

Article

# Humanitarian Rescue Scheme Selection under the Covid-19 Crisis in China: Based on Group Decision-Making Method

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**Abstract:** Humanitarian rescue has become an important part of government emergency management in China. In order to select the optimal humanitarian rescue scheme accurately and in a timely manner in an emergency, reduce the harm of disasters to human life and health, and improve the government's emergency management ability, a multi-attribute emergency group decision-making method is proposed. First, interval-valued intuitionistic fuzzy sets are used to express the preferences of decision-makers, and interval-valued intuitionistic fuzzy entropy is used to calculate attribute weights. Then, based on the technique for order preference by similarity to an ideal solution (TOPSIS) method, the weight of the decision-maker is calculated. Then, the relevant interval intuitionistic fuzzy operators are used to summarize the preferences of decision-makers in group decision-making. Finally, we will use the closeness ranking method to choose the optimal scheme, and the feasibility and practicability of the proposed method are demonstrated by an example. The example shows that the model is more scientific, objective, and comprehensive in solving the problem of multi-attribute group decision-making than the traditional scheme selection, which only depends on the subjective discussion of decision-makers.



**Citation:** Deng, X.; Kong, Z. Humanitarian Rescue Scheme Selection under the Covid-19 Crisis in China: Based on Group Decision-Making Method. *Symmetry* **2021**, *13*, 668. <https://doi.org/10.3390/sym13040668>

Academic Editor: José Carlos R. Alcantud

Received: 30 March 2021  
Accepted: 11 April 2021  
Published: 13 April 2021

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## 1. Introduction

The rate of growth of natural disasters (e.g., droughts, hurricanes, floods, famines, viruses, and earthquakes) and manmade disasters (e.g., conflicts among and within nations, refugee crises, and wars) has been impacting the social existence of mankind [1]. This trend could continue in the future.

The occurrence of a disaster is uncertain, making it difficult for people to predict it. Sudden disasters pose a major threat to human life and health and severely affect economic development and social stability, such as the COVID-19 pandemic, which poses unprecedented challenges for governments and societies around the world [2].

Humanitarian rescue operations have emerged as a new area of research which has attracted the attention of both academicians and researchers [3]. The importance of humanitarian rescue has been discussed in the United Nations' (UN) operations for mitigating risk and streamlining disaster rescue operations across the globe [4].

Humanitarian rescue plays an important role in responding to emergencies. The main task of humanitarian rescue is the need to respond quickly in a short time. The implementation of humanitarian rescue needs to choose the best option from a set of alternatives based on actual scenarios. However, how to choose one is still an urgent problem.

Because the scene and the external environment are complex and dynamic to changes, the rescue activities present complex characteristics, such as being multi-stage and multi-agent. In particular, humanitarian rescue is a systematic project [5] which involves various government departments. The humanitarian rescue process in China involves departments such as transportation, communications, first aid, electric power, medical treatment,

water conservancy, and air defense. Although their overall goals are the same, there is a large number of decision-makers who represent the interests of different departments, which have intricate relationships. When an emergency occurs, issues related to resource scheduling, material allocation, and sequencing of rescue activities may cause certain conflicts of interest, which will eventually affect the rescue. Therefore, the process of the selection of the humanitarian rescue scheme is essentially a multi-agent, multi-attribute group decision-making process.

Researchers have explored the scientific rationality of applying group decision-making methods in many fields. Li et al. [6] proposed a partner selection model based on interval-valued intuitionistic fuzzy set multi-attribute decision-making in military–civilian scientific and technological collaborative innovation (MCSTCI). Lin et al. [7] proposed an extended linguistic multi-attribute group decision-making (MAGDM) framework for evaluating online teaching quality. Zhu et al. [8] proposed a group decision-making framework for measuring urban resilience to flooding and applying it to the resilience evaluation problem of 41 cities in the Yangtze River Basin. Moghadas et al. [9] proposed a hybrid multi-criteria decision-making (MCDM) method, which is a combination of the analytical hierarchy process (AHP) to weigh the selected indicators and the technique for order preference by similarity to an ideal solution (TOPSIS) to order urban districts in Tehran based on their resilience levels.

Multi-attribute emergency group decision-making methods have been widely used in emergencies. Yin et al. [10] proposed gray relational multi-attribute group decision-making methods with respect to multi-attribute group decision-making problems, where attribute values take the form of interval gray trapezoid fuzzy linguistic variables, and the expert weight and the attribute weight are determined by the maximum deviation method. Aiming at the special type of emergency response solution evaluation problems that hold the two characteristics, Qi et al. [11] investigated effective multiple criteria group decision making (MCGDM) approaches by hiring an interval-valued dual hesitant fuzzy set (IVDHFS) to comprehensively depict decision hesitancy, and they defined a fuzzy entropy measure for IVDHFS so that its derivative decision models could avoid potential information distortion in models based on classic IVDHFS distance measures with a subjective supplementing mechanism. Liang et al. [12] proposed a novel emergency decision method, developing the linguistic distribution power average (LDPA) and linguistic distribution weighted power average (LDWPA) operators to aggregate the subgroups' evaluations. Li et al. [13] proposed a novel multiple attribute group decision-making algorithm based on a group compromise framework without determining the weight of the decision-maker. The algorithm utilized an uncertain multiplicative linguistic variable to measure the individual original preference. The attribute weight was calculated by maximizing the differences among alternatives. It determined the ranking of the individual alternatives according to the net flow of each alternative.

At present, there are many studies on the humanitarian rescue scheme, mainly involving the improvement of the humanitarian rescue scheme system [14], the humanitarian assistance practices [15], and the connection with the emergency scheme [16]. However, there is no research on the selection process and decision-making methods of humanitarian rescue. Therefore, it is very necessary to conduct a study to determine the selection process and decision-making methods of humanitarian rescue.

The multi-attribute emergency group decision-making method can weaken the subjective incompleteness of decision-makers, gather their professional knowledge and experience, and quickly select the optimal scheme in a limited time, which is of great significance to improve the efficiency of humanitarian rescue. This paper focuses on the selection processes of humanitarian rescue schemes under emergencies and using the guidance of group decision theory to improve the efficiency of scheme selection and reduce the losses caused by emergencies. This paper will (1) compare the advantages and disadvantages of existing multiple attribute group decision-making methods, (2) analyze the characteristics of scheme selection and clarify that the selection of the humanitarian rescue scheme is a multi-

subject, multi-attribute group decision-making process, and (3) construct a multi-attribute emergency group decision model based on the actual situation of humanitarian rescue.

The multi-attribute group decision-making method has been applied in many fields, and its scientificity and rationality have been widely confirmed. However, its application in humanitarian rescue has not yet been discussed. Based on the importance of humanitarian rescue, the authors propose the use the multi-attribute group decision-making method in the selection of humanitarian rescue schemes. According to the requirements of rapid scheme selection, we propose the multi-attribute group decision-making method for humanitarian rescue and the selection of the optimal scheme in a scientific and timely manner.

The structure of this paper is as follows. In Section 2, the concept and the key content of the multi-attribute emergency group decision-making methods are introduced, and the advantages and disadvantages of existing multiple attribute group decision-making methods are compared to choose a suitable method. In Section 3, we analyze the features of the selection of the humanitarian rescue scheme in China and find it is a multi-subject, multi-attribute group decision-making process. Then, the multi-attribute emergency group decision model is proposed in Section 4. In Section 5, an example of selecting earthquake rescue alternatives is presented to illustrate the feasibility and practicability of the proposed method. Finally, discussion and conclusions are given in Sections 6 and 7, respectively.

## 2. Multi-Attribute Emergency Group Decision-Making Method

Multi-attribute emergency group decision-making refers to the process of aggregating the decision-making information of different decision-makers within a limited time to obtain the optimal solution.

The key content of the multi-attribute emergency group decision-making method includes determining the preference expression of decision-makers, determining the attribute weight of the plan, and determining the weight of decision-makers. This is the basis of the paper for exploring applicable emergency group decision-making methods.

Due to the complexity and uncertainty of emergencies, decision-makers are unable to give more accurate preference information in the cognitive process of emergencies due to the lack of expertise and limited time, which means hesitation. In order to solve the problem of measuring the hesitation of decision-makers in group decision-making, scholars have introduced the values of different data types instead of real-valued evaluation values. At present, most studies use interval intuitionistic fuzzy sets to describe decision-makers' preference information expressions for the scheme [17]. Interval intuitionistic fuzzy sets express membership, non-membership, and hesitation information in the form of interval numbers, which are more flexible than fuzzy sets [18] and intuitionistic fuzzy sets [19] in dealing with fuzzy issues such as emergency group decision-making. Some scholars have carried out research on the basic theory and practical application of interval intuitionistic fuzzy sets. Xu [20] applied the theory of interval intuitionistic fuzzy sets to the field of decision-making, which provides an application basis for the selection of schemes in this paper. Based on this, we will use interval intuitionistic fuzzy sets as a tool to express decision-makers' preferences.

Compared with a single decision-maker participating in group decision-making, group decision-making can avoid arbitrary situations, but some decision-makers only consider their own interests in the process of group decision-making. To avoid this problem, the decision-maker weights need to be determined in the group decision-making process. Scholars have proposed some methods to determine the weight of decision-makers, such as the projection method [21], TOPSIS method [22], goal planning method [23], gray correlation [24], relative distance [25], and relative proximity [26]. Compared with several other methods, the TOPSIS method is based on the Hamming distance between alternative plans and ideal plans. This method is easy to calculate and can quickly determine the weight of decision-makers, which is suitable for the selection of a humanitarian rescue scheme.

In order to reflect the importance of the scheme attributes, the scheme attributes need to be weighted. There are also many studies on attribute weights, which can be roughly

divided into the subjective weighting method and objective weighting method. The subjective weighting method is subjective and arbitrary, while the objective weighting method determines weights based on raw data. At present, a better method to determine the attribute weight is the comprehensive subjective and objective weighting method. Xu [20] proposed a method for solving attribute weights based on the idea of maximum deviation; Sun et al. [27] used the subjective weighting method, AHP, and objective weighting method to calculate two attribute weight vectors and then used the objective programming method to obtain comprehensive attribute weights; Gao et al. [28] proposed a method for determining weights based on improved interval intuitionistic fuzzy entropy; and Fu et al. [29] proposed an attribute determination method based on information entropy. We found that there are many studies on using entropy to determine attribute weights. Entropy is a tool for measuring the degree of ambiguity. The smaller the amount of information, the greater the degree of ambiguity, and the larger the entropy value. When emergencies occur, the selection of a humanitarian rescue scheme faces the risks of time constraints and incomplete information. Therefore, we propose using entropy to determine attribute weights to solve these problems.

### 3. Characteristics of the Selection of the Humanitarian Rescue Scheme

The selection of the humanitarian rescue scheme refers to the process by which multiple decision-makers evaluate and select the best plan in a limited time based on multiple attributes. It is a typical multi-attribute emergency group decision-making process, which mainly has several characteristics.

First, there are many decision-makers. According to the concept of integration [30], in the process of implementing humanitarian rescue, the government is the responsible body, its various departments are the executing bodies, and the humanitarian rescue agencies affiliated with the government are the coordinating bodies.

Second, the interests of decision-makers are different. The common goal of all decision-makers is to complete the protection of emergency resources, but each participant will safeguard their own interests. Throughout the decision-making process, decision-makers have heterogeneity [31]; that is, decision-makers have different levels of specialization, which leads them to have different understandings of the natures of tasks.

Third, decision-making objectives are diverse. When the common goal is broken down, there will be many subgoals, such as improving the efficiency of resource security, improving the quality of resource security, and reducing costs. However, sometimes these goals are conflicting. For example, we must improve the efficiency of resource protection and control costs as much as possible.

Finally, there is a risk of incomplete information in the selection of a humanitarian rescue scheme. The appearance of emergency needs is accidental and non-repeatable. Despite the increasing power of modern information technology, the problems of information asymmetry and incompleteness remain unsolved.

In fact, according to the analysis of the above characteristics, the selection of a humanitarian rescue scheme is not only a group decision-making process but also a multi-attribute and multi-objective group decision-making process. In order to simplify the research, we propose a model based on multi-attribute group decision-making. The multi-objective problem will be considered in future research.

### 4. Multi-Attribute Emergency Group Decision Model

#### 4.1. Problem Representation

Let the alternative set of multi-attribute emergency group decision-making be  $F = \{f_1, f_2, \dots, f_m\}$ , let the group of decision-makers participating in group decision-making be  $E = \{e_1, e_2, \dots, e_p\}$ , and let the attribute weight be  $W = \{w_1, w_2, \dots, w_n\}$  ( $0 \leq w_j \leq 1, \sum_{j=1}^n w_j = 1, j = 1, 2, \dots, n$ ). Let the decision-maker weight be  $\lambda_k (0 \leq \lambda_k \leq 1)$ . Use  $[a_{ij}^k, b_{ij}^k]$  and  $[c_{ij}^k, d_{ij}^k]$  to represent the evaluation value of decision-maker  $e_k (k = 1, 2, \dots, p)$

in choosing scheme  $f_i (i = 1, 2, \dots, m)$ , based on attribute  $A_j (j = 1, 2, \dots, n)$ ,  $([a_{ij}^k, b_{ij}^k] \subseteq [0, 1], [c_{ij}^k, d_{ij}^k] \subseteq [0, 1], b_{ij}^k + d_{ij}^k \leq 1)$ , and let the hesitation be  $[g, h]$  [32,33]. Use interval intuitionistic fuzzy numbers  $r_{ij}^k = ([a_{ij}^k, b_{ij}^k], [c_{ij}^k, d_{ij}^k])$  to represent decision-makers' evaluation values. The decision matrix is expressed as  $R^k = (r_{ij}^k)_{m \times n}$  ( $k = 1, 2, \dots, p$ ).

#### 4.2. Determining Attribute Weights Based on Improved Interval Intuitionistic Fuzzy Entropy

Interval intuitionistic fuzzy entropy can reflect the information amount of interval intuitionistic fuzzy sets. The larger the entropy value, the higher the degree of ambiguity and uncertainty of the attribute information; that is, the smaller the amount of information available for the humanitarian rescue scheme will be, which leads to a smaller attribute weight. When using entropy to calculate attribute weights, researchers often consider the membership and non-membership degrees of interval intuitionistic fuzzy sets but ignore the hesitation, which will cause the obtained attribute weights to deviate from the true will of the decision-maker. We propose determining attribute weights based on improved interval intuitionistic fuzzy entropy and then considering the membership, non-membership, and hesitation of interval intuitionistic fuzzy sets to make the obtained attribute weights closer to the true will of the decision-maker.

Let the decision-maker's interval intuitionistic fuzzy entropy about an attribute be

$$E(X_j^k) = \frac{1}{p} \sum_{i=1}^p e(r_{ij}) = \frac{1}{p} \sum_{i=1}^p \frac{4 - [|a_i - c_i| + |b_i - d_i|]^2 + [g_i + h_i]^2}{8}, j = 1, 2, \dots, n \quad (1)$$

where  $X_j^k$  represents the evaluation value of the decision-maker  $k$  on the attribute  $j$ ;  $r_{ij}$  represents the evaluation value of the attribute  $j$  of the scheme  $i$  by the decision-maker;  $p$  represents the total number of decision-makers; and  $n$  represents the total number of attributes.

Let the decision-maker's attribute weight about an attribute be

$$w_j = \frac{1 - E(X_j^k)}{n - \sum_{j=1}^n E(X_j^k)} \quad (2)$$

#### 4.3. Determining the Weight of Decision-Makers: An Interval Intuitionistic Fuzzy Ideal Point Method Based on TOPSIS

The interval intuitionistic fuzzy ideal point method based on TOPSIS uses the Hamming distance [34] between the humanitarian rescue scheme and the ideal scheme as the basis for ranking. It is easy to understand and calculate.

The decision-maker's positive ideal scheme  $r_{ij}^{k+}$  and negative ideal scheme  $r_{ij}^{k-}$  can be determined as follows:

$$r_{ij}^{k+} = ([a_1^{k+}, b_1^{k+}], [c_1^{k+}, d_1^{k+}], [a_2^{k+}, b_2^{k+}], [c_2^{k+}, d_2^{k+}], \dots, [a_n^{k+}, b_n^{k+}], [c_n^{k+}, d_n^{k+}]) \quad (3)$$

$$\begin{aligned} r_{ij}^{k-} &= ([a_1^{k-}, b_1^{k-}], [c_1^{k-}, d_1^{k-}], [a_2^{k-}, b_2^{k-}], [c_2^{k-}, d_2^{k-}], \dots, [a_n^{k-}, b_n^{k-}], [c_n^{k-}, d_n^{k-}]) \\ &\quad ([a_j^{k+}, b_j^{k+}], [c_j^{k+}, d_j^{k+}]) = ([\max_a a_{ij}^k, \max_b b_{ij}^k], [\min_c c_{ij}^k, \min_d d_{ij}^k]), \\ &\quad ([a_j^{k-}, b_j^{k-}], [c_j^{k-}, d_j^{k-}]) = ([\min_a a_{ij}^k, \min_b b_{ij}^k], [\max_c c_{ij}^k, \max_d d_{ij}^k]) \end{aligned} \quad (4)$$

$$j \in 1, 2, \dots, n; k \in 1, 2, \dots, p$$

Calculate the distance from each humanitarian rescue scheme to the positive and negative ideal scheme, respectively, based on the Hamming distance:

$$dr_i^{k+} = d(r_{ij}^{k+}, r_{ij}^k) = \frac{1}{4} \sum_{j=1}^n w_j [ |a_j^{k+} - a_j^k| + |b_j^{k+} - b_j^k| + |c_j^{k+} - c_j^k| + |d_j^{k+} - d_j^k| ] \quad (5)$$

$$dr_i^{k-} = d(r_{ij}^k, r_{ij}^{k-}) = \frac{1}{4} \sum_{j=1}^n w_j [\left| a_j^k - a_j^{k-} \right| + \left| b_j^k - b_j^{k-} \right| + \left| c_j^k - c_j^{k-} \right| + \left| d_j^k - d_j^{k-} \right|] \quad (6)$$

where  $r_{ij}^k$  represents the evaluation value of the attribute  $j$  of the scheme  $i$  by the decision-maker  $k$ .

The assignment is based on the principle that the larger the decision-maker's preference for the optimal scheme is, the smaller the decision weight is [35]. If the decision-maker's evaluation of the positive ideal scheme is higher, and the negative evaluation of the negative ideal scheme is lower, the degree of preference is greater. Therefore, decision-makers' preferences are measured by the distance between the positive ideal scheme and the negative ideal scheme. The specific calculation is as follows:

$$\mu_k = \sum_{j=1}^n (dr_i^{k+} - dr_i^{k-}), i \in 1, 2, \dots, m \quad (7)$$

$$\lambda_k = \frac{1/\mu_k}{\sum_{k=1}^p 1/\mu_k} \quad (8)$$

where  $\mu_k$  represents the preference of decision-makers  $k$  and  $\lambda_k$  represents the weight of decision-makers  $k$ .

#### 4.4. Ranking

Researchers explore the ranking method of interval intuitionistic fuzzy numbers. Xu proposed the comparison rule of interval intuitionistic fuzzy numbers. Ye [36] proposed a new interval intuitionistic fuzzy number exact function. Lakshmana et al. [37] constructed a generalized exact function. Wu et al. [38] determined the superiority and inferiority of the scheme set based on the relative closeness. By comparing and analyzing several methods through examples, Tan et al. [39] verified that the closeness ranking method of interval intuitionistic fuzzy numbers based on TOPSIS could achieve the rankings of all interval intuitionistic fuzzy numbers. They confirmed that the calculation results of this method were closer to the actual situation. Therefore, we chose this method to solve the ranking of schemes.

Calculate the relative closeness of decision-makers on humanitarian rescue schemes with the following equation:

$$C_i^k = \frac{dr_i^{k-}}{dr_i^{k+} + dr_i^{k-}} \quad (9)$$

Use the interval intuitionistic fuzzy weighted geometric average operator to aggregate the decision-makers' weight values and relative closeness to obtain the relative closeness of the comprehensive group decision of the scheme:

$$S_i = \prod_{k=1}^p (C_i^k)^{\lambda_k} \quad (10)$$

The ranking is based on the principle that the larger the relative closeness, the larger the relatively intuitionistic fuzzy numbers.

#### 4.5. Steps

In summary, we propose a multi-attribute group decision-making method based on improved interval intuitionistic fuzzy entropy and TOPSIS when the attribute weights and decision-maker weights are completely unknown. The specific decision steps are as follows:

- Step 1: Determine the evaluation value  $r_{ij}^k = ([a_{ij}^k, b_{ij}^k], [c_{ij}^k, d_{ij}^k])$  of the scheme by the decision-maker, so as to obtain the decision matrix  $R^k = (r_{ij}^k)_{m \times n}$ ;

- Step 2: Determine the attribute weight of the scheme. Combined with the decision matrix, Equations (1) and (2) are used to calculate the weights of the attributes;
- Step 3: Determine the weights of the decision-makers. First, determine the positive ideal scheme and negative ideal scheme of the alternative scheme, use the Hamming distance to calculate the distance between the positive and negative ideal scheme, and then obtain the decision maker's weight;
- Step 4: For ranking, calculate the relative closeness of each scheme to the positive ideal scheme, and rank them according to the principle that the greater the relative closeness, the better the scheme.

### 5. Example

As the research on humanitarian rescue programs in the academic community has just begun, there are no cases that can be used to compare whether the proposed multi-attribute emergency group decision model is better. Nevertheless, this paper used the COVID-19 pandemic as the background and analyzed examples to prove the feasibility of the proposed model.

The COVID-19 pandemic poses unprecedented challenges for governments and societies around the world and represents a global crisis of hitherto unexperienced proportions [2]. After the outbreak of the COVID-19 pandemic, a city government established a humanitarian rescue team to better combat the risks brought by the epidemic. The team was composed of four experts from different departments, including materials purchasing, transportation, medical treatment, and finance. The goal of humanitarian rescue is to require the rescue of people affected or threatened to be completed in a short period of time. When the COVID-19 pandemic occurs, more people can be guaranteed to obtain relevant relief materials, such as masks and disinfectant, in a shorter period of time.

The humanitarian rescue team selected three existing schemes ( $F_1, F_2, F_3$ ) according to the situation. In order to complete the emergency work scientifically and effectively, the three decision-makers ( $D_1, D_2, D_3$ ) in different fields evaluated the three schemes. It was assumed that the evaluation of the humanitarian rescue scheme was mainly measured by the four attributes of the type of material supply  $A_1$ , the total number of people rescued  $A_2$ , the delivery time of relief supplies  $A_3$ , and the cost of implementing the scheme  $A_4$ .

We will use interval intuitionistic fuzzy numbers to represent the values that decision-makers evaluated for each attribute. The evaluation decision matrix of the three decision-makers is given below in Tables 1–3.

**Table 1.** Decision matrix for the decision-maker  $D_1$ .

	$A_1$	$A_2$	$A_3$	$A_4$
$F_1$	([0.4,0.5],[0.4,0.5])	([0.5,0.8],[0.1,0.2])	([0.5,0.6],[0.2,0.3])	([0.6,0.8],[0.1,0.2])
$F_2$	([0.6,0.7],[0.2,0.3])	([0.3,0.6],[0.2,0.4])	([0.6,0.8],[0.1,0.2])	([0.4,0.5],[0.2,0.3])
$F_3$	([0.3,0.7],[0.3,0.3])	([0.7,0.9],[0.0,0.1])	([0.4,0.6],[0.3,0.4])	([0.5,0.6],[0.2,0.3])

**Table 2.** Decision matrix for the decision-maker  $D_2$ .

	$A_1$	$A_2$	$A_3$	$A_4$
$F_1$	([0.5,0.7],[0.1,0.2])	([0.6,0.7],[0.2,0.3])	([0.5,0.6],[0.2,0.3])	([0.5,0.8],[0.0,0.1])
$F_2$	([0.6,0.7],[0.2,0.3])	([0.5,0.7],[0.2,0.3])	([0.6,0.8],[0.1,0.2])	([0.4,0.7],[0.1,0.3])
$F_3$	([0.4,0.6],[0.3,0.4])	([0.7,0.9],[0.0,0.1])	([0.4,0.6],[0.3,0.4])	([0.6,0.7],[0.2,0.3])

**Table 3.** Decision matrix for the decision-maker  $D_3$ .

	$A_1$	$A_2$	$A_3$	$A_4$
$F_1$	([0.7,0.8],[0.1,0.2])	([0.7,0.8],[0.1,0.2])	([0.5,0.7],[0.2,0.3])	([0.8,0.9],[0.0,0.1])
$F_2$	([0.6,0.7],[0.2,0.3])	([0.5,0.6],[0.2,0.3])	([0.7,0.8],[0.1,0.2])	([0.4,0.6],[0.1,0.3])
$F_3$	([0.4,0.7],[0.2,0.3])	([0.8,0.9],[0.0,0.1])	([0.5,0.6],[0.3,0.4])	([0.6,0.7],[0.2,0.3])

The three tables show the evaluation values of three decision-makers ( $D_1, D_2, D_3$ ) for three schemes ( $F_1, F_2, F_3$ ) under four attributes ( $A_1, A_2, A_3, A_4$ ).

The results of calculating the weights of the attributes based on the decision-makers' evaluation decision matrices are shown in Table 4.

**Table 4.** Attribute weight.

	$A_1$	$A_2$	$A_3$	$A_4$
$D_1$	0.2333	0.2756	0.2474	0.2437
$D_2$	0.2368	0.2729	0.2397	0.2506
$D_3$	0.2392	0.2716	0.2345	0.2547

Table 4 shows the weight of the decision-maker ( $D_1, D_2, D_3$ ) on the attribute ( $A_1, A_2, A_3, A_4$ ).

The positive ideal scheme and negative ideal scheme for the decision-makers are determined as follows:

$$\begin{aligned} r_{ij}^{1+} &= ([0.6, 0.7], [0.2, 0.3], [0.7, 0.9], [0.0, 0.1], [0.6, 0.8], [0.1, 0.2], [0.6, 0.8], [0.1, 0.2]) \\ r_{ij}^{1-} &= ([0.3, 0.5], [0.4, 0.5], [0.3, 0.6], [0.2, 0.4], [0.4, 0.6], [0.3, 0.4], [0.4, 0.5], [0.2, 0.3]) \\ r_{ij}^{2+} &= ([0.6, 0.7], [0.1, 0.2], [0.7, 0.9], [0.0, 0.1], [0.6, 0.8], [0.1, 0.2], [0.6, 0.8], [0.0, 0.1]) \\ r_{ij}^{2-} &= ([0.4, 0.6], [0.3, 0.4], [0.5, 0.7], [0.2, 0.3], [0.4, 0.6], [0.3, 0.4], [0.4, 0.7], [0.2, 0.3]) \\ r_{ij}^{3+} &= ([0.7, 0.8], [0.1, 0.2], [0.8, 0.9], [0.0, 0.1], [0.7, 0.8], [0.1, 0.2], [0.8, 0.9], [0.0, 0.1]) \\ r_{ij}^{3-} &= ([0.4, 0.7], [0.2, 0.3], [0.5, 0.6], [0.2, 0.3], [0.5, 0.6], [0.3, 0.4], [0.4, 0.6], [0.2, 0.3]) \end{aligned}$$

The results for calculating the distances from each scheme to the positive and negative ideal schemes are shown in Table 5.

**Table 5.** The distance from the scheme to the positive and negative ideal schemes.

	$dr_i^{1+}$	$dr_i^{1-}$	$dr_i^{2+}$	$dr_i^{2-}$	$dr_i^{3+}$	$dr_i^{3-}$
$F_1$	0.112	0.1153	0.0899	0.0979	0.0565	0.1643
$F_2$	0.1253	0.102	0.104	0.0838	0.1555	0.0652
$F_3$	0.1033	0.124	0.1207	0.0671	0.1337	0.087

From Table 5, we found that for the decision-maker  $D_1$ , the distances from scheme  $F_1$  to the positive and negative ideal schemes were 0.112 and 0.1153, respectively.

We calculated the weights of the three decision-makers, and the results were

$$\lambda_1 = 0.3086, \lambda_2 = 0.3735, \lambda_3 = 0.3179$$

The calculated relative closeness of the decision-makers to the scheme is shown in Table 6.

**Table 6.** The relative closeness.

	$D_1$	$D_2$	$D_3$
$F_1$	0.5073	0.5213	0.7441
$F_2$	0.4487	0.4462	0.2954
$F_3$	0.5455	0.3573	0.3942

Table 6 shows that the decision-maker  $D_3$  had the highest relative closeness value for scheme  $F_1$ , which was 0.7441.

The calculated relative closeness of the integrated group decision-making for humanitarian rescue schemes ( $F_1, F_2, F_3$ ) were

$$S_1 = 0.6055, S_2 = 0.3478, S_3 = 0.4423$$

We obtained the ranking results of the relative closeness as follows:  $S_1 > S_3 > S_2$ . According to Step 4, the greater the relative closeness, the better the scheme. Therefore, the scheme  $F_1$  was optimal.

## 6. Discussion

After an emergency breaks out, humanitarian rescue needs to evaluate the rescue plan within a short period of time. In actual situations, it is generally through the subjective decision of the department leaders that a plan is chosen. Such a method violates the scientific nature of decision-making and may even affect the efficiency of the rescue. By analyzing the characteristics of the selection of the humanitarian rescue, we found that the selection of a humanitarian rescue scheme is a multi-subject, multi-attribute group decision-making process. The incompleteness of emergency information and the heterogeneity and hesitation of decision-makers all bring difficulties to the choice of the scheme.

In order to solve these difficulties and make up for the lack of present research on the selection of the humanitarian rescue scheme, a multi-attribute emergency group decision-making model based on interval intuitionistic fuzzy entropy was constructed. First, the expert was required to score the rescue schemes, the preference of the expert was presented through the interval intuitionistic fuzzy number, and the weight of the expert was calculated in combination with the improved TOPSIS method to reduce the influence of the expert's subjective ideas on the result. Finally, the scheme was sorted to get the optimal scheme.

Compared with existing research, the model is more scientific, objective, and comprehensive in solving the problem of multi-attribute group decision-making than the traditional scheme selection, which only depends on the subjective discussion of decision-makers. Therefore, in the face of an emergency, this model can be applied in practice to select schemes more scientifically and rationally to increase the efficiency of the rescue.

## 7. Conclusions

This paper addresses the selection of a humanitarian rescue scheme in the emergency context. According to the importance of the choice of humanitarian rescue schemes currently, a multi-attribute emergency group decision-making method is proposed. The superiority of the proposed method is reflected in the following aspects. First, we propose the use of quantitative methods and models to analyze the process of a humanitarian rescue scheme and propose the use of multi-attribute group decision-making methods to solve the problem of humanitarian rescue scheme selection. Secondly, based on the original research, which was based on interval intuitionistic fuzzy entropy, adding hesitation to calculate attribute weights should be considered so that the calculated attribute weights are closer to the real wishes of the decision-makers. Finally, in order to provide a humanitarian rescue scheme for unconventional emergencies in a short time and avoid the complicated calculation process in real applications, this paper proposes a sorting method of the Hamming distance between the TOPSIS-based calculation scheme and the ideal scheme, which helps decision-makers choose the optimal scheme in a limited time and improve rescue efficiency. At present, most of the research on humanitarian rescue schemes in academia is only focused on how to formulate the scheme, with almost no consideration of the choice of the scheme, and the method of choosing the scheme in practical applications is not scientific enough. We proved the feasibility and practical application value of the proposed method by a numerical example.

Although the research results of this paper have certain reference significance for the selection of the humanitarian rescue scheme, there are some limitations. First of all, the data in this paper mainly came from the scoring by experts. Each expert came from a different department, and the study did not consider whether the expert could represent the opinion of the department. Secondly, richer data will help us analyze and verify the accuracy of the model. Finally, although the proposed method in this paper effectively

combined expert experience, the evolution of emergencies changes dynamically over time, but this paper did not cover more complex dynamic models.

In future research, we will consider increasing the decision-makers from a few experts to experts from multiple groups, where each subgroup represents a government department in order to get closer to the actual situation. The research will simultaneously consider both the selection of experts within the group and the decisions of each group, and we will consider combining dynamic models to strengthen the analysis of decision-making.

**Author Contributions:** X.D. and Z.K. worked collectively; Z.K. gave constructive suggestions for the idea and the writing; X.D. conceived and designed the study with the support of Z.K. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The authors would like to thank the anonymous reviewers for their valuable comments which increased this paper's quality.

**Conflicts of Interest:** The authors declare no conflict of interest.

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