of Kurdistan province in Iran (Figure 1). Kurdistan province is located in the northwestern part of Iran. Iran is located in the alpine-Himalayan seismic belt and is one of the most active tectonic areas in the world. Historically, this country often suffers from large and destructive earthquakes, and has experienced several major earthquakes in the last few decades. More than 70 percent of Iran's major cities are located near seismic faults. In some cases, active faults cross the cities [21]. Regulations for the Design of Buildings against earthquakes [8] divide Iran into four parts in terms of seismic risk which include relatively low, moderate, high, and very high-risk areas (Table 1). According to this standard, Sanandaj is located in high risk area of earthquakes.

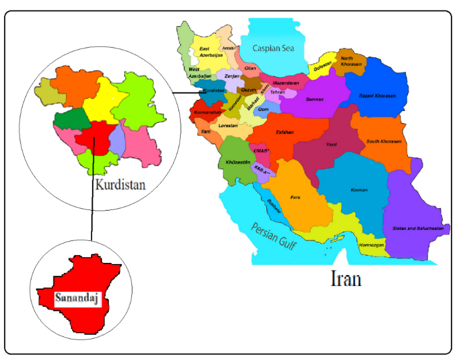


Figure 1: Location of Kurdistan Province and Sanandaj City in Iran.

## 3 Research methodology

This research is a descriptive-applied study, which used documentary methods, interview and holding a storm meeting for data collection. In the documentary study, previous studies on the process of post-earthquake temporary accommodation in Iran and the world have been investigated. Furthermore, in this section, geographic conditions, topographic conditions, population amount, places and the existing infrastructure of Sanandaj were studied. In this study, the combination of risk management and intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) has been used to locate the post-earthquake temporary accommodation site. This paper is part of a research carried out by the authors which identified the risks involved in the temporary accommodation process in its previous sections, and has prioritized 94 identified risks in its results including Lack of desire among people for living in determined temporary accommodation sites outside of the city limits; challenges related to hot and cold weather; challenge of waste disposal, snow and rain challenge; trash disposal challenge; blocking of roads due to snow and rain and subsequent disruption in services during winter; the outbreak of infectious diseases; challenges of wind and storm; unsittable positioning of the temporary accommodation site and lack of attention to required criteria (including access to services, distance from fault lines and flood paths, access to gas lines, etc.); and challenges related to provision of drinking water and health products. These risks were combined in a brainstorming session with crisis management experts of Kurdistan province until 6 criteria were selected including the existence of infrastructure, proper availability, distance from fault lines and flood paths and other natural hazards, appropriate land gradient, proximity to service centers, and capacity for receiving victims, in order to locate and prioritize the existing locations in Sanandaj for temporary accommodation sites. In this research, the Fuzzy Delphi method was also used to identify the risks of temporary accommodation, and the questionnaire was completed by specialists and experts in the field of crisis management in Kurdistan, which consists of 18 departments and organizations. The challenge of people's disclination to reside in established sites of temporary out-of-town accommodation has been introduced as a risk in this process. Furthermore, due to the mountainous conditions of the surrounding studied area, this study attempts to use the existing urban spatial areas that were previously considered by the crisis management authorities to accommodate emergency situations. If these predetermined sites met the necessary conditions, they were used for temporary accommodation after a short period of emergency accommodation. To summarize the comments, in order to select the appropriate criteria for determination of the available alternatives determining the weight against each option, and also the weight of the Alternatives against the criteria, the brainstorming session was conducted with 9 specialists and experts in the field of crisis management in Kurdistan province. Figure 2 shows the schematic illustration of research methodology for this research.

## 3.1 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) was first introduced by Saaty [33]. AHP is a measurement theory through dual comparisons and depends on the judgment of the experts to obtain prioritization scales [34]. Some key steps in this approach are [39]: (i) Statement of the problem, (ii) Expanding the goals of the problem or considering all the actors, goals and their consequences, (iii) Identifying effective criteria for decision making, (iv) Creating the hierarchy structure of the problem consisting of different levels of purpose, criteria, sub-criteria, and alternatives, (v) Comparing each element at the corresponding level and calibrating them on a numerical scale. This requires n (n-1)/2 comparisons, where n is the number of elements with case of comparison. The diagonal elements equal 1, or other elements are simply intertwined with previous values, (iv) Calculating the maximum specific values consisting of compatibility index, CI, compatibility ratio, CR and normalized values for each criterion/option, and (vii) If the maximum Eigen value, CI and CR are satisfactory, the decision is made on the basis of normal values. Otherwise, this method will be repeated until the values are within the desired range.

## 3.2 Introducing intuitionistic fuzzy sets

In the classical logic of mathematics, the value or correctness of a proposition is defined with 1 as true and zero as false. Zadeh introduced fuzzy sets for the first time [41]. In fuzzy logic, the accuracy value is a real number which is selected from the range of [0, 1]. Atanassov added, another real number in the range [0, 1] entitled "Degree of non-accuracy" to this definition in the presentation of intuitionistic fuzzy sets [6]. Therefore, two values of $\nu(p)$ and $\mu(p)$ are attributed to the proposition p, such that: $\nu(p) + \mu(p) \leq 1$. An intuitionistic Fuzzy set of A in the reference set X is defined as follows:

$$\begin{aligned}
&A = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in X\} \\
&\mu_A : X \longrightarrow [0,1] \\
&\nu_A : X \longrightarrow [0,1] \\
&\forall x \in X : 0 \leq \mu_A(x) + \nu_A(x) \leq 1.
\end{aligned}$$

The real values of $\mu_A(x)$ and $\nu_A(x)$ are the degree of membership and the degree of non-membership of x to A, which belongs to the interval [0, 1]. Each set A', is a special case of intuitionistic fuzzy sets and can be represented as an

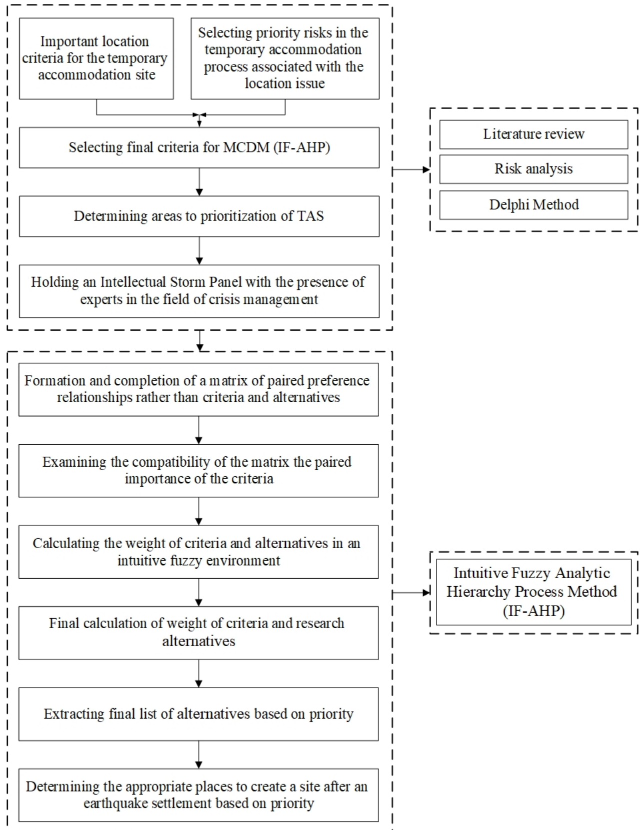


Figure 2: Schematic illustration of research methodology.

intuitionistic fuzzy set A' [28]. For each intuitionistic fuzzy set, A' from X, we have:

$$A' =' \{\langle x, \mu_{A'}(x), 1-\mu_{A'}(x)\rangle | x \in X\},$$
$$\pi_{A'}(x) : 1-\mu_{A'}(x)-\nu_{A'}(x).$$

$\pi_{A'}(x)$, is called the intuitionistic index $x$ in $A'$. In fact, this is the degree of $x$ hesitancy in $A'$. Clearly, for each $x$ belonging to $X$, we have: $0 \leq \pi_{A'}(x) \leq 1$. In each fuzzy set of $A'$ from $X$ we have:

$$\forall x \in X : \pi_{A'}(x) = 1-\mu_{A'}(x)-[1-\mu_{A'}(x)] = 0.$$

The sum of the multiplication of two intuitionistic fuzzy sets is in accordance with formulas 1 and 2 [40], [11].

$$r_{tl} = (\mu_{tl}, v_{tl}), \qquad r_{ik} = (\mu_{ik}, v_{ik}),$$
$$n = 1, 2, 3, \cdots, \qquad k = 1, 2, 3, \cdots.$$

$$\text{degree of membership} = \mu_{ik},$$
$$\text{degree of non-membership} = \nu_{ik},$$
$$\text{degree of uncertainly} = \pi_{ik}.$$

$$r_{ik} \oplus r_{tl} = (\mu_{ik} + \mu_{tl} - \mu_{ik}\mu_{tl}, \quad v_{ik}v_{tl}), \tag{1}$$
$$r_{ik} \otimes r_{tl} = (\mu_{ik}\mu_{tl}, \quad v_{ik} + v_{tl} - v_{ik}v_{tl}). \tag{2}$$

# 4 Intuitionistic fuzzy analytic Hierarchy

The purpose of this example is to prioritize available places in Sanandaj to determine the best post-earthquake temporary accommodation site.

Table 3: Examined alternatives table for locating and prioritizing the temporary accommodation site

| No. | Site Name | Area (hectare) | Useful Area (hectare) | Moderate slope (percent) | Available facilities | | | Capacity (preson) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Water | Electricity | W.C | |
| 1 | A1 | 81 | 63.2 | 15 | Yes | Yes | Yes | 21067 |
| 2 | A2 | 10 | 10 | 4 | Yes | Yes | Yes | 3333 |
| 3 | A3 | 17.6 | 14.3 | 12 | No | No | No | 4767 |
| 4 | A4 | 0.95 | 0.96 | 1 | Yes | Yes | Yes | 320 |
| 5 | A5 | 7.6 | 6.4 | 9 | Yes | Yes | Yes | 2133 |
| 6 | A6 | 8.4 | 7.2 | 11 | Yes | Yes | Yes | 2400 |
| 7 | A7 | 70 | 57.4 | 13 | No | No | No | 19133 |
| 8 | A8 | 18.5 | 16.3 | 10 | No | No | No | 5433 |
| 9 | A9 | 6.5 | 6 | 4 | Yes | Yes | No | 2000 |
| 10 | A10 | 26 | 25.5 | 4 | No | No | No | 8500 |
| 11 | A11 | 3.3 | 3 | 4 | Yes | Yes | Yes | 1000 |
| 12 | A12 | 4.25 | 3.4 | 14 | Yes | Yes | Yes | 1133 |
| 13 | A13 | 3.7 | 2.7 | 18 | Yes | Yes | Yes | 900 |

## 4.1 Recognizing the effective criteria for multi-criteria decision making

In this study, six criteria are considered, including (i) Distance from fault lines, flood paths and other natural hazards, (ii) Appropriate ground gradient, (iii) Existence of necessary infrastructure, (iv) Availability, (v) Proximity to service centers, and (vi) Admission Capacity. These 6 criteria were used to rank places in Sanandaj to determine the best site of temporary accommodation. Specifications of the places examined in this research are as shown in Table 3.

## 4.2 Formation of decision-making structure

The overall decision-making structure in this example consists of three levels of goals, criteria and alternatives (Fogure 3). Often the set of criteria is presented with $C = \{C_1, C_2, C_3, \cdots, C_n\}$ and the set of Alternatives or available methods for prioritize is presented with $A = \{A_1, A_2, A_3, \cdots, A_n\}$.

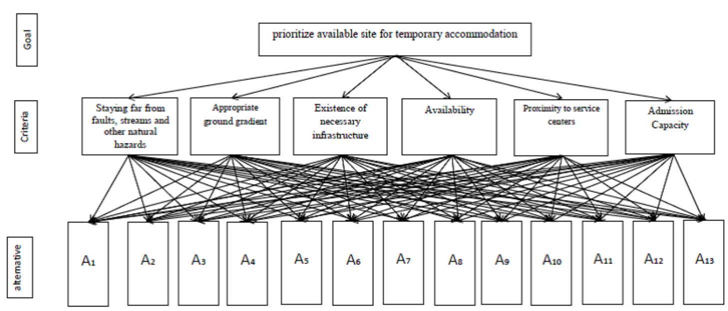


Figure 3: The multicriteria decision-making structure (IF-AHP) of the study .

## 4.3 Determining the intuitionistic fuzzy linguistic variables to pairwise comparison

Since difference in linguistic variables used by different individuals might lead to different interpretations, in this study, in order to create a unify procedure in evaluating experts opinions regarding the importance of each criterion compared to others, intuitionistic fuzzy linguistic variables $(\mu_A, \nu_A)$ are used. Here, $\mu_A$ is the degree of membership and $\nu_A$ is the degree of non-membership. Table 4 shows the intuitionistic fuzzy linguistic variables used for pairwise comparisons.

Table 4: Intuitionistic fuzzy linguistic variables for determining the priority in pairwise comparison

| Scale | Variables |
|---|---|
| (0.00 , 1.00) | Absolutely low importance |
| (0.05 , 0.90) | Very very low importance |
| (0.10 , 0.80) | Very low importance |
| (0.20 , 0.70) | Low importance |
| (0.30 , 0.60) | Slightly low importance |
| (0.50 , 0.50) | Equally importance |
| (0.60 , 0.30) | Slightly high importance |
| (0.70 0.20) | High importance |
| (0.80 0.10) | Very high importance |
| (0.90 0.05) | Very very high importance |
| (1.00 0.00) | Absolutely high importance |

Table 5: The pairwise comparison matrix of criteria

| | Staying far from faults, streams and other natural hazards | Appropriate ground gradien | Existence of necessary infrastructure | Availability | Proximity to service centers | Admission Capacity |
|---|---|---|---|---|---|---|
| Staying far from faults, streams and other natural hazards | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) | (0.5 , 0.5) |
| Appropriate ground gradient | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) |
| Existence of necessary infrastructure | (0.2 , 0.7) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5 , 0.5) | (0.5 , 0.5) | (0.5 , 0.5) |
| Availability | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5 , 0.5) | (0.7 , 0.2) | (0.7 , 0.2) |
| Proximity to service centers | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.2 , 0.7) | (0.5 , 0.5) | (0.7 , 0.2) |
| Admission Capacity | (0.5 , 0.5) | (0.7 , 0.2) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.5 , 0.5) |

## 4.4 Determination of intuitionistic fuzzy linguistic variables for pairwise comparison of options

Intuitionistic fuzzy linguistic variables used to determine the pairwise comparison of options for each criterion in this study are presented in Table 4.

## 4.5 Formation of matrix the importance of criteria paired with each other

Pairwise comparison of criteria based on intuitionistic fuzzy linguistic variables ( $\mu_A, \nu_A$) carried out in a brainstorming session with 9 disaster management experts and according to regional conditions and the results are presented in Table 5.

$$r_{ik} = (\mu_{ik}, v_{ik})$$

$$n = 1, 2, 3, \cdots , \qquad k = 1, 2, 3, \cdots$$

Degree of membership $=\mu_{ik}$
Degree of non-membership $= v_{ik}$

## 4.6 Formation of preferential - paired relationship alternatives with the criteria

The pairwise priority relation matrices of options based on criteria, determined based on the values presented in Table 4 by experts are presented in Appendixes 1 - 6.

Table 6: Matrix R (Relationship of the importance of the criteria paired with each other)

| | Staying far from faults, streams and other natural hazards | Appropriate ground gradient | Existence of necessary infrastructure | Availability | Proximity to service centers | Admission Capacity |
|---|---|---|---|---|---|---|
| Staying far from faults, streams and other natural hazards | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) | (0.5 , 0.5) |
| Appropriate ground gradient | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) | (0.2 , 0.7) |
| Existence of necessary infrastructure | (0.2 , 0.7) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5 , 0.5) | (0.5 , 0.5) | (0.5 , 0.5) |
| Availability | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5 , 0.5) | (0.7 , 0.2) | (0.7 , 0.2) |
| Proximity to service centers | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.2 , 0.7) | (0.5 , 0.5) | (0.7 , 0.2) |
| Admission Capacity | (0.5 , 0.5) | (0.7 , 0.2) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.5 , 0.5) |

## 4.7 Investigating the compatibility of matrix, the importance of criterion paired- intuitionistic with each other

### 4.7.1 Formation of matrix R (Relationship of the importance of the criteria paired with each other) [40]

. The pairwise comparison of the criteria was calculated based on the results of the brainstorm panel and intuitionistic fuzzy verbal variables (Table 4). The results have been shown in Table 6.

### 4.7.2 Forming matrix $\overline{R}$

In order to determine the memberships and non-membership degrees in this matrix, the following equations can be used [40]

$$\overline{\mu}_{ik} = \frac{\sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}\mu_{it}\mu_{tk}}}{\sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}\mu_{it}\mu_{tk}} + \sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}(1-\mu_{it})(1-\mu_{tk})}} \qquad k > i+1, \tag{3}$$

$$\overline{v}_{ik} = \frac{\sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}v_{it}v_{tk}}}{\sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}v_{it}v_{tk}} + \sqrt[k-i-1]{\Pi_{t=i+1}^{k-1}(1-v_{it})(1-v_{tk})}} \qquad k > i+1. \tag{4}$$

In order to carry out the pairwise comparison of the criteria, intuitionistic fuzzy linguistic variables were calculated based on formulas (3) and (4). The results of Matrix $\overline{R}$ are presented in Table 7.

### 4.7.3 Calculating the distance between matrix $\overline{R}$ and matrix R [40]

$$d(\overline{R}-R) = \frac{1}{2(n-1)(n-2)}\sum_{i=1}^{n}\sum_{k=1}^{n}|\overline{\mu_{ik}}-\mu_{tl}| + |\overline{v_{ik}}-v_{tl}| + |\overline{\pi_{ik}}-\pi_{tl}|, \tag{5}$$

$$(\overline{R}-R) = \frac{1}{2(6-1)(6-2)}(0.6463+0.6463+1.2926) = 0.0646$$

After calculating this gap, we will have: $d(\overline{R}-R) = 0.0646$

Since the distance between R̦ and $\overline{R}$ is less than 0.10, it is possible to move to the next step without revising the pairwise comparison matrix created in this step [36], [40].

Table 7: Matrix $\overline{R}$

| Matrix $\overline{R}$ | Staying far from faults, streams and other natural hazards | Appropriate ground gradient | Existence of necessary infrastructure | Availability | Proximity to service centers | Admission Capacity |
|---|---|---|---|---|---|---|
| Staying far from faults, streams and other natural hazards | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.249 , 0.595) | (0.276 , 0.538) |
| Appropriate ground gradient | (0.5 , 0.5) | (0.5 , 0.5) | (0.2 , 0.7) | (0.2 , 0.7) | (0.276 , 0.529) | (0.305 , 0.481) |
| Existence of necessary infrastructure | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5 , 0.5) | (0.7 , 0.2) | (0.7 , 0.2) |
| Availability | (0.7 , 0.2) | (0.7 , 0.2) | (0.5 , 0.5) | (0.5  0.5) | (0.7 , 0.2) | (0.849 , 0.059) |
| Proximity to service centers | (0.595 , 0.249) | (0.529 , 0.276) | (0.2 , 0.7) | (0.2 , 0.7) | (0.5  0.5) | (0.7 , 0.2) |
| Admission Capacity | (0.538 , 0.276) | (0.481 , 0.305) | (0.2 , 0.7) | (0.059 , 0.845) | (0.2 , 0.7) | (0.5  0.5) |

## 4.8 Calculating weight of criteria and Alternatives in an intuitionistic fuzzy environment

The following formula can be used to calculate the weight of criteria and Alternatives [40] Therefore, the weight of criteria were calculated based on formula (6) and the results are presented in Table 8.

Table 8: The weight of criteria with each other

| | | 1* | | 2* | | 3* | | 4* | | 5* | | 6* | | $w_j$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | | $C_5$ | | $C_6$ | | | |
| | | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| Staying far from faults, streams and other natural hazards | $C_1$ | 0.5 | 0.5 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.249 | 0.595 | 0.276 | 0.538 | 0.098 | 0.849 |
| Appropriate ground gradient | $C_2$ | 0.5 | 0.5 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.277 | 0.529 | 0.305 | 0.481 | 0.101 | 0.842 |
| Existence of necessary infrastructure | $C_3$ | 0.7 | 0.2 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.193 | 0.743 |
| Availability | $C_4$ | 0.7 | 0.2 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.845 | 0.059 | 0.201 | 0.734 |
| Proximity to service centers | $C_5$ | 0.595 | 0.249 | 0.529 | 0.276 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.7 | 0.2 | 0.139 | 0.794 |
| Admission Capacity | $C_6$ | 0.538 | 0.276 | 0.481 | 0.305 | 0.2 | 0.7 | 0.059 | 0.845 | 0.2 | 0.7 | 0.5 | 0.5 | 0.101 | 0.836 |

1*: Staying far from faults, streams and other natural hazards.
2*: Appropriate ground gradient.
3*: Existence of necessary infrastructure.
4*: Availability.
5*: Proximity to service centers.
6*: Admission Capacity.

$$\omega_i = \left(\frac{\sum_{k=1}^{n} \mu_{ik}}{\sum_{i=1}^{n}\sum_{k=1}^{n}(1 - v_{ik})}, 1 - \frac{\sum_{k=1}^{n}(1 - v_{ik})}{\sum_{i=1}^{n}\sum_{k=1}^{n}\mu_{ik}}\right). \tag{6}$$

For example, in order to calculate the weight for C1 (Distance from fault lines, flood paths and other natural hazards) we have:

$$\omega_1 = (\frac{\sum_{k=1}^{6}\mu_{ik}}{\sum_{i=1}^{6}\sum_{k=1}^{6}(1-v_{ik})}, 1-\frac{\sum_{k=1}^{6}(1-v_{ik})}{\sum_{i=1}^{6}\sum_{k=1}^{6}\mu_{ik}})$$
$$\omega_1 = (\frac{1.9254}{4.0746+4.0182+2.2+2.0552+3.2763+4.022},$$
$$1-\frac{2.4665}{3.5335+3.4094+1.8+1.6588+2.6254+3.3266})$$
$$\omega_1 = (\frac{1.9254}{19.6463}, 1-\frac{2.4665}{16.3537})$$
$$\omega_1 = (0.0980, 0.8492).$$

In order to calculate the weight of alternatives according to each criterion, fuzzy numbers presented in Apendixes 1-6 as well as equation (6) are used. For example, in order to calculate the alternatives weights in regards to C1 (Distance from fault lines, flood paths and other natural hazards), the intuitionistic fuzzy numbers of table 4 and equation (6) are used. These results are presented in Table 9.

Table 9: The weight of alternatives in regard to criterion (distance from fault lines, flood paths and other natural hazards)

| Criterion $C_1$ | $\sum_{k=1}^{n}\mu_{ik}$ | $\sum_{k=1}^{n}(1-v_{ik})$ | $\sum_{i=1}^{n}\sum_{k=1}^{n}(1-v_{ik})$ | $\sum_{i=1}^{n}\sum_{k=1}^{n}\mu_{ik}$ | $\omega_i$ | |
|---|---|---|---|---|---|---|
| | | | | | $\frac{\sum_{k=1}^{n}\mu_{ik}}{\sum_{i=1}^{n}\sum_{k=1}^{n}(1-v_{ik})}$ | $1-\frac{\sum_{k=1}^{n}(1-v_{ik})}{\sum_{i=1}^{n}\sum_{k=1}^{n}\mu_{ik}}$ |
| A1 | 5.3 | 8.1 | 88.8 | 80.2 | 0.0822 | 0.8990 |
| A2 | 5.3 | 8.1 | 88.8 | 80.2 | 0.0822 | 0.8990 |
| A3 | 7.3 | 8.1 | 88.8 | 80.2 | 0.0822 | 0.8990 |
| A4 | 5.5 | 8.1 | 88.8 | 80.2 | 0.0822 | 0.8990 |
| A5 | 5.5 | 6.6 | 88.8 | 80.2 | 0.0653 | 0.9177 |
| A6 | 5.5 | 5.9 | 88.8 | 80.2 | 0.0597 | 0.9264 |
| A7 | 5.5 | 5.9 | 88.8 | 80.2 | 0.0597 | 0.9264 |
| A8 | 5.3 | 5.9 | 88.8 | 80.2 | 0.0597 | 0.9264 |
| A9 | 5.3 | 8.1 | 88.8 | 80.2 | 0.0822 | 0.8990 |
| A10 | 7.3 | 6 | 88.8 | 80.2 | 0.0619 | 0.9252 |
| A11 | 5.5 | 6 | 88.8 | 80.2 | 0.0619 | 0.9252 |
| A12 | 5.5 | 6 | 88.8 | 80.2 | 0.0619 | 0.9252 |
| A13 | 5.5 | 6 | 88.8 | 80.2 | 0.0619 | 0.9252 |

Table 10 shows the results of pairwise comparison calculations for all alternatives for each criterion.

## 4.9 Final weights of research criteria and alternatives

Equation (7) is used to calculate the final weight of each alternative based on intuitionistic fuzzy set [40]:

$$w_i = \oplus_{j=1}^{6}(w_j \otimes w_{ij}) \tag{7}$$

To calculate equation (7) requires the use of equations (1) and (2) [40], [11]. An example of calculations for alternative 1 is shown below:

$$\begin{aligned} w_1 &= \oplus_{j=1}^{6}(w_j \otimes w_{1j}) \\ &= (0.0980, 0.8492) \otimes (0.822, 0.899) \oplus (0.1009, 0.8416) \otimes (0.211, 0.9659) \\ &\oplus (0.1934, 0.7432) \otimes (0.0813, 0.9033) \oplus (0.2008, 0.7345) \otimes (0.0866, 0.8965) \\ &\oplus (0.1386, 0.7936) \otimes (0.0836, 0.8953) \oplus (0.1007, 0.8365) \otimes (0.1036, 0.871) \\ &= (0.654, 0.8896). \end{aligned}$$

Table 11 shows the final weignts of alternatives and criteria.

Table 10: The weight calculation for each alternative based on criteria

| Alternative | 1* | | 2* | | 3* | | 4* | | 5* | | 6* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | | $C_5$ | | $C_6$ | |
| A1 | 0.0822 | 0.899 | 0.0211 | 0.9659 | 0.0813 | 0.9033 | 0.0866 | 0.8965 | 0.0836 | 0.8953 | 0.1036 | 0.871 |
| A2 | 0.0822 | 0.899 | 0.1036 | 0.8762 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0836 | 0.8953 | 0.0634 | 0.9208 |
| A3 | 0.0822 | 0.899 | 0.0581 | 0.9267 | 0.0601 | 0.9207 | 0.0785 | 0.9135 | 0.0836 | 0.8953 | 0.0691 | 0.9144 |
| A4 | 0.0822 | 0.899 | 0.0939 | 0.8907 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0635 | 0.9193 | 0.0351 | 0.9489 |
| A5 | 0.0653 | 0.9177 | 0.0581 | 0.9267 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0836 | 0.8953 | 0.0634 | 0.9208 |
| A6 | 0.0597 | 0.9264 | 0.0717 | 0.9154 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 |
| A7 | 0.0597 | 0.9264 | 0.0581 | 0.9267 | 0.0445 | 0.938 | 0.0855 | 0.8989 | 0.0424 | 0.9382 | 0.0991 | 0.8761 |
| A8 | 0.0597 | 0.9264 | 0.0615 | 0.9217 | 0.0445 | 0.938 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 |
| A9 | 0.0822 | 0.899 | 0.1002 | 0.8812 | 0.0579 | 0.9219 | 0.0704 | 0.9233 | 0.0836 | 0.8953 | 0.0691 | 0.9144 |
| A10 | 0.0619 | 0.9252 | 0.1002 | 0.8812 | 0.0412 | 0.9418 | 0.0704 | 0.9233 | 0.0424 | 0.9382 | 0.0895 | 0.8838 |
| A11 | 0.0619 | 0.9252 | 0.1002 | 0.8812 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0521 | 0.9298 |
| A12 | 0.0619 | 0.9252 | 0.0535 | 0.9305 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 |
| A13 | 0.0619 | 0.9252 | 0.0211 | 0.9659 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0351 | 0.9489 |

1*: Staying far from faults, streams and other natural hazards.
2*: Appropriate ground gradient.
3*: Existence of necessary infrastructure.
4*: Availability.
5*: Proximity to service centers.
6*: Admission Capacity.

Table 11: The weight calculation for each alternative based on criteria

| | 1* | | 2* | | 3* | | 4* | | 5* | | 6* | | $w_j$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | | $C_5$ | | $C_6$ | | | |
| | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| | 0.0980 | 0.8492 | 0.1009 | 0.8416 | 0.1934 | 0.7432 | 0.2008 | 0.7345 | 0.1386 | 0.7936 | 0.1007 | 0.8365 | | |
| A1 | 0.0822 | 0.899 | 0.0211 | 0.9659 | 0.0813 | 0.9033 | 0.0866 | 0.8965 | 0.0836 | 0.8953 | 0.1036 | 0.871 | 0.0654 | 0.8896 |
| A2 | 0.0822 | 0.899 | 0.1036 | 0.8762 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0836 | 0.8953 | 0.0634 | 0.9208 | 0.0659 | 0.8909 |
| A3 | 0.0822 | 0.899 | 0.0581 | 0.9267 | 0.0601 | 0.9207 | 0.0785 | 0.9135 | 0.0836 | 0.8953 | 0.0691 | 0.9144 | 0.0599 | 0.8988 |
| A4 | 0.0822 | 0.899 | 0.0939 | 0.8907 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0635 | 0.9193 | 0.0351 | 0.9489 | 0.0592 | 0.9016 |
| A5 | 0.0653 | 0.9177 | 0.0581 | 0.9267 | 0.0813 | 0.9033 | 0.0681 | 0.9245 | 0.0836 | 0.8953 | 0.0634 | 0.9208 | 0.0596 | 0.9007 |
| A6 | 0.0597 | 0.9264 | 0.0717 | 0.9154 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 | 0.0586 | 0.9036 |
| A7 | 0.0597 | 0.9264 | 0.0581 | 0.9267 | 0.0445 | 0.938 | 0.0855 | 0.8989 | 0.0424 | 0.9382 | 0.0991 | 0.8761 | 0.0532 | 0.9054 |
| A8 | 0.0597 | 0.9264 | 0.0615 | 0.9217 | 0.0445 | 0.938 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 | 0.0505 | 0.9128 |
| A9 | 0.0822 | 0.899 | 0.1002 | 0.8812 | 0.0579 | 0.9219 | 0.0704 | 0.9233 | 0.0836 | 0.8953 | 0.0691 | 0.9144 | 0.0620 | 0.8948 |
| A10 | 0.0619 | 0.9252 | 0.1002 | 0.8812 | 0.0412 | 0.9418 | 0.0704 | 0.9233 | 0.0424 | 0.9382 | 0.0895 | 0.8838 | 0.0531 | 0.9066 |
| A11 | 0.0619 | 0.9252 | 0.1002 | 0.8812 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0521 | 0.9298 | 0.0600 | 0.9008 |
| A12 | 0.0619 | 0.9252 | 0.0535 | 0.9305 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0691 | 0.9144 | 0.0570 | 0.9056 |
| A13 | 0.0619 | 0.9252 | 0.0211 | 0.9659 | 0.0813 | 0.9033 | 0.0704 | 0.9233 | 0.0635 | 0.9193 | 0.0351 | 0.9489 | 0.0503 | 0.9160 |

1*: Staying far from faults, streams and other natural hazards.
2*: Appropriate ground gradient.
3*: Existence of necessary infrastructure.
4*: Availability.
5*: Proximity to service centers.
6*: Admission Capacity.

## 4.10 Prioritize temporary accommodation site based on intuitionistic fuzzy analytic Hierarchy process

After the defuzzification of the final weights of alternatives in the process of selecting the intuitionistic fuzzy hierarchical multi criteria, alternatives or locations are prioritized based on the final defuzzification weights for each location. In this study, the geometrical average calculated using equation (8) is used for defuzzification of variables [2]:

$$M_G(\mu, v) = \sqrt{\mu(1-v)}. \tag{8}$$

Table 12: Prioritize alternatives for selecting temporary post-earthquake accommodation

| Prioritized arrangement | Option | Defuzzification weights |
|---|---|---|
| 1 | A1 | 0.0850 |
| 2 | A2 | 0.0848 |
| 3 | A9 | 0.0808 |
| 4 | A3 | 0.0779 |
| 5 | A11 | 0.0772 |
| 6 | A5 | 0.0769 |
| 7 | A4 | 0.0763 |
| 8 | A6 | 0.0752 |
| 9 | A12 | 0.0733 |
| 10 | A7 | 0.0710 |
| 11 | A10 | 0.0704 |
| 12 | A8 | 0.0663 |
| 13 | A13 | 0.0650 |

For example, the final defuzzified weight of A1 alternative is calculated as follows:

$$M_{A1}(\mu, v) = \sqrt{0.0654(1 - 0.8896)} = 0.085.$$

Table 12 shows the defuzzified weight of all options in the order of their priority.

# 5 Conclusions

Pairwise comparison of the criteria and alternatives based on each criterion is one of the main stipulations and steps of the multi-criteria decision-making process. One of the important features of risk-based preventive planning for the post-earthquake temporary accommodation process is the presence of multiple uncertainties. In fact, due to the nature of the risk, a number of uncertainties will be added in the decision-making process. Given the fact that uncertainty factor is not considered in the classical studies, using intuitionistic fuzzy sets can be very useful in multi-criteria planning and decision making. In expert's opinions, the result is more accurate in calculations and optimal selection, when taking into account the three elements of degree of membership, the degree of non-membership, and degree of doubt and uncertainty. In this study, the combination risk-based approach was applied to post-earthquake temporary accommodation site selection in Sanandaj-Iran. The proposed model combines risk management and Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP). Some of the practical features of this approach include: (i) Ability to measure the compatibility between the pairwise comparison of the criteria and therefore the judgment of the experts opinions regarding the importance of each criterion with the intended goal; (ii) Participation of all organizations and departments involved in preventive decision-making of crisis management (This is useful not only due to the use of various specializations and disciplines but also due to improved cooperation between various crisis management elements); and (iii) Planning to respond to risks while choosing a suitable location for the post-earthquake temporary accommodation (Given that the criteria for selecting a location are determined by the expert in charge of the temporary accommodation process and based on the risks). The decision-making included six criteria. These criteria were selected using the brainstorming method and were based on opinions of crisis management experts of Kurdistan Province organizations. The criteria were determined by combining the identified risks of the temporary accommodation process after the earthquake in the region and the location criteria. In this study, 13 alternative locations were assessed for temporary accommodation after the earthquake. According to the results of the IF-AHP approach, the top five options among the 13 alternatives for the post-earthquake temporary accommodation site in the Sanandaj-Iran include: (i) The alternative A1 is known to be the most suitable site for the post-earthquake temporary accommodation; (ii) The alternative A2 was recognized as the second-best alternative; (iii) The alternative A9 is the third-best suitable place for the temporary accommodation site in Sanandaj; and (iv) The alternative A3 and A11 were ranked fourth and fifth, respectively. It is worth mentioning that this prioritization is carried out based on the stated criteria and their weights as calculated through agreement between crisis management experts of Kurdistan province during this study and might be different for other regions or in studies using different criteria. This is due to the fact that each region has its specific characteristics including climate, city structure, city type, medical centers, etc. Therefore, while the authors believe that the presented method to be applicable and highly recommend its application, it is recommended that the terms and conditions of the study area be carefully considered when selecting criteria for selecting a temporary accommodation site.

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# 6 Apendix

Table 13: Preferential - paired relationship Alternatives with criterion C1 (staying far from faults, streams and other natural hazards)

| | A1 | | A2 | | A3 | | A4 | | A5 | | A6 | | A7 | | A8 | | A9 | | A10 | | A11 | | A12 | | A13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alternatives* | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A5 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A7 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A8 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A9 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A10 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A11 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A12 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A13 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

Table 14: Preferential - paired relationship Alternatives with criterion C2 (Appropriate ground gradient)

| | A1 | | A2 | | A3 | | A4 | | A5 | | A6 | | A7 | | A8 | | A9 | | A10 | | A11 | | A12 | | A13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alternatives* | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.05 | 0.9 | 0.1 | 0.8 | 0.05 | 0.9 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.05 | 0.9 | 0.05 | 0.9 | 0.05 | 0.9 | 0.1 | 0.8 | 0.5 | 0.5 |
| A2 | 0.9 | 0.05 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 | 0.9 | 0.05 |
| A3 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.5 | 0.5 | 0.8 | 0.1 |
| A4 | 0.05 | 0.5 | 0.5 | 0.5 | 0.8 | 0.8 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 | 0.9 | 0.05 |
| A5 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.5 | 0.5 | 0.8 | 0.1 |
| A6 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 |
| A7 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.5 | 0.5 | 0.8 | 0.1 |
| A8 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.8 | 0.1 | 0.8 | 0.1 |
| A9 | 0.9 | 0.05 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 | 0.9 | 0.05 |
| A10 | 0.9 | 0.05 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 | 0.9 | 0.05 |
| A11 | 0.9 | 0.05 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 0.1 | 0.9 | 0.05 |
| A12 | 0.8 | 0.1 | 0.1 | 0.8 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.5 | 0.5 | 0.8 | 0.1 |
| A13 | 0.5 | 0.5 | 0.05 | 0.9 | 0.1 | 0.8 | 0.05 | 0.9 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.1 | 0.8 | 0.05 | 0.9 | 0.05 | 0.9 | 0.05 | 0.9 | 0.1 | 0.8 | 0.5 | 0.5 |

Table 15: Preferential - paired relationship Alternatives with criterion C3 (Existence of necessary infrastructure)

| | A1 | | A2 | | A3 | | A4 | | A5 | | A6 | | A7 | | A8 | | A9 | | A10 | | A11 | | A12 | | A13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alternatives* | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 |
| A4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.3 | 0.6 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 |
| A8 | 0.2 | 0.7 | 0.2 | 0.7 | 0.3 | 0.6 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 |
| A9 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 |
| A10 | 0.2 | 0.7 | 0.2 | 0.7 | 0.3 | 0.6 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 |
| A11 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A12 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A13 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.7 | 0.2 | 0.6 | 0.3 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

Table 16: Preferential - paired relationship Alternatives with criterion C4 (Availability)

| *Alternatives* | *A1* | | *A2* | | *A3* | | *A4* | | *A5* | | *A6* | | *A7* | | *A8* | | *A9* | | *A10* | | *A11* | | *A12* | | *A13* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A2 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A4 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A7 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A8 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A9 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A10 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A11 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A12 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A13 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

Table 17: Preferential - paired relationship Alternatives with criterion C5 (Proximity to service centers)

| *Alternatives* | *A1* | | *A2* | | *A3* | | *A4* | | *A5* | | *A6* | | *A7* | | *A8* | | *A9* | | *A10* | | *A11* | | *A12* | | *A13* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.3 | 0.5 | 0.5 | 0.7 | 0.2 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.3 | 0.5 | 0.5 | 0.7 | 0.2 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.3 | 0.5 | 0.5 | 0.7 | 0.2 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A4 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.3 | 0.5 | 0.5 | 0.7 | 0.2 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.3 | 0.6 | 0.2 | 0.7 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.2 | 0.7 | 0.5 | 0.5 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 |
| A8 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A9 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.6 | 0.3 | 0.7 | 0.2 | 0.6 | 0.3 | 0.5 | 0.5 | 0.7 | 0.2 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 |
| A10 | 0.2 | 0.7 | 0.2 | 0.7 | 0.2 | 0.7 | 0.3 | 0.6 | 0.2 | 0.7 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.2 | 0.7 | 0.5 | 0.5 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 |
| A11 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A12 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| A13 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | 0.5 | 0.5 | 0.6 | 0.3 | 0.5 | 0.5 | 0.3 | 0.6 | 0.6 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

Table 18: Preferential - paired relationship Alternatives with criterion C6 (Admission capacity)

| *Alternatives* | *A1* | | *A2* | | *A3* | | *A4* | | *A5* | | *A6* | | *A7* | | *A8* | | *A9* | | *A10* | | *A11* | | *A12* | | *A13* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ | $\mu_A$ | $\nu_A$ |
| A1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.9 | 0.05 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.7 | 0.2 | 0.05 | 0.9 | 0.8 | 0.1 | 0.9 | 0.05 |
| A2 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.2 | 0.7 | 0.5 | 0.5 | 0.7 | 0.2 |
| A3 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.7 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 |
| A4 | 0.05 | 0.9 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.05 | 0.9 | 0.2 | 0.7 | 0.2 | 0.7 | 0.1 | 0.8 | 0.5 | 0.5 | 0.2 | 0.7 | 0.5 | 0.5 |
| A5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.2 | 0.7 | 0.5 | 0.5 | 0.7 | 0.2 |
| A6 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.7 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 |
| A7 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.9 | 0.05 | 0.8 | 0.1 | 0.8 | 0.1 | 0.5 | 0.5 | 0.8 | 0.1 | 0.8 | 0.1 | 0.3 | 0.6 | 0.05 | 0.9 | 0.8 | 0.1 | 0.9 | 0.05 |
| A8 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.7 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 |
| A9 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.7 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 |
| A10 | 0.2 | 0.7 | 0.6 | 0.3 | 0.6 | 0.3 | 0.8 | 0.1 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.5 | 0.5 | 0.8 | 0.1 | 0.6 | 0.3 | 0.8 | 0.1 |
| A11 | 0.05 | 0.9 | 0.7 | 0.2 | 0.2 | 0.7 | 0.5 | 0.5 | 0.7 | 0.2 | 0.2 | 0.7 | 0.05 | 0.9 | 0.7 | 0.2 | 0.2 | 0.7 | 0.1 | 0.8 | 0.5 | 0.5 | 0.2 | 0.7 | 0.5 | 0.5 |
| A12 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.6 | 0.7 | 0.2 | 0.5 | 0.5 | 0.7 | 0.2 |
| A13 | 0.05 | 0.9 | 0.2 | 0.7 | 0.2 | 0.7 | 0.5 | 0.5 | 0.2 | 0.7 | 0.2 | 0.7 | 0.05 | 0.9 | 0.2 | 0.7 | 0.2 | 0.7 | 0.1 | 0.8 | 0.5 | 0.5 | 0.2 | 0.7 | 0.5 | 0.5 |

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# A combination risk-based approach to post-earthquake temporary accommodation site selection: A case study in Iran

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## رویکرد ترکیبی مبتنی بر ریسک برای انتخاب محل اسکان موقت پس از زلزله: مطالعه موردی در ایران

**چکیده**. یکی از مهم‌ترین مسائل پس از بلایای طبیعی در هر کشور، فراهم نمودن اسکان موقت حادثه‌دیدگان است. توسعه‌دهندگان برنامه‌های پیشگیرانه نیز با عدم قطعیت‌های فراوانی در این قسمت از مدیریت بحران روبرو هستند. علاوه براین، موضوع عدم قطعیت در مجموعه ریاضیات کلاسیک تعریف نشده‌است. بنابراین، استفاده از مجموعه‌های فازی شهودی، که ملاحظات مربوط به عدم قطعیت را در بر می‌گیرد، می‌تواند در برنامه‌ریزی‌های پیشگیرانه و به منظور مقابله با ریسک‌های احتمالی مفید باشد. هدف اصلی این مطالعه، ارائه یک روش ترکیبی با بهره‌گیری از مدیریت ریسک و فرآیند تحلیل سلسله مراتبی فازی شهودی (IF-AHP) برای مکانیابی و اولویت‌بندی محل‌های اسکان موقت پس از زلزله است. بدین منظور شهر سنندج در استان کردستان-ایران به عنوان نمونه موردی برای انجام این روش انتخاب شد. در ابتدا برای تعیین ۶ معیار تصمیم‌گیری از پانل‌های طوفان فکری و با حضور ۹ کارشناس مدیریت بحران از سازمان‌های مختلف استان کردستان استفاده شد. این معیارها بر اساس ریسک‌های مشخص شده در فرآیند اسکان موقت پس از وقوع زلزله در منطقه و معیارهای استخراج شده از مطالعات قبلی در مورد محل‌های اسکان موقت انتخاب شده‌اند. همچنین در این مطالعه، ۱۳ فضای عمومی مختلف شهری به عنوان گزینه‌های احتمالی برای انتخاب محل اسکان در نظر گرفته شدند. مقایسه زوجی معیارها بر اساس هدف و مقایسه زوجی گزینه‌های جایگزین اسکان موقت بر اساس هر معیار توسط متخصصان و با استفاده از مجموعه‌های فازی شهودی انجام شد. در نهایت، از فرآیند IF-AHP برای تعیین اولویت هر یک از گزینه استفاده گردید.