

Article

Analyzing the Shelter Site Selection Criteria for Disaster Preparedness Using Best–Worst Method under Interval Type-2 Fuzzy Sets

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Abstract: Shelters are vital for affected people after a disaster because of the accommodation, safety, and security. In this paper, we analyze the shelter site selection criteria for disaster preparedness applying the best–worst method under interval type-2 fuzzy sets. The proposed approach utilizes the advantages of fewer pairwise comparisons with the best–worst method and better reflection of uncertainty with interval type-2 fuzzy sets. For this reason, the criteria are determined based on a literature review and the opinion of nine disaster experts. The experts have worked as disaster officers in a variety of locations, including Sivrice (Elazığ), Pazarcık, and Elbistan (Kahramanmaraş) and Syrian refugee camps such as Nizip container city. In this step, 6 main criteria and 25 sub-criteria are evaluated using the proposed approach. According to the nine experts' opinions, the most important main criterion is determined as proximity. Distribution center capacity, adequate distribution logistics personnel, available electricity, distance to settlement, and landslides and flooding are also determined as the five most important sub-criteria. For disaster preparedness, responsible organizations and managers should consider these important criteria for temporary shelter site selection.

Keywords: disaster preparedness; shelter site selection; best–worst method; interval type-2 fuzzy sets



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1. Introduction and Background

A shelter site is a protected place where disaster victims can live temporarily after a disaster such as an earthquake. Therefore, it is important for local authorities and managers to know how to assign the affected people to shelter sites [1]. Shelter site selection enables authorities to immediately concentrate on assisting the victims and injured people in disaster areas. Therefore, decisions about shelter site location are crucial [2] and have a significant impact on how well relief efforts function [3]. Different location models are proposed by researchers as single-objective, multi-objective, and hierarchical models [4]. Details of the models are presented in the review paper by Ma et al. [3]. Interested researchers and practitioners may analyze the detail of the models in this review paper.

In addition to models, various scholars have presented multi-criteria decision-making approaches for site selection in times of disaster. Turgut et al. [5] proposed the fuzzy analytical hierarchy process (AHP) approach for disaster center location selection. Omidvar et al. [6] integrated MCDM and geographical information system approaches for site selection of temporary shelters before an earthquake. Thirteen shelter site criteria and fourteen alternative zones are considered for the case of Iran. Nappi and Souza [7] applied AHP for hierarchical criteria of temporary shelter location. Hosseini et al. [8] implemented AHP to determine the importance weights of temporary housing. Çetinkaya et al. [9] integrated GIS, fuzzy AHP, and TOPSIS approaches for siting refugee camps. Celik [10] proposed the DEMATEL approach as a cause and effect relationship model for the location of temporary shelters. The Delphi panel method is used by Soltani et al. [11] to list the criteria in choosing appropriate sites of temporary sheltering. Song et al. [12] applied QUALFLEX as a multi-criteria decision-making method for sustainable shelter

site selection. Geng et al. [13] also applied fuzzy AHP and fuzzy TOPSIS for choosing shelter sites to generate actual data for certain areas in Sichuan Province, China. Yilmaz and Kabak [14] presented an AHP and TOPSIS approach using interval type-2 fuzzy sets for prioritizing distribution centers in humanitarian logistics. Wu et al. [15] proposed a hesitant multiplicative linguistic preference relation for shelter site selection in response to the Wenchuan earthquake. Hosseini et al. [16] applied the AHP method to determine the importance weights of indicators for emergency shelter site selection after an earthquake in Iran. Choukolaei et al. [17] also applied the fuzzy Delphi method and triangular fuzzy aggregation method to determine the weights of the criteria. The efficiency of the shelter sites (relief centers) is prioritized using the PROMETHEE.

Sustainable measures implemented after a disaster effectively allocate resources to impacted individuals, aiming to safeguard their well-being and foster community restoration. The impacted individuals need sheltering, which is hence a major global humanitarian issue. Félix et al. [18] presented a state-of-the-art survey for temporary housing after disasters. They analyzed the literature with respect to the two main problems that are sustainability and cultural inadequacy. Unsustainability in terms of costs and environmental issues are issues in the sustainability in temporary housing. Abrahams [19] addressed the gaps in the existing knowledge of post-disaster environmental sustainability efforts and examined the benefits, trade-offs, and practicality of considering environmental sustainability in a post-disaster setting. Potangaroa [20] presented three case studies of shelter design in the context of sustainability. Hosseini et al. [21] presents a new model for choosing optimized temporary housing units based on the sustainability concept. Pomponi et al. [22] applied AHP for determining the weight of technical and sustainability indicators on shelter sustainability by tapping into interdisciplinary expertise on both the African context and refugees' sheltering. Ghomi et al. [23] investigated the performance of post-disaster housing reconstruction projects and investigated its applicability to provide sustainable post-disaster housing following natural-hazard-induced disasters. Hosseini et al. [24] presented a model for selecting the most suitable temporary housing sustainability based on the characteristics and requirements. The model consists of the integrated value model for sustainability assessment, a simplified life cycle assessment, interviews, and sensibility analyses.

When we analyzed the literature, we found that different versions of multi-criteria decision-making methods and fuzzy sets have been applied. For example, intuitionistic fuzzy sets should be also applied for selecting shelter sites. Atanassov et al. [25] developed a generalized net model using intuitionistic fuzzy sets based on intercriteria analysis. The advantage of the intuitionistic fuzzy set is that it separates the degree of membership and the degree of nonmembership of an element in the set. On the other hand, the interval type-2 fuzzy sets handle uncertainty in more realistic ways in comparison to the type-1 fuzzy sets [26,27] by making fewer assumptions. The aim of this study is to propose a weighting approach for shelter site selection criteria. Therefore, we proposed the best–worst method based on the interval type-2 fuzzy sets for evaluating the shelter site selection criteria in a more effective way. Also, due to the interval type-2 fuzzy concept in the proposed approach, the integration reveals and solves uncertainty and ambiguity in a more reasonable way. In addition, different criteria should be taken into consideration when selecting the location of shelter sites. It also involves different experts of criteria evaluation together during the selection process. Because of the different criteria evaluations, the shelter site selection process and the evaluation of the different criteria require a multi-criteria approach.

The rest of the paper is structured as follows. Section 2 presents the literature review of the shelter site selection criteria. Section 3 gives the details of the information of the experts. Section 4 introduces the proposed methodology that integrated the BWM and interval type-2 fuzzy sets. Section 5 includes the applied BWM and the steps of the case study. It also validates the feasibility and applicability of the proposed method. The conclusions are presented in the last section.

2. Literature Review of Shelter Site Selection Criteria

This section presents the definition of the main shelter site selection criteria and sub-criteria. Table 1 gives the considered main criteria and sub-criteria.

Table 1. The shelter site selection criteria.

Main Criteria	Sub Criteria
Favorability of terrain (FT) (C1)	Topography (C11) Slope (C12) Presence of trees (C13) Ownership status (C14) Population density (area per capita) (C15) Suitable for disabled and elderly transportation (C16)
Electrical infrastructure (EI) (C2)	Available electricity (C21) Electric lighting (C22) Telecommunication facility (C23)
Hygiene and sanitary system (HSS) (C3)	Drinking water (C31) Drainage system and sewer infrastructure (C32) Solid waste disposal (C33)
Safety and security (SS) (C4)	Landslides, flooding, etc. (C41) Warning systems (sound systems) (C42) Access to livelihoods (C43) Fire safety (C44)
Transport–distribution capacity (TDC) (C5)	Optimum distribution condition (C51) Distribution center capacity (C52) Adequate distribution logistics personnel (C53)
Proximity (P) (C6)	Distance to settlement (accessibility) (C61) Distance to disaster debris storage areas (C62) Distance to market/warehouses (C63) Distance from major roads (C64) Distance to health facility (C65) Distance from transport centers (C66)

2.1. Favorability of Terrain (FT) (C1)

The first main criteria consist of six sub-criteria that are topography (C11), slope (C12), presence of trees (C13), ownership status (C14), population density (C15), and suitable for disabled and elderly transportation (C16). For example, the first three sub-criteria are considered by Trivedi and Singh [28] and Trivedi [29] as important criteria of favorability of terrain. In addition to these three criteria, the remaining three criteria (ownership status, population density, and suitable for disabled and elderly transportation) should be also considered for temporary shelters.

2.2. Electrical Infrastructure (EI) (C2)

Electrical infrastructure consists of three sub-criteria that are available electricity, electric lighting, and telecommunication facility. The presence of a reliable electricity source (C21) is essential for providing power to various amenities and infrastructure for shelter sites along the route, such as lighting, signage, and emergency call stations [30]. Adequate lighting (C22) is crucial for ensuring the safety and visibility of victims. Access to telecommunication facilities (C23), such as mobile phone networks and public Wi-Fi, enables victims to stay connected and reach out for assistance in case of an emergency [29,31,32].

2.3. Hygiene and Sanitary System (HSS) (C3)

Hygiene and sanitary systems consist of three sub-criteria that are drinking water, drainage system and sewer infrastructure, and solid waste disposal. The availability of drinking water (C31) fountains along the route is essential for providing hydration to victims. Water and sanitary is determined as one of the sustainability categories in major sustainability tools for post-disaster reconstruction [20,33]. A well-functioning drainage system and sewer infrastructure (C32) is crucial for managing rainwater and preventing

flooding, which can pose safety hazards for victims [34]. The availability of solid waste disposal (C33) in the shelter sites is necessary for proper waste management [8] and for preventing litter, which can create obstacles and potential hazards for victims using the shelter site.

2.4. Safety and Security (SS) (C4)

The main criteria of safety and security consist of four sub-criteria that are landslides and flooding, warning systems (sound systems), access to livelihoods, and fire safety. The shelter site should be located in an area with a low risk of natural hazards such as landslides, floods, and earthquakes (C41) [34–36]. In areas with a risk of natural hazards, it is important to have an early warning system (C42) in place to alert residents of potential danger. These systems should include sound systems, as well as other means of communication such as text messages or social media alerts. The shelter sites should be located in an area with access to livelihoods (C43), such as jobs, and education and healthcare. This will help to ensure that victims can live independently and participate in their communities. The shelter sites should have adequate fire safety (C44) measures in place, such as fire hydrants, fire alarm systems, and evacuation routes [16]. This will help to protect victims in the event of a fire.

2.5. Transport–Distribution Capacity (TDC) (C5)

Optimum distribution condition, distribution center capacity, and adequate distribution logistics personnel are three sub-criteria of transport–distribution capacity. Transportation capacity effects proximity to important facilities such as health facilities, major roads, and transport centers [28]. The optimum distribution condition (C51) for victims' transportation involves a well-coordinated system that efficiently delivers necessary goods and services to their doorsteps. Distribution center capacity (C52) and adequate distribution logistics personnel (C53) are two other important criteria for shelter site selection. A lack of personnel with disaster expertise is identified as a barrier in sustainable shelter implementation [19]. The availability of adequate distribution logistics personnel will significantly improve the efficiency and effectiveness of distribution of shelter sites [10]. Sufficiently trained and equipped distribution personnel can handle the collection, packing, transporting, and delivery of goods.

2.6. Proximity (P) (C6)

Distance to settlement, disaster debris storage areas, market/warehouses, major roads, health facilities, and transport centers are considered for shelter site selection [35,37]. Proximity is taken into account as a satisfaction-increasing factor for post-disaster sustainable housing [23]. The route should be located in close proximity to settlements (C61) to provide easy access for victims. The shelter sites should avoid areas with disaster debris storage areas (C62) to minimize exposure to potential hazards such as hazardous materials, toxic fumes, or unstable debris piles. The shelter sites should be located within a reasonable distance from markets and warehouses (C63) to provide convenient access to essential goods and supplies [38]. The shelter sites should be located at a safe distance from major roads (C64) to minimize exposure to traffic noise, air pollution, and potential accidents. The shelter sites should be in close proximity to a health facility to provide easy access to medical care in case of emergencies or for routine checkups. The shelter sites should be located near to transport centers (C66), such as bus stops, train stations, or airports, to provide convenient connections to public transportation. The proximity of shelter points to the needed facilities can provide social opportunities for disaster victims [18]. Sociality is suggested as the fourth sustainability dimension by Pomponi et al. [22].

3. Experts' Information

A detailed survey was employed with experts who have had adequate experience in shelter site selection over many years. The survey consists of two sections that include

information on the experts and evaluation by the experts using the proposed method. In the first section, information on the occupation, education level, working department, expertise area, and experience is gathered. In the second section, the proposed method is described containing an imaginary example for help on how to fill out the survey. Then, the survey is filled out by each expert. The evaluations are taken using expert judgments in different papers [10,28]. Table 2 presents the shelter site experts' details. For obtaining the importance weights of shelter sites, the six main criteria and twenty-four sub-criteria considered are evaluated by experts for shelter site selection based on linguistic assessments.

Table 2. The experts' information details.

	Occupation	Education Level	Department	Expertise Area	Experience (Years)	Disaster Worked as Officer
Expert 1	Business Administration	Undergraduate	Planning and Mitigation (Manager)	Temporary shelter location selection	29	24.01.2020 Sivrice (Elazığ) Mw 6.8, 06.02.2023 Pazarcık and Elbistan (Kahramanmaraş) Mw 7.8 and 7.5
Expert 2	Civil Engineer	Graduate (MSc)	Improvement	Temporary shelter location selection	9	
Expert 3	Chemistry Engineer	Graduate (MSc)	Disaster and Emergency Management Center	Camp manager	9	
Expert 4	Mechanical Engineer	Undergraduate	Disaster and Emergency Management Center	Technician	6	24.01.2020 Sivrice (Elazığ) Mw 6.8, 06.02.2023 Pazarcık and Elbistan (Kahramanmaraş) Mw 7.8 and 7.5
Expert 5	Topographical Engineer	Undergraduate	Improvement	Temporary shelter location selection	8	
Expert 6	Civil Engineer	Undergraduate	Improvement	Temporary shelter location selection	9	
Expert 7	Civil Engineer	Undergraduate	Improvement	Temporary shelter location selection	9	
Expert 8	Geophysics Engineer	Undergraduate	Improvement	Location service	6	
Expert 9	Industrial Engineer	Graduate (PhD)	Information System (Manager)	Location service Information system	10	

The nine experts, who have a range of expertise, experience, education, and occupations, evaluated the shelter site selection criteria. Experts 1, 2, 5, 6, and 7 all have experience working as disaster officers, with Expert 1 having the most experience at 29 years. Experts 3, 4, 8, and 9 have expertise in location services, with Expert 9 having the most experience at 10 years. The experts have a range of education levels, including undergraduate, graduate (MSc or PhD). These different degrees include business administration, civil engineering, chemistry engineering, mechanical engineering, topographical engineering, geophysics engineering, and industrial engineering. The experts come from a variety of departments, including planning and mitigation, improvement, disaster and emergency management centers, and information systems. The experts have worked as disaster officers in a variety of locations, including Sivrice (Elazığ), Pazarcık and Elbistan (Kahramanmaraş), and Syrian refugee camps (Nizip container city).

4. Methodology

The current section offers a fundamental explanation of the best–worst method in the context of interval type-2 fuzzy sets. The inception of fuzzy sets was initially proposed by

Zadeh [39]. Consequently, in 1975, Zadeh expanded the classical fuzzy sets to type-2 fuzzy sets [40–42]. The application of interval type-2 fuzzy sets is predominantly observed in decision-making scenarios due to their manageable and straightforward computational nature [8,34–46].

Celik et al. [43] provides an in-depth analysis of multi-criteria decision-making problems by employing interval type-2 fuzzy sets. However, this article is not exploring a detailed explanation of interval type-2 fuzzy sets. Consequently, interested readers and researchers are encouraged to thoroughly examine this extensive literature review. Several rudimentary definitions pertaining to interval type-2 fuzzy sets can be found in the works of Mendel et al. [47], Soner et al. [48], and Celik and Gumus [49,50].

Definition 1. This introduces the notion of a type-2 fuzzy set $\tilde{\tilde{A}}$ in the universe of conversation X , which is represented by a type-2 membership function $\mu_{\tilde{\tilde{A}}}$. This function is defined as an interval in the scope of $[0, 1]$. If all the intervals satisfy this condition, the type-2 fuzzy set is referred to as an interval type-2 fuzzy set.

$$\tilde{\tilde{A}} = \left\{ ((x, u), \mu_{\tilde{\tilde{A}}}(x, u)) | \forall x \in X, \forall u \in J_X \subseteq [0, 1], 0 \leq \mu_{\tilde{\tilde{A}}}(x, u) \leq 1 \right\}$$

where J_X represents an interval in $[0, 1]$. If all $\mu_{\tilde{\tilde{A}}}(x, u) = 1$, then $\tilde{\tilde{A}}$ is called an interval type-2 fuzzy set.

Definition 2. This explains that the upper and lower membership functions of an interval type-2 fuzzy set are classical membership functions. Figure 1 provides a visual representation of an interval type-2 fuzzy set. Here, type-1 fuzzy sets and reference points of the interval type-2 fuzzy set are denoted as variables. T2FSs has the lower and upper membership functions that are classical membership functions. Figure 1 demonstrates an interval type-2 fuzzy set.

$$\tilde{\tilde{A}}_{Ei} = (\tilde{\tilde{A}}_{Ei}^U, \tilde{\tilde{A}}_{Ei}^L) = \left(\left(a_{Ei1}^U, a_{Ei2}^U, a_{Ei3}^U, a_{Ei4}^U; H_1(\tilde{\tilde{A}}_{Ei}^U), H_2(\tilde{\tilde{A}}_{Ei}^U) \right), \left(a_{Ei1}^L, a_{Ei2}^L, a_{Ei3}^L, a_{Ei4}^L; H_1(\tilde{\tilde{A}}_{Ei}^L), H_2(\tilde{\tilde{A}}_{Ei}^L) \right) \right)$$

where $\tilde{\tilde{A}}_{Ei}^L$ and $\tilde{\tilde{A}}_{Ei}^U$ are type-1 fuzzy sets, $H_j(\tilde{\tilde{A}}_{Ei}^L)$ represents the membership value of $a_{i(j+1)}^L$ in the lower trapezoidal membership function $\tilde{\tilde{A}}_{Ei}^L$, $H_j(\tilde{\tilde{A}}_{Ei}^U)$ represents the membership value of $a_{i(j+1)}^U$ in the upper trapezoidal membership function $\tilde{\tilde{A}}_{Ei}^U$.

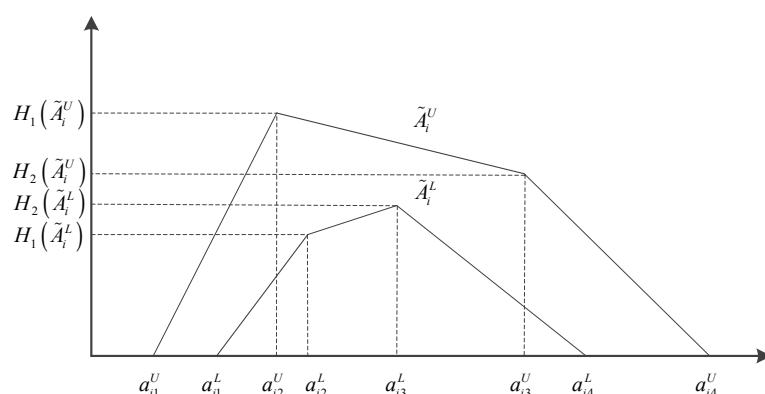


Figure 1. Demonstration of the membership function in interval type 2 fuzzy set.

Kahraman et al. [51] used the center of area defuzzification method. In this paper, this method is applied for calculating the importance weights of each criterion in IT2F-BWM as follows:

$$COA(\tilde{w}_j) = \frac{\frac{(a_{j4}^U - a_{j1}^U) + (H_1(\tilde{A}_j^U) * a_{j2}^U - a_{j1}^U) + (H_2(\tilde{A}_j^U) * a_{j3}^U - a_{j1}^U)}{4} + a_{j1}^U + \frac{(a_{j4}^L - a_{j1}^L) + (H_1(\tilde{A}_j^L) * a_{j2}^L - a_{j1}^L) + (H_2(\tilde{A}_j^L) * a_{j3}^L - a_{j1}^L)}{4} + a_{j1}^L}{2} \quad (1)$$

IT2F-BWM

The best–worst method (BWM) was created and developed by Rezaei in 2015 as a decision-making approach that considers multiple criteria [52]. Its purpose is to determine the significance weights of these criteria and subsequently rank the alternative options through pairwise comparisons. According to Rezaei’s research in 2015, this method proves to be less robust in comparison to the analytic hierarchy process (AHP) due to its increased reliance on pairwise comparison matrices. At the initial stage of the BWM, two vectors are obtained, representing the best and worst criterion, as proposed by Rezaei in 2016 [53]. The BWM has been widely implemented in various domains and contexts involving multi-criteria decision making, as highlighted by Mi et al. in [54]. Within this section, we shall outline the procedural steps of the IT2F-BWM with the center of area method.

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

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

where $\tilde{e}_{ij}$ explains the IT2F preference degree of criterion i over criterion j . In this step, the linguistic variables presented in Table 3 are used. These linguistic variables are also used in the AHP method. For example, if the experts select EI, it means that there is no difference between the best criterion and the other criterion.

Table 3. Linguistic variables for importance weighting [43].

Linguistic Variable	Interval Type-2 Fuzzy Sets
Equally Important (EI)	((1;1;1;1;1), (1;1;1;1;0.9;0.9))
IV2	((1;2;2;3;1;1), (1.5;2;2;2.5;0.9;0.9))
Moderately More Important (MMI)	((2;3;3;4;1;1), (2.5;3;3;3.5;0.9;0.9))
IV4	((3;4;4;5;1;1), (3.5;4;4;4.5;0.9;0.9))
Strongly More Important (SMI)	((4;5;5;6;1;1), (4.5;5;5;5.5;0.9;0.9))
IV6	((5;6;6;7;1;1), (5.5;6;6;6.5;0.9;0.9))
Very Strongly More Important (VSMI)	((6;7;7;8;1;1), (6.5;7;7;7.5;0.9;0.9))
IV8	((7;8;8;9;1;1), (7.5;8;8;8.5;0.9;0.9))
Extremely More Important (EMI)	((8;9;9;10;1;1), (8.5;9;9;9.5;0.9;0.9))

Step 2. The experts assign the best and the worst criterion.

Step 3. The preferences of the best and the worst criterion over all the other criteria are assigned using interval type-2 fuzzy sets. The resulting best-to-others (BO) vector would

$$\text{be: } \tilde{E}_B = \left(\tilde{e}_{B1}, \tilde{e}_{B2}, \dots, \tilde{e}_{Bn} \right),$$

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

Step 4. The optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ are obtained. The center of area defuzzification method is applied in this step. We also constructed the constrained optimization model as in Wu et al. [55]. In addition to constructing the model, the consistency ratio is also checked.

$$\min \max \left\{ \left| \tilde{w}_{BE} \tilde{w}_{jE} - \tilde{E}_{BEj} \right|, \left| \tilde{w}_{jE} \tilde{w}_{WE} - \tilde{E}_{jWE} \right| \right\}$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^n \text{COA}(\tilde{w}_{jE}) = 1 \\ w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\ w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\ w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\ w_{jE1}^U \geq 0, j = 1, 2, \dots, N \end{cases}$$

where

$$\tilde{w}_{BE} = (\tilde{w}_{BE}^U, \tilde{w}_{BE}^L) = \left(\begin{array}{c} (w_{BE1}^U, w_{BE2}^U, w_{BE3}^U, w_{BE4}^U; H_1(\tilde{w}_{BE}^U), H_2(\tilde{w}_{BE}^U)), \\ (a_{BE1}^L, a_{BE2}^L, a_{BE3}^L, a_{BE4}^L; H_1(\tilde{w}_{BE}^L), H_2(\tilde{w}_{BE}^L)) \end{array} \right)$$

$$\tilde{w}_{WE} = (\tilde{w}_{WE}^U, \tilde{w}_{WE}^L) = \left(\begin{array}{c} (w_{WE1}^U, w_{WE2}^U, w_{WE3}^U, w_{WE4}^U; H_1(\tilde{w}_{WE}^U), H_2(\tilde{w}_{WE}^U)), \\ (a_{WE1}^L, a_{WE2}^L, a_{WE3}^L, a_{WE4}^L; H_1(\tilde{w}_{WE}^L), H_2(\tilde{w}_{WE}^L)) \end{array} \right)$$

$$\tilde{w}_{jE} = (\tilde{w}_{jE}^U, \tilde{w}_{jE}^L) = \left(\begin{array}{c} (w_{jE1}^U, w_{jE2}^U, w_{jE3}^U, w_{jE4}^U; H_1(\tilde{w}_{jE}^U), H_2(\tilde{w}_{jE}^U)), \\ (a_{jE1}^L, a_{jE2}^L, a_{jE3}^L, a_{jE4}^L; H_1(\tilde{w}_{jE}^L), H_2(\tilde{w}_{jE}^L)) \end{array} \right)$$

$$\tilde{w}_{BE,jE} = (\tilde{w}_{BE,jE}^U, \tilde{w}_{BE,jE}^L) = \left(\begin{array}{c} \left(\begin{array}{c} w_{BE,jE1}^U, w_{BE,jE2}^U, w_{BE,jE3}^U, w_{BE,jE4}^U \\ H_1(\tilde{w}_{BE,jE}^U), H_2(\tilde{w}_{BE,jE}^U) \end{array} \right), \\ \left(\begin{array}{c} a_{BE,jE1}^L, a_{BE,jE2}^L, a_{BE,jE3}^L, a_{BE,jE4}^L \\ H_1(\tilde{w}_{BE,jE}^L), H_2(\tilde{w}_{BE,jE}^L) \end{array} \right) \end{array} \right)$$

$$\tilde{w}_{jE,WE} = (\tilde{w}_{jE,WE}^U, \tilde{w}_{jE,WE}^L) = \left(\begin{array}{c} \left(\begin{array}{c} w_{jE1,WE}^U, w_{jE2,WE}^U, w_{jE3,WE}^U, w_{jE4,WE}^U \\ H_1(\tilde{w}_{jE,WE}^U), H_2(\tilde{w}_{jE,WE}^U) \end{array} \right), \\ \left(\begin{array}{c} a_{jE1,WE}^L, a_{jE2,WE}^L, a_{jE3,WE}^L, a_{jE4,WE}^L \\ H_1(\tilde{w}_{jE,WE}^L), H_2(\tilde{w}_{jE,WE}^L) \end{array} \right) \end{array} \right)$$

We aimed to minimize the maximum absolute gap in nonlinear programming. In this process, nonlinear programming is used for transforming the model to minimize the absolute gap as $\delta^* = ((\delta^*; \delta^*; \delta^*; \delta^*; 1; 1), (\delta^*; \delta^*; \delta^*; \delta^*; 0.9; 0.9))$.

$$\begin{aligned} \min & \delta^* \\ \text{s.t.} & \left\{ \begin{array}{l} \left| \tilde{w}_{BE1}^U - \tilde{w}_{j1}^U \tilde{w}_{BEj,1}^U \right| \leq \delta^*, \left| \tilde{w}_{BE2}^U - \tilde{w}_{j2}^U \tilde{w}_{BEj,2}^U \right| \leq \delta^*, \\ \left| \tilde{w}_{BE3}^U - \tilde{w}_{j3}^U \tilde{w}_{BEj,3}^U \right| \leq \delta^*, \left| \tilde{w}_{BE4}^U - \tilde{w}_{j4}^U \tilde{w}_{BEj,4}^U \right| \leq \delta^*, \\ \left| \tilde{w}_{BE1}^L - \tilde{w}_{j1}^L \tilde{w}_{BEj,1}^L \right| \leq \delta^*, \left| \tilde{w}_{BE2}^L - \tilde{w}_{j2}^L \tilde{w}_{BEj,2}^L \right| \leq \delta^*, \\ \left| \tilde{w}_{BE3}^L - \tilde{w}_{j3}^L \tilde{w}_{BEj,3}^L \right| \leq \delta^*, \left| \tilde{w}_{BE4}^L - \tilde{w}_{j4}^L \tilde{w}_{BEj,4}^L \right| \leq \delta^*, \\ \left| \tilde{w}_{j1}^U - \tilde{w}_{WE1}^U \tilde{w}_{jWE,1}^U \right| \leq \delta^*, \left| \tilde{w}_{j2}^U - \tilde{w}_{WE2}^U \tilde{w}_{jWE,2}^U \right| \leq \delta^*, \\ \left| \tilde{w}_{j3}^U - \tilde{w}_{WE3}^U \tilde{w}_{jWE,3}^U \right| \leq \delta^*, \left| \tilde{w}_{j4}^U - \tilde{w}_{WE4}^U \tilde{w}_{jWE,4}^U \right| \leq \delta^*, \\ \left| \tilde{w}_{j1}^L - \tilde{w}_{WE1}^L \tilde{w}_{jWE,1}^L \right| \leq \delta^*, \left| \tilde{w}_{j2}^L - \tilde{w}_{WE2}^L \tilde{w}_{jWE,2}^L \right| \leq \delta^*, \\ \left| \tilde{w}_{j3}^L - \tilde{w}_{WE3}^L \tilde{w}_{jWE,3}^L \right| \leq \delta^*, \left| \tilde{w}_{j4}^L - \tilde{w}_{WE4}^L \tilde{w}_{jWE,4}^L \right| \leq \delta^*, \\ \sum_{j=1}^n COA(\tilde{w}_{jE}) = 1 \\ w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\ w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\ w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\ w_{jE1}^U \geq 0, j = 1, 2, \dots, N \end{array} \right. \end{aligned}$$

5. Application

5.1. Mathematical Model of IT2F-BWM

In this sub-section, we present the steps of the proposed IT2F-BWM approach for obtaining the importance weights of shelter site selection criteria. Table 4 presents the linguistic variable of each criterion for Expert 1. For example, the evaluation of the main criteria by Expert 1 is presented in the first row. C6 (proximity) is determined as the best criterion and C2 (electrical infrastructure) is determined as the worst criterion by Expert 1.

Table 4. BO and OW vectors on all criteria and sub-criteria by Expert 1.

Main Criteria	BO	C1	C2	C3	C4	C5	C6
	C6	VSMI	EMI	SMI	MMI	VSMI	EI
	OW	C1	C2	C3	C4	C5	C6
	C2	MMI	EI	IV4	MMI	IV6	EMI
FT	BO	C11	C12	C13	C14	C15	C16
	C14	MMI	SMI	EMI	EI	VSMI	SMI
	OW	C11	C12	C13	C14	C15	C16
	C13	VSMI	SMI	EI	EMI	MMI	SMI
EI	BO	C21	C22	C23			
	C22	SMI	EI	EMI			
	OW	C21	C22	C23			
	C23	SMI	EMI	EI			
HSS	BO	C31	C32	C33			
	C32	SMI	EI	EMI			
	OW	C31	C32	C33			
	C33	SMI	EMI	EI			
SS	BO	C41	C42	C43	C44		
	C41	EI	EMI	MMI	SMI		
	OW	C41	C42	C43	C44		
	C42	EMI	EI	MMI	SMI		

Table 4. Cont.

TDC	BO	C51	C52	C53			
	C52	EMI	EI	SMI			
	OW	C51	C52	C53			
	C51	EI	EMI	SMI			
P	BO	C61	C62	C63	C64	C65	C66
	C64	MMI	EMI	MMI	EI	MMI	MMI
	OW	C61	C62	C63	C64	C65	C66
	C62	MMI	EI	MMI	EMI	MMI	MMI

In addition to the evaluations conducted by Expert 1, we present BO and OW vectors for the main criteria assessed by the nine experts. The sub-criteria are also assessed, and BO and OW vectors are obtained for each one. In the subsequent stage of the IT2FB-WM, a nonlinear model is developed for both the main criteria and all sub-criteria. The step-by-step computation process for constructing a mathematical model of the main criteria by Expert 1 is provided below:

$$\begin{aligned}
 & \min \delta^* \\
 & \text{s.t.} \left\{ \begin{aligned}
 & \left| \tilde{w}_{61}^U - 6\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 7\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 7\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 8\tilde{w}_{14}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^L - 6.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 7\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 7\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 7.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^U - 8\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 9\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 9\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 10\tilde{w}_{24}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^L - 8.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 9\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 9\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 9.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^U - 4\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 5\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 5\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 6\tilde{w}_{34}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^L - 4.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 5\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 5\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 5.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^U - 2\tilde{w}_{41}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 3\tilde{w}_{42}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 3\tilde{w}_{43}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 4\tilde{w}_{44}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^L - 2.5\tilde{w}_{41}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 3\tilde{w}_{42}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 3\tilde{w}_{43}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 3.5\tilde{w}_{44}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^U - 6\tilde{w}_{51}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 7\tilde{w}_{52}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 7\tilde{w}_{53}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 8\tilde{w}_{54}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{61}^L - 6.5\tilde{w}_{51}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 7\tilde{w}_{52}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 7\tilde{w}_{53}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 7.5\tilde{w}_{54}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{11}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{11}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{31}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{31}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{41}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 & \left| \tilde{w}_{51}^U - 5\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{52}^U - 6\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{53}^U - 6\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{54}^U - 7\tilde{w}_{24}^U \right| \leq \delta^*, \\
 & \left| \tilde{w}_{51}^L - 5.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{52}^L - 6\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{53}^L - 6\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{54}^L - 6.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 & \sum_{j=1}^6 COA(\tilde{w}_{jE}) = 1 \\
 & w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
 & w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
 & w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
 & w_{jE1}^U \geq 0, j = 1, 2, \dots, 6
 \end{aligned} \right.
 \end{aligned}$$

The detailed calculating steps of a mathematical model of the favorability of terrain (FT) (C1) for Expert 1 are given in the following:

$$\begin{aligned}
 & \min \delta^* \\
 & \text{s.t.} \left\{ \begin{array}{l}
 \left| \tilde{w}_{41}^U - 2\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{14}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 4\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 5\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 5\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 6\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 4.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 5\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 5\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 5.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 8\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 9\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 9\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 10\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 8.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 9\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 9\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 9.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 6\tilde{w}_{51}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 7\tilde{w}_{52}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 7\tilde{w}_{53}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 8\tilde{w}_{54}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 6.5\tilde{w}_{51}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 7\tilde{w}_{52}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 7\tilde{w}_{53}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 7.5\tilde{w}_{54}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 4\tilde{w}_{61}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 5\tilde{w}_{62}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 5\tilde{w}_{63}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 6\tilde{w}_{64}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 4.5\tilde{w}_{61}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 5\tilde{w}_{62}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 5\tilde{w}_{63}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 5.5\tilde{w}_{64}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{11}^U - 2\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 3\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 3\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 4\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{11}^L - 2.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 3\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 3\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 3.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{21}^U - 2\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 3\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 3\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 4\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{21}^L - 2.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 3\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 3\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 3.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{51}^U - 5\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{52}^U - 6\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{53}^U - 6\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{54}^U - 7\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{51}^L - 5.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{52}^L - 6\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{53}^L - 6\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{54}^L - 6.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{61}^U - 2\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 3\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 3\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 4\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{61}^L - 2.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 3\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 3\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 3.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \sum_{j=1}^6 COA(\tilde{w}_{jE}) = 1 \\
 w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
 w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
 w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
 w_{jE1}^U \geq 0, j = 1, 2, \dots, 6
 \end{array} \right.
 \end{aligned}$$

The detailed calculating computational steps of a mathematical model of the electrical infrastructure (EI) (C2) for Expert 1 are given in the following:

$$\begin{aligned}
& \min \delta^* \\
& \text{s.t.} \left\{ \begin{array}{l}
\left| \tilde{w}_{21}^U - 4\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 5\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 5\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 6\tilde{w}_{14}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 4.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 5\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 5\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 5.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^U - 8\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 9\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 9\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 10\tilde{w}_{34}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 8.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 9\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 9\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 9.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^U - 4\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 5\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 5\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 6\tilde{w}_{24}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^L - 4.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 5\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 5\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 5.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
\sum_{j=1}^3 COA(\tilde{w}_{jE}) = 1 \\
w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
w_{jE1}^U \geq 0, j = 1, 2, 3
\end{array} \right.
\end{aligned}$$

The detailed calculating steps of a mathematical model of the hygiene and sanitary system (HSS) (C3) for Expert 1 are given in the following:

$$\begin{aligned}
& \min \delta^* \\
& \text{s.t.} \left\{ \begin{array}{l}
\left| \tilde{w}_{21}^U - 4\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 5\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 5\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 6\tilde{w}_{14}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 4.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 5\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 5\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 5.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^U - 8\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 9\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 9\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 10\tilde{w}_{34}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 8.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 9\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 9\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 9.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^U - 4\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 5\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 5\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 6\tilde{w}_{24}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^L - 4.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 5\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 5\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 5.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
\sum_{j=1}^3 COA(\tilde{w}_{jE}) = 1 \\
w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
w_{jE1}^U \geq 0, j = 1, 2, 3
\end{array} \right.
\end{aligned}$$

The detailed calculating steps of a mathematical model of the safety and security (SS) (C4) for Expert 1 are given in the following:

$$\begin{aligned}
& \min \delta^* \\
& \text{s.t.} \left\{ \begin{array}{l}
\left| \tilde{w}_{31}^U - 8\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 9\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 9\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 10\tilde{w}_{14}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^L - 8.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 9\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 9\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 9.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^U - 4\tilde{w}_{41}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 5\tilde{w}_{42}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 5\tilde{w}_{43}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 6\tilde{w}_{44}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^L - 4.5\tilde{w}_{41}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 5\tilde{w}_{42}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 5\tilde{w}_{43}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 5.5\tilde{w}_{44}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{11}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{41}^U - 4\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 5\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 5\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 6\tilde{w}_{24}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{41}^L - 4.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 5\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 5\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 5.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
\sum_{j=1}^4 COA(\tilde{w}_{jE}) = 1 \\
w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
w_{jE1}^U \geq 0, j = 1, 2, 3, 4
\end{array} \right.
\end{aligned}$$

The detailed calculating steps of a mathematical model of the transport–distribution capacity (TDC) (C5) for Expert 1 are given in the following:

$$\begin{aligned}
& \min \delta^* \\
& \text{s.t.} \left\{ \begin{array}{l}
\left| \tilde{w}_{21}^U - 8\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 9\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 9\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 10\tilde{w}_{14}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 8.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 9\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 9\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 9.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^U - 4\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{22}^U - 5\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{23}^U - 5\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{24}^U - 6\tilde{w}_{34}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{21}^L - 4.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{22}^L - 5\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{23}^L - 5\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{24}^L - 5.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^U - 4\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 5\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 5\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 6\tilde{w}_{14}^U \right| \leq \delta^*, \\
\left| \tilde{w}_{31}^L - 4.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 5\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 5\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 5.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
\sum_{j=1}^3 COA(\tilde{w}_{jE}) = 1 \\
w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
w_{jE1}^U \geq 0, j = 1, 2, 3
\end{array} \right.
\end{aligned}$$

The detailed calculating steps of a mathematical model of the proximity (P) (C6) for Expert 1 are given in the following:

$$\begin{aligned}
 & \min \delta^* \\
 & \text{s.t.} \left\{ \begin{array}{l}
 \left| \tilde{w}_{41}^U - 2\tilde{w}_{11}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{12}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{13}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{14}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{11}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{12}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{13}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{14}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 8\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 9\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 9\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 10\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 8.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 9\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 9\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 9.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 2\tilde{w}_{31}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{32}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{33}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{34}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{31}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{32}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{33}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{34}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 2\tilde{w}_{51}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{52}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{53}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{54}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{51}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{52}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{53}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{54}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^U - 2\tilde{w}_{61}^U \right| \leq \delta^*, \left| \tilde{w}_{42}^U - 3\tilde{w}_{62}^U \right| \leq \delta^*, \left| \tilde{w}_{43}^U - 3\tilde{w}_{63}^U \right| \leq \delta^*, \left| \tilde{w}_{44}^U - 4\tilde{w}_{64}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{41}^L - 2.5\tilde{w}_{61}^L \right| \leq \delta^*, \left| \tilde{w}_{42}^L - 3\tilde{w}_{62}^L \right| \leq \delta^*, \left| \tilde{w}_{43}^L - 3\tilde{w}_{63}^L \right| \leq \delta^*, \left| \tilde{w}_{44}^L - 3.5\tilde{w}_{64}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{11}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{12}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{13}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{14}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{11}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{12}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{13}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{14}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{31}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{32}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{33}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{34}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{31}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{32}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{33}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{34}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{51}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{52}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{53}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{54}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{51}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{52}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{53}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{54}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \left| \tilde{w}_{61}^U - 2\tilde{w}_{21}^U \right| \leq \delta^*, \left| \tilde{w}_{62}^U - 3\tilde{w}_{22}^U \right| \leq \delta^*, \left| \tilde{w}_{63}^U - 3\tilde{w}_{23}^U \right| \leq \delta^*, \left| \tilde{w}_{64}^U - 4\tilde{w}_{24}^U \right| \leq \delta^*, \\
 \left| \tilde{w}_{61}^L - 2.5\tilde{w}_{21}^L \right| \leq \delta^*, \left| \tilde{w}_{62}^L - 3\tilde{w}_{22}^L \right| \leq \delta^*, \left| \tilde{w}_{63}^L - 3\tilde{w}_{23}^L \right| \leq \delta^*, \left| \tilde{w}_{64}^L - 3.5\tilde{w}_{24}^L \right| \leq \delta^*, \\
 \sum_{j=1}^6 COA(\tilde{w}_{jE}) = 1 \\
 w_{jE1}^U \leq w_{jE1}^L, w_{jE4}^L \leq w_{jE4}^U \\
 w_{jE1}^L \leq w_{jE2}^L \leq w_{jE3}^L \leq w_{jE4}^L \\
 w_{jE1}^U \leq w_{jE2}^U \leq w_{jE3}^U \leq w_{jE4}^U \\
 w_{jE1}^U \geq 0, j = 1, 2, \dots, 6
 \end{array} \right.
 \end{aligned}$$

At the final step of the proposed IT2F-BWM, we have obtained the final and local weight values of main criteria and sub-criteria. The results for Expert 1 are given in Figure 2. According to the obtained results of Expert 1, the proximity (C6) is determined as the best main criterion with 49.64%. When checking the proximity (C6) criterion, the distance from major roads (C64) is determined as the best sub-criterion for Expert 1.

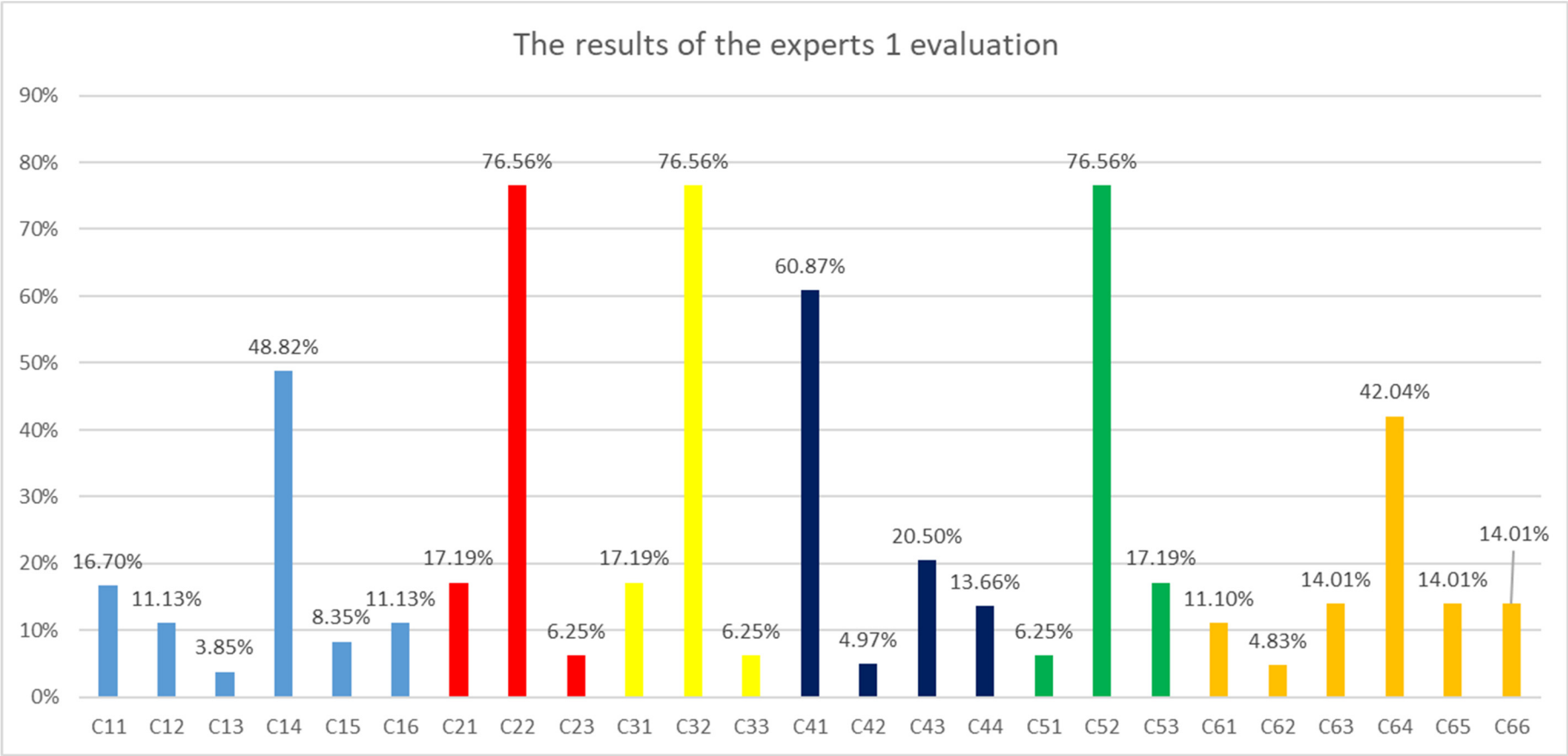


Figure 2. Local weight values of sub-criteria by IT2F-BWM for Expert 1.

The importance weights of the criteria for selecting shelter sites are calculated, and the consistency ratio for all expert evaluations is determined and displayed in Table 5. Since all consistency ratios are less than 10%, it is confirmed that the evaluations are more reliable when using IT2F-BWM. For instance, when evaluating the main criteria, Expert 1's consistency ratio is calculated as 2.04%, which is a valid and reasonable consistency ratio. The overall consistency ratio for the main criteria is calculated as 1.90% and is presented in Table 5.

Table 5. The consistency ratios for all criteria.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Overall
Main Criteria	2.04%	0.54%	1.63%	0.54%	1.63%	2.18%	1.96%	1.46%	5.15%	1.90%
C1	5.47%	3.77%	5.64%	0.54%	5.64%	5.64%	1.63%	2.18%	1.63%	3.57%
C2	2.47%	2.47%	2.47%	2.47%	2.47%	3.65%	3.65%	0.89%	0.89%	2.38%
C3	2.47%	2.47%	2.47%	3.65%	2.47%	0.89%	3.65%	3.65%	3.65%	2.82%
C4	1.96%	0.73%	2.11%	0.73%	2.11%	2.83%	0.73%	2.11%	2.11%	1.71%
C5	2.47%	0.89%	2.47%	3.65%	2.47%	2.47%	2.47%	3.65%	2.47%	2.56%
C6	0.99%	2.06%	3.39%	1.68%	1.68%	1.21%	3.39%	1.63%	4.49%	2.28%

5.2. Results and Discussion

Table 6 presents the results of the nine experts. The last two columns of the table present the local and global weights of the main and sub-criteria, respectively. Figure 3 also shows the distribution of importance weights of sub-criteria for the nine experts. The main criteria are evaluated at the beginning of the analysis. Proximity (C6) has the highest importance weight, implying that the distance to various important locations (like settlements, markets, health facilities, etc.) is the most significant factor for shelter site selection. Transport–distribution capacity (C5) follows closely, suggesting the ability to transport and distribute is also vital. Aspects like hygiene and sanitary system (C3) and favorability of terrain (C1) have comparatively lower weights, but still, they play a role in the shelter site selection.

Table 6. The results of the experts' evaluation.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Local Weights	Global Weights
C1	0.0876	0.1327	0.0365	0.1327	0.1134	0.0332	0.1548	0.1528	0.0667	0.1011	
C2	0.0365	0.1327	0.1582	0.1327	0.1134	0.1726	0.1548	0.1019	0.1100	0.1236	
C3	0.1168	0.1327	0.1055	0.0442	0.1134	0.1150	0.1548	0.0370	0.0055	0.0917	
C4	0.1752	0.1327	0.4625	0.4252	0.0412	0.0863	0.0298	0.1019	0.1467	0.1779	
C5	0.0876	0.4252	0.0791	0.1327	0.1134	0.4779	0.4286	0.1528	0.2200	0.2352	
C6	0.4964	0.0442	0.1582	0.1327	0.5052	0.1150	0.0774	0.4537	0.4511	0.2704	
C11	0.1670	0.1327	0.1134	0.1327	0.5052	0.5052	0.5052	0.1150	0.1134	0.2544	0.02573
C12	0.1113	0.1327	0.1134	0.1327	0.1134	0.1134	0.1134	0.1150	0.1134	0.1176	0.01190
C13	0.0385	0.0442	0.0412	0.1327	0.1134	0.1134	0.1134	0.0863	0.1134	0.0885	0.00895
C14	0.4882	0.1327	0.1134	0.0442	0.0412	0.0412	0.0412	0.1726	0.1134	0.1320	0.01335
C15	0.0835	0.4252	0.5052	0.1327	0.1134	0.1134	0.1134	0.4779	0.5052	0.2744	0.02775
C16	0.1113	0.1327	0.1134	0.4252	0.1134	0.1134	0.1134	0.0332	0.0412	0.1330	0.01345
C21	0.1719	0.7656	0.7656	0.7656	0.7656	0.8000	0.8000	0.7062	0.7062	0.6941	0.08581
C22	0.7656	0.0625	0.1719	0.1719	0.0625	0.0556	0.0556	0.2203	0.2203	0.1985	0.02453
C23	0.0625	0.1719	0.0625	0.0625	0.1719	0.1444	0.1444	0.0734	0.0734	0.1074	0.01328
C31	0.1719	0.7656	0.1719	0.8000	0.1719	0.2203	0.8000	0.1444	0.1444	0.3767	0.03453
C32	0.7656	0.1719	0.7656	0.1444	0.7656	0.7062	0.1444	0.8000	0.8000	0.5627	0.05157
C33	0.0625	0.0625	0.0625	0.0556	0.0625	0.0734	0.0556	0.0556	0.0556	0.0606	0.00556
C41	0.6087	0.5787	0.1467	0.1806	0.1467	0.6207	0.5787	0.1467	0.6533	0.4067	0.07237
C42	0.0497	0.1806	0.0533	0.0602	0.0533	0.0431	0.0602	0.0533	0.0533	0.0675	0.01200
C43	0.2050	0.0602	0.6533	0.5787	0.6533	0.1121	0.1806	0.6533	0.1467	0.3603	0.06411
C44	0.1366	0.1806	0.1467	0.1806	0.1467	0.2241	0.1806	0.1467	0.1467	0.1655	0.02944

Table 6. Cont.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Local Weights	Global Weights
C51	0.0625	0.0734	0.0625	0.0556	0.0625	0.1719	0.0625	0.0556	0.0625	0.0743	0.01748
C52	0.7656	0.7062	0.1719	0.1444	0.7656	0.0625	0.1719	0.8000	0.7656	0.4838	0.11380
C53	0.1719	0.2203	0.7656	0.8000	0.1719	0.7656	0.7656	0.1444	0.1719	0.4419	0.10396
C61	0.1110	0.0314	0.4399	0.0934	0.0934	0.4086	0.4399	0.5052	0.4445	0.2852	0.07714
C62	0.0483	0.0816	0.0543	0.0540	0.0540	0.0463	0.0543	0.1134	0.0572	0.0626	0.01693
C63	0.1401	0.1088	0.1264	0.4567	0.1320	0.1363	0.1264	0.1134	0.1428	0.1648	0.04456
C64	0.4204	0.1632	0.1264	0.1320	0.4567	0.1363	0.1264	0.1134	0.1063	0.1979	0.05351
C65	0.1401	0.4519	0.1264	0.1320	0.1320	0.1363	0.1264	0.1134	0.1428	0.1668	0.04511
C66	0.1401	0.1632	0.1264	0.1320	0.1320	0.1363	0.1264	0.0412	0.1063	0.1227	0.03317

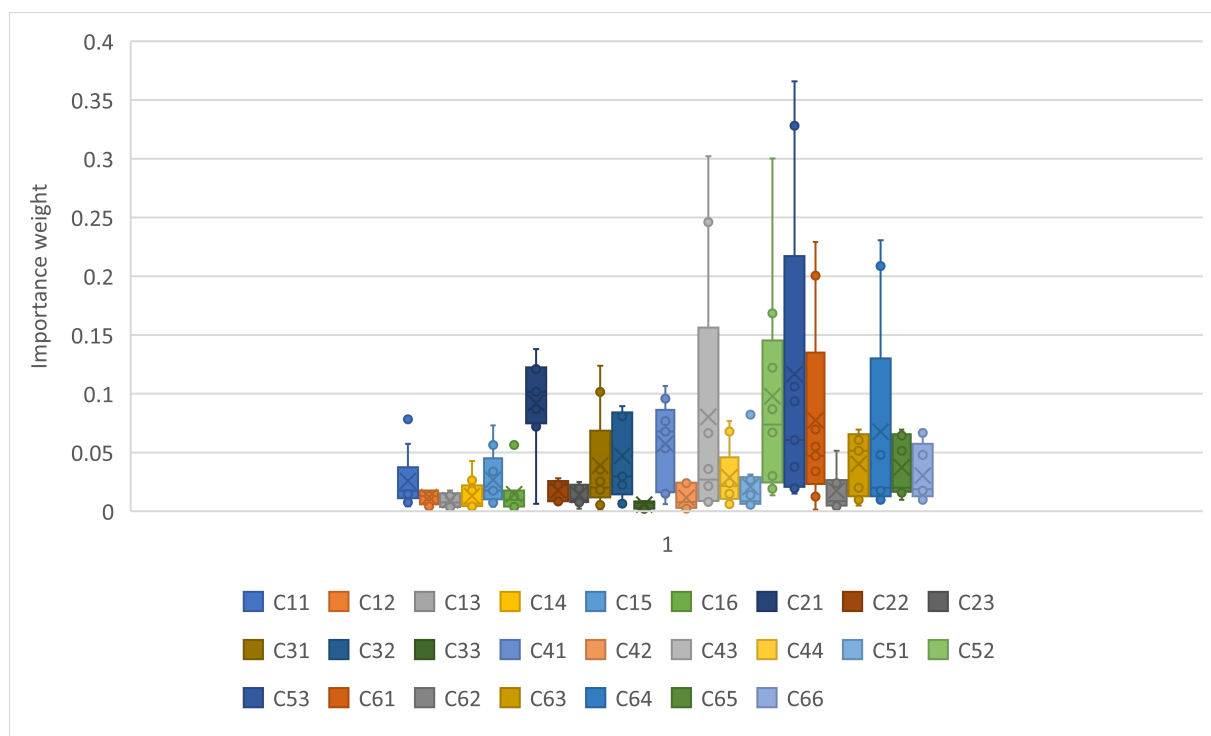


Figure 3. The boxplot of sub-criteria for 9 experts.

Then, the sub-criteria of each main criterion concerning local weights are evaluated for shelter site selection. The three most important sub-criteria of the favorability of terrain are population density (area per capita) (C15), topography (C11), and ownership status (C14). Shelters should be in areas with a population density that is low enough to accommodate a large number of people without overcrowding. They should be located on flat ground to avoid the risk of flooding or landslides.

The most important sub-criterion of the electrical infrastructure is electricity with an importance weight of 0.6941. Available electricity (C21) is critical for lighting, heating, cooking, and communication in shelters. Shelters should be located near a reliable source of electricity or generate electricity using alternative means, such as generators or solar panels.

The drainage system and sewer infrastructure (C32) has the highest importance weight (0.5627) of the main hygiene and sanitary system criterion. The drainage system and sewer infrastructure is essential for protecting public health and the environment.

Landslides and flooding (C41) is the most important criterion of safety and security with an importance weight of 0.4067. When selecting a shelter site, it is important to choose a location that is not at risk of landslides or flooding.

The distribution center capacity (C52) is the most important criterion of the main transport–distribution capacity criterion. The distribution center must have the capacity to

handle the volume of goods needed for the shelter site. This includes the ability to store and distribute food, water, medical supplies, and other essential items.

The most important criterion of the proximity is distance to settlement (accessibility) (C61). This is given an importance weight of 0.2852. This suggests that it is important for the shelter site to be located close to where people live, so that they can easily reach it in the event of a disaster. The next most important factor is distance to major roads (C64), with an importance weight of 0.1979. This suggests that it is also important for the shelter site to be located near major roads, so that people can easily get to it from other parts of the city or region.

The five most important criteria with respect to global weights are also analyzed. Distribution center capacity (C52) is the most important criterion for a shelter site, as it determines how many people the site can accommodate. This affects the proximity to important facilities as health facilities, major roads, and transport centers [28]. Adequate distribution logistics personnel (C53) is also a very important criterion, as it ensures that there are enough people to staff the distribution center and ensure that supplies are distributed efficiently. It will increase the efficiency of the distribution of shelter sites [10]. Available electricity (C21) is essential for many aspects of a shelter site, such as lighting, cooking, and providing medical care. It is determined as one of the influences [28] that directly affect the sustainability of shelter sites. Electricity should also be considered as one of the indicators that impact the environment in shelter sites [8]. The shelter site should be close enough to a settlement (accessibility) (C61) that people can easily access it, but not so close that it is in the way of emergency services [37]. Another criterion is landslides, flooding, etc. (C41) for eliminating the risk of natural disasters such as landslides and flooding [28,37,56]. On the other hand, the five least important criteria for shelter sites are also analyzed. While optimum distribution condition (C51) is an important criterion, it is not as essential as the others. It is possible to operate a shelter site even if the distribution conditions are not optimal. The distance to disaster debris storage areas (C62) criterion is only relevant in the immediate aftermath of a disaster. Once the debris has been cleared, it is no longer a concern. While suitable for disabled and elderly transportation (C16) is important to make the shelter site accessible to everyone, this is not as essential as some of the other criteria. If necessary, people with disabilities can be assisted in getting to and from the shelter site. The ownership status (C14) criterion is not relevant to the operation of the shelter site. The site can be owned by the government, a private organization, or even an individual. While solid waste disposal (C33) is important to dispose of solid waste properly, this is not as essential as some of the other criteria. It is possible to operate a shelter site even if the solid waste disposal system is not optimal.

6. Conclusions

The victims need a protected place to live temporarily after a disaster such as an earthquake for assisting their initial humanitarian relief. The local authorities and managers must assign the victims to a suitable shelter site in a reliable manner. Shelter site selection plays an important role and directly affects humanitarian relief operations. This paper analyzes the shelter site selection criteria based on experts' opinion. We applied the best–worst method under interval type-2 fuzzy sets for determining the importance weights of the main criteria and sub-criteria. The best–worst method is simple and needs few comparison matrices. In addition to the advantages of the best–worst method, interval type-2 fuzzy sets reflect the uncertainty more suitably and involve manageable and easy computation.

The study's findings have practical implications for local authorities, managers, and decision makers. Firstly, the importance weights of the main criteria and sub-criteria are determined and analyzed. In this paper, the six main criteria and sub-criteria are evaluated by experts for shelter site selection based on linguistic assessments. The nine experts, who have a range of expertise, experience, education, and occupations, evaluated the shelter site selection criteria. The proximity and transport–distribution capacity are determined as the two most important main criteria. Distribution center capacity, adequate distribu-

tion logistics personnel, available electricity, settlement (accessibility), and landslides and flooding are determined as the five most important sub-criteria.

For future studies, the considered shelter site selection criteria should be evaluated using the best–worst method under different versions of fuzzy sets such as intuitionistic fuzzy sets, interval-valued intuitionistic fuzzy sets, and triangular fuzzy sets.

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