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A Framework for Assessment of Logistics Enterprises' Safety Standardization Performance Based on Prospect Theory

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ABSTRACT

To evaluate the performance of the logistics safety standard system, we propose an evaluation framework based on the performance evaluation theory. First, we construct the performance evaluation indicator of the safety standard system for logistics enterprises. It is based on the existing performance evaluation indicator and combined with the construction goal of the logistics safety standard system. Second, we combine the triangular fuzzy number and prospect theory to determine the indicator state according to the characteristics of performance evaluation indicators. Then, we use the Choquet integral, fuzzy method, and Shapley value methods to evaluate the information, which considers the interaction of indicators. Third, we use the entropy and fuzzy analytic hierarchy process to determine the expert weight. The performance evaluation information of the logistic enterprise's safety standard system is aggregated to obtain the assessment results. Finally, the proposed framework is validated by an example analysis. The results show that the proposed framework can be used to evaluate the performance of logistics enterprise safety standard systems.

1. Introduction

With the rapid development of e-commerce and cross-border e-commerce, the logistics industry is vital in connecting the online market and real consumers. However, many logistics safety events occurred, which poses a challenge to the safety of logistics enterprise production [1, 2]. China's State Administration of Work Safety formulated the "Evaluation Standard of Warehouse Logistics Enterprise Safety Production Standardization" in 2011. It aims to promote the standardization and institutionalization of safe operation in the production process of warehouse logistics enterprises. It also aims to reduce operational safety accidents, the possibility of casualties, environmental pollution, property loss, and other consequences. It improves the safety management level of warehouse logistics enterprises. However, safety production accidents in the logistics industry occur frequently [3]. The efficiency of the construction of the safety standard system of logistics enterprises has attracted a lot of attention [4]. By evaluating the performance of the safety standard system of logistics enterprises, we can comprehensively judge the construction level, implementation process,

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and effect of the safety standard system. Further, we can also provide advice for rectifying, improving, and implementing the safety standard system of logistics enterprises.

Many safety management systems exist, such as Health, Safety, and Environment, DuPont safety management systems, Occupational Health and Safety (OHS) management systems, and safety production standard systems [5-7]. They are widely used in enterprises. However, there are still various accidents. Therefore, how to effectively evaluate and regulate the implementation effect of these safety management systems has attracted the attention of researchers and enterprises [8]. Many scholars have actively explored the performance evaluation of safety management systems and produced valuable research results. Some scholars have used different methods to comprehensively select the performance evaluation indicators for safety management systems. For example, Spyropoulos *et al.*, [6] introduced a new hybrid indicator for monitoring and evaluating the occupational health and well-being of the rail sector's workforce. Singh and Misra, [9] developed a decision-making method and identified the critical indicators for assessing the safety performance of the workforce in the Indian construction industry. Ortiz-Barrios *et al.*, [10] used the multi-criteria decision-making (MCDM) method and identified critical indicators for evaluating OHS performance in the context of the aging workforce. Frankish *et al.*, [11] identified the essential indicators under four main aspects to evaluate the performance of safety management systems in the food field. Golabchi *et al.*, [12] reviewed and identified the leading indicators for safety management in the construction field and assessed the effectiveness of their implementation on construction projects. Yuan *et al.*, [13] presented a helpful classification method for safety barriers, which can effectively identify the peroformance indicators and collect the indicator-related data. Hayes *et al.*, [14] examined the importance of safety performance indicators in evaluating safety management. Hammond *et al.*, [15] studied the relationship between safety performance indicators and safety culture, taking nuclear waste cleanup operations in the U.S. as an example. Based on the performance indicator system established, some scholars utilized many methods to evaluate the performance of the safety management system. Such as the analytic hierarchy process [16, 17], DEA method [18, 19], fuzzy methods [20, 21], comprehensive evaluation combination method [22], and so on. In addition, some scholars constructed the performance evaluation indicator system for the specific implementation objects of the safety management system. Tonka and Ekmekci, [17] utilized a two-stage MCDM model to create the performance evaluation indicator of OHS in the geothermal energy field. Phinias, [7] identified the challenges and benefits of implementing leading indicators for health and safe management in construction through a systematic review. Jahanvand *et al.*, [19] proposed a mixed method to determine the essential indicator for selecting risk evaluation techniques in OHS management. Riascos *et al.,* [23] indentified indicators for assessing OHS performance, including 126 specific indicators under four areas. Küçükarslan *et al.*, [24] proposed a MCDM model under four main indicators and seventeen sub-indicators for assessing OHS performance in forest fire management.

The above research results provide a theoretical basis and practical guidance for the performance evaluation of safety standard systems. However, the existing performance evaluation of safety standard systems is still insufficient to solve some problems. Firstly, determining indicator weight is usually based on the assumption that the indicators are independent in the evaluation process. Secondly, experts often have bounded behavior when evaluating results, such as reference dependence, loss aversion, and diminishing sensitivity. These bounded behaviors will affect the objectivity of the evaluation results, so they should be considered in the performance evaluation of the safety standard system of logistics enterprises. The prospect theory considers the irrational behavior of experts in uncertain and risky environments during the evaluation process, which can more accurately describe the decision-making behavior characteristics of experts [25]. At present, the prospect theory has been applied to many fields, such as risk assessment [26], failure analysis [27], emergency plan selection [28], and so on.

In summary, to evaluate the implementation effect of the logistics safety standard system, this paper proposes a performance evaluation method for logistics enterprise safety standardization, which considers the correlation of performance indicators. The rest of the study is as follows. Firstly, according to the construction goal of logistics safety standardization, we establish a performance evaluation indicator system of logistics safety standardization in section 2. Secondly, the Choquet integral and prospect theory methods are used to establish the performance evaluation model of logistics enterprise safety standardization in section 3. It considers the interaction of indicators and the psychological behavior of experts. Next, an example is provided to examine the established method's effectiveness in section 4. Finally, section 5 gives the conclusion.

2. Construction of performance evaluation indicator of logistics enterprise safety standard system

2.1 Evaluation indicator

The performance evaluation indicator should reflect the current situation of logistics enterprises' safety standard systems and provide advice for managing and improving the effect of safety standard system construction. Therefore, the performance evaluation indicator of the safety standard system for logistics enterprises is identified from the four dimensions of the input-output perspective. It includes personal safety, process safety, standard systems, and occupational health. It is based on the existing research for performance evaluation indicators of safety management systems and combined with the "Evaluation Standard of Warehouse Logistics Enterprise Safety Production Standardization." Then, the performance evaluation indicators of the safety standard system for logistics enterprises are constructed and shown in Figure 1.

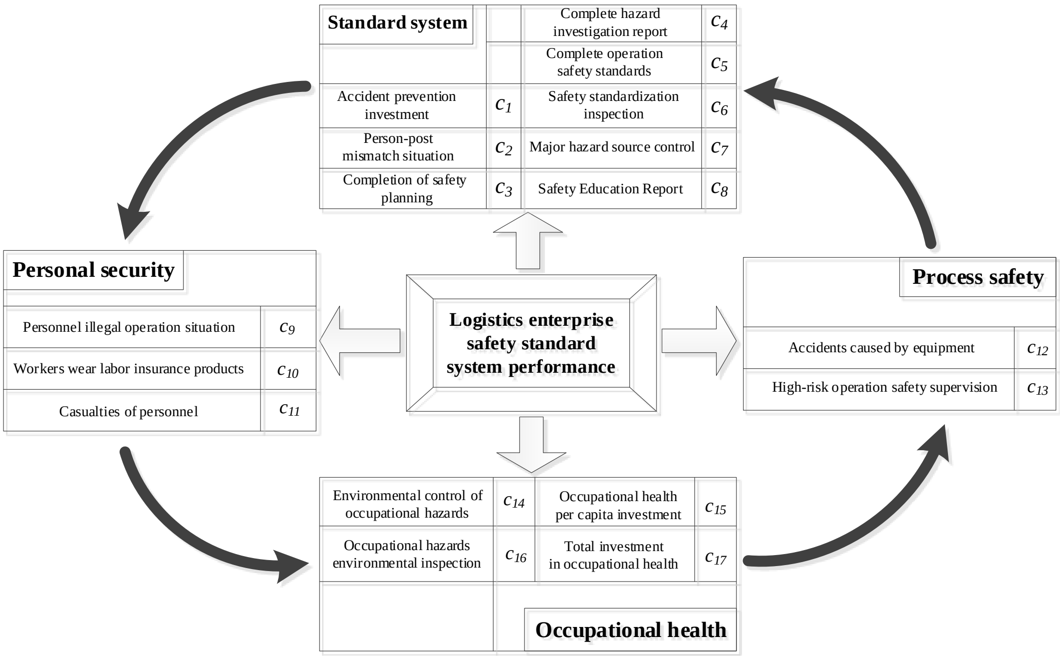

Fig. 1. Performance evaluation indicators of safety standard system for logistics enterprises.

According to Fig.1, the indicator system mainly analyzes the performance factors from the perspective of input and output in the construction process of the logistics enterprise safety standard system. Experts' performance evaluation of the safety standard system of logistics enterprises mainly evaluates the status of the performance factors involved. However, the performance evaluation indicator constructed lacks a unified evaluation standard, and it is impossible to determine the state of each performance factor by the accurate digital scoring method. Therefore, this paper organizes experts to use the linguistic terms set shown in Table 1 to evaluate.

Table 1
Linguistic terms set of evaluation [29]

Real numbers	Linguistic terms	Triangular fuzzy number
5	Very good	(0.75,1.00,1.00)
4	Good	(0.50,0.75,1.00)
3	Slight good	(0.25,0.50,0.75)
2	Bad	(0.00,0.25,0.50)
1	Very bad	(0.00,0.00,0.25)

3. Performance evaluation model based on prospect theory

To intuitively describe the performance evaluation of the safety standard system for logistics enterprises, we use the following symbols to represent the model variables and sets involved in the performance evaluation process.

① $L=\{l_1,l_2,l_3,\cdots l_m\}$: There are m logistics enterprises to be evaluated; where l_i is the i th logistics enterprise and $i=1,2,3\cdots m$.

② $P=\{p_1,p_2,p_3,\cdots p_t\}$: There are t experts; where p_k is the k th experts and $k=1,2,3\cdots t$.

③ $\lambda=\{\lambda_1,\lambda_2,\lambda_3\cdots\lambda_t\}$: It is the weight vector of experts; where λ_k represents the weight of the k th experts, $0\le\lambda_k\le1$, and $\sum_{k=1}^{t}\lambda_k=1$.

④ $C=\{c_1,c_2,c_3,\cdots c_n\}$: There are n indicator, where c_j is the j th criteria of the performance evaluation and $j=1,2,3\cdots n$.

⑤ $X=\left(\tilde{X}^k\right),\tilde{X}^k=\left(x_{ij}^k\right)_{m\times n},k=1,2,\cdots t$: It is the evaluation value corresponding to the performance evaluation indicator. $\tilde{X}^k$ is the evaluation value given by the k th expert, and x_{ij}^k is the evaluation value of the i th expert on the th logistics enterprise to be evaluated under the j th performance indicator.

3.1 Prospect value calculation

The performance evaluation of the safety standard system for logistics enterprises refers to the judgment of the actual situationof m enterprises under n evaluation indicators by t experts. The evaluation result vector of the k th expert on the i th logistics enterprise can be expressed as $V_i'^k=\left(x_{ij}^k\right),j=1,2,\cdots n$. We use the prospect theory to aggregate the performance evaluation results and the Choquet integral method to aggregate the comprehensive prospect value of the performance evaluation indicator. Then, the performance evaluation results of the safety standard system for each logistics enterprise are determined. The prospect theory mainly analyzes the decision-making problem based on the two dimensions of gain and loss. The income and loss are determined based on the selected reference point. Then, according to the theory of the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, the highest x^+ and lowest performance levels x^- are taken as reference points.

From the above analysis, combined with the TOPSIS theory, the distance between the evaluation value of each performance indicator and the reference point can be obtained as follows:

$$\begin{aligned} \mu_{ij}^{k(*)} &= d(x_{ij}^{k}, x_{j}^{+}) \\ \mu_{ij}^{k(0)} &= d(x_{ij}^{k}, x_{j}^{-}) \end{aligned} \tag{1}$$

where $\mu_{ij}^{k(*)}$ and $\mu_{ij}^{k(0)}$ are the distance between the evaluation value and the performance level reference value of the k th expert on the i th logistics enterprise under the j th indicator.

Then, combined with the prospect theory [26], the prospect value is calculated as follows:

$$v_{ij}^{k(+)} = \begin{cases} (\mu_{ij}^{k(*)})^{\alpha} & x_{ij}^{k} \geq x_{j}^{+} \\ (1-\mu_{ij}^{k(0)})^{\alpha} & x_{ij}^{k} \geq x_{j}^{-} \end{cases} \tag{2}$$

$$v_{ij}^{k(-)} = \begin{cases} -\theta[-(\mu_{ij}^{k(*)}-1)]^{\beta} & x_{ij}^{k} < x_{j}^{+} \\ -\theta(-\mu_{ij}^{k(0)})^{\beta} & x_{ij}^{k} < x_{j}^{-} \end{cases} \tag{3}$$

where α, β represent the convexity of the power function of the gain and loss value of the performance evaluation indicator, respectively. Additionally, the value reflects the psychological behavior characteristics of the experts on the change of the sensitivity of the gain and loss. $\theta > 1$ is used to describe the psychological and behavioral characteristics of loss aversion of experts in the evaluation process. The larger the θ value is, the higher the degree of loss aversion of experts, where $i = 1, 2, 3 \cdots m$, $j = 1, 2, 3 \cdots n$, and $k = 1, 2, 3 \cdots t$, respectively.

Assume that the expert faces two cases of gain and loss, $\pi_{j}^{k(+)}$ and $\pi_{j}^{k(-)}$ are subjective probability weighting functions, respectively. Then, the complex prospect value of the k th expert is calculated as follows:

$$v_{ij}^{k} = v_{ij}^{k(+)} \pi_{j}^{k(+)} + v_{ij}^{k(-)} \pi_{j}^{k(-)} \tag{4}$$

The construction of the subjective probability weight function needs to consider the deviation of the expert's processing of probability events during evaluation. Therefore, according to the prospect theory, the expert subjective probability weighting function can be counted as follows [30]:

$$\pi_{j}^{k} = \begin{cases} \pi_{j}^{k(+)} = \dfrac{(p_{j}^{k})^{\chi}}{\left[(p_{j}^{k})^{\chi} + (1-p_{j}^{k})^{\chi}\right]^{1/\chi}} \\ \pi_{j}^{k(-)} = \dfrac{(p_{j}^{k})^{\delta}}{\left[(p_{j}^{k})^{\delta} + (1-p_{j}^{k})^{\delta}\right]^{1/\delta}} \end{cases} \tag{5}$$

where χ and δ represent the curvature degree of the subjective probability function when the expert faces two situations of gain and loss, $j = 1, 2, 3 \cdots n$, and $k = 1, 2, 3 \cdots t$. Here, we set $\alpha = \beta = 0.88$, $\theta = 2.25$, $\chi = 0.61$, $\delta = 0.69$ according to Gao *et al.*, [30].

Finally, the comprehensive prospect matrix of the k th expert can be obtained as follows:

$$V^{k} = \begin{bmatrix} v_{11}^{k} & v_{12}^{k} & \cdots & v_{1n}^{k} \\ v_{21}^{k} & v_{22}^{k} & \cdots & v_{2n}^{k} \\ \vdots & \vdots & & \vdots \\ v_{m1}^{k} & v_{m2}^{k} & \cdots & v_{mn}^{k} \end{bmatrix} \tag{6}$$

3.2 The aggregation of performance evaluation information based on the Choquet integral method

Most of the current indicator aggregation methods assume that the indicators are independent. However, indicators interact in the performance evaluation of the logistics enterprise safety standard system. Based on the fuzzy measure theory, the Choquet integral and Shapley value coupling method can better solve the indicators' correlation [31]. Therefore, we use the integrated method combined with the Choquet integral, fuzzy measure, and Shapley value to aggregate the comprehensive prospect matrix of each evaluation expert. The specific calculation process is as follows.

① Definition of fuzzy measure concept

The power set of indicators $C^k = \left\{c_1^k, c_2^k, \cdots c_n^k\right\}$ with the expert t_k needs to evaluate is $P(C^k)$. Then, let $\mu : P\left(C^k\right) \to [0,1]$ be the set function of $P(C^k)$. If the set function satisfies the following conditions simultaneously, the set function μ is defined as a fuzzy measure.

ⓐ $\mu(\varnothing) = 0, \mu(C^k) = 1$; ⓑ $A, B \in P(C^k), A \subseteq B$, then $\mu(A) \le \mu(B)$.

Based on satisfying the above conditions, if the set function μ satisfies the following formula, the set function is defined as λ fuzzy measure.

$$\mu(A \cup B) = \mu(A) + \mu(B) + \lambda\mu(A)\mu(B), \lambda \in (-1, \infty) \tag{7}$$

② The λ fuzzy measure of the indicator set

For each subset $A \subseteq C^k$ of the evaluation indicator set $C^k = \left\{c_1^k, c_2^k, \cdots c_n^k\right\}$, then the λ fuzzy measure $\mu(A)$ can use the following Eq. (8) to calculate [32]:

$$\mu(A) = \begin{cases} \frac{1}{\lambda}\left(\prod_{j \in A}[1 + \lambda\mu(c_j^k)] - 1\right) & \lambda \neq 0 \\ \sum_{j \in A} \mu(c_j^k) & \lambda = 0 \end{cases} \tag{8}$$

Then, according to $\mu(C^k) = 1$, Eq. (8) can be expressed an equality of parameter λ, which is as follows:

$$\lambda + 1 = \prod_{j=1}^{n}(1 + \lambda\mu(c_j^k)) \tag{9}$$

③ Shapley value calculation

As $\forall A \in P(C^k)$, the extended Shapley value can be denoted as [32]:

$$\Phi\left(A\right) = \sum_{B \subseteq C^k / A} \frac{(\left|C^k\right| - |A| - |B|)!|B|!}{(\left|C^k\right| - |A| + 1)!} \cdot (\mu(A \cup B) - \mu(B)) \tag{10}$$

Further, when $A = c_j^k$, the Shapley value in Eq. (10) will become the formula in Eq. (11).

$$\Phi\left(c_j^k\right) = \sum_{B \subseteq C^k / c_j^k} \frac{(\left|C^k\right| - 1 - |B|)!|B|!}{(\left|C^k\right|)!} \cdot (\mu(c_j^k \cup B) - \mu(B)) \tag{11}$$

where $\left|C^k\right|$、$|A|$、$|B|$ are the potential indicators of their corresponding sets, respectively. $\Phi\left(A\right)$ refers to the correlation between set A and other indicator set B. It can express the contribution of performance indicator set A in the whole performance evaluation indicator set. Moreover, $\Phi\left(c_j^k\right)$ refers to the contribution of performance evaluation indicator c_j^k in all performance evaluation indicators so that it can be the weight of c_j^k.

④ Comprehensive prospect value aggregation based on the Choquet integral method, fuzzy measure, and Shapley value. To fully consider the relationship between the indicator and the weight of each indicator, the λ-fuzzy measure and Shapley value are combined to form the λ-Shapley value, which is shown in Eq. (12).

$$\Phi\left(c_j^k\right) = \sum_{B \subseteq C^k / c_j^k} \frac{(\left|C^k\right| - 1 - |B|)!|B|!}{(\left|C^k\right|)!} \cdot \mu(c_j^k) \prod_{j=1}^{n} [1 + \lambda \mu(c_j^k)] \tag{12}$$

According to Eq. (12) and combined with the Choquet integral method, the λ-Shapley Choquet integral is as follows:

$$C_{\Phi(c_j^k)}(v_{i(1)}^k, v_{i(2)}^k, \cdots v_{i(n)}^k) = \sum_{i=1}^{n} v_{i(j)}^k [\Phi_{A(i)}(c_j^k) - \Phi_{A(i+1)}(c_j^k)] \tag{13}$$

In summary, the comprehensive prospect value V^k of each expert is aggregated by the correlation aggregation operator of the performance evaluation indicator combined with the Choquet integral method, λ fuzzy measure, and Shapley value, which is shown as follows:

$$V = (v_i^k)_{m \times t} = \begin{bmatrix} v_1^1 & v_1^2 & \cdots & v_1^t \\ v_2^1 & v_2^2 & \cdots & v_2^t \\ \vdots & \vdots & & \vdots \\ v_m^1 & v_m^2 & \cdots & v_m^t \end{bmatrix} \tag{14}$$

3.3 Expert weight determination and performance evaluation information aggregation

It is necessary to calculate the expert weight to determine the final performance situation of each logistics enterprise. At present, the methods of expert weight calculation include the subjective weighting method, objective weighting method, and subjective and objective integrated weighting method [33, 34]. The subjective and objective integrated weighting method is widely used in expert weight calculation, which can effectively combine the advantages of the single weighting method and avoid its shortcomings [34]. The knowledge level, the preference characteristic of experts, and the amount of decision-making judgment information will impact the performance evaluation results. This paper uses the fuzzy analytic hierarchy process (FAHP) to calculate the weight of experts, which considers these issues [35]. In addition, the entropy method is used to measure the amount of information for experts during evaluation. The specific calculation process is as follows.

① Determination of expert weight based on the FAHP method

Firstly, according to the experts' industry background and participation in the safety system evaluation, the Delphi method is used to judge the importance of the prior information of each expert relative to the performance evaluation. Then, according to Ben Rabia and Bellabdaoui, [35], we calculate the expert weight $\left\{\lambda_1^1, \lambda_2^1, \cdots \lambda_t^1\right\}$ based on the FAHP method.

② Determination of expert weight based on entropy method

The entropy method effectively describes the importance of experts in the decision-making process. We use the entropy method to calculate the expert weight. The entropy value and weight of the evaluation experts can be obtained by the entropy method, as shown in Eqs. (15-17).

$$e_k = -K \sum_{i=1}^{m} v_i^k \ln v_i^k \tag{15}$$

$$d_k = 1 - e_k \tag{16}$$

$$\lambda_k^2 = d_k \Big/ \sum_{k=1}^{t} d_k \tag{17}$$

③ Expert weight determination

The comprehensive weight of experts is as follows.

$$\lambda_k = \vartheta_1 \lambda_k^1 + \vartheta_2 \lambda_k^2 \tag{18}$$

where ϑ_1 and ϑ_2 are the relative degrees of the two methods, respectively.

Finally, the comprehensive prospect value of the performance of the safety standard system of logistics enterprises is as follows.

$$v_i = \sum_{k=1}^{t} \lambda_k v_i^k \tag{19}$$

4. Case study

To illustrate the effectiveness of the proposed framework, a food logistics enterprise in Anhui Province is taken as an example to evaluate the performance of its safety standard system. The food logistics enterprise comprises three links: packing, transportation, and storage. The three links have carried out the construction project of a logistics safety standard system. Therefore, this paper takes three links $\{l_1, l_2, l_3\}$ as the evaluation objects and uses the proposed method to evaluate the performance of their safety standard system. We invite three relevant experts $\{p_1, p_2, p_3\}$ to assess the performance of the safety standard system for the three logistics links. Based on the company's actual situation and experts' professional knowledge, the performance of the safety standard system for the three logistics links is evaluated. Then, according to Antão *et al.*, [36], we use the statistical frequency of performance evaluation indicators in existing research as the probability value p_j^k of performance indicators. Here, we take the first expert as an example, as shown in Table 2, where $i = 1,2,3$, $k = 1,2,3$, and $j = 1,2,3,\cdots 17$, respectively.

Table 2
The performance valuation value from expert p_1

Indicator	Probability	l_1	l_2	l_3
c_1	0.047	(0.25,0.50,0.75)	(0.25,0.50,0.75)	(0.00,0.25,0.50)
c_2	0.012	(0.00,0.25,0.50)	(0.25,0.50,0.75)	(0.00,0.00,0.25)
c_3	0.188	(0.50,0.75,1.00)	(0.00,0.25,0.50)	(0.25,0.50,0.75)
c_4	0.035	(0.00,0.25,0.50)	(0.25,0.50,0.75)	(0.00,0.25,0.50)
c_5	0.047	(0.25,0.50,0.75)	(0.25,0.50,0.75)	(0.50,0.75,1.00)
c_6	0.024	(0.00,0.00,0.25)	(0.25,0.50,0.75)	(0.00,0.00,0.25)
c_7	0.035	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.75,1.00,1.00)
c_8	0.071	(0.00,0.00,0.25)	(0.25,0.50,0.75)	(0.50,0.75,1.00)
c_9	0.047	(0.00,0.00,0.25)	(0.00,0.25,0.50)	(0.00,0.25,0.50)
c_{10}	0.024	(0.00,0.00,0.25)	(0.00,0.25,0.50)	(0.00,0.25,0.50)
c_{11}	0.176	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)
c_{12}	0.035	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.75,1.00,1.00)
c_{13}	0.141	(0.00,0.00,0.25)	(0.25,0.50,0.75)	(0.00,0.00,0.25)
c_{14}	0.012	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)
c_{15}	0.035	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)
c_{16}	0.047	(0.00,0.00,0.25)	(0.25,0.50,0.75)	(0.00,0.00,0.25)
c_{17}	0.024	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)

Then, using Eqs. (1-3) to calculate the prospect values of each performance evaluation indicator, as shown in Table 3. Next, using Eq. (6), we calculate the comprehensive performance prospect values of the three links under each indicator given by the expert p_1, and the results are shown in Table 4. Similarly, we count the comprehensive prospect value of each indicator of the performance evaluation value given by the expert p_2 and the expert p_3, as shown in Table 5 and Table 6.

Table 3
The positive and negative prospect value from expert p_1

Indicator	l_1		l_2		l_3	
	Positive value	Negative value	Positive value	Negative value	Positive value	Negative value
c_1	0.073	-0.139	0.099	-0.139	0.102	-0.080
c_2	0.048	-0.033	0.047	-0.057	0.061	-0.010
c_3	0.084	-0.444	0.253	-0.185	0.145	-0.320
c_4	0.087	-0.067	0.085	-0.116	0.087	-0.067
c_5	0.073	-0.139	0.099	-0.139	0.042	-0.192
c_6	0.089	-0.016	0.069	-0.089	0.089	-0.016
c_7	0.036	-0.161	0.060	-0.161	0.011	0.000
c_8	0.157	-0.032	0.122	-0.178	0.052	-0.247
c_9	0.128	-0.025	0.128	-0.080	0.102	-0.080
c_{10}	0.089	-0.016	0.089	-0.052	0.071	-0.052
c_{11}	0.081	-0.428	0.081	0.000	0.081	-0.428
c_{12}	0.036	-0.161	0.060	-0.161	0.011	0.000
c_{13}	0.220	-0.049	0.171	-0.270	0.220	-0.049
c_{14}	0.020	-0.079	0.020	0.000	0.020	-0.079
c_{15}	0.036	-0.161	0.060	-0.161	0.036	-0.161
c_{16}	0.128	-0.025	0.099	-0.139	0.128	-0.025
c_{17}	0.009	0.000	0.048	-0.124	0.029	-0.124

Table 4
Comprehensive prospect value under each indicator from expert p_1

l_1				l_2			
Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values
c_1	-0.065	c_{10}	0.072	c_1	-0.040	c_{10}	0.037
c_2	0.015	c_{11}	-0.346	c_2	-0.010	c_{11}	0.081
c_3	-0.360	c_{12}	-0.124	c_3	0.068	c_{12}	-0.101
c_4	0.021	c_{13}	0.172	c_4	-0.030	c_{13}	-0.099
c_5	-0.065	c_{14}	-0.059	c_5	-0.040	c_{14}	0.020
c_6	0.072	c_{15}	-0.124	c_6	-0.021	c_{15}	-0.101
c_7	-0.124	c_{16}	0.103	c_7	-0.101	c_{16}	-0.040
c_8	0.125	c_{17}	0.009	c_8	-0.056	c_{17}	-0.076
c_9	0.103			c_9	0.047		

l_3			
Indicator	Prospect values	Indicator	Prospect values
c_1	0.021	c_{10}	0.019
c_2	0.050	c_{11}	-0.346
c_3	-0.175	c_{12}	0.011
c_4	0.021	c_{13}	0.172
c_5	-0.150	c_{14}	-0.059
c_6	0.072	c_{15}	-0.124
c_7	0.011	c_{16}	0.103
c_8	-0.195	c_{17}	-0.095
c_9	0.021		

Table 5
Comprehensive prospect value under each indicator from expert p_2

l_1				l_2			
Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values
c_1	-0.034	c_{10}	0.068	c_1	-0.038	c_{10}	0.039
c_2	0.035	c_{11}	-0.374	c_2	-0.013	c_{11}	0.076
c_3	-0.287	c_{12}	-0.125	c_3	0.063	c_{12}	-0.107
c_4	0.029	c_{13}	0.175	c_4	-0.028	c_{13}	-0.093
c_5	-0.056	c_{14}	-0.057	c_5	-0.036	c_{14}	0.024
c_6	0.083	c_{15}	-0.118	c_6	-0.024	c_{15}	-0.105
c_7	-0.131	c_{16}	0.108	c_7	-0.106	c_{16}	-0.042
c_8	0.129	c_{17}	0.006	c_8	-0.057	c_{17}	-0.073
c_9	0.107			c_9	0.043		

l_3			
Indicator	Prospect values	Indicator	Prospect values
c_1	0.019	c_{10}	0.023
c_2	0.053	c_{11}	-0.338
c_3	-0.173	c_{12}	0.019
c_4	0.021	c_{13}	0.178
c_5	-0.148	c_{14}	-0.052
c_6	0.067	c_{15}	-0.127
c_7	0.016	c_{16}	0.106
c_8	-0.121	c_{17}	-0.091
c_9	0.035		

Table 6
Comprehensive prospect value under each indicator from expert p_3

l_1				l_2			
Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values	Indicator	Prospect values
c_1	-0.056	c_{10}	0.083	c_1	-0.043	c_{10}	0.041
c_2	0.019	c_{11}	-0.339	c_2	-0.016	c_{11}	0.079
c_3	-0.353	c_{12}	-0.128	c_3	0.072	c_{12}	-0.098
c_4	0.026	c_{13}	0.176	c_4	-0.036	c_{13}	-0.102
c_5	-0.058	c_{14}	-0.053	c_5	-0.043	c_{14}	0.017
c_6	0.076	c_{15}	-0.129	c_6	-0.027	c_{15}	-0.106
c_7	-0.126	c_{16}	0.108	c_7	-0.106	c_{16}	-0.038
c_8	0.128	c_{17}	0.003	c_8	-0.053	c_{17}	-0.065
c_9	0.098			c_9	0.051		

l_3			
Indicator	Prospect values	Indicator	Prospect values
c_1	0.023	c_{10}	0.015
c_2	0.046	c_{11}	-0.349
c_3	-0.171	c_{12}	0.016
c_4	0.025	c_{13}	0.175
c_5	-0.143	c_{14}	-0.063
c_6	0.076	c_{15}	-0.127
c_7	0.015	c_{16}	0.106
c_8	-0.197	c_{17}	-0.094
c_9	0.018		

After that, experts are invited to give the fuzzy measure value of the performance evaluation indicator and use the MATLAB software to solve the value λ . The calculation result is $\lambda^t = \{0.719, 0.696, 0.787\}$. According to Eqs. (9-12), we calculate the extended Shapley value based on the λ -Shapley Choquet interval method. Due to space limitations, only part of the results are shown in Table 7. According to Tables 4 to 7 and Eq. (13), we can obtain the comprehensive prospective value of performance evaluation of the standard system, as shown in Table 8.

Table 7
The extended Shapley values under each indicator from 3 experts

	$\Phi(c_1)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$
P1	0.31	0.23	0.18	0.26	0.29	0.17	0.27	0.19	0.12
P2	0.28	0.19	0.24	0.28	0.26	0.08	0.26	0.17	0.09
P3	0.29	0.25	0.17	0.31	0.25	0.13	0.21	0.12	0.15

	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$	$\Phi(c_2)$
P1	0.28	0.23	0.09	0.21	0.25	0.11	0.15	0.23
P2	0.21	0.25	0.12	0.18	0.23	0.18	0.19	0.18
P3	0.27	0.19	0.15	0.17	0.19	0.13	0.16	0.21

Table 8
The final prospect values of three logistics links

	P1	P2	P3
l_1	-0.285	-0.487	-0.238
l_2	-0.294	-0.502	-0.256
l_3	-0.256	-0.479	-0.237

The calculation of expert weight is divided into two parts. Firstly, the calculation weight of experts using the FAHP method is $\lambda^1 = \{0.371, 0.285, 0.344\}$. Secondly, the calculation weight of experts using the entropy method is $\lambda^2 = \{0.333, 0.334, 0.333\}$. According to Eq. (18-19), the evaluation results of safety performance for the three links are as follows: $l_i = \{-0.278, -0.489, -0.243\}$. According to the evaluation results, the three links of the logistics enterprise which have the best performance in the safety standard system are link l_3 . The logistics enterprise involved in this paper are mainly engaged in food warehousing and food logistics distribution business. Therefore, according to the “Evaluation Standard of Warehouse Logistics Enterprise Safety Production Standardization” and the existing performance evaluation indicator of the safety management system, the evaluation indicator system is established. Then, the evaluation information is obtained through the expert evaluation method. Finally, the best performance of the safety standard system in the logistics links of the enterprise is l_3 .

5. Conclusions

Logistics safety standardization is a crucial way to improve the safety management level of logistics enterprises. The performance evaluation of safety standardization can provide advice reference for enterprises and relevant departments to promote the construction of safety standardization. This paper proposes a performance evaluation framework based on the λ -Shapley Choquet integral method and prospect theory. It considers the characteristic attributes of indicator correlation and uncertainty of safety standardization during performance evaluation for logistics enterprises. An example analysis verifies the practicability of this framework, and the conclusions are as follows.

(1) The triangular fuzzy number and prospect theory are used to process information. It can not only describe the uncertainty in the process of expert evaluation but also effectively simulate psychological behavior, such as the subjective preference of experts.

(2) Using the λ-Shapley Choquet integral to aggregate evaluation information of experts can effectively consider the indicator correlation in the performance evaluation of the logistics safety standard system. Further, we propose an approach to calculate the expert weight based on the entropy and FAHP method. It considers the influence of evaluation experts' bounded behavior and makes the evaluation results conform to reality.

In future research on the performance evaluation of safety standardization for logistics enterprises, researchers could consider applying the proposed performance evaluation method to other industries. Meanwhile, researchers could focus on constructing an evaluation method for safety standardization under the objective and subjective data-integrated environment.

Author Contributions

Conceptualization, Y.C.; methodology, Y.C.; software, Y.C.; validation, Y.C.; formal analysis, L.D.; investigation, L.D.; resources, L.D.; data curation, L.D.; writing—original draft preparation, Y.C.; writing—review and editing, Y.C.; visualization, L.D.; supervision, L.D.; project administration, L.D.; funding acquisition, L.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

There is no data in this study.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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