

## *Retraction*

# **Retracted: Fire Safety Evaluation for Scenic Spots: An Evidential Best-Worst Method**

### **Journal of Mathematics**

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] D. Chen and H. Xie, "Fire Safety Evaluation for Scenic Spots: An Evidential Best-Worst Method," *Journal of Mathematics*, vol. 2021, Article ID 5592150, 10 pages, 2021.

## Review Article

# Fire Safety Evaluation for Scenic Spots: An Evidential Best-Worst Method

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Fire safety plays a vital role in tourism management, which can cause significant loss of life and property. It is necessary to present an efficient fire safety evaluation for scenic spots. However, some key issues are not well addressed in existing methods. For example, how to model experts' opinions and how to combine them are still open problems. To address these issues, a new evaluation method based on the Dempster–Shafer evidence theory and best-worst method is presented. First, a fire safety evaluation index system is constructed using the domino model. Domain experts can evaluate different factors with linguistic assessments. The best-worst method is used to determine the weights of different factors. Then, these weighted linguistic assessments are efficiently fused by Dempster's combination rule to obtain the evaluation result. Finally, a case study is illustrated to demonstrate the efficiency of the proposed method in fire safety evaluation for scenic spots. The main contribution of the proposed method is to represent and handle the uncertainty in experts' linguistic assessments, so as to decrease the uncertainty and improve decision making. In addition, the weight determination method BWM is easier and more reliable than the existing method AHP.

## 1. Introduction

Safety is of great significance for the development of tourism. A tourism accident can cause a great damage to the economy of tourism and tourists' lives and properties. Tourism safety has been an unavoidable problem since accidents occur frequently. Studies concerning tourism safety mainly focus on food safety [1], terrorist incidents [2], natural disasters [3], social crime [4], and road accidents [5]. However, there is not enough focus on fire safety.

Fire accident in tourism reminds us of the importance of fire safety in scenic spots. For example, on September 30, 2018, Longji Terraced Fields Scenic Area, a famous scenic spot in Guilin, Guangxi Zhuang Autonomous Region, China, caught fire. 48 ancient houses burned down and the fire almost destroyed the whole scenic area. Scenic spots afford a remarkable tourism service and have capacity for a great number of tourists, so it is necessary and significant to establish a fire safety evaluation system for scenic spots.

Reviewing the existing literature, we find that there are very few articles concerning fire safety in tourism, but only some research on related situations has been carried out. For example, Spyrou et al. [6] proposed a general risk model for evaluating the fire safety of passenger ships. Chen et al. [7] carried out a quantitative risk assessment of cotton storage fire accidents. Brzezinska et al. [8] presented a new evaluation and indicating approach for sustainable fire safety in the process industry. However, it is still an open problem to handle uncertainty in evaluation models.

A common idea in evaluating a fire system is to ask authoritative experts for opinions and then to make a comprehensive consideration for decision. Hence, the fire system evaluation problem is a kind of multicriteria decision-making (MCDM) problem. One of the important problems in MCDM is to deal with uncertainty [9,10]. Many mathematical tools such as fuzzy sets [11–14], neutrosophic sets [15], and Z-numbers [16] are used. For example, Xue et al. [17] addressed the uncertain database retrieval problem

based on intuitionistic fuzzy set. Li et al. [18] proposed a new uncertainty measure of discrete Z-numbers and applied it to solve MCDM problems. Harish and Gagandeep [19] developed a method to solve MCDM problems under the probabilistic dual hesitant fuzzy set environment.

In view of the uncertainty in experts' linguistic assessments and the need for opinion integration, a suitable tool, named Dempster–Shafer evidence theory (DSET) [20–22], can solve the two problems perfectly. DSET is an efficient tool for decision making under uncertain environment and provides a combination rule for uncertainty fusion [23, 24]. In addition, in this paper, we apply the best-worst method (BWM) [25, 26] to determine different weights of factors. Actually, there are some research studies on the combination of DSET and BWM. For example, Fei et al. [27] extended BWM by belief functions in DSET and implemented the algorithm in hospital service evaluation. Liu et al. [28] developed a MCDM method in combination with DSET and BWM to solve the sustainable development alternative selection problem.

Therefore, based on DSET and BWM, this paper presents an evidential fire safety evaluation method for scenic spots, which can help managers to assess fire risk and take measures to prevent fire accidents. The proposed model can well deal with the uncertainty flexibly. In summary, the main contribution of the proposed method is that it can well deal with the uncertainty flexibly by modeling and fusing uncertain information, which is useful to reduce uncertainty and improve decision making. In addition, the weight determination method BWM is easier and more reliable than the existing method AHP (analytic hierarchy process).

The remainder of the paper is organized as follows. Section 2 introduces the accident model and the related theory including DSET and BWM. In Section 3, we present the index system and the evidential BWM for fire safety. Section 4 illustrates a case of fire safety evaluation. Finally, we conclude this paper in Section 5.

## 2. Preliminaries

**2.1. Accident Model.** The accident model plays a critical part in processing safety management, since it can provide a better understanding of accident scenarios and describe the relation between causes and consequences [29]. Heinrich [30] originally proposed the domino theory to illustrate sequential aspects of accident occurrence. This considers the accident as the outcome of series of successive events, rather than an isolated incident, and distinguishes five stages or factors in an accident, including ancestry and social environment, fault of person, unsafe act and/or mechanical or physical hazard, accident, and injury [31].

Updating and modifying the domino theory, which stressed on inherent shortcomings of humans, the loss causation model was proposed and many different variations appeared subsequently [32]. The loss causation model applied in the current work is usually called the domino model [33], which places more emphasis on management and organizational factors. In the domino model, an accident is directly caused by human's unsafe behaviors and objects'

insecurity state and indirectly caused by personal factors and work-related factors. Management deficiency is the root cause, namely, the problem or deficiency in management leads to the remote cause, which then results in the immediate cause and ultimately brings about an accident. In summary, person, work-related object, and management comprise the accident model.

The domino model is appropriate for tourism, and this article applies it to construct a safety evaluation index system for touristic scenic spots (Figure 1).

**2.2. Dempster–Shafer Evidence Theory.** Dempster–Shafer evidence theory, abbreviated as DSET, was first proposed by Dempster [34] and then developed by Shafer [35]. DSET has two unique characteristics: one is to assign belief values to multi-subset propositions and the other is to fuse bodies of evidence. However, DSET still has some unresolved issues, like conflict management [36–39], dependence evidence combination [40–42], and belief entropy [43–45]. Considering its superiority under uncertain environment and its practicability in engineering [46–48], DSET has a broad application in many areas, such as risk assessment [49–52], fault diagnosis [53–55], and classification and clustering [56–58].

Assume a random variable  $X$  taking values from  $\Theta = \{\Theta_1, \Theta_2, \dots, \Theta_n\}$ , where  $\Theta$  is called a frame of discernment (FOD).  $2^\Theta$  denotes the power set of  $\Theta$ .

A mass function (also called a basic probability assignment, BPA) is a mapping from  $2^\Theta$  to  $[0, 1]$ , formally defined by [34, 35]

$$m: 2^\Theta \longrightarrow [0, 1], \quad (1)$$

satisfying the following condition:

$$\sum_{A \in 2^\Theta} m(A) = 1, \quad m(\emptyset) = 0, \quad (2)$$

where  $m(A)$  represents the belief value that supports  $A$ .

Assuming two BPAs  $m_1$  and  $m_2$  are from two pieces of dependent evidence, Dempster's combination rule, represented as  $m = m_1 \oplus m_2$ , is defined as follows [34, 35]:

$$m(A) = \frac{\sum_{A_1 \cap A_2 = A} m_1(A_1) m_2(A_2)}{1 - K}, \quad (3)$$

where  $K$  is called the conflict coefficient of two BPAs and is calculated by  $\sum_{A_1 \cap A_2 = \emptyset} m_1(A_1) m_2(A_2)$ .

**2.3. Best–Worst Method.** The best-worst method (BWM) was put forward by Rezaei to manage multicriteria decision problems [59, 60]. One of the common applications of BWM is to determine weights. By making comparisons between the most important (best)/least important (worst) criteria and the others, BWM establishes a minimum optimization problem to derive weights. BWM has been broadly applied in many fields such as medical system [61, 62], risk assessment [63, 64], and supplier selection [65]. The detailed procedures of BWM are described below.

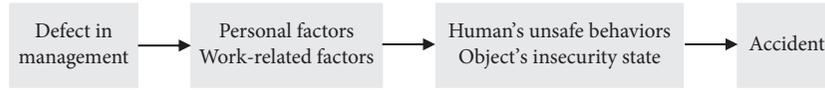


FIGURE 1: The domino model.

Given a list of  $l$  criteria, experts should identify the most and least important criteria, respectively, and then give a preference judgment of the most important criteria over all criteria with a scale from 1 to 9. A larger number means more preference. The results are stored in two vectors  $U_{BO}$  and  $V_{OW}$  as follows [59]:

$$\begin{aligned} U_{BO} &= (u_{B1}, u_{B2}, \dots, u_{Bl}), \\ V_{OW} &= (v_{1W}, v_{2W}, \dots, v_{lW}), \end{aligned} \quad (4)$$

where  $u_{Bj}$  means the preference of the best criteria  $B$  over the criteria  $j$ , and  $u_{BB} = 1$ .  $v_{jW}$  means the preference of the criteria  $j$  over the worst criteria  $W$ , and  $v_{WW} = 1$ .

With the two vectors obtained, an optional linear programming model is established to determine the optimal weight  $(w_1^*, w_2^*, \dots, w_l^*)$  [59]:

$$\begin{aligned} &\text{mine} \\ &\text{s.t.} \begin{cases} \left\| \frac{w_B}{w_j} - u_{Bj} \right\| \leq \varepsilon & \text{for all } j \\ \left\| \frac{w_j}{w_W} - v_{jW} \right\| \leq \varepsilon & \text{for all } j \\ \sum_j w_j = 1 \\ w_j \geq 0 & \text{for all } j. \end{cases} \end{aligned} \quad (5)$$

Furthermore, to guarantee the consistency of comparison, the definition of consistency ratio (CR) is given by BWM [59]:

$$CR = \frac{\varepsilon^*}{CI} \quad (6)$$

where  $\varepsilon^*$  is the best solution of  $\varepsilon$  corresponding to equation (5) and  $CI$  is determined by  $u_{BW}$  (the preference of the most important criteria  $B$  over the least important one  $W$ ), as shown in Table 1. The range of  $CR$  is  $[0, 1]$ ; the larger  $CR$  is, the more inconsistent the comparison vector is. In general,  $CR \leq 0.1$  shows that the comparison vector is acceptable.

### 3. Evaluation Methodology

**3.1. Establishing the Evaluation Index System.** The domino model is applicable to evaluate fire safety in tourism scenic spots, wherein person includes tourists and staff, work-related object contains firefighting equipment and surroundings of scenic spots, and management means how to mobilize persons and work-related objects to be out of fire danger.

TABLE 1: Consistency index.

$u_{BW}$	1	2	3	4	5	6	7	8	9
CI	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Combining this with the general actual situation of tourism scenic spots and reference to the prior related studies [66–68], we establish a fire safety evaluation index system as shown in Table 2. As we can see, the system is a hierarchical structure, including the target level, the base level, and the criteria level. The target level contains three factors: management ( $\eta_1$ ), person ( $\eta_2$ ), and work-related job ( $\eta_3$ ). The base level is in the second level, such as inner management ( $\eta_{11}$ ). There are 6 factors at the base level. The criteria level contains the most specific factors, such as fire safety education and training ( $\eta_{111}$ ). There are 14 indexes at the criteria level.

**3.2. Evaluation Method.** Following the construction of the evaluation index system for fire safety, this section presents an evaluation model using DSET and BWM. The main idea is to use BWM to weight different factors at all levels, and then based on experts' linguistic evaluations on fire safety levels, the corresponding mass functions of factors at the target level can be constructed for each expert; finally, using the combination rule to fuse experts' opinions, we can determine the fire security level of scenic spots, along with the confidence degree of the assessment result. The flowchart of the proposed model is given in Figure 2. The procedure of the fire safety evaluation method is divided into six steps.

Step 1: expert evaluation on the fire security level.

Based on the fire safety evaluation index system in Table 2, experts should evaluate the fire safety status of the project on factors at the criteria level and then give linguistic assessments with a range of  $[0, 1]$ . A value closer to 0 means that the safety status of the corresponding project is more dangerous, or the working ability of the project is lower, and hence the possibility of a fire is greater. The linguistic evaluation corresponding to different scores is shown in Table 3.  $A_{ijz}^h$  means the value of the factor  $\eta_{ijz}$  assessed by the  $h$ th expert,  $i \in [1, 3]$ ,  $j \in [1, 2]$ ,  $z \in [1, 3]$ .

Step 2: weight all factors at different levels based on the BWM.

According to the fire safety evaluation index system in Table 2, BWM is applied to compute the weight of indexes on the same level. Here we use  $w_{ijz}$  to represent the weight of the criteria  $\eta_{ijz}$ . For example,  $w_2$  means the weight of person ( $\eta_2$ ) and  $w_{21}$  means the weight of tourists ( $\eta_{21}$ ).

TABLE 2: The fire safety evaluation index system.

Target level	Base level	Criteria level
Management ( $\eta_1$ )	Inner management ( $\eta_{11}$ )	Fire safety education and training ( $\eta_{111}$ ) Fire emergency response plan ( $\eta_{112}$ ) Regular fire safety inspection ( $\eta_{121}$ )
	External management ( $\eta_{12}$ )	Inspection for inflammable and explosive dangerous goods before entering the scenic spot ( $\eta_{122}$ )
Person ( $\eta_2$ )	Tourists ( $\eta_{21}$ )	Tourists' fire safety awareness and firefighting skills ( $\eta_{211}$ ) Tourist quantity ( $\eta_{212}$ )
	Staff members ( $\eta_{22}$ )	Staff's fire safety awareness and firefighting skills ( $\eta_{221}$ ) Firefighting quantity ( $\eta_{222}$ )
Work-related object ( $\eta_3$ )	Firefighting device ( $\eta_{31}$ )	Fire detection alarm system ( $\eta_{311}$ ) Fire extinguishing equipment ( $\eta_{312}$ ) Evacuation equipment ( $\eta_{313}$ )
	Surroundings of scenic spots ( $\eta_{32}$ )	Distance from the nearest fire station ( $\eta_{321}$ ) Fire resistance of building materials ( $\eta_{322}$ ) Traffic planning and spatial layout of scenic area ( $\eta_{323}$ )

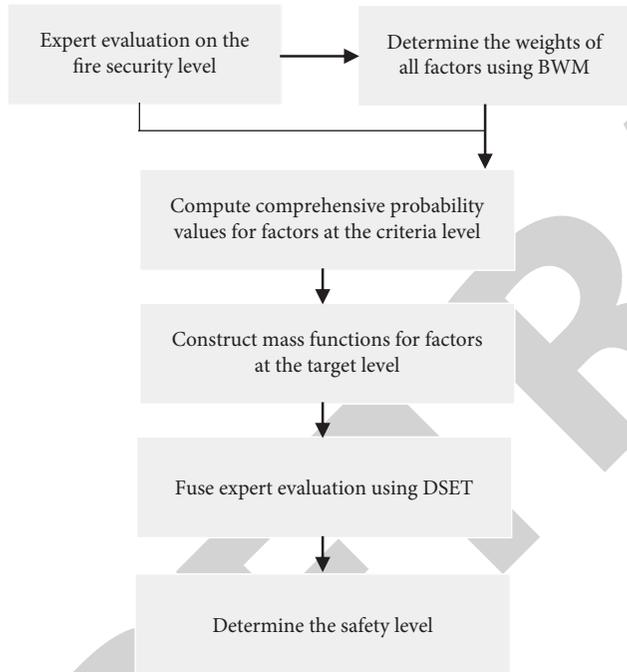


FIGURE 2: The flowchart of the proposed method.

TABLE 3: The linguistic assessment on fire safety levels.

Fire safety status	Dangerous	General	Subsafe	Safe
Scale	0 ~ < 0.25	0.25 ~ < 0.5	0.5 ~ < 0.75	0.75 ~ < 1

*Example 1.* Suppose experts are requested to evaluate the weight of three factors  $\eta_{321}$ ,  $\eta_{322}$ , and  $\eta_{323}$ . After their discussion, they identify  $\eta_{323}$  and  $\eta_{321}$  as the most important and the least important factors, respectively.  $U_{BO} = (8, 2, 1)$ ,  $V_{OW} = (1, 5, 8)$ . The optional linear programming model is established based on equation (6):

$$\begin{aligned}
 & \min \varepsilon \\
 & \text{s.t.} \begin{cases} \left\| \frac{w_3}{w_1} - 8 \right\| \leq \varepsilon \\ \left\| \frac{w_3}{w_2} - 2 \right\| \leq \varepsilon \\ \left\| \frac{w_2}{w_1} - 5 \right\| \leq \varepsilon \\ \sum_{i=1}^3 w_i = 1 \\ w_i \geq 0. \end{cases} \quad (7)
 \end{aligned}$$

Using Matlab R2018a to solve this model, we can get  $w_{321}^* = 0.0714$ ,  $w_{322}^* = 0.3387$ ,  $w_{323}^* = 0.5589$ ,  $\varepsilon^* = 0.26$ , and  $CR = (0.26/4.47) = 0.058 < 0.1$ , which means a good consistency. That is,  $w_{321} = 0.0714$ ,  $w_{322} = 0.3387$ , and  $w_{323} = 0.5589$ .

Step 3: compute weighted probability values for factors at the criteria level.

Based on the level of each factor, the weighted probability value for the  $h$ th expert is computed as follows:

$$p^h(\eta_{ijz}) = A_{ijz}^h * w_{ijz} * w_{ij} * w_i. \quad (8)$$

*Example 2.* As shown in Table 1, we take the subsystem of management ( $\eta_1$ ) as an example. It has two factors on the base level,  $\eta_{11}$  and  $\eta_{12}$ . Each base factor includes two criteria factors, that is,  $\eta_{111}$ ,  $\eta_{112}$  and  $\eta_{121}$ ,  $\eta_{122}$ . Supposing that two experts participate in the evaluation, the weights of factors and the experts' scale are shown in Tables 4 and 5, respectively.

TABLE 4: Weights of factors.

Factor	$\eta_1$	$\eta_{11}$	$\eta_{12}$	$\eta_{111}$	$\eta_{112}$	$\eta_{121}$	$\eta_{122}$
Weight	0.1	0.6	0.4	0.5	0.5	0.2	0.8

TABLE 5: The experts' evaluation.

	Expert 1's evaluation	Expert 2's evaluation	Weighted probability values
$\eta_{111}$	0.3	0.5	$p^1(\eta_{111}) = 0.009, p^2(\eta_{111}) = 0.015$
$\eta_{112}$	0.7	0.7	$p^1(\eta_{112}) = 0.021, p^2(\eta_{112}) = 0.021$
$\eta_{121}$	0.6	0.5	$p^1(\eta_{121}) = 0.048, p^2(\eta_{121}) = 0.016$
$\eta_{122}$	0.4	0.8	$p^1(\eta_{122}) = 0.016, p^2(\eta_{122}) = 0.0256$

Hence, the weighted probability values for  $\eta_{111}$  are calculated by  $p^1(\eta_{111}) = 0.3 \cdot 0.5 \cdot 0.6 \cdot 0.1 = 0.009$ .  $p^2(\eta_{111}) = 0.5 \cdot 0.5 \cdot 0.6 \cdot 0.1 = 0.015$ . Other results are shown in the fourth column of Table 5.

Step 4: construct mass functions for factors at the target level.

Under the framework of DSET, mass functions are obtained by the sum of weighted probability values of factors at the criteria level. The specified formula is shown as follows:

$$m^h(\eta_i) = \sum_{z=1}^f \sum_{j=1}^f m^h(\eta_{ijz}), \quad (9)$$

$$m^h(\Theta) = 1 - \sum_i m^h(\eta_i), \quad (10)$$

where  $f$  is the number of all factors at the criteria level and  $m^h(\Theta)$  can be regarded as the uncertainty of experts' evaluation.

*Example 3.* Calculate the mass functions of the target factor  $\eta_1$  in Table 5:

$$\begin{aligned} m^1(\eta_1) &= p^1(\eta_{111}) + p^1(\eta_{112}) + p^1(\eta_{121}) + p^1(\eta_{122}) = 0.094, \\ m^2(\eta_1) &= p^2(\eta_{111}) + p^2(\eta_{112}) + p^2(\eta_{121}) + p^2(\eta_{122}) = 0.0776. \end{aligned} \quad (11)$$

Step 5: fuse experts' evaluations using DSET.

According to Dempster's combination rule (see equation (3)), the fused experts' evaluation can be obtained. The specified formula is shown below.

$$m(\eta_i) = m^1(\eta_i) \oplus m^2(\eta_i) \oplus \dots \oplus m^n(\eta_i). \quad (12)$$

Step 6: determine the safety level.

The comprehensive belief value for safety assessment can be obtained by equation (13), i.e., the sum of the fused belief value for each factor at the target value. According to the criteria in Table 2, the safe level is finally determined.

$$p = \sum_i m(\eta_i). \quad (13)$$

The confidence of the assessment result is calculated by  $1 - m(\Theta)$ .

#### 4. An Evaluation Case

In this paper, a case study of fire safety evaluation for one scenic spot is provided based on the proposed model. Assume that 3 experts are required to evaluate the security level on all factors at the criteria level based on Table 2; the detailed assessments are shown in Table 6. The weights of different factors based on BWM are given in Table 7.

According to Step 3 of this model, with the weights of factors at all levels and experts' linguistic assessments on security status, we can calculate the weighted probability values of indexes at the criteria level using equation (8). The results are shown in Table 8.

Based on Step 4 and Step 5 of the model, we can construct mass functions using equations (9) and (10) for each expert and then fuse them using equation (12). The results are shown below:

$$\begin{aligned} m^1(\eta_1) &= 0.2174, m^1(\eta_2) = 0.1743, m^1(\eta_3) = 0.1073, m^1(\Theta) = 0.5010, \\ m^2(\eta_1) &= 0.1952, m^2(\eta_2) = 0.1766, m^2(\eta_3) = 0.1444, m^2(\Theta) = 0.4838, \\ m^3(\eta_1) &= 0.2350, m^3(\eta_2) = 0.1649, m^3(\eta_3) = 0.1666, m^3(\Theta) = 0.4335, \\ m(\eta_1) &= 0.3611, m(\eta_2) = 0.2643, m(\eta_3) = 0.2029, m(\Theta) = 0.1716. \end{aligned} \quad (14)$$

TABLE 6: Experts' assessments on security level.

	Expert 1	Expert 2	Expert 3
$\eta_{111}$	0.75	0.60	0.70
$\eta_{112}$	0.80	0.75	0.80
$\eta_{121}$	0.45	0.55	0.65
$\eta_{122}$	0.65	0.50	0.70
$\eta_{211}$	0.65	0.70	0.65
$\eta_{212}$	0.70	0.75	0.85
$\eta_{221}$	0.60	0.65	0.50
$\eta_{222}$	0.35	0.30	0.25
$\eta_{311}$	0.15	0.35	0.45
$\eta_{312}$	0.35	0.50	0.60
$\eta_{313}$	0.45	0.35	0.50
$\eta_{321}$	0.80	0.70	0.65
$\eta_{322}$	0.70	0.80	0.75
$\eta_{323}$	0.30	0.50	0.45

TABLE 7: The weights of different factors based on BWM.

Target level	Base level	Criteria level
$\eta_1 = 0.333$	$\eta_{11} = 0.456$	$\eta_{111} = 0.655$
	$\eta_{12} = 0.544$	$\eta_{112} = 0.345$
		$\eta_{121} = 0.5$
		$\eta_{122} = 0.5$
$\eta_2 = 0.333$	$\eta_{21} = 0.450$	$\eta_{211} = 0.604$
	$\eta_{22} = 0.550$	$\eta_{212} = 0.396$
		$\eta_{221} = 0.215$
		$\eta_{222} = 0.785$
$\eta_3 = 0.333$	$\eta_{31} = 0.701$	$\eta_{311} = 0.595$
	$\eta_{32} = 0.299$	$\eta_{312} = 0.083$
		$\eta_{313} = 0.321$
		$\eta_{321} = 0.071$
		$\eta_{322} = 0.339$
		$\eta_{323} = 0.560$

TABLE 8: Weighted probability values of factors at the criteria level.

	$P^1_{\eta_{ijz}}$	$P^2_{\eta_{ijz}}$	$P^3_{\eta_{ijz}}$
$\eta_{111}$	0.0746	0.0597	0.0696
$\eta_{112}$	0.0431	0.0404	0.0431
$\eta_{121}$	0.0408	0.0498	0.0589
$\eta_{122}$	0.0589	0.0453	0.0634
$\eta_{211}$	0.0588	0.0634	0.0588
$\eta_{212}$	0.0415	0.0445	0.0504
$\eta_{221}$	0.0236	0.0256	0.0197
$\eta_{222}$	0.0503	0.0431	0.0359
$\eta_{311}$	0.0208	0.0486	0.0625
$\eta_{312}$	0.0068	0.0097	0.0116
$\eta_{313}$	0.0337	0.0262	0.0375
$\eta_{321}$	0.0057	0.0049	0.0046
$\eta_{322}$	0.0236	0.0270	0.0253
$\eta_{323}$	0.0167	0.0279	0.0251

TABLE 9: The weight results of two groups of factors by BWM and AHP.

	Method	Comparison data	Weights	CR
$\{\eta_{311}, \eta_{312}, \eta_{313}\}$	BWM	$U_{BO} = (1, 7, 2)$ $V_{OW} = (7, 1, 4)$	$w = \{0.5954, 0.0833, 0.3213\}$	$0.04 < 0.1$
	AHP	$\begin{bmatrix} 1 & 7 & 2 \\ 1/7 & 1 & 1/4 \\ 1/2 & 4 & 1 \end{bmatrix}$	$w = \{0.6026, 0.0823, 0.3150\}$	$0.0017 < 0.1$
$\{\eta_{321}, \eta_{322}, \eta_{323}\}$	BWM	$U_{BO} = (8, 2, 1)$ $V_{OW} = (1, 5, 8)$	$w = \{0.0714, 0.3387, 0.5589\}$	$0.058 < 0.1$
	AHP	$\begin{bmatrix} 1 & 1/5 & 1/8 \\ 5 & 1 & 1/2 \\ 8 & 2 & 1 \end{bmatrix}$	$w = \{0.0701, 0.3255, 0.6044\}$	$0.0048 < 0.1$

TABLE 10: The fire safety evaluation result by Chen and Deng’s method [69].

The fused experts’ result	$m(\eta_1) = 0.3607, m(\eta_2) = 0.2641, m(\eta_3) = 0.2039, m(\Theta) = 0.1712$
The final belief value	$p = 0.3607 + 0.2641 + 0.2039 = 0.8287$ (The safe level)
The confidence of the result	$1 - 0.1712 = 0.8288$

Finally, the overall belief value of safety assessment can be computed using equation (13):

$$p = m(\eta_1) + m(\eta_2) + m(\eta_3) = 0.8283. \quad (15)$$

Hence, according to Table 2, we can conclude that the comprehensive evaluation result is safe, and the confidence of the result is  $1 - 0.1716 = 0.8284$ .

In addition, we compare the proposed method with Chen and Deng’s method [69]. An evidential AHP method was presented in [69] to evaluate sustainable transport solutions, where AHP was applied to determine weights and Dempster–Shafer evidence theory was used for handling uncertain information. The two methods are different in the weight determination methods by AHP and BWM, respectively, which will be analyzed next.

From Table 2, we can find that in most situations, there are just two factors that can be compared to determine weights, like  $\eta_{11}$  and  $\eta_{12}$ . It is easy for experts to determine the relative importance between them and get reasonable weights. Therefore, two groups with three compared factors  $\{\eta_{311}, \eta_{312}, \eta_{313}\}$  and  $\{\eta_{321}, \eta_{322}, \eta_{323}\}$  are taken as examples to show the advantages of BWM. It should be noted that for simplicity and fair comparison, the relative importance in the comparison matrix in AHP refers to the values in comparison vectors in BWM. Table 9 shows the weight results by AHP and BWM, respectively.

As shown in Table 9, the weights of factors for each group are very similar, and their consistency ratios (CRs) are all less than 0.1. On the one hand, the third column gives the comparison data required by BWM and AHP, which shows that BWM needs less comparison data than AHP. Exactly, BWM needs to have  $(2n - 3)$  comparisons while for AHP,  $n(n - 1)/2$  comparisons are needed, where  $n$  means the number of factors. On the other hand, the fifth column gives CR values computed by BWM and AHP. In AHP, the values of CR are far smaller than 0.1; it means that the comparison relationship given by BWM performs well in AHP. This shows that BWM provides consistent comparison data.

Since BWM considers the best and worst factors to compare, the weights derived by BWM are highly reliable as it provides more consistent comparison data compared to AHP. Actually, Rezaei has analyzed the two advantages of BWM compared to AHP in [59]. In conclusion, BWM is easier and more reliable than AHP.

Based on the weights determined by AHP in Table 9, the safety evaluation result by Chen and Deng’s method [69] can be obtained. For simplicity we just display the results of the last two steps, as shown in Table 10. Compared with the proposed method, both suggest that the comprehensive evaluation result is safe, the belief values of safety assessment are very similar (0.8283 vs 0.8287), and so is the confidence of results (0.8284 vs 0.8288), which shows the effectiveness of the proposed method. However, considering the superiority of BWM compared to AHP, the proposed method is easier and more reliable than Chen and Deng’s method [69].

## 5. Conclusion

In tourism management, fire safety is a significant problem worthy of attention, since a fire security accident will have a great negative impact on the loss of life and property. In this paper, a new evidential BWM is presented to address the fire safety evaluation for scenic spots. First, a fire safety evaluation index system is constructed using the domino model, which constructs a three-level hierarchical structure of factors. Based on the established index model, experts are required to assess the safety level using fuzzy linguistic variables. Combined with the weights determined by BWM, these linguistic assessments can be transformed into mass functions in DSET. Finally Dempster’s combination rule is applied to fuse mass functions to obtain the overall belief value of safety level. The proposed method has an advantage to represent and handle the uncertainty in experts’ linguistic assessments, so as to decrease the uncertainty and improve decision making. Furthermore, the weight determination method BWM is easier and more reliable than the existing

method AHP. In conclusion, the proposed method can address the fire safety evaluation issue for scenic spots under uncertain environment, which is useful to lower the risk of fire and prevent fire accidents.

However, there still exist some problems to be considered. One is that the weights of experts can also be considered into the model, such as using the belief entropy [70]. The other is that using interval-valued linguistic variables as in [71, 72] may be a more flexible way to represent uncertain information.

## Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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