Journal of Information Analytics, 1(1), 23-37

Journal of Information Analytics

Submit	12.12.2024
Revision	26.02.2025
Accept	13.03.2025
Publish	18.03.2025

Open Access

Research Article

Analyzing the Emergency Assembly Points Criteria Using the Best-Worst Method under Interval Type-2 Fuzzy Sets

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Abstract

More than 400 high-impact natural disasters affect the global population each year. There have been many disasters in our country throughout its history. Earthquakes are the most common and most damaging type of disaster in our country. Within the scope of this paper, especially in the first 72 hours after the earthquake, which is called the golden times, the priority of the emergency assembly areas and the prioritization of the emergency assembly points, which should be planned within the scope of the disaster management system, were examined in order for the citizens who were not yet affected by the disaster or were affected with less damage to continue their shelter and vital activities. .

First, 5 main criteria and 13 sub-criteria were determined within the scope of emergency assembly points site selection criteria. The main criteria were determined as the preferability of the land, electrical infrastructure, plumbing system, safety and security and proximity. The weights of the criteria for location selection of emergency assembly points were calculated with 20 different decision makers who are experts in their fields. At this stage, the weights of each main criterion and sub-criteria were calculated using the Best-Worst approach in the literature. According to these results, the preferability of the land was determined as the most important main criterion, while landslides, flooding, etc. was determined as an important sub-criterion.

Keywords Disaster, disaster management system, earthquake, emergency assembly areas,

intermittent type-2 fuzzy sets, best-worst method

Citation: Yigit, T., & Celik, E. (2025). Analyzing the emergency assembly points criteria using the best-worst method under interval type-2 fuzzy sets. *Journal of Information Analytics*, 1(1), 23-37.

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1. Introduction

Disaster management systems aim to prevent, mitigate, or eliminate the impacts of any disaster, regardless of its type. These systems involve coordinated planning that encompasses pre-disaster phases (risk reduction and preparedness) and post-disaster phases (response and recovery), ensuring the efficient and purposeful use of resources for the benefit of society and all living beings. Earthquakes, the most common natural disaster in our country, are a primary focus for disaster risk management efforts. As part of these efforts, emergency assembly areas were designated in collaboration between AFAD and municipalities in 2018.

In the literature, emergency assembly areas also referred to as emergency gathering areas or post-disaster assembly areas are predefined locations identified by AFAD and relevant municipalities. These areas are intended to prevent panic during the critical first 72 hours following a disaster, facilitate efficient information exchange, and provide safe locations where the public can gather away from hazardous zones. These areas are free of physical risks and are crucial for post-disaster management. The location of emergency assembly areas within urban settings is a critical aspect of urban planning and disaster management. These areas must meet specific criteria, including appropriate distribution, adequate size, visibility, accessibility, and suitable infrastructure features.

This study focuses on prioritizing 16 emergency assembly points in the Muş province. To achieve this, the criteria for emergency assembly area selection were first examined in the literature. Five main criteria and 13 sub-criteria were determined, including land suitability, electrical infrastructure, sanitation systems, safety and security, and proximity. Since multiple criteria are involved in prioritizing emergency assembly points, this problem is considered a multi-criteria decision-making (MCDM) problem. The weights of the criteria were calculated with the participation of 20 experts in the field. The Best-Worst Method (BWM), developed by Rezaei (2015), was employed to determine the weights of each main and sub-criterion.

The BWM is a multi-criteria decision-making method used in various fields such as disaster management, logistics and supply chain management, engineering, and agriculture. One notable feature of the BWM is its reduced need for pairwise comparison data, making it more consistent than the Analytical Hierarchy Process (AHP). According to the results of the BWM, land suitability was identified as the most important main criterion, while sub-criteria such as landslides and flooding were found to be significant considerations.

2. Proposed Method

This section presents the fundamental steps of the Best-Worst Method (BWM) under interval type-2 fuzz sets, which was used in this study to determine the importance weights of 5 main criteria and their 13 sub-criteria for prioritizing emergency assembly points. The BWM was developed using pairwise comparison for alternatives and criteria by Rezaei (2015). The best and worst criterion are used as two vectors as that needs fewer data here, and it leads to more reliability (Rezaei, 2016; Rezaei et al. 2016). Some fuzzy versions of the BWM is presented for different application areas. The triangular fuzzy BWM is applied by Hafezalkotob and Hafezalkotob (2017), Guo and Zhao (2017), and Moslem et al. (2020). Tian et al. (2018a) proposed F-BWM for calculating the risk factors of FMEA. Mou et al. (2016) proposed the intuitionistic fuzzy multiplicative BWM for healthcare. The best power plant alternative is selected by Omrani et al. (2018) using fuzzy BWM. Tian et al. (2018b) proposed the intuitionistic F-BWM for the green supplier selection problem. Wu et al. (2019) integrated the IT2Fs and BWM using centroids for green supplier selection problems. Altay et al. (2023) applied BWM under IT2FSs for for location selection of e-scooter sharing stations. A detailed survey about BWM was presented by Mi et al. (2019). This detailed review can be analyzed by interested researchers for taking inspire the later research related to the BWM. In this section, we will present the steps of the IT2F-BWM using center of area method.

Step 1. A set of decision criteria n is determined. The criteria $(c_1, c_1, \dots, c_n)$ is used to calculate the importance weights.

$$\tilde{\tilde{E}} = \begin{array}{c} \\ c_1 \\ c_2 \\ \vdots \\ c_n \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{pmatrix} \tilde{\tilde{e}}_{11} & \tilde{\tilde{e}}_{12} & \cdots & \tilde{\tilde{e}}_{1n} \\ \tilde{\tilde{e}}_{21} & \tilde{\tilde{e}}_{22} & \cdots & \tilde{\tilde{e}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{e}}_{n1} & \tilde{\tilde{e}}_{n1} & \cdots & \tilde{\tilde{e}}_{nn} \end{pmatrix} \end{array} \tag{1}$$

where $\tilde{\tilde{e}}_{ij}$ shows the IT2F preference degree of criterion i over criterion j. IT2F pairwise comparisons on these n criteria can be applied based on the linguistic terms of decision-makers. All linguistic variables and IT2FSs are presented in Table 1. In this evaluation matrix, the diagonal elements are considered as Equally important (EI) and $\tilde{\tilde{e}}_{11}, \tilde{\tilde{e}}_{22}, \dots, \tilde{\tilde{e}}_{nn} = ((1;1;1;1;1;1),(1;1;1;1;0.9;0.9))$.

Table 1. Linguistic terms for importance weights (Celik et al. 2015)

Linguistic term	IT2FSs
EMI	((8;9;9;10;1;1), (8.5;9;9;9.5;0.9;0.9))
IV8	((7;8;8;9;1;1), (7.5;8;8;8.5;0.9;0.9))
VSMI	((6;7;7;8;1;1), (6.5;7;7;7.5;0.9;0.9))
IV6	((5;6;6;7;1;1), (5.5;6;6;6.5;0.9;0.9))
SMI	((4;5;5;6;1;1), (4.5;5;5;5.5;0.9;0.9))
IV4	((3;4;4;5;1;1), (3.5;4;4;4.5;0.9;0.9))
MMI	((2;3;3;4;1;1), (2.5;3;3;3.5;0.9;0.9))
IV2	((1;2;2;3;1;1), (1.5;2;2;2.5;0.9;0.9))
EI	((1;1;1;1;1;1), (1;1;1;1;0.9;0.9))

Step 2. The best and the worst criterion is decided using decision-maker preference.

Step 3. the preference of the best criterion and the worst criterion over all the other criteria is determined using IT2FSs. The resulting Best-to-Others (BtO) vector would be: $\tilde{\tilde{E}}_B = (\tilde{\tilde{e}}_{B1}, \tilde{\tilde{e}}_{B2}, \dots, \tilde{\tilde{e}}_{Bn})$,

where $\tilde{\tilde{e}}_{Bj}$ indicates the preference of the best criterion B over criterion j. It is clear that $\tilde{\tilde{e}}_{BB} = ((1;1;1;1;1;1),(1;1;1;1;0.9;0.9))$

The resulting Others-to-Worst (OtW) vector would be $\tilde{\tilde{E}}_B = (\tilde{\tilde{e}}_{1W}, \tilde{\tilde{e}}_{2W}, \dots, \tilde{\tilde{e}}_{nW})^T$

where a_{jW} indicates the preference of the criterion j over the worst criterion W. It is clear that $\tilde{\tilde{e}}_{WW} = ((1;1;1;1;1;1),(1;1;1;1;0.9;0.9))$.

Step 4. The optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ is calculated. In this process, the center of area is utilized. The constrained optimization model is built as Wu et al. (2019). The optimal weight for the criteria is the one where, for each pair of $\tilde{\tilde{w}}_B / \tilde{\tilde{w}}_j$ and $\tilde{\tilde{w}}_j / \tilde{\tilde{w}}_W$. The maximum absolute differences $\left|\tilde{\tilde{w}}_B / \tilde{\tilde{w}}_j - \tilde{\tilde{E}}_{Bj}\right|$ and

$\left|\tilde{\tilde{w}}_j / \tilde{\tilde{w}}_W - \tilde{\tilde{E}}_{jW}\right|$ should be minimized for finding optimal solutions. The consistency index as shown in Table 2 is used to calculate consistency ratio. It is created using the same process of Rezaei (2015) and Wu et al. (2019). The bigger the δ^*, the higher the consistency ratio.

Table 2. Consistency Index table

Linguistic Term	EI	IV	MMI	IV	SMI	IV	VSMI	IV	EMI
Defuzzified	0.975	1.95	2.925	3.9	4.875	5.85	6.825	7.8	8.775
CI	2.9582	4.4872	5.8948	7.2373	8.5373	9.8069	11.0533	12.2812	13.494

$$\min\max\left\{\left|\tilde{\tilde{w}}_B \,\tilde{\tilde{/}}\, w_j - \tilde{\tilde{E}}_{Bj}\right|,\left|\tilde{\tilde{w}}_j \,\tilde{\tilde{/}}\, w_W - \tilde{\tilde{E}}_{jW}\right|\right\}$$
$$s.t.\begin{cases}\sum_{j=1}^{n} COA\left(\tilde{\tilde{w}}_j\right)=1\\ w_{j1}^U \le w_{j1}^L, w_{j4}^L \le w_{j4}^U,\\ w_{j1}^L \le w_{j2}^L \le w_{j3}^L \le w_{j4}^L\\ w_{j1}^U \le w_{j2}^U \le w_{j3}^U \le w_{j4}^U,\\ w_{j1}^U \ge 0,\ j=1,2,\ldots,N\end{cases} \tag{2}$$

where $\tilde{\tilde{w}}_B=\left(\tilde{w}_B^U,\tilde{w}_B^L\right)=\left(\left(w_{B1}^U,w_{B2}^U,w_{B3}^U,w_{B4}^U;H_1\left(\tilde{w}_B^U\right),H_2\left(\tilde{w}_B^U\right)\right),\left(a_{B1}^L,a_{B2}^L,a_{B3}^L,a_{B4}^L;H_1\left(\tilde{w}_B^L\right),H_2\left(\tilde{w}_B^L\right)\right)\right)$

$\tilde{\tilde{w}}_W=\left(\tilde{w}_W^U,\tilde{w}_W^L\right)=\left(\left(w_{W1}^U,w_{W2}^U,w_{W3}^U,w_{W4}^U;H_1\left(\tilde{w}_W^U\right),H_2\left(\tilde{w}_W^U\right)\right),\left(a_{W1}^L,a_{W2}^L,a_{W3}^L,a_{W4}^L;H_1\left(\tilde{w}_W^L\right),H_2\left(\tilde{w}_W^L\right)\right)\right)$

$\tilde{\tilde{w}}_j=\left(\tilde{w}_j^U,\tilde{w}_j^L\right)=\left(\left(w_{j1}^U,w_{j2}^U,w_{j3}^U,w_{j4}^U;H_1\left(\tilde{w}_j^U\right),H_2\left(\tilde{w}_j^U\right)\right),\left(a_{j1}^L,a_{j2}^L,a_{j3}^L,a_{j4}^L;H_1\left(\tilde{w}_j^L\right),H_2\left(\tilde{w}_j^L\right)\right)\right)$

$\tilde{\tilde{w}}_{B,j}=\left(\tilde{w}_{B,j}^U,\tilde{w}_{B,j}^L\right)=\left(\left(w_{B,j1}^U,w_{B,j2}^U,w_{B,j3}^U,w_{B,j4}^U;H_1\left(\tilde{w}_{B,j}^U\right),H_2\left(\tilde{w}_{B,j}^U\right)\right),\left(a_{B,j1}^L,a_{B,j2}^L,a_{B,j3}^L,a_{j4}^L;H_1\left(\tilde{w}_{B,j}^L\right),H_2\left(\tilde{w}_{B,j}^L\right)\right)\right)$

$\tilde{\tilde{w}}_{j,W}=\left(\tilde{w}_{j,W}^U,\tilde{w}_{j,W}^L\right)=\left(\left(w_{j1,W}^U,w_{j2,W}^U,w_{j3,W}^U,w_{j4,W}^U;H_1\left(\tilde{w}_{j,W}^U\right),H_2\left(\tilde{w}_{j,W}^U\right)\right),\left(a_{j1,W}^L,a_{j2,W}^L,a_{j3,W}^L,a_{j4,W}^L;H_1\left(\tilde{w}_{j,W}^L\right),H_2\left(\tilde{w}_{j,W}^L\right)\right)\right)$

The maximum absolute gaps between $\left|\tilde{\tilde{w}}_B \,\tilde{\tilde{/}}\, w_j - \tilde{\tilde{E}}_{Bj}\right|$ and $\left|\tilde{\tilde{w}}_j \,\tilde{\tilde{/}}\, w_W - \tilde{\tilde{E}}_{jW}\right|$ are aimed to minimize to eliminate for $\left|\tilde{\tilde{w}}_B \,\tilde{\tilde{/}}\, w_j - \tilde{\tilde{E}}_{Bj}\right|$ and $\left|\tilde{\tilde{w}}_j \,\tilde{\tilde{/}}\, w_W - \tilde{\tilde{E}}_{jW}\right|$. The model is transformed to nonlinear programming for minimizing the absolute gap as $\delta^* = ((\delta^*;\delta^*;\delta^*;\delta^*;1;1),(\delta^*;\delta^*;\delta^*;\delta^*;0.9;0.9))$.

$$\min \delta^*$$

$$s.t.\begin{cases}\left|\tilde{\tilde{w}}_{B1}^U-\tilde{\tilde{w}}_{j1}^U\tilde{\tilde{w}}_{Bj,1}^U\right|\le\delta^*,\left|\tilde{\tilde{w}}_{B2}^U-\tilde{\tilde{w}}_{j2}^U\tilde{\tilde{w}}_{Bj,2}^U\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{B3}^U-\tilde{\tilde{w}}_{j3}^U\tilde{\tilde{w}}_{Bj,3}^U\right|\le\delta^*,\left|\tilde{\tilde{w}}_{B4}^U-\tilde{\tilde{w}}_{j4}^U\tilde{\tilde{w}}_{Bj,4}^U\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{B1}^L-\tilde{\tilde{w}}_{j1}^L\tilde{\tilde{w}}_{Bj,1}^L\right|\le\delta^*,\left|\tilde{\tilde{w}}_{B2}^L-\tilde{\tilde{w}}_{j2}^L\tilde{\tilde{w}}_{Bj,2}^L\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{B3}^L-\tilde{\tilde{w}}_{j3}^L\tilde{\tilde{w}}_{Bj,3}^L\right|\le\delta^*,\left|\tilde{\tilde{w}}_{B4}^L-\tilde{\tilde{w}}_{j4}^L\tilde{\tilde{w}}_{Bj,4}^L\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{j1}^U-\tilde{\tilde{w}}_{W1}^U\tilde{\tilde{w}}_{jW,1}^U\right|\le\delta^*,\left|\tilde{\tilde{w}}_{j2}^U-\tilde{\tilde{w}}_{W2}^U\tilde{\tilde{w}}_{jW,2}^U\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{j3}^U-\tilde{\tilde{w}}_{W3}^U\tilde{\tilde{w}}_{jW,3}^U\right|\le\delta^*,\left|\tilde{\tilde{w}}_{j4}^U-\tilde{\tilde{w}}_{W4}^U\tilde{\tilde{w}}_{jW,4}^U\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{j1}^L-\tilde{\tilde{w}}_{W1}^L\tilde{\tilde{w}}_{jW,1}^L\right|\le\delta^*,\left|\tilde{\tilde{w}}_{j2}^L-\tilde{\tilde{w}}_{W2}^L\tilde{\tilde{w}}_{jW,2}^L\right|\le\delta^*,\\ \left|\tilde{\tilde{w}}_{J3}^L-\tilde{\tilde{w}}_{W3}^L\tilde{\tilde{w}}_{JW,3}^L\right|\le\delta^*,\left|\tilde{\tilde{w}}_{J4}^L-\tilde{\tilde{w}}_{W4}^L\tilde{\tilde{w}}_{jW,4}^L\right|\le\delta^*,\\ \sum_{j=1}^{n}COA\left(\tilde{\tilde{w}}_j\right)=1\\ w_{j1}^U\le w_{j1}^L,w_{j4}^L\le w_{j4}^U,w_{j1}^L\le w_{j2}^L\le w_{j3}^L\le w_{j4}^L\\ w_{j1}^U\le w_{j2}^U\le w_{j3}^U\le w_{j4}^U,w_{j1}^U\ge 0,\ j=1,2,\dots,N\end{cases} \tag{3}$$

3. Application

3.1. Criteria for Selecting Assembly Areas

In its 2018 report, AFAD listed the criteria for determining assembly areas as follows: "Population density, accessibility, and ease of evacuation, suitability for access by the elderly and disabled, flat and unobstructed terrain, and areas that are not affected by secondary hazards such as fire, flood, or tsunami. The areas should also not be near seas, rivers, or locations prone to liquefaction, and they must be distant from fault lines. They should be close to residential areas but not affected by structural or non-structural hazards, and they should be public spaces that can provide basic needs such as electricity, water, and toilets" (AFAD, 2018). Studies in the literature on emergency assembly areas consider different criteria.

Çınar et al. (2018) examined the factors influencing assembly area planning in Karşıyaka District, İzmir Province. They highlighted that assembly areas were initially determined in 2006 under İzmir's provincial emergency assistance plan and later revised by AFAD in 2018 to include district-based assembly areas. Their study revealed that the 30 assembly areas designated for 15 of the 27 neighborhoods in Karşıyaka were insufficient in both quantity and size and did not meet international standards. Özel (2019) conducted a thesis study on assembly areas in Kastamonu Province. The purpose was to designate green spaces in zoning plans as assembly areas and propose additional areas where needed. His study found that the number of designated areas was inadequate and some were deemed risky. He emphasized that assembly areas should be open or green spaces large enough for the population, accessible, and evenly distributed. Taylan (2018) investigated whether the assembly areas in Çankırı Province were effectively planned to serve citizens post-disaster. He found that public awareness of these areas was low, and there were no regulations or laws setting national standards for assembly areas. Palazca (2020) analyzed the qualitative and quantitative characteristics of the 93 assembly areas in Denizli's 64 neighborhoods. Criteria included land use, slope, area size, and neighborhood population. He stated that assembly areas must be accessible, safe, and suitable for use during emergencies, with at least 2.5 m^2 of space per person. Dursun (2021) examined the standards and requirements for determining assembly areas in

Esenler District, Istanbul. His findings revealed that the assembly areas were insufficient, not easily accessible, and had low usability. Studies from various articles, theses, and reports emphasize the following main criteria for assembly areas: Accessibility, connectivity to road axes, usability, multi-functionality, ownership, and area size (Ju et al., 2012; Nappi & Souza, 2014; Kılcı et al., 2014; Trivedi & Singh, 2016; Yu & Wen, 2016; Çelik, 2017; Trivedi, 2018). Based on a literature review, this study identifies five main criteria and 13 sub-criteria, described below:

Soil Hardness, Slope, Topography, and Tree Presence: The hardness of the soil, slope, topographical features, and the presence of trees are crucial for shelter areas. The soil should be resistant to the effects of rainfall. The slope of the area should not be excessive, and rugged terrains should be avoided as much as possible. The presence of trees is particularly important for providing shade during hot summer months. Wetlands are unsuitable for shelter areas (Trivedi, 2018). Soil hardness is especially significant in terms of rainfall. Hard soil is less affected by precipitation and is more suitable for daily living (Kılcı et al., 2014).

Topography: Green areas are preferred for shelter areas due to their ability to provide shade and abundant oxygen, particularly during the summer months (Kılcı et al., 2014). Savannas are considered the most suitable type of terrain for these areas. Plains are more favorable than hilly terrains for this purpose (Kılcı et al., 2014).

Slope: According to data from the Turkish Red Crescent (Kızılay), the slope of the area should not exceed 7%, with the optimal slope ranging between 2% and 4% (Kılcı et al., 2014).

Ownership Status: Land controlled by central or local governments can be transformed into shelter areas more easily compared to privately or corporately owned lands. Publicly owned lands are more accessible (Trivedi, 2018). Compared to privately or corporately owned lands, public ownership facilitates the acquisition of permissions (Kılcı et al., 2014). In its 2002 report, JICA recommended that gathering areas should generally include green spaces, playgrounds, neighborhood or district parks, as well as the yards of schools, mosques, and hospitals. Each designated area should not be smaller than 500 m^2 (JICA and IBB, 2002).

Population Density (Per Capita Area): In its 2002 report, JICA recommended that areas designated as "Preliminary Evacuation Zones" should provide 1.5 m^2 per person. In their study, Tarabanis and Tsionas (1999) suggested an area of approximately 2 m^2 per person. However, in IZAMP and TAMP-Izmir, a significantly higher value of 4 m^2 per person, exceeding international standards, was specified (Çınar et al., 2018). Gathering areas, which are crucial to prevent chaos, should be selected based on the population of the settlement. Multiple areas, rather than a single large one, should be identified, and their locations should be communicated to the public (Taylan, 2018).

Accessibility for the Elderly and Disabled: Post-disaster and emergency gathering areas must be accessible to elderly and disabled individuals. The pathways leading to these areas and the routes continuing to safe zones should feature wheelchair-friendly paving and appropriate gradients.

Electrical Infrastructure: Electricity is a critical resource for maintaining daily life. Heaters, medical equipment when necessary, and many devices used today rely on electricity. Furthermore, shelters must be equipped with infrastructure to support communication, telecommunications, and alert systems (Trivedi, 2018).

Operational Electricity: Electricity is essential for heating and powering devices used in daily life. Areas must have optimal levels of electrical infrastructure (Kılcı et al., 2014).

Lighting Electricity: Since gathering areas are expected to be used during the first 72 hours following a disaster or emergency, it is crucial to provide sufficient lighting for citizens sheltered in these areas at night.

Telecommunication Facilities: The distance of designated gathering areas from telecommunication facilities is critical. These areas should support the network infrastructure of all GSM providers.

Sanitation System: Shelter areas must be equipped with infrastructure such as drainage and clean water systems. In particular, sewage infrastructure is vital to prevent the spread of epidemics and infectious diseases (Trivedi, 2018).

Drinking Water: Water, one of the basic human necessities, is essential not only for survival but also for cooking and personal hygiene (Kılcı et al., 2014).

Toilet Facilities: Sewage infrastructure should be available in the designated areas for citizens who will be sheltered for approximately 72 hours following a disaster or emergency (Kılcı et al., 2014).

Safety and Security: When planning the locations of shelter areas, safety and security are of utmost importance. Since shelter areas tend to be crowded, they should be situated on terrains that are not vulnerable to secondary natural disasters such as landslides, rockfalls, or floods (Trivedi, 2018).

Landslides, Floods, etc.: It is crucial to select gathering areas that are free from additional disaster risks and will not be affected by secondary disasters (Taylan, 2018).

Warning Systems (Audio Systems): Following a disaster or emergency, citizens require areas where they can obtain accurate information and gather safely. Gathering areas are especially critical during the first 12 to 24 hours post-disaster to ensure that victims have access to reliable information (Taylan, 2018).

Proximity: Potential areas should be located near healthcare facilities, supply depots, and transportation routes (Trivedi, 2018).

Distance to Settlements (Accessibility): Proximity to healthcare facilities is vital for early intervention for those in need. Similarly, being close to supermarkets or supply depots is important for the provision of goods to these areas (Kılcı et al., 2014). Each block within the zoning plan should be no more than a 15-minute walk or 500 meters from a gathering area. In cases where access to a designated gathering area is disrupted (e.g., due to damaged or blocked transportation networks), continuity must be ensured with alternative gathering areas (Çınar et al., 2018).

Distance from Potential Disaster Debris: Gathering areas, where citizens may stay for up to 72 hours post-disaster, should be located at a safe distance from potential disaster debris zones to facilitate effective crisis management.

3.2. Best-Worst Method Results

In this section, the importance weights of the 5 main criteria and the 13 sub-criteria for determining emergency gathering points are determined using the Best-Worst Method. In this phase, evaluations from 20 experts with competence in the field were considered. These 20 experts work in various units in Muş province, specializing in disaster and emergency management. Three of the experts are from the Muş Provincial Disaster and Emergency Directorate, thirteen work at Muş Municipality, Muş Provincial Governorship Environmental and Urbanism Directorate, and two at Muş Provincial Special Administration. One expert holds a master's degree, one holds an associate degree, and the rest have bachelor's degrees. Among the experts, 2 are Electrical Engineers, 1 is a Geomatics Engineer, 1 is a Geomatics Technician, 7 are Civil Engineers, 1 is a Geological Engineer, 4 are Architects, 3 are Urban Planners, and 1 is a branch manager. 11 of the experts have 5-10 years of work experience, 4 have 10-15 years of work experience, and 5 have over 15 years of experience.

For example, Expert 1 works at the Muş Provincial Disaster and Emergency Directorate. According to the evaluation of the main criteria by Expert 1, the best criterion is safety and security (C4), while the worst criterion is electrical infrastructure (C2). The evaluations made are shown in Table 3 below.

Table 3. Evaluation of best and worst criteria for main criteria using linguistic terms

Criteria	C1	C2	C3	C4	C5
Best Criterion (C4)	MMI	VSMI	VSMI	EI	SMI
Worst Criterion (C2)	VSMI	1 (Equal)	MMI	VSMI	SMI

This table reflects the evaluation made by Expert 1, where "C4" (Safety and Security) is rated as the best criterion, and "C2" (Electrical Infrastructure) is rated as the worst.

$$
\begin{aligned}
&\min\ \xi \\
&\textit{subject to} \\
&\left|\frac{w_4}{w_1}-\tilde{\tilde{3}}\right| \le \xi, \left|\frac{w_4}{w_2}-\tilde{\tilde{7}}\right| \le \xi, \\
&\left|\frac{w_4}{w_3}-\tilde{\tilde{7}}\right| \le \xi, \left|\frac{w_4}{w_5}-\tilde{\tilde{5}}\right| \le \xi, \\
&\left|\frac{w_2}{w_1}-\tilde{\tilde{7}}\right| \le \xi, \left|\frac{w_2}{w_3}-\tilde{\tilde{3}}\right| \le \xi, \\
&\left|\frac{w_2}{w_5}-\tilde{\tilde{5}}\right| \le \xi, \\
&w_1+w_2+w_3+w_4+w_5=1 \\
&w_1, w_2, w_3, w_4, w_5 \ge 0
\end{aligned}
$$

When the mathematical model obtained from the evaluations made by Expert 1 was solved, the importance of the criteria were as follows:

- Land Preference (C1) = 0.217
- Electrical Infrastructure (C2) = 0.052
- Sanitation System (C3) = 0.093
- Safety and Security (C4) = 0.507
- Proximity (C5) = 0.130

Similarly, based on the evaluation of the sub-criteria for Land Preference (C1), the best sub-criterion is Population Density (Area per Person) (C13), while the worst criterion is Property Status (C12). The evaluations are shown in Table 4 below.

Table 4. Evaluation of best and worst criteria for sub-criteria using linguistic terms

Criteria	C11	C12	C13	C14
Population Density (Area per Person) (C13)	MMI	VSMI	EI	SMI
Property Status (C12)	VSMI	EI	VSMI	SMI

Table 4 reflects the evaluation by Expert 1, where C13 (Population Density) is the best sub-criterion, and C12 (Property Status) is the worst sub-criterion.

$$
\begin{aligned}
&\min \ \xi \\
&ş.k.a \\
&\left|\frac{w_{13}}{w_{11}} - \tilde{\tilde{3}}\right| \le \xi, \left|\frac{w_{13}}{w_{12}} - \tilde{\tilde{7}}\right| \le \xi, \\
&\left|\frac{w_{13}}{w_{14}} - \tilde{\tilde{5}}\right| \le \xi, \left|\frac{w_{12}}{w_{11}} - \tilde{\tilde{7}}\right| \le \xi, \\
&\left|\frac{w_{12}}{w_{14}} - \tilde{\tilde{5}}\right| \le \xi, \\
&w_{11} + w_{12} + w_{13} + w_{14} = 1 \\
&w_{11}, w_{12}, w_{13}, w_{14} \ge 0
\end{aligned}
$$

Evaluation of the best and worst criteria for the electric infrastructure (C2) sub-criteria is as follows: Telecommunication Facility (C23) is determined as the best criterion, while Lighting Electricity (C22) is identified as the worst criterion. The evaluations are shown in Table 5.

Table 5. Evaluation of the best and worst criteria for the main criteria with linguistic terms

Criteria	C21	C22	C23
Telecommunication Facility (C23)	MMI	SMI	EI
Lighting Electricity (C22)	MMI	EI	SMI

$$
\begin{aligned}
&\min \ \xi \\
&ş.k.a \\
&\left|\frac{w_{23}}{w_{21}} - \tilde{\tilde{3}}\right| \le \xi, \left|\frac{w_{23}}{w_{22}} - \tilde{\tilde{5}}\right| \le \xi, \\
&\left|\frac{w_{22}}{w_{21}} - \tilde{\tilde{3}}\right| \le \xi, \\
&w_{21} + w_{22} + w_{23} = 1 \\
&w_{21}, w_{22}, w_{23} \ge 0
\end{aligned}
$$

When the mathematical model obtained from the evaluations made by Expert 1 is solved, the importance of the criteria is as follows:

- Usable electricity (C11) = 0.245
- Lighting electricity (C12) = 0.111
- Telecommunication facility (C13) = 0.644

For the sub-criteria of the Sanitary Plumbing System (STS) (C3), the weight of the Drinking water (C31) criterion is 0.756, while the weight of the Toilet condition (C32) criterion is 0.244. For the Safety and Security (GE) sub-criteria, the weight of the Landslides, floods, etc. (C41) criterion is 0.836, showing a very prominent importance, while the Warning systems (Sound systems) (C42) criterion has a weight of 0.164, indicating a less significant importance. Finally, in the evaluation of the sub-criteria under the Proximity (Yk) (C5) main criterion, the Distance from the settlement (Accessibility) (C51) sub-criterion is 0.756, and the Distance from potential disaster debris areas (C52) sub-criterion is 0.244. Each evaluation made by the expert was calculated using the best-worst method. The results for each main and sub-criterion are shown in Table 6.

Table 6. The importance of criteria for experts

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Expert 11	Expert 12	Expert 13	Expert 14	Expert 15	Expert 16	Expert 17	Expert 18	Expert 19	Expert 20
(C1)	0.217	0.489	0.224	0.36	0.507	0.497	0.206	0.51	0.497	0.132	0.124	0.085	0.19	0.37	0.53	0.504	0.253	0.139	0.124	0.184
(C2)	0.052	0.116	0.053	0.062	0.13	0.071	0.054	0.053	0.091	0.054	0.088	0.198	0.056	0.109	0.101	0.119	0.05	0.1	0.061	0.054
(C3)	0.093	0.193	0.09	0.082	0.093	0.091	0.088	0.092	0.071	0.073	0.061	0.04	0.082	0.064	0.051	0.119	0.101	0.051	0.088	0.111
(C4)	0.507	0.145	0.409	0.36	0.052	0.128	0.498	0.129	0.128	0.22	0.521	0.198	0.482	0.182	0.177	0.059	0.427	0.477	0.521	0.184
(C5)	0.13	0.057	0.224	0.136	0.217	0.213	0.154	0.216	0.213	0.52	0.206	0.478	0.19	0.274	0.141	0.199	0.169	0.232	0.206	0.466
(C11)	0.24	0.226	0.547	0.095	0.569	0.528	0.475	0.493	0.572	0.136	0.126	0.437	0.144	0.185	0.528	0.518	0.572	0.547	0.256	0.226
(C12)	0.057	0.066	0.078	0.429	0.069	0.075	0.055	0.29	0.066	0.066	0.07	0.197	0.057	0.074	0.226	0.196	0.066	0.078	0.083	0.066
(C13)	0.559	0.572	0.234	0.286	0.121	0.226	0.188	0.101	0.136	0.226	0.315	0.296	0.559	0.278	0.075	0.196	0.226	0.234	0.154	0.572
(C14)	0.144	0.136	0.141	0.19	0.241	0.17	0.282	0.116	0.226	0.572	0.49	0.07	0.24	0.463	0.17	0.089	0.136	0.141	0.508	0.136
(C21)	0.245	0.257	0.571	0.429	0.429	0.644	0.292	0.536	0.257	0.244	0.542	0.244	0.244	0.244	0.244	0.6	0.244	0.257	0.321	0.244
(C22)	0.111	0.6	0.143	0.143	0.143	0.111	0.542	0.143	0.143	0.644	0.167	0.111	0.111	0.111	0.111	0.257	0.111	0.6	0.143	0.111
(C23)	0.644	0.143	0.286	0.429	0.429	0.244	0.167	0.321	0.6	0.111	0.292	0.644	0.644	0.644	0.644	0.143	0.644	0.143	0.536	0.644
(C31)	0.756	0.75	0.333	0.75	0.667	0.75	0.667	0.667	0.25	0.75	0.25	0.75	0.75	0.75	0.75	0.25	0.75	0.25	0.75	0.75
(C32)	0.244	0.25	0.667	0.25	0.333	0.25	0.333	0.333	0.75	0.25	0.75	0.25	0.25	0.25	0.25	0.75	0.25	0.75	0.25	0.25
(C41)	0.836	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.833	0.75	0.25	0.833	0.75	0.75	0.75	0.75	0.833	0.75	0.833
(C42)	0.164	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.167	0.25	0.75	0.167	0.25	0.25	0.25	0.25	0.167	0.25	0.167
(C51)	0.756	0.25	0.667	0.75	0.333	0.75	0.333	0.75	0.25	0.75	0.25	0.75	0.75	0.75	0.167	0.75	0.75	0.75	0.667	0.75
(C52)	0.244	0.75	0.333	0.25	0.667	0.25	0.667	0.25	0.75	0.25	0.75	0.25	0.25	0.25	0.833	0.25	0.25	0.25	0.333	0.25

The cumulative local and global weights of the evaluations made by 20 experts were calculated using the simple average approach, and the results are shown in Table 7. When the main criteria are examined, it is observed that the most important main criterion is Land Preference (ATE) (C1), with an importance weight of 0.307. The second most important main criterion is Safety and Security (GE) (C4), with a weight of 0.290. The third most important main criterion is also Safety and Security (GE) (C4), with the same weight of 0.290. Considering the five main criteria, the relatively less important main criteria are Sanitary Plumbing System (STS) (C3) and Electric Infrastructure (EA) (C2), with weights of 0.087 and 0.084, respectively.

Table 7. The local and global weights

Criteria	Local weights	Global weights
(C1)	0.307	
(C2)	0.084	
(C3)	0.087	
(C4)	0.290	
(C5)	0.232	
(C11)	0.371	0.114
(C12)	0.118	0.036
(C13)	0.278	0.085
(C14)	0.233	0.072
(C21)	0.349	0.029
(C22)	0.228	0.019
(C23)	0.418	0.035
(C31)	0.617	0.054
(C32)	0.383	0.033
(C41)	0.746	0.216
(C42)	0.254	0.074
(C51)	0.596	0.138
(C52)	0.404	0.094

When the cumulative global weight is examined, the most important sub-criterion is Landslides, floods, etc. (C41). The importance weight for this sub-criterion is determined to be 0.216. The other two most important sub-criteria are Distance from the settlement (Accessibility) (C51), with an importance weight of 0.138, and Topography and slope (C11), with an importance weight of 0.114. Landslides, Floods, etc. (C41) hold significant global importance because natural disasters (such as landslides, floods, and storms) can lead to substantial losses worldwide and are a critical factor when considering environmental risks. These types of disasters are not only significant at the local level but also draw attention due to their impact on the global economy and environment. Global disaster management focuses on preparedness and risk mitigation strategies for such events. On a global scale, Distance from the settlement (Accessibility) (C51) is an important criterion, particularly during disasters. Accessibility is a fundamental factor for quickly delivering aid and providing logistical support to disaster-stricken areas. Additionally, the operational efficiency of international aid organizations and disaster response teams on a global scale depends on the accessibility of settlements. Therefore, access and reach are of critical importance on a global level. Topography is particularly important under the influence of natural disasters. The slope of mountainous regions, for example, can affect the frequency of landslides and floods, making it a key factor in shaping global disaster strategies. The management of such terrains is critical for construction and settlement planning, thus holding significant importance at the global level.

According to the cumulative global weights, the three least important criteria are Lighting electricity (C22), Ownership status (C12), and Usable electricity (C21). Lighting electricity (0.019) holds very low importance on a global scale. Most developed countries and regions have largely completed their lighting infrastructure, so it is less emphasized as a global priority. However, this issue may be more significant in developing regions, but on a global scale, the focus tends to be more on basic infrastructure elements (e.g., drinking water, energy infrastructure). Ownership status (0.036) may be important at the local level, but it is a less prioritized factor on a global scale. Globally, ownership status is not directly related to managing environmental risks, especially in the context of disaster management and environmental planning. Instead, broader-scale issues such as the conservation of natural resources and the environment take precedence. The global importance of electric infrastructure is not as pronounced as it is at the local level. On a global scale, energy access is more closely related to energy policies and sustainable energy production. Electric infrastructure (0.029) is generally sufficient in developed countries and is considered an element that needs to be restored after disaster situations or energy crises. On a global level, elements such as water supply or disaster preparedness are prioritized over electricity.

4. Conclusion

Disasters are naturally occurring events that cause loss of life and property. For an event to be classified as a disaster, it must be large enough to significantly impact people or the environment where people live. From this perspective, a disaster is not just an event but the consequence of an event. Disaster management, due to the nature of disasters, follows a cyclical structure consisting of four consecutive phases. As a result of this structure, the risk and damage reduction phase does not begin and end in a specific place within the cycle. On the contrary, after a disaster, risk and damage reduction efforts, which start with the recovery phase, continue until the next disaster. The anticipation of a disaster is the phase where efforts are made to reduce the potential impact of the disaster threat. Efforts are made through structural and non-structural measures to prevent the negative impacts of environmental and technological hazards caused by natural dangers. During the damage reduction phase, the negative impacts of hazards and risks cannot be entirely prevented, but the area or severity of these threats can be significantly reduced through various strategies and actions. To successfully manage disaster risk, it is essential to strengthen the damage reduction phase and ensure investments in risk and hazard-reducing measures to build resilience against disasters.

The identification of the locations of emergency gathering points used after a disaster is one of the most important aspects of urban planning and disaster management. The distribution, size, visibility, accessibility, and infrastructure requirements of these areas must be ensured to make them suitable for their purpose.

In this study, 16 different emergency gathering points have been considered for prioritization in Muş province. To prioritize these gathering points, the criteria for emergency gathering locations were first examined in the literature. In this stage, five main criteria and 13 sub-criteria were determined within the context of emergency gathering points' location selection. The main criteria are land preference, electric infrastructure, sanitary plumbing system, safety and security, and proximity.

This paper presents a model for prioritizing emergency gathering points in Muş province based on the established criteria, which is applicable to other provinces in Turkey. The model proposed for other provinces in our country can be implemented. In addition to the five main criteria and 13 sub-criteria, other criteria can also be considered. The Bayesian Best-Worst Method can be used as an alternative approach for determining the criteria's weights. Furthermore, the interval type-2 fuzzy set-based approach can be developed with heuristic fuzzy sets, value-range fuzzy sets, and other different fuzzy sets.

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