Developing a Hybrid Risk Assessment Method for Prioritizing the Critical Risks of Temporary Accommodation Sites After Destructive Earthquakes

Abstract

One of the most critical challenges in preventive planning and disaster management is the multitudinous uncertainties involved in decision-making. Previous studies showed the usefulness of intuitionistic fuzzy sets for considering uncertainties in decision-making process. Hence, the current study aims to present a combined model using Intuitionistic Fuzzy Sets and Risk Failure Mode and Effects Analysis (IF-RFMEA) to determine and prioritize the critical risks of temporary accommodation sites after destructive earthquakes in Iran and bridge the existing research gaps in the literature. To this end, 49 temporary accommodation common risks after earthquakes were identified via a desktop literature survey. Then, the fuzzy Delphi technique was used to determine the top 20 critical risks with the highest priorities according to experts for evaluation using the proposed method. The Delphi panel members included 18 experts with relevant hands-on experience in crisis management and risk management. Finally, 20 identified critical risks were evaluated using three criteria of the probability of occurrence, level of effect, and detection value using the IF-RFMEA technique. According to the analytical results, infectious disease challenges, mental and psychological disorders among survivors, and unemployment and closing of businesses were the most critical risks after earthquakes in the region. The proposed method of analysis can reduce uncertainties and use the main criteria of the probability of occurrence, effect, and detection value to improve risk assessment results and analysis in relation to the critical risks of temporary accommodation sites after destructive earthquakes.

Keywords: Earthquakes; Risk Assessment; Intuitionistic Fuzzy Sets; RFMEA; Iran.

1. Introduction

Hazards such as tsunamis, flooding, and earthquakes are almost a yearly occurrence that brings several human losses, disruption of the ecosystem, and financial damages. According to the United Nations Office for Disaster Risk Reduction (UNISDR) reports, the average annual damages due to hazards show an increasing trend. Furthermore, these damages have disproportionally affected developing countries and low-income communities (Afify et al., 2016). According to Kreibich et al. (2014), the frequency and magnitude of such hazards lie in the vulnerability of such cities or landscapes to such hazards.

Large-scale hazards (disasters) often lead to significant damage to buildings, threatening the occupants. Despite concerted efforts to decrease the effects of hazards, the destruction of houses and the ecosystem is still a common risk with the resultant displacement of people (Félix et al., 2015). As a result, housing reconstruction plans, including providing temporary accommodations, play an essential role in hazard relief efforts (Félix et al., 2013). Temporary accommodation is one of the crucial but controversial parts of hazard relief efforts. People who have lost their homes require access to private and secure locations to restart their daily lives at the first possible opportunity after the hazards (Davidson et al., 2007). Identifying the risks of the temporary post-earthquake resettlement process can help develop a hazard prevention plan. It can also help promote various aspects of sustainable development, including social, environmental, and economic factors (Dabiri et al., 2021).

Urban planning variables should consider providing suitable temporary accommodation solutions. However, these planning variables can, in turn, result in a large number of uncertainties (Dabiri et al., 2020). Therefore, it is necessary to assess the various risks and uncertainties regarding the temporary accommodations of survivors before the hazard. Increasing the probability and effects of positive events while decreasing the possibility and impact of negative ones is one of the main goals of risk management (Sarvari et al., 2019a). Risk management aims to provide a comprehensive and orderly method to identify, analyze, and answer any risks against achieving project aims (PMI, 2017). Project risk management is a logical chain of methods planned and implemented by executive operators to prevent results and maintain certain levels of project conditions (including time, cost, and quality) (Rodrigues-da-Silva et al., 2014).

Therefore, risk management is a significantly multidisciplinary field that involves the input of experts and stakeholders from several disciplines (Aven & Zio, 2014). Several assessment methods have been developed in the extant literature and practice to manage risk resulting from hazards. For instance, the World Bank developed a spatial map of risk indexes (Gallina et al., 2016) which captures the mortality and other potential losses from hazards like flood and earthquakes. However, the tool lacks detailed information on the likely causes and effects of the hazards. Other tools include the HAZUS GIS-based tool (FEMA, 2011), which is unsuitable for multi-hazards assessment and RiskScape by GNS Science and NIWA (Schmidt et al., 2011).

Also, apart from these qualitative methods, there have been quantitative approaches to multi-risk risk assessment for hazards. The MATRIX and ESPON HAZARD are typical hazard risk assessments that use the Delphi questionnaire surveys to rank the importance of the analyzed hazards (Farrokh and Zhongqiang, 2013). The quantitative approach integrates the knowledge of end-users with the expertise of professionals in the multi-risk assessment process. Other quantitative methods in the extant literature include using Bayesian networks, probabilistic, and weighted sum approaches (Greiving et al., 2006; Marzocchi et al., 2012; Farrokh and Zhongqiang, 2013). Moreover, experts' opinions are subjective with resultant uncertainty and ambiguity in risk management decisions. Hence, according to Olawumi and Chan (2022), fuzzy logic can be used to objectively evaluate the expert's opinions and reduces or even eliminate these uncertainties with the benefits of a better and more accurate risk assessment approach. In classical mathematics, a statement's value or truth is 1 for true and 0 for false statements (Dabiri et al., 2020; Sadeghi et al., 2021). Zadeh (1965) introduced fuzzy sets to solve the problems of classic sets. In fuzzy logic, the truth of a statement is an actual number in the range of [0, 1]. This value is known as a statement's "degree of correctness."

One of the essential characteristics of risk-based preventive planning for temporary accommodation after earthquakes is the large number of uncertainties the planners face. Studies indicate that intuitionistic fuzzy sets (IFS) can consider these uncertainties (Dabiri et al., 2020). These intuitionistic fuzzy sets have specific advantages over fuzzy sets in managing ambiguity and uncertainty (Xu & Liao, 2013). In both classic and fuzzy sets, no ambiguity or uncertainty factor is defined. However, intuitionistic fuzzy sets include degrees of membership and lack of membership, and another factor called degree of uncertainty. Thus, using the IFS contribute to preventive measures in risk management by enhancing the accuracy of the assessment results. Risk Failure Mode and Effects Analysis (RFMEA) is an advanced risk tool that is simple and intuitionistic. It is based on the well-known FMEA technique modified for project risk management. With minor changes to the FMEA standard, the RFMEA method provides more value to the risk management process. RFMEA extends the concept of a simple risk rating based solely on probability of occurrence and level of impact by adding a detection feature to a risk event (Carbone and Tippett, 2004).

Therefore, the current study aims to provide a combined method using Risk Failure Mode and Effects Analysis and IFS to prioritize risks during the temporary accommodation after earthquakes by integrating literature review and RFMEA intuitionistic fuzzy set methods. This IF-

RFMEA technique considers uncertainties while using the probability of occurrence, effect, and detection value criteria to improve risk assessment results.

2. Literature Review

2.1 Temporary Accommodations after Earthquakes

The formation of government hazard management organizations is one of the important actions during destructive earthquakes. This proactive approach to hazard management is termed disaster risk reduction by Innocenti and Albrito (2011). Hazard management is a multidisciplinary topic and can include various fields, including social sciences, medicine, engineering, and many other areas, to evaluate important matters in unpredictable events (Bakos, 2018). Also, Innocenti and Albrito (2011) and Gamper and Turcanu (2009) discuss the coordinating and participatory role that government departments and individuals can play in managing the risks from hazards. Hazards management includes three states: before the hazard (prevention and preparation), during the hazard (reaction), and after the hazard (learning and revision) (Coombs and Laufer, 2018). Hazard management is a set of predesigned processes used before, during, and after hazards to prevent or mitigate their effects and damages (Nikbakhsh and Farahani, 2011).

Usually, there are three types of necessary accommodations after the occurrence of a destructive earthquake in a populated region: (i) emergency accommodations such as tents; (ii) temporary accommodations, which are usually built for 1 to 2 years of occupancy and (iii) permanent housing or accommodations (Forouzandeh et al., 2008). The construction of emergency and temporary accommodations after earthquakes uses up large amounts of resources in a short time (Seike et al., 2019). This means that the problem of initial, temporary, and permanent accommodations for victims after an earthquake is one of the most significant challenges in hazard management (Li et al., 2019). According to the Disaster Relief Act of Japan, the maximum usage duration of temporary accommodation locations and units is two years. However, studies have shown that some survivors have used these sites for more than seven years, especially after the earthquake of 2011 in eastern Japan (Seike et al., 2019).

The design of temporary accommodation sites must be considered during decisions regarding temporary accommodation after earthquakes to ensure that these sites meet the actual needs of the disaster victims. Therefore, architecture and design are also part of the solution. This process must start before the disaster and not afterwards by assigning sufficient time and a multidisciplinary team including humanities experts and technical expertise in various fields, production companies, and other necessary participants (Bris and Bendito, 2019). Assessment of multiple risks and challenges after disasters can facilitate disaster relief and temporary accommodation efforts.

2.2 Temporary Accommodation Risks and Challenges after Earthquakes

Social developments have always been about adapting and responding to challenges, including hazards and their risks. The ability to recognize and deal with such challenges tends to define each society (Accastello et al., 2021). Various methods are used in defining risk. These methods are primarily empirical and are based on previous studies. Risk identification depends on the skill and judgment of the key personnel in projects, and the project team's experiences can be a valuable source for risk identification (PMI, 2017). ISO Norm 31000 on risk management expresses risk as the "effect of uncertainty on objectives". Per ISO Norm, risk can be evaluated in terms of its sources, potential events, consequences, and the likelihood of occurrence (GIZ and EURAC, 2014; ISO, 2018).

The risk identification process is dependent on various factors such as previous experiences, personal preferences, and information available to experts. If the personnel have no personal experience in similar projects, gathering individuals with suitable expertise and qualifications in the required fields can be helpful in a brainstorming session. A good example is the participatory approach discussed by Gamper and Turcanu (2009). However, risk identification is a complex activity since risks are different in different projects. There are no standardized and precise methods for risk identification in projects, including construction projects (Hlaing et al., 2019). Sound and correct judgment is required for precise risk identification. Increasing the confidence during the risk identification step can improve the success of subsequent risk management steps. Various methods can be used for risk identification and can be divided into three main categories: identification process carried out solely by a risk assessor based on personal experiences; risk identification through interviews with leading project team members and their qualifications; and risk identification through brainstorming sessions with the presence of all interested parties (Chapman, 1998 & Gamper and Turcanu, 2009).

However, every project is unique and similar risks might not be present in a similar project. In practice, a checklist is an essential tool used during risk identification (Wood and Ellis, 2003; Valipour et al., 2018; Siraj and Fayek, 2019; Sarvari et al., 2019b). Researchers have evaluated the temporary accommodation process after earthquakes and its challenges and risks to decrease financial and human damages and use the lessons learned from previous disasters. Furthermore, official organizations and experts have provided guidelines to improve the temporary accommodation process after possible earthquakes. For example, in a study, Johnson (2007) evaluated temporary accommodation strategic plans after disasters. The author analyzed the strengths and weaknesses of temporary accommodations after the Marmara earthquake of Turkey (1999), Kobe earthquake of Japan (1995), Kalamata earthquake of Greece (1986), and Mexico City earthquake of Mexico (1985), and Feriolo earthquake of Italy (1976). The study indicated that an orderly and preventive strategy is essential in overcoming temporary accommodation challenges after the disaster. Dabiri et al. (2020) presented a combined method for risk management and intuitionistic fuzzy analytical hierarchy process (IF-AHP) for locating and prioritizing temporary accommodation locations after earthquakes. To this end, they selected 13 public areas in the Sanandaj city of Iran and prioritized each space for use in preventive disaster management plans.

Yüksel and Hasircl (2012) evaluated the psychological and physical expectations of earthquake victims regarding temporary accommodations. They presented recommendations to improve temporary accommodations after earthquakes, including psychological factors and personal needs. Moreover, Zare (2011) highlighted factors such as lack of integrated management based on local potentials, legal disagreements resulting from the earthquake, and artificial increase in the local population after the quake due to many volunteers as the main challenges after an earthquake. Perrucci et al. (2016) investigated the barriers to constructing stable temporary accommodations after disasters and essential factors in Haiti. They reported that attention to the preparation of suitable plans and concerns for the environment is crucial for preventing damages. In another study, Bettemir (2016) investigated the challenges of temporary accommodation in past earthquakes. Accordingly, the paper provided an effective and efficient management strategy for repairing damaged buildings and reducing housing problems after destructive earthquakes. Proffered solutions included a decrease in costs, time, and environmental effects.

Moreover, Rezaei and Tahsili (2018) identified 20 main factors of urban vulnerability and categorized them into three main categories. The study used the AHP method to prioritize the identified factors. Ahadnejad-Reveshty et al. (2012) proposed a similar approach for determining temporary accommodation locations. Accordingly, 14 natural and human factors and the AHP technique were used to choose suitable temporary accommodation locations. The study's findings indicated that the lack of sufficient spaces such as parks and open urban areas for accommodating earthquake victims was the most critical factor in the investigated region and was more severe in older city regions. Also, Ishii et al. (2015) reported that ignoring living areas during the design and construction of temporary accommodations can negatively affect the physical performance of individuals, especially the elderly. Abulnour et al. (2014) proposed five guidelines of risk management, damage management, event management, resource management, and hazard effects mitigation as the main strategies to provide a better hazard and accommodation management process in Egypt. Several other researchers have used multivariable decision-making methods. Their combination with other methods such as GIS optimized locating temporary accommodation spaces for earthquake victims in urban areas (Ahadnejad-Reveshty et al., 2012).

Asefi and Farokhi (2018) evaluated the earthquake victims' satisfaction regarding temporary accommodations in Iran. The study introduced social, cultural, physical, technical, technological, and construction factors for this evaluation. Victims mentioned various temporary accommodation challenges, including security factors, privacy, recreational areas, compatibility with culture and lifestyle, hygiene, internal spaces, facilities and energy, hot and cold weather challenges, health facilities, wind, maintenance, and utilities. Other challenges during temporary accommodation include lack of compatibility between tents and long-term accommodation needs of the victims, lack of suitable space for livestock, problems in the distribution of tents, lack of access to regular construction facilities, prioritizing reconstruction of infrastructure over economic areas, lack of control over building materials' prices and the resulting inflation in the market, lack of planning, lack of responsibility and lack of warehousing for properties recovered from the wreckage (Khorshidian, 2012).

A desktop review of extant studies shows that temporary accommodation after earthquakes has been among the 'hot topics' in hazard management. Several studies identify the risks and challenges of temporary accommodations. In the current research regarding evaluating temporary accommodation risks for future earthquakes in Iran, 30 different temporary accommodation challenges were first identified from previous studies, as presented in Table 1. However, previous studies have only used qualitative approaches for categorizing temporary accommodation risks and challenges. A few that used quantitative methods utilized approaches that failed to deal with expert subjective opinions. This imprecise risk identification can negatively affect risk assessment and management processes. Therefore, the current study aims to address the existing gap in the literature by providing a quantitative IF-RFMEA technique for temporary accommodation risk assessment after earthquakes.

Table 1. The challenges of temporary accommodation in post-earthquake

S/N	Challenges	References
1	Difficulties of displacements' psychological (fear of the future, worry, humiliation, etc.)	Va´Zquez et al. (2005); Yuksel and Hasirci (2012); Tierney et al. (2004); Tomioka (1997); Comerio (1998)
2	Outbreak of disease	Raviola et al. (2013); Perrucci et al. (2016); Uddin (2016)
3	Prolonged the temporary accommodation period	Perrucci et al. (2016); Johnson (2007); Bettemir (2016); Omidvar and Binesh (2012); Tomioka (1997); Comerio (1998)
4	Lack of information regarding the people affected in a short time (number, etc.)	Bettemir (2016); Johnson (2007)
5	Incorrect prioritization and estimation of the requirements	Félix et al. (2015); Bettemir (2016)
6	The difficulty of supplying drinking water	Yuksel and Hasirci (2012); Cordero-Reyes et al. (2017)
7	Lack of equal access to humanitarian aid in different camps	Dabiri et al. (2021)
8	Prolongation of deployment time of planned accommodation, such as prefabricated structures Conex boxes	Bettemir (2016)
9	Earthquake victims' resistance to evacuating temporary accommodation camps for various reasons	Bettemir (2016)
10	Fire problem	Yuksel and Hasirci (2012); Bettemir (2016); Hui (2012)
11	Challenge of sewage disposal	Bettemir (2016); Omidvar and Binesh (2012)
12	The electricity and lighting difficulties	Bettemir (2016); Yuksel and Hasirci (2012)
13	the challenge of the permanent buildings insurance, as a result, lengthening the reconstruction time/temporary accommodation	Bettemir (2016)
14	The occupation difficulties and challenges of victims	Félix et al. (2015); Tierney et al. (2004)
15	lack of proper infrastructure (road, water and wastewater, electricity, etc.)	Félix et al. (2015)
16	Lack of formal services for psychological health	Raviola et al. (2013)
17	Inaccessibility to proper medical facilities	Félix et al. (2015); Tomioka (1997); Comerio (1998)
18	Lack of attention to local culture	Félix et al. (2015)

S/N	Challenges	References
19	Environmental degradation	Félix et al. (2015)
20	Vegetation degradation	Félix et al. (2015)
21	Soil degradation	Félix et al. (2015)
22	Earthquake victims' social isolation	Félix et al. (2015)
23	Incidence of strongly rains and flood	Asefi and Farrokhi (2018); Yuksel and Hasirci (2012)
24	Lack of medical and psychiatric infrastructure	Raviola et al. (2013); Tomioka (1997) Comerio (1998)
25	Failure to consider local facilities in the relief program	Raviola et al. (2013)
26	Disorganization and fragmentation of NGOs in presenting health care services	Raviola et al. (2013)
27	Accumulation of waste from temporary settlement collection	Félix et al. (2015)
28	Problems caused by extremes of heat and cold	Bettemir (2016); Asefi and Farrokhi (2018); Yuksel and Hasirci (2012); Tierney et al. (2004)
29	Loss of social capital (social communication changes in society)	Dabiri et al. (2021)
30	The issues of education/social health/economic	Tierney et al. (2004)
31	The difficulties of health spaces (toilet, bathroom, etc.)	Asefi and Farrokhi (2018); Yuksel and Hasirci (2012); Tierney et al. (2004)
32	Facility maintenance issues	Asefi and Farrokhi (2018); Tierney et al. (2004)
33	Privacy related issues	Cordero-Reyes et al. (2017); Asefi and Farrokhi (2018)
34	The challenge of moving people from temporary accommodation camps to permanent housing after the residency period	Johnson (2007)
35	The challenge of choosing the type of shelter	Yuksel and Hasirci (2012); Tierney et al. (2004); Hui (2015); Omidvar and Binesh (2012); Hikichi et al. (2017); Perrucci et al. (2016); Asefi and Farrokhi (2018)
36	Lack of comfort/sense of belonging to the place of accommodation	Yuksel and Hasirci (2012)
37	Inadequacy of space in the shelter	Omidvar and Binesh (2012) Asefi & Farrokhi (2018)
38	unfair shelter distribution	Omidvar and Binesh (2012)
39	Refusal of people to stay in temporary accommodation camps	Omidvar and Binesh (2012)

S/N	Challenges	References
40	Environmental health problem	Cordero-Reyes et al. (2017); Asefi and Farrokhi (2018)
41	Waste disposal issue	Cordero-Reyes et al. (2017)
42	The difficulty of storing perishable food	Cordero-Reyes et al. (2017)
43	The issue of non-native immigrants	Uddin (2016)
44	Non-natives immigrants have more suitable facilities than earthquake victims	Uddin (2016)
45	Feeling less secure and accessing fewer facilities for women than men	Uddin (2016)
46	the high population density in camps with more facilities due to differences in the presenting services between camps	Uddin (2016)
47	Demand for urban camps due to the difference in presenting services between rural and urban camps	Uddin (2016)
48	The difficulties of diet change for people	Uddin (2016)
49	The issue of service organizations' coordination	Tierney et al. (2004)

3. Research methods

The current study aims to provide a combined model using Intuitionistic Fuzzy Sets and Risk Failure Mode and Effects Analysis (IF-RFMEA) to identify and prioritize the critical temporary accommodation risks after destructive earthquakes. To this end, the temporary accommodation risks in Table 1 were identified through a comprehensive literature review. These risks were then reviewed and assessed by conducting a brainstorming session with 18 experts in crisis management and hazard management. Based on the context of the study area, the critical temporary accommodation risks after destructive earthquakes were selected for the risk assessment procedure. More so, via a structured questionnaire survey and a Delphi panel of 18 experts, the probability of occurrence and level of impact of each of identified critical risks were measured and were determined.

After two rounds of the Delphi survey, the necessary convergence of the most critical risk factors between the experts were achieved as adopted in previous Delphi technique studies (*such as* Olawumi & Chan, 2018; Wachinger et al., 2013). The diagnostic value of each of these 20 critical risks was determined through the brainstorming method with the presence of the same 18

Delphi experts. Finally, 20 critical risks were determined and evaluated using the IF-RFMEA technique based on three criteria: the probability of occurrence, level of impact, and detection value. In this study, the intuitionistic fuzzy linguistic variables were applied to analyze the identified critical risks. Figure 1 shows the process of the proposed IF-RFMEA technique applied in this study.

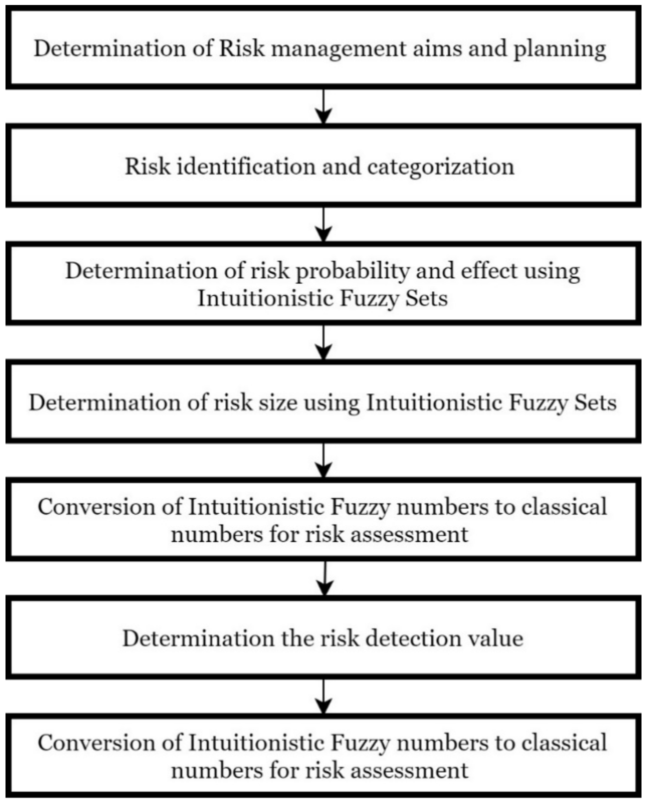

Figure 1. The process of the proposed IF-RFMEA technique

The participants of the Delphi panel included 18 experts working as members of the crisis management team of general administrations and government departments in the Kurdistan province of Iran. They were also responsible for representing their respective organizations in the general administration of the provincial crisis and hazard management. In addition, they have gained relevant hands-on experience of participating and providing relief in disasters such as floods and earthquakes. The Delphi experts have earned at least a bachelor’s degree and hence they could provide genuine and representative opinions and observations to the current study.

3.1 Intuitionistic Fuzzy Sets

In order to present the intuitionistic fuzzy sets, Atanassov (1986) added another actual number from the range of [0,1] to the fuzzy definition. This value is known as a statement's "degree of incorrectness". Therefore, the statement p can be assigned two values of μ(p) and ν(p) so that:

$\mu(p) + \nu(p) \leq 1$

An Intuitionistic Fuzzy Set such as A from the reference set X is defined as follows:

$A = \{< x. \mu_A(x). \nu_A(x) > | x \in X\}$

$\mu_A: X \to [0.1]$

$\nu_A: X \to [00 .1]$

$\forall x \in X: 0 \leq \mu_A(x) + \nu_A(x) \leq 1$

The actual values of μA(p) and νA(p) belonging to the range of [0,1] are known as the degrees of membership and lack of membership of x for the set A, respectively. Each A' set is a particular state of Intuitionistic Fuzzy Set A (Pasha and Fatemi, 2006). For Intuitionistic Fuzzy Set A' from X, it can be said that:

$A' = \{< x. \mu_{A'}(x). 1 - \mu_{A'}(x) > | x \in X\},$

$\nu_{A'}(x) = 1 - \mu_{A'}(x)$

$\pi_{A'}(x) = 1 - \mu_{A'}(x) - \nu_{A'}(x)$

In which, $\pi_{A'}(x)$ is the Intuitionistic factor of x in A' and is equal to the degree of uncertainty regarding x in A'. It is clear that for every x belonging to X, we have:

$0 \leq \pi_{A'}(x) \leq 1$

According to the studies regarding the comparison of two Intuitionistic fuzzy values (Xu and Lia, 2013; Ejegwa et al., 2014):

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

n = 1, 2, 3, ... , k = 1, 2, 3, …

in which μ_{ik} is the degree of membership, v_{ik} is the degree of lack of membership and π_{ik} is the uncertainty:

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

$$r_{ik} \otimes r_{tl} = (\mu_{ik}\mu_{tl} . \; v_{ik} + v_{tl} - v_{ik}v_{tl}) \quad (2)$$

$$\lambda r_{ik} = \left(1 - (1 - \mu_{ik})^{\lambda}. v_{ik}^{\lambda}\right), \quad \lambda > 0 \quad (3)$$

$$(r_{ik}^{\lambda}) = (\mu_{ik}^{\lambda} . 1 - (1 - v_{ik})^{\lambda}), \quad \lambda > 0 \quad (4)$$

Interval-valued intuitionistic fuzzy sets (IVIFS) are an effective and convenient tool for constructing advanced multi-attribute group decision-making (MAGDM) models. Furthermore, this method can help deal with uncertainty in developing support systems for complex decision-making (Jia and Zhang, 2019).

3.2 Risk Failure Mode and Effects Analysis (RFMEA)

Failure Mode and Effects Analysis (FMEA) was introduced as a design method with reliability and safety requirements (Sankar and Prabhu, 2001; Santos and Cabral, 2008). Carbone and Tippett (2004) then introduced the Risk Failure Mode and Effects Analysis (RFMEA) technique (Santos & Cabral, 2008). Increased emphasis on imminent risks, prioritization of planning for possible risks, improved team participation in the risk management process, and development of risk improvement controls are among the advantages of the RFMEA technique (Carbone and Tippett, 2004).

Triple factors used in the RFMEA technique for risk prioritization include the probability of risk occurrence, the effect of risk in case of occurrence, and the risk discovery coefficient. The product of all these values for each risk is used to determine the priority of that risk. Each risk is assigned a Risk Priority Number (RPN), and risks with larger RPN values have a higher priority (Carbone and Tippett, 2004). RPN value is determined as follows: RPN = (probability of occurrence × severity × detection value).

The coefficient or detection value includes identifying and tracking the risk and sufficient time for creating a suitable plan for risk management (Carbone and Tippett, 2004). The risk detection coefficient or value is between 1 to 10, with 1 being the best and 10 being the worst condition (Shariati S, 2014; Mohamadinejad et al., 2019). Table 2 shows the values of risk detection coefficients.

Table 2. Guidelines for determination of risk detection value (Carbone and Tippett, 2004)

Identification method	Risk detection value
There are no known detection methods available that can be used in a suitable time frame to warn us regarding the risk and provide us with sufficient time for planning for possible conditions.	9 or 10
The detection method is unreliable or uncertain, or the effectiveness of the method for timely identification is unknown.	7 or 8
The detection method has mediocre effectiveness.	5 or 6
The detection method has relatively high effectiveness.	3 or 4

Identification method	Risk detection value
The detection method is significantly effective and can identify the risk with sufficient time to react.	1 or 2

4. Discussion of analytical results

The combined Risk Failure Mode and Effects Analysis and Intuitionistic Fuzzy Sets model (IF-RFMEA) was used to identify and prioritize 20 critical risks for temporary accommodation after the earthquakes. As can be seen in Figure 1, this process is carried out in 6 steps.

4.1 Risk identification

Based on a review of previous studies, 49 potential risks and challenges were identified in past earthquakes. Then, through two rounds of the Delphi survey involving 18 experts and specialists of the crisis management team, 20 critical risks pertaining to the study area context were selected for quantitative assessment and prioritization. The Delphi expert team identified the critical risks taking into account the conditions in the study area. Table 3 shows the critical risks identified by the Delphi panel.

Table 3. Critical risks in the temporary accommodation process

Risk description	Risk Code
Challenge of hot and cold weather	R_1
Challenge of wastewater disposal	R_2
Incidence of strong rains and flood	R_3
Challenge of waste disposal	R_4
Mental health problems among survivors	R_5
Unemployment and damage and closure of businesses	R_6
Lack of insurance for permanent residences of the victims and the resulting lengthy reconstruction and temporary accommodation duration	R_7
Roadblocks due to rain and snow resulting in disruption of relief efforts in winter	R_8
Challenge of infectious diseases	R_9
Challenge of wind and storm	R_{10}
Inadequate accommodation camp location due to failure to pay attention to the relevant criteria for site selection	R_{11}
The water resources accessibility problem	R_{12}
Difficulties in access to fuel	R_{13}
Incompatibility of the shelter type with the duration of accommodation	R_{14}
Inadequate distribution of humanitarian aid and lack of coordination of relevant organizations in this regard	R_{15}
Weakness in shelter distribution (tent etc.)	R_{16}

Risk description	Risk Code
Prolongation of setting the temporary accommodation camp due to lack of shelter provision before the accident	R_{17}
The problem of maintaining the source of income for the earthquake victims during the period of temporary accommodation	R_{18}
Demand for urban camps due to the difference in presenting services between rural and urban camps	R_{19}
Differences in the type of shelters offered to people and creating a sense of discrimination	R_{20}

4.2 Determination of the probability of occurrence and level of effect of risks based on Intuitionistic Fuzzy Sets

Since linguistic variables can be interpreted differently by different individuals, in this study, and to create a uniform process in experts' judgments regarding the probability and effects of risks, an Intuitionistic Fuzzy Set of (μA, νA) was employed. In this set, μA is the degree of membership, and νA shows the degree of non-membership of each item. Table 4 shows the Intuitionistic Fuzzy variables used to determine the probability and effect of risks. Table 5 shows the expert's opinions regarding the likelihood and impact of risks based on Intuitionistic Fuzzy Sets.

Table 4. Linguistic and Intuitionistic Fuzzy variables

Linguistic variable	Intuitionistic Fuzzy Numbers
Absolutely small	(0.00, 1.00)
Extremely low	(0.05, 0.9)
Very low	(0.1, 0.8)
Low	(0.2, 0.7)
Somewhat low	(0.3, 0.6)
Average	(0.5, 0.5)
Somewhat high	(0.6, 0.3)
High	(0.7, 0.2)
Very High	(0.8, 0.1)
Extremely High	(0.9, 0.05)
Absolutely large	(1.00, 0.00)

Table 5. Expert's perception of the critical risks

Code	**Risk Description**	**Probability of Occurrence**		**Level of Effect**	
		μ_A	ν_A	μ_B	ν_B
R_1	Challenge of hot and cold weather	Very high		Very high	
		0.8	0.1	0.8	0.1
R_2	Challenge of wastewater disposal	Very high		High	
		0.8	0.1	0.7	0.2
R_3	Incidence of strong rains and flood	Very high		Very high	
		0.8	0.1	0.8	0.1
R_4	Challenge of waste disposal	Very high		High	
		0.8	0.1	0.7	0.2
R_5	Mental health problems among survivors	High		High	
		0.7	0.2	0.7	0.2
R_6	Unemployment and damage and closure of businesses	High		High	
		0.7	0.2	0.7	0.2
R_7	Lack of insurance for permanent residences of the victims and the resulting lengthy reconstruction and temporary accommodation duration	Somewhat high		High	
		0.6	0.3	0.7	0.2
R_8	Roadblocks due to rain and snow resulting in disruption of relief efforts in winter	High		High	
		0.7	0.2	0.7	0.2
R_9	Challenge of infectious diseases	High		Very high	
		0.7	0.2	0.8	0.1
R_{10}	Challenge of wind and storm	High		High	
		0.7	0.2	0.7	0.2
R_{11}	Inadequate accommodation camp location due to failure to pay attention to the relevant criteria for site selection	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{12}	The water resources accessibility problem	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{13}	Difficulties in access to fuel	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{14}	Incompatibility of the shelter type with the duration of accommodation	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{15}	Inadequate distribution of humanitarian aid and lack of coordination of relevant organizations in this regard	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{16}	Weakness in shelter distribution (tent etc.)	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{17}	Prolongation of setting the temporary accommodation camp due to lack of shelter provision before the accident	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{18}	The problem of maintaining the source of income for the earthquake victims during the period of temporary accommodation	Very high		Somewhat high	
		0.8	0.1	0.6	0.3
R_{19}	Demand for urban camps due to the difference in presenting services between rural and urban camps	Average		Somewhat high	
		0.5	0.5	0.6	0.3
R_{20}	Differences in the type of shelters offered to people and creating a sense of discrimination	Average		Somewhat high	
		0.5	0.5	0.6	0.3

4.3 Determination of Risk Detection value

Using the risk detection value table (Carbone and Tippett, 2004), the detection value for each risk was determined. The detection values risks were determined according to Table 2 and experts' opinions and are presented in Table 6.

Table 6. The detection values for each of the critical risks

Risk number	Detection method	Detection value
R_1	The detection method has relatively high effectiveness	3
R_2	The detection method has relatively high effectiveness	3
R_3	The detection method has relatively high effectiveness	3
R_4	The detection method has relatively high effectiveness	3
R_5	The detection method has relatively high effectiveness	3
R_6	The detection method has relatively high effectiveness	3
R_7	The detection method has relatively high effectiveness	3
R_8	The detection method has relatively high effectiveness	3
R_9	The detection method has mediocre high effectiveness	5
R_{10}	The detection method has relatively high effectiveness	3
R_{11}	The detection method has relatively high effectiveness	3
R_{12}	The detection method has relatively high effectiveness	3
R_{13}	The detection method has relatively high effectiveness	3
R_{14}	The detection method has relatively high effectiveness	3
R_{15}	The detection method has relatively high effectiveness	3
R_{16}	The detection method has relatively high effectiveness	3
R_{17}	The detection method has relatively high effectiveness	3
R_{18}	The detection method has relatively high effectiveness	3
R_{19}	The detection method has relatively high effectiveness	3
R_{20}	The detection method has relatively high effectiveness	3

4.4 Determination of Risk size based on Intuitionistic Fuzzy Sets

Equation (2) is used to determine RPN. The probably Intuitionistic value is multiplied by the Intuitionistic value of the effect. Table 7 shows the impact of risks based on Intuitionistic Fuzzy Sets.

Table 7. Calculation of Risk Priority Number (RPN) in IF-RFMEA technique

Risk title	Probability of occurrence of risk based on IFS		Level of effect of risk based on IFS		Size of risk based on IFS $r_{ik} \otimes r_{tl}$		Defuzzied risk size number	Detection Value	Risk Priority Number (RPN)
					$\mu_{ik}\mu_{tl}$	$v_{ik} + v_{tl} - v_{ik}v_{tl}$	$M_{G(}\mu, v) = \sqrt{\mu(1-v)}$		
	μ_A	v_A	μ_B	v_B	μ_R	v_R			
R_1	0.8	0.1	0.8	0.1	0.64	0.19	0.720	3	2.16
R_2	0.8	0.1	0.7	0.2	0.56	0.28	0.635	3	1.91
R_3	0.8	0.1	0.8	0.1	0.64	0.19	0.720	3	2.16
R_4	0.8	0.1	0.7	0.2	0.56	0.28	0.635	3	1.91
R_5	0.7	0.2	0.7	0.2	0.49	0.36	0.560	3	1.68
R_6	0.7	0.2	0.7	0.2	0.49	0.36	0.560	3	1.68
R_7	0.6	0.3	0.7	0.2	0.42	0.44	0.485	3	1.46
R_8	0.7	0.2	0.7	0.2	0.49	0.36	0.560	3	1.68
R_9	0.7	0.2	0.8	0.1	0.56	0.28	0.635	5	3.18
R_{10}	0.7	0.2	0.7	0.2	0.49	0.36	0.560	3	1.68
R_{11}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{12}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{13}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{14}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{15}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{16}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{17}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{18}	0.8	0.1	0.6	0.3	0.48	0.37	0.550	3	1.65
R_{19}	0.5	0.5	0.6	0.3	0.3	0.65	0.324	3	0.97
R_{20}	0.5	0.5	0.6	0.3	0.3	0.65	0.324	3	0.97

4.5 Conversion of Intuitionistic fuzzy risk size values to classical numbers

This study used geometrical average and equation 5 to create defuzzied risk size values and convert Intuitionistic fuzzy risk size values to classical numbers (Abdullah et al., 2013).

$$M_{G(}\mu . v) = \sqrt{\mu(1-v)} \qquad (5)$$

4.6 Prioritization of risks

The priority of each risk is determined based on its RPN value. Table 8 shows the preferences for critical risks identified in the current study.

The analysis of the results shows that risks of infectious diseases (R_9), heat and cold weather (R_1), the incidence of strong rains and floods (R_3), and risks regarding wastewater disposal (R_2)

and waste disposal (R_4) as the critical risks of temporary accommodations after earthquakes with the highest priorities. Furthermore, risks of mental health problems among survivors (R_5), unemployment and damage and closure of businesses (R_6), roadblocks due to rain and snow resulting in disruption of relief efforts in winter (R_8), and challenges of wind and storm (R_{10}) all had equal RPN values and were in the fourth place. The findings are similar to a study by Merz and Emmermann (2006) which identified lightning, torrential rain and hail as critical hazards in Germany. A study by Kreibich et al. (2014) expatiated on the EM-DAT (2014) data which characterized extreme temperatures, floods, and earthquakes as the most important hazard in Germany. Though Iran and Germany are of differing climatic conditions, the risks from hazards are very comparable to each other.

The following risks ranked fifth: (i) inadequate accommodation camp location due to failure to pay attention to the relevant criteria for site selection (R_{11}); (ii) the water resources accessibility problem (R_{12}); (iii) difficulties in access to fuel (R_{13}); (iv) incompatibility of the shelter type with the duration of accommodation (R_{14}); (v) inadequate distribution of humanitarian aid and lack of coordination of relevant organizations in this regard (R_{15}); (vi) weakness in shelter distribution (tent etc.) (R_{16}); (vii) prolongation of setting the temporary accommodation camp due to lack of shelter provision before the disaster (R_{17}); and (viii) the problem of maintaining the source of income of the earthquake victims during the period of temporary accommodation (R_{18}). A study by Meyer et al. (2013) affirmed some of the risks identified in this study which they referred to as the cost of hazards. These include' ecosystem services distribution' (which is related to R_{15}), 'production interruption' (R_{13}), 'inconvenience of post-hazard recovery' (R_{17}, R_{14}, R_{16}), 'increased vulnerability of survivors' (R_{15}, R_{11}, R_{18}), 'environmental damage' (R_{12}) among others. Also, Shin and Ji (2021) evidenced some of these risks when examining risks due to hazards in the United States. These include risks such as R_9 and R_5 (Aitsi-Selmi et al., 2016; Hobfoll et al., 2011); R_7, R_{14}, R_{13}, R_{11} and R_{12} (Greenough et al., 2008; Shin and Ji, 2021).

Also, Wachinger et al. (2013) reviewed some risk factors and critical hazards in European countries such as the Netherlands, Italy, England, and Poland, among others. Flooding is the most frequent hazard in Europe, followed by seismic risks and volcanic hazards at a distance. Previous studies (*such as* Raviola et al., 13; Perrucci et al., 2016; Uddin, 2016) identified the risks of infectious diseases (R_9) in the temporary housing process after past earthquakes as a profound. Extant literature (Bettemir, 2016; Asefi & Farrokhi, 2018; Yuksel & Hasirci, 2012; Tierney et al.,

2004) categorized the problems caused by heat and cold weather (R_1) and the challenge of incidence of strong rains and floods (R_3) as the second-highest risks of the temporary settlement process after the earthquakes.

The results of this study are also consistent with the investigations by Omidvar and Binesh (2012), Va'Zquez et al. (2005), and Yuksel and Hasirci (2012), which regarded risks related to R_2, R_4, R_5, R_6, R_8, R_{10}, and R_{11} as significant hazard risks. Also, previous studies confirmed that the risks identified in this study have been among the critical risks in the temporary accommodation processes in other climes (Tomioka, 1997; Comerio, 1998; Tierney et al., 2004; Yuksel & Hasirci, 2012; Félix et al., 2015; Cordero-Reyes et al., 2017; Asefi & Farrokhi, 2018).

The critical risk of lack of insurance for permanent residences of the victims and the resulting lengthy reconstruction and temporary accommodation duration (R_7) was in the sixth place. Finally, the lowest priorities among critical risks include demand for urban camps due to the difference in presenting services between rural and urban camps (R_{19}), differences in the type of shelters offered to people and creating a sense of discrimination (R_{20}).

Table 8. Ranking of critical temporary accommodation risks after earthquakes

Risk Ranking	Risk No.	RPN	Risk Ranking	Risk No.	RPN
1	R9	3.18	11	R12	1.65
2	R1	2.16	12	R13	1.65
3	R3	2.16	13	R14	1.65
4	R2	1.91	14	R15	1.65
5	R4	1.91	15	R16	1.65
6	R5	1.68	16	R17	1.65
7	R6	1.68	17	R18	1.65
8	R8	1.68	18	R7	1.46
9	R10	1.68	19	R19	0.97
10	R11	1.65	20	R20	0.97

In Table 9, all the critical risks are divided into 6 risk areas: infrastructure, climate, logistics, health, economy and planning and the sum of RPNs for each risk area is calculated and the priority of each risk area is determined based on the magnitude. The rankings of different risk areas in temporary housing after the earthquake in the study area is given in Table 9. Also, the classification labels of the six risk areas are subjective in nature and based on the authors' perceptions of the risk categories in the study context. More so, according to the propositions by Chan & Hung (2015) and Olawumi & Chan (2022), it is beneficial to provide an attributable tags or representative labels to the factor clusters to aid their descriptions and explanations.

Table 9. Classification of temporary housing risks after the earthquake

Risk Areas	Risk No.	Risk Description	RPN	Sum of RPN	Ranking
Healthcare	3.18	Risks of infectious diseases	R_9	4.86	4
	1.68	Risks of mental health problems among survivors	R_5		
Climate	2.16	Heat and cold weather	R_1	7.68	2
	2.16	Incidence of strongly rains and flood	R_3		
	1.68	Roadblocks due to rain and snow resulting in disruption of relief efforts in winter	R_8		
	1.68	Challenge of wind and storm	R_{10}		
Infrastructure	1.91	Risks regarding wastewater disposal	R_2	8.77	1
	1.91	Waste disposal	R_4		
	1.65	Water resources accessibility problem	R_{12}		
	1.65	Difficulties in access to fuel	R_{13}		
	1.65	Incompatibility of the shelter type with the duration of accommodation	R_{14}		
Economy	1.68	Unemployment and damage and closure of businesses	R_6	4.79	5
	1.65	The problem of maintaining the source of income for the earthquake victims during the period of temporary accommodation	R_{18}		
	1.46	The critical risk of lack of insurance for permanent residences of the victims and the resulting lengthy reconstruction and temporary accommodation duration	R_7		
Planning	1.65	Inadequate accommodation camp location due to failure to pay attention to the relevant criteria for site selection	R_{11}	1.65	6
Logistics	1.65	Inadequate distribution of humanitarian aid and lack of coordination of relevant organizations in this regard	R_{16}	5.24	3
	1.65	Prolongation of setting the temporary accommodation camp due to lack of shelter provision before the hazard.	R_{17}		
	0.97	Demand for urban camps due to the difference in presenting services between rural and urban camps	R_{19}		
	0.97	Differences in the type of shelters offered to people and creating a sense of discrimination	R_{20}		

5. Conclusions

The current study results indicated that it is possible to identify and prioritize the risks of a project or operational process such as a temporary accommodation process after future earthquakes using the IF-RFMEA technique. This technique can also be used to identify the most critical risks. Using intuitionistic fuzzy sets during the RFMEA process helps resolve uncertainty in determining the probability and effects of risks during disaster management. In contrast, uncertainty is not considered in mathematical settings and even in fuzzy sets.

People often have different understandings regarding linguistic variables. Therefore, using intuitionistic fuzzy phrases for each linguistic variable can facilitate the agreement between experts in a project management team for determining the probability and effect of risks. Furthermore, this method can enable the quantitation of qualitative variables. In general, the characteristics of the technique proposed in this study include (i) using the opinions of disaster management experts; (ii) considering the uncertainties and ambiguities in experts' judgments and applying them during preventive planning; (iii) simultaneous application of three factors of the probability of occurrence, effect, and risk detection value for risk prioritization and (iv) facilitating the quantitation of qualitative judgments.

The critical risks identified in the current study are specific to the studied region and context. These critical risks can change depending on climate, geography, infrastructure, and other regional characteristics. Therefore, future research studies should use the proposed technique to assess and prioritize risks in different vulnerable areas with other factors. Furthermore, project managers and related key project stakeholders can use this technique as a Decision Support System (DSS) for determining and assessing various acute crises and profound risks associated with the temporary accommodation sites after strong earthquakes worldwide.

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