Retraction

Retracted: Safety Risk Evaluation of Construction Site Based on Unascertained Measure and Analytic Hierarchy Process

Discrete Dynamics in Nature and Society

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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) Manipulated or compromised peer review

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] B. Liang, S. Zhang, D. Li et al., "Safety Risk Evaluation of Construction Site Based on Unascertained Measure and Analytic Hierarchy Process," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 7172938, 14 pages, 2021.

Research Article

Safety Risk Evaluation of Construction Site Based on Unascertained Measure and Analytic Hierarchy Process

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Due to the high risk of construction sites, it is necessary to make safety risk evaluation. With the synthetic consideration of the complexity and uncertainty of construction sites, a comprehensive evaluation index system with two levels has been based on the emphases and difficulties of the current safety work in construction industry; the index system includes civilized construction site, management of machinery, equipment, materials, occupation health protection, and the subpackage management, such as 6 one-level evaluation indexes, inspection system of safety risk, safety awareness education, and prevention and control of occupation disease, such as 33 two-level evaluation indexes. The research takes "No. A residential building and other 8 projects" as the empirical analysis object, with the weights of the first indexes and second indexes being calculated by the analytic hierarchy process (AHP) and the information entropy, and applies the unascertained measure to comprehensively evaluate the safety risk of the construction project. The overall score of the project is 6.4475, the evaluation result is good, which is consistent with the actual situation, and the feasibility and effectiveness of the evaluation index system and evaluation model are verified, which provides a reference for safety risk management in the construction stage of construction projects.

1. Introduction

In recent years, under the background of the steady development of the national economy, the construction industry, as one of the pillar industries in China, has greatly enhanced its development space. According to the 13th Five-Year Plan for the Development of the Construction Industry released by the Ministry of Housing and Urban-Rural Development this year, the construction industry will remain the guarantee for the steady growth of the national economy in the next few years. The construction industry continues to develop rapidly, and the safety situation of construction projects is becoming more and more serious. Due to the particularity of construction engineering products, there are many hazardous sources on the construction site. If these hazardous sources are not handled

properly, they will cause property losses or endanger the life safety of the construction personnel.

According to data released by the Ministry of Housing and Urban-Rural Development at the beginning of 2020, from January to December 2019, a total of 773 work safety accidents occurred in housing and municipal projects, resulting in 904 deaths shown in Figures 1 and 2, 5.31% and 7.62% higher than those in 2018, respectively. These accidents have brought heavy losses to the country. In order to reduce the harm caused by construction safety accidents, construction units must carry out accurate safety evaluation and effective risk early warning on the construction site. With the deepening of the development concept of "people-oriented," the country is now paying more and more attention to the field of construction safety, and construction

safety assessment and early warning have gradually become a research hotspot [1, 2].

Because the construction project has the characteristics of high management difficulty, long cycle, large personnel mobility, large scale, complex technology, and so on, especially, it has many uncertain factors in the construction process, so there is a greater risk than the general product production [3–5]. Especially, the modern construction projects driven by urbanization, their technical complexity, construction scale, resource consumption, and capital input are much larger than the previous construction projects, and the risks of the project in the process of operation have increased a lot than the previous construction projects [6–8]. At the same time, the scale of loss is becoming larger and larger, which makes the personnel engaged in construction management at home and abroad pay more and more attention to the research and practice of systematic risk management of construction engineering projects [9–11]. The theoretical management research and practical exploration of building safety abroad started early. In 1978, Hinze [12, 13] carried out a series of research on building safety and achieved many guiding results. Based on the research basis of Hinze [12, 13], Samelson and Levitt [14] conducted research on the owner's selection of safety contractors; Jannadi [15] believes that the most important factors affecting building safety can be divided into six categories; Blair [16] proposed from the perspective of comprehensive safety management that all people involved in the building are responsible for safety issues. In the 1980s, after the safety problem was introduced into China as a system engineering, the research on construction risk control and management [17], construction risk evaluation method [18], and basic management method of construction safety [19] was started in China, and suggestions were put forward from the essence of construction safety [20].

Risk in the construction project is defined as follows: in the whole construction process of the construction project, due to the occurrence of a variety of reasons, it is the possibility or probability of causing casualties, accidents or dangers, and property losses [21–23]. Risk assessment, also known as "safety assessment," uses the principles and methods of safety systems engineering to identify and evaluate the risks and harmful factors existing in the project, carry out qualitative or quantitative analysis, and evaluate the possibility and severity of the risk, in order to pursue the least economic loss, the lowest probability of accident [24–26]. However, the safety management of most construction enterprises in China is only limited to the inspection and rectification of the construction site, and the safety evaluation of subordinate sites is basically evaluated by experts and on-site safety personnel according to their own experience, which leads to the strong subjectivity of the evaluation results and the lack of a strong scientific basis.

The construction site risk assessment needs feasible methods, and the commonly used safety assessment methods at home and abroad mainly include safety checklist (SCL) [27, 28], fuzzy comprehensive evaluation method (Fuzzy) [9, 29, 30], analytic hierarchy process (AHP) [31–33], fault tree analysis (FTA) [34, 35], support vector
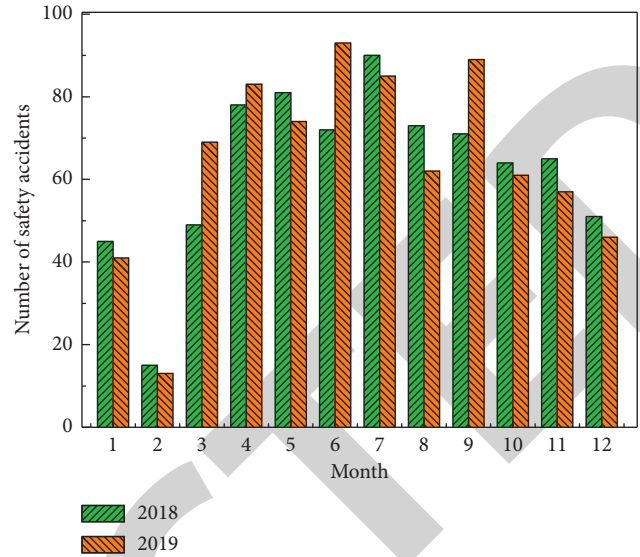

Figure 1: The number of production safety accidents in China's housing and municipal engineering in 2019.
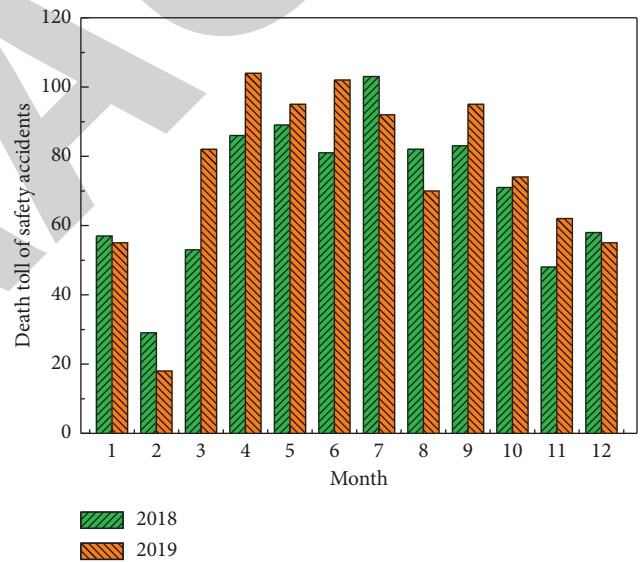

Figure 2: The death toll from production safety accidents in housing and municipal projects in China in 2019.

machine (SVM) [36, 37], and Fuzzy-Analytical Hierarchy process (FAHP) [38]. These methods not only provide the theoretical basis for the production practice, but also lay the foundation for the subsequent theoretical research. But due to the construction site hazards and influence on each other, at the same time, the scene of the security check data along with the advancement of engineering is also in constant change and causes the construction risk assessment theory, method, and some problems existing in the application: (1) the existing building construction safety inspection and evaluation index is not enough, as well as the deviation and the application of risk assessment technology and applicability; (2) the selection of evaluation indexes is unreasonable; (3) the collection of basic data is insufficient, and the

boundary between qualitative and quantitative analysis is not clear enough; (4) the comprehensive consideration of human, machine, and environment factors in risk assessment is not ideal. In addition, construction site safety assessment is a decision-making process involving multi-index uncertainty, which requires consideration of not only a lot of quantitative indicators, but also a large number of qualitative indicators, resulting in great uncertainty and concealment. Unascertained measure theory is a mathematical method, which can effectively analyze and deal with all kinds of inaccurate, incomplete, and uncertain information. In the process of evaluation, some unascertained factors can be considered, and various factors can be integrated to evaluate things, which provides a better method to solve such problems. However, there are some shortcomings in using the unascertained measure theory to determine the weight of complex index system. Analytic hierarchy process (AHP) to the object of study as a system, according to the decomposition, comparative judgment, and comprehensive way of thinking, to make decisions, to the various factors of the problem of complex system, is divided into interconnected orderly level and streamline, through the study of the judgment of objective reality, according to the relative importance to give the quantitative analysis said at each level, A mathematical method is used to determine the order weights of relative importance for all elements representing each level. This method not only has strict quantitative description, but also has qualitative description to the fuzzy phenomenon, which is difficult to be quantitatively analyzed. The qualitative description and quantitative analysis are closely combined, which is a very effective multifactor decision-making method.

This paper introduces the unascertained measure theory to study the safety risk of construction site. Through the stages of the construction of safety risk factors identification, find out the main risk factors; according to the principle of safety risk evaluation index selection, build the scene of the construction safety risk evaluation index system, created based on the unascertained measure construction site safety risk evaluation model, to verify the validity of the model. Comprehensive utilization of Chinese coal group company of Beijing "A on residential buildings, such as eight engineering as an example with analytic hierarchy process (AHP) and entropy weight, improving the construction site safety risk evaluation index system of building of each index weight" is set scientifically, making the safety management focused and targeted, the optimal safety investment benefits.

2. Cause and Types of Safety Risk in Construction Sites

2.1. Analysis on Causes of Safety Risk in Construction Sites. The volume of construction engineering products is huge, fixed, and single, as well as the fluidity of production workers and the diversity of construction materials, construction machines and tools, and the long-term nature of construction time. Towards the objective of safety construction and safety management, the difficulty has increased. According to the investigation and statistical analysis, the main reasons for the construction safety accidents are as follows:

(1) Construction products are fixed, large in volume, and long in production cycle. Construction products are generally large in volume and relatively fixed in position. Once the construction is finished, they will be fixed, and the production activities are carried out around the building. Therefore, a large number of workers, building materials, equipment parts, and construction machinery and tools are highly concentrated in a limited site, operating at the same time, and the production cycle is long. It is also a significant feature of the construction industry.

(2) Large mobility of construction personnel: generally speaking, after the end of a construction project, the construction team will immediately move to a new location for the next construction project. Besides, the seasonal workers, temporary workers, and labor personnel in the construction team occupy a considerable proportion, so the mobility of the construction team is significantly higher than that of other industries.

(3) There are many open-air and high-altitude operations in construction, and the working conditions are poor. The construction team works outdoors for a long time, accounting for about 70% of the work in the open air during the whole construction process. Hot in summer and cold in winter, the working conditions are harsh due to exposure to the weather. In recent years, buildings are mainly high-rise buildings, ranging from more than ten to dozens of floors, so the construction conditions of most workers are high altitude and open-air operation.

(4) The construction technology and method are diverse, and the regularity is poor. There are many processes in the construction from the foundation, the main structure to the level building. Even the same process will lead to different production processes due to the different technology and construction methods, and the unsafe factors are different. Besides, with the change of the construction schedule, the working conditions and unsafe factors on the construction site are also changing. Although the construction has a certain regularity, the construction team will take more temporary measures in order to complete the construction task, thus affecting its regularity, the diversity of building products, and construction conditions of the difference, also making the construction of the construction have no fixed, general construction scheme.

2.2. Types of Safety Risk in Construction Sites. The construction site conditions are complex, and there are many uncertain risk sources. If the risk types are not identified and controlled in the construction, they may cause the occurrence of safety risk accidents and huge economic losses.

Construction safety has a variety of forms of expression, according to the "Construction Safety Inspection Standards" (JGJ59-2011), combined with a huge amount of safety accident analysis data in construction, through the long-term field research on the construction site, summing up the main risk sources of construction safety as follows: falling from high altitude, collapse, electric shock, object strike, fire, and mechanical injury.

(1) Falling from high altitude: work at height refers to the work carried out at a height of 2 m (including 2 m) above the datum plane. During high-altitude construction, operators and constructors will fall from a high place if their feet are empty, their hands are empty when moving, they are collided by other objects, the load-bearing materials are not strong enough, or they do not stand firmly.

(2) Collapse: accidents in which buildings or structures collapse during construction or after they are put into use, resulting in property losses and casualties. The collapse accidents include the inclined instability of buildings, cracks in walls and columns, the collapse of roof cantilever plates, uneven settlement of foundation, landslide caused by changes in geological structure, balcony, cornice, and other floors.

(3) Electric shock: temporary power lines and electrical mechanical equipment are often used on the construction site. Due to the poor external conditions of the construction site, the mechanical equipment and temporary power lines are subject to adverse conditions such as rain, wind, and water splashing, and the use of power lines and electrical equipment fails, resulting in electric leakage. When the construction personnel on the site are splashed and rained, due to the decrease of human impedance caused by wet skin, electric shock accidents are easy to occur.

(4) Object strike: in the process of building construction, human injury occurs when objects used in the building, such as materials, parts, and tools, fall from high altitude. Object strikes mainly include falling objects from high places such as tools, bricks, and tiles, and wood blocks and parts that hurt people; when assembling and disassembling hoisting equipment, materials fall and hurt people; minor failure or aging of the equipment is still in use; and flying out of parts or materials in the equipment will hurt people; construction personnel throw sundries and waste to hurt people.

(5) Fire: in the construction site, there are dangerous factors such as combustion supporting oxidant or oxygen, fire source that can burn combustibles, and combustible materials. If there is a careless operation, it will lead to fire accidents.

(6) Mechanical injury: when the construction site uses hand-held electric tools, small- and medium-sized machinery, and other equipment for mechanical operation, the personal injury caused by imperfect protection or illegal operation is called mechanical injury. In building construction, the machines often used mainly include electric welding machine, mixer, cutting machine, and crane.

In 2019, production safety accidents in housing and municipal projects nationwide were classified by type. In Figure 3, 415 accidents involved falling from high places, accounting for 53.69% of the total. 123 object striking accidents accounted for 15.91% of the total; 69 earthwork and foundation pit collapse accidents accounted for 8.93% of the total; 42 crane machinery injury accidents accounted for 5.43% of the total; 23 construction machinery and tools injury accidents accounted for 2.98% of the total; 20 electric shock accidents accounted for 2.59% of the total; other types of accidents were 81, accounting for 10.47% of the total.

According to the types of major and above accidents in the production safety of municipal housing projects in China, 9 earthwork and foundation pit collapse accidents accounted for 39.13% of the total number of accidents; 7 hoisting machinery injury accidents accounted for 30.43% of the total; 3 building reconstruction, maintenance, and demolition collapse accidents accounted for 13.04% of the total; collapse of formwork support system, fall of attached lifting scaffold, fall from height, and other types of accidents each occurred once, accounting for 4.35% of the total, as shown in Figure 4. In terms of large and above accidents, the accidents represented by earthwork and foundation pit excavation, formwork support system, and construction hoisting machinery, which are more dangerous, account for 82.61% of the total and remain the focus and difficulty of risk prevention and control. The collapse accidents of trench excavation accounted for 13.04% of the total, which were mainly caused by extensive site management, inadequate safety protection, and carelessness of personnel. Collapse accidents in the reconstruction, maintenance, and demolition of existing houses account for 13.04% of the total, and risks and hidden dangers in related fields are becoming increasingly prominent. The problem of market subject's violation of laws and regulations is prominent. The accidents involving illegal command and operation account for about 80% of the total, 60% of the cases involving violation of legal construction procedures, and 40% of the cases involving personnel in key positions who are not available to perform their duties.

According to the construction site safety risk characteristics and types of accident analysis, the construction site of the construction industry has the characteristics of openness, multitype of work, multidepartment cooperation, and environmental variability. The various risk factors are not independent of each other. They influence and interact with each other, which increases many difficulties for the safety management. Therefore, the safety management of the construction site identifies the risk sources, studies the relationship between the risk sources, then selects the influencing factors on the site, and constructs the construction site safety monitoring index system. Through the effective evaluation of the safety of the construction site, it finds the safety hidden dangers in time.
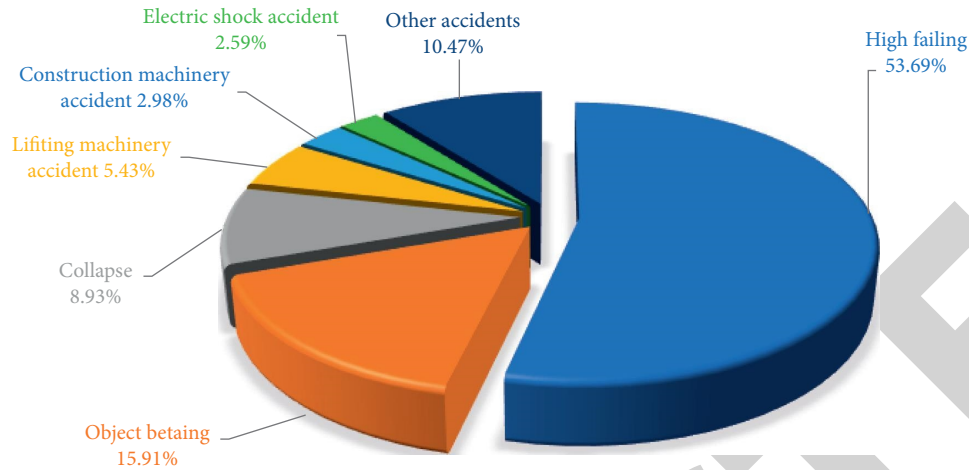
FIGURE 3: Types of production safety accidents of housing and municipal projects in China in 2019.
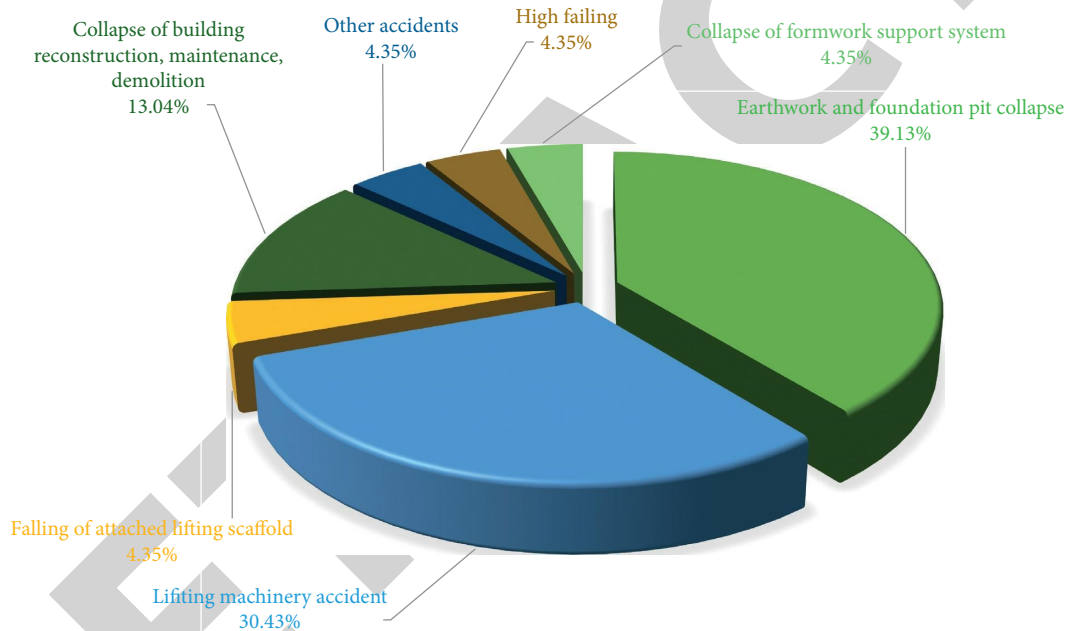

FIGURE 4: Major and above accidents in safety production of housing and municipal projects in China in 2019.

3. Building the Safety Risk Assessment Index System of Construction Site

Firstly, through the literature review [1, 2, 36] and field research to establish the interview outline, the construction enterprises, supervision units, design units, and scientific research institutes and other experts on the basis of structured interviews, the questionnaire of safety risk assessment index of construction site was designed, and samples were selected for pretest investigation. After the reliability and validity test, the questionnaire was optimized and improved to form a formal questionnaire. Then, through field research, factor analysis method is used to extract common factors, and the internal relationship among factors is comprehensively considered to construct the construction site safety risk assessment index system. A total of three levels of indicators are set up: the target

layer (Main Index), the criterion layer (First Index), and the subcriterion layer (Secondary). The construction process of construction site safety risk evaluation system is shown in Figure 5, and the evaluation index system is shown in Table 1.

4. Unascertained Measure Theory

The uncertain information was called fuzzy or random information for a long time, and the nature of fuzzy and random information was considered to be the same. Actually, in terms of their nature, there is tremendous difference between them. Random information refers to the information that the number of the types is confirmed, but their types remain unconfirmed. Fuzzy information refers to the information that the number of the types is unconfirmed, and unknown condition and situation may occur.
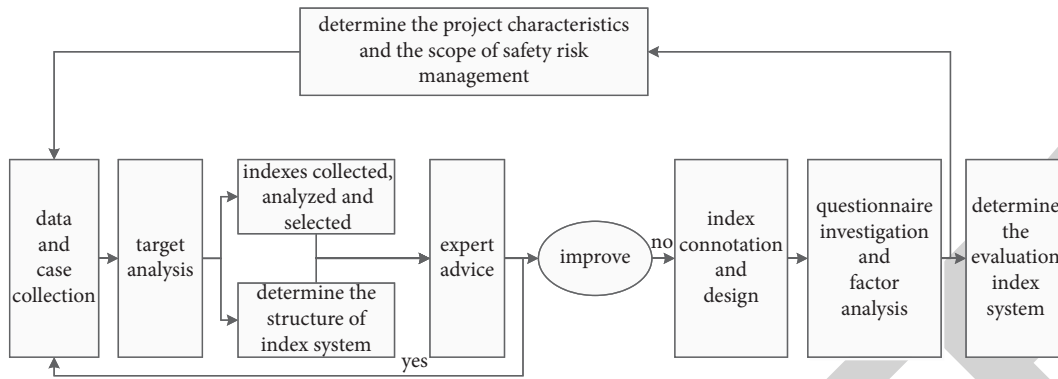
FIGURE 5: The establishing process of evaluation index system of safety risk.

TABLE 1: The evaluation index system of safety risk in construction site [1, 2, 37].

Main index	First index	Secondary index
Safety risk evaluation of construction site X	Organization management system of safety risk X_1	Management organization and personnel setup X_{11}
		Safety risk check X_{12}
		Management responsibility system X_{13}
		Emergency rescue system X_{14}
		Construction organization design X_{15}
		Safety accident reporting system X_{16}
		Disclosure of safety technology X_{17}
	Safety education and training X_2	Quality of education and training personnel X_{21}
		Safety operation standard training X_{22}
		Special operation personnel training X_{23}
		Safety awareness education X_{24}
	Civilized construction on-site X_3	Site enclosure X_{31}
		Site safety signs X_{32}
		Enclosed management X_{33}
		Site fire prevention X_{34}
		Electric safety X_{35}
		Material stacking X_{36}
		Construction site X_{37}
		Living facilities X_{38}
	Management of machinery, equipment and material X_4	Quality of machinery, equipment and material X_{41}
		Maintenance of machinery and equipment X_{42}
		Loading and unloading of machinery and equipment X_{43}
	Occupational health protection X_5	Accommodation environment X_{51}
		Insurance emergency conditions X_{52}
		Distribution of labor protection articles X_{53}
		Use of labor protection supplies X_{54}
		Waste disposal X_{55}
		Prevention of seasonal climate X_{56}
		Prevention and treatment of occupational diseases X_{57}
	Subcontract management X_6	Management monitoring X_{61}
		Credit evaluation X_{62}
		Employment agreement X_{63}
		Employment with certificates X_{64}

In 1990, Wang [39] proposed various types of information concepts, namely, unascertained information, that are distinct from random and fuzzy information in the study of architectural engineering theory. The concepts of unascertained information and the previous gray information are the same, and both of them are used to describe the "incomplete information." However, the unascertained and the gray differ from each other, since gray information expresses more certain information than the uncertain information. Based on academician Wang's idea of unascertained

information coupled with the work from scholars like Wu et al. [40] and Álvaro et al. [41], the unascertained information now has already become a systematic theory and method. In recent years, unascertained measure theory has been widely used in structural soft design theory, generalized reliability theory, structural maintenance theory, mine construction theory, and related theories of expert system and is also being applied in the study of earthquake focal mechanism and seismic risk analysis. It is believed that, with the development of unascertained mathematics theory, especially the publication of applied theory and unascertained number operation program, unascertained mathematics will be applied and successful in various scientific and technological fields.

Set F for the property space of a certain universe U, $\{F_1 F_2, \ldots, F_n\}$ is some of the division of F, and there are a lot of factors x to affect universe U that are called attributes or indexes. Suppose that there are m attributes $\{I_1 I_2, \ldots, I_m\}$ that affect factors x, and then $I = \{I_1 I_2, \ldots, I_m\}$ can be called attribute space on universe U. If there is x_i where any given $\in U$, set observed value I_j of factors x about some kind of attribute j as x_{ij} that can be specific measured. But when information is incomplete or under the conditions of unknown, it is difficult or even impossible to show the properties F of factor x_i with observed value x_{ij}. In fact, the embodiment of varying degrees in the nature reflects the difference in quantization of some attributes, and then the

degree of quantization can be present in the form of data that can be estimated or indirectly measured. But the measurement standards and conditions, including normalization, additivity, and nonnegativity, must be met. Only with this can we get a measurement to describe the degree of the nature, which is called "unascertained measure."

5. Establishment of Unascertained Measure Model

Set $x_1, x_2, \ldots, x_n$ as evaluation objects of news sensitivity, and set universe $U = \{x_1, x_2, \ldots, x_n\}$. The evaluation $x_i \in U (i = 1, 2, \ldots, n)$ has m first indices $I_1, I_2, \ldots, I_n$, and $\overline{I} = \{I_1, I_2, \cdots, I_n\}$. For $I_i \in \overline{I}$ has k secondary evaluation indexes $I_{i1}, I_{i2}, \ldots, I_{ik}$, and $\overline{I}_i = \{I_{i1}, I_{i2}, \ldots, I_{ik}\}$, therefore, X_{ij} can be expressed as k dimensional vector $x_{ij} = \{x_{ij1}, x_{ij2}, \ldots, x_{ijk}\}$, and x_{ijr} means the value of the secondary indexes of I_j, which is x_i's first index. Each x_{ijr} has p evaluated grades $c_1, c_2, \ldots, c_p$, and the evaluation space is $C = \{c_1, c_2, \ldots, c_p\}$.

5.1. The Second-Grade Index Measure

5.1.1. The Single-Index Measure.
Set $\mu_{ijrq} = \mu(x_{ijr} \in c_q)$ expressing the degree that x_{ijr} belongs to c_q, which is the q th evaluation class (rating). μ must meet the conditions as follows:

$$0 \le \mu(x_{ijrq} \in c_q) \le 1, \quad i = 1, 2, \ldots, n, j = 1, 2, \ldots, m, r = 1, 2, \ldots, k \, q = 1, 2, \ldots, p, \tag{1}$$

$$u(x_{ijr} \in C) = 1, \quad i = 1, 2, \ldots, n, j = 1, 2, \ldots, m, r = 1, 2, \ldots, k, \tag{2}$$

$$\mu\left(x_{ijr} \in \bigcup_{l=1}^{q} c_l\right) = \sum_{l=1}^{q} \mu(x_{ijr} \in c_l), \quad q = 1, 2, \ldots, p. \tag{3}$$

Define equation (2) as the "normalization" and equation (3) as the "additivity." μ that meets the three equations above is unascertained measurement. The matrix

$$(\mu_{ijrq})_{k \times p} = \begin{bmatrix} \mu_{ij11} & \mu_{ij12} & \cdots & \mu_{ij1p} \\ \mu_{ij21} & \mu_{ij22} & \cdots & \mu_{ij2p} \\ \cdots & \cdots & \ddots & \cdots \\ \mu_{ijk1} & \mu_{ijk2} & \cdots & \mu_{ijkp} \end{bmatrix} i = 1, 2, \ldots, n; j = 1, 2, \ldots,$$

m is single index measure matrix.

5.1.2. The Distinction Weight of Single Index.
Using the concept of information entropy to define the peak of index I_{ijr},

$$V_{ijr} = 1 + \frac{1}{\ln p} \sum_{q=1}^{p} u_{ijrq} \ln u_{ijrq}, \tag{4}$$

where P represents the number of the evaluated ratings, μ_{ijrq} is the measure of single index, and the value of V_{ijr} expresses

the degree that I_{ijr} is different to each evaluation class. The distinction weight is as follows:

$$\omega_{ijr} = \frac{V_{ijr}}{\sum_{r=1}^{k} V_{ijr}}, \quad i = 1, 2, \ldots, n, j = 1, 2, \ldots, m, r = 1, 2, \ldots, k. \tag{5}$$

$\sum_{r=1}^{k} \omega_{ijr} = 1, 0 \le \omega_{ijr} \le 1$, ω_{ijr} is the classification weights of I_{jr}. $\omega_{ij=}(\omega_{ij1}, \omega_{ij}, \ldots, \omega_{ijk})$ is the classification weight vector of second grade index.

5.2. The First-Grade Index Measure.
Set $\mu_{iq} = \mu(x_i \in c_q)$ expressing the degree that sample x_i belongs to c_r, which is the r th evaluation class (rating).

$$\mu_{iq} = \sum_{j=1}^{m} \omega_{ij} \mu_{ijq}, \quad i = 1, 2, \ldots, n, q = 1, 2, \ldots, p. \tag{6}$$

Due to $0 \leq \mu_{iq} \leq 1$, and $\sum_{q=1}^{p} \mu_{iq} = \sum_{q=1}^{p} \sum_{j=1}^{m} \omega_{ij} \mu_{ijq} = \sum_{j=1}^{m} \omega_{ij} \sum_{q=1}^{p} \mu_{ijq} = \sum_{j=1}^{m} \omega_{ij} = 1$, μ_{iq} is the unascertained measure. Define $(\mu_{i1}, \mu_{i2,\ldots}, \mu_{ip})$ as measure evaluation vector of x_i's composite indicator. The matrix

$$(\mu_{iq})_{n \times p} = \begin{bmatrix} \mu_{11} & \mu_{12} & \cdots & \mu_{1p} \\ \mu_{21} & \mu_{22} & \cdots & \mu_{2p} \\ \cdots & \cdots & \ddots & \cdots \\ \mu_{n1} & \mu_{n2} & \cdots & \mu_{np} \end{bmatrix}$$ is measure matrix of comprehensive index.

Among them, μ_{iq} represents the importance of μ_i relative to μ_q, which is represented by numbers from 1 to 9 in pair-to-pair comparison. This scale is adopted in matrices to determine the weights of relative criteria and to compare the alternatives linked to every criterion. Table 2 summarizes the basic ratio scale. All final weighted coefficients are shown in matrices. Alternatives and criteria can be ranked based on the overall aggregated weights in the matrices. The alternative with the highest overall weight would be the most preferable.

Based on this primary index's judgment matrix, the weights of every first-grade index can be calculated by the geometric calculation method of mean.

$$\overline{w_i} = \sqrt[n]{\prod_{j=1}^{n} s_{ij}}, \quad i = 1, 2, \ldots, n. \tag{7}$$

Then, making the normalized processing of index weight vector ω_i, the equation is shown as follows:

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}}, \quad i = 1, 2, \ldots, n. \tag{8}$$

Get the weight vector of primary index: $\omega = (\omega_1, \omega_2, \ldots, \omega_n)^T$.

The biggest characteristic roots $\lambda_{\max}$ can be calculated by the following equation:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{W_i}, \quad i = 1, 2, \ldots, n. \tag{9}$$

But due to the extreme complexity of objective things, the influence factors of subjective understanding cannot match the requirement of consistency condition entirely sometimes. So, consistency checking of matrix is necessary, and the process is as follows.

The consistency ratio requirements: $C.R = (C.I/R.I) < 0.1$, $C.I = (\lambda_{\max}/n - 1)$. The mean random consistency index RI is shown in Table 3.

5.3. Identification. Due to the evaluation space C is an ordered partition class, the recognition criterion of maximum membership degree is inapplicable. Therefore, credible degree criteria are introduced.

$$k_0 = \min_{k} \left\{ k: \sum_{l=1}^{k} \mu_{il} \geq \lambda, k = 1, 2, \ldots, p \right\}. \tag{10}$$

TABLE 2: Saaty's scale for AHP pairwise comparisons [42, 43].

Weight	Description
1	Equal importance
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Dominant importance
2, 4, 6, 8	Reciprocals

Usually, $\lambda = 0.6$ or 0.7, so the evaluation objects can be classified into c_{ko}.

6. Empirical Analysis

6.1. Case Overview. Taking the project of "No.A residential building and other 8 projects" undertaken by China Coal Construction Group Engineering Co., Ltd. as an example, "A residential building and other 8 projects" are located in the courtyard A 4, Dayang Fang, Olympic Village Area, Chaoyang District, Beijing. The construction area is $62354\,m^2$, and the construction land area is $23212.84\,m^2$. The project is I building. The fire resistance rating of the basement and the ground structure is grade I. It is fortified according to the seismic intensity of 7 degrees, and the design service life is 50 years. The roof waterproof grade of the project is grade II, and the reasonable service life of the waterproof layer is 15 years. The basement waterproof grade is grade II, and the distribution room waterproof grade is grade I.

Through the expert investigation method, 10 experts with a sense of responsibility in the industry issued the investigation and consultation form, and the investigation and consultation were carried out. The experts evaluated the safety risk of the project based on their own experience and knowledge and combined with the actual situation of the construction site and gave the quantitative score of each secondary index, respectively, as shown in Table 4.

Based on cascade theory of rationality of the agricultural trade, it is divided into 5 grades as shown in Table 5: $V = \{$very poor poor qualified good excellent$\}$ correspond to $V = \{v_1, v_2, v_3, v_4, v_5\}$. The direct choice of experts is given according to the multilayered set of factors, with the number of experts supported as judgment of the index. In light of Saaty's 1–9 ratio scale estimation, $V = \{1, 3, 5, 7, 9\}$.

According to the grade structure of membership functions, it is as follows:

$$\mu(x \in c_1) = \begin{cases} 1 & x \leq 60 \\ \dfrac{70 - x}{70 - 60} & 60 < x \leq 70 \\ 0 & x > 70 \end{cases},$$

TABLE 3: The mean random consistency index [43, 45].

Order	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0.52	0.86	1.10	1.26	1.34	1.40	1.43	1.49	1.51	1.54	1.56	1.58

TABLE 4: Construction site safety risk evaluation index score and the corresponding single index measure vector.

First index	Secondary index	Expert score (average score)	Single index measure vector
X_1	X_{11}	88	(0, 0, 0.2, 0.8, 0)
	X_{12}	79	(0, 0.1, 0.9, 0, 0)
	X_{13}	94	(0, 0, 0, 0.2, 0.8)
	X_{14}	77	(0, 0.3, 0.7, 0, 0)
	X_{15}	94	(0, 0, 0, 0.2, 0.8)
	X_{16}	92	(0, 0, 0, 0.6, 0.4)
	X_{17}	82	(0, 0, 0.8, 0.2, 0)
X_2	X_{21}	78	(0, 0.2, 0.8, 0, 0)
	X_{22}	89	(0, 0, 0.1, 0.9, 0)
	X_{23}	98	(0, 0, 0, 0, 1)
	X_{24}	92	(0, 0, 0, 0.6, 0.4)
X_3	X_{31}	100	(0, 0, 0, 0, 1)
	X_{32}	100	(0, 0, 0, 0, 1)
	X_{33}	58	(1, 0, 0, 0, 0)
	X_{34}	63	(0.7, 0.3, 0, 0, 0)
	X_{35}	89	(0, 0, 0.1, 0.9, 0)
	X_{36}	74	(0, 0.6, 0.4, 0, 0)
	X_{37}	81	(0, 0, 0.9, 0.1, 0)
	X_{38}	90	(0, 0, 0, 1, 0)
X_4	X_{41}	87	(0, 0, 0.3, 0.7, 0)
	X_{42}	74	(0, 0.6, 0.4, 0, 0)
	X_{43}	92	(0, 0, 0, 0.6, 0.4)
X_5	X_{51}	65	(0.5, 0.5, 0, 0, 0)
	X_{52}	89	(0, 0, 0.1, 0.9, 0)
	X_{53}	91	(0, 0, 0, 0.8, 0.2)
	X_{54}	90	(0, 0, 0, 1, 0)
	X_{55}	92	(0, 0, 0, 0.6, 0.4)
	X_{56}	78	(0, 0.2, 0.8, 0, 0)
	X_{57}	88	(0, 0, 0.2, 0.8, 0)
X_6	X_{61}	95	(0, 0, 0, 0, 1)
	X_{62}	97	(0, 0, 0, 0, 1)
	X_{63}	94	(0, 0, 0, 0.2, 0.8)
	X_{64}	92	(0, 0, 0, 0.6, 0.4)

TABLE 5: Classification standard.

Level	Very poor (R_1)	Poor (R_2)	Qualified (R_3)	Good (R_4)	Excellent (R_5)
Score	60~70	70~80	80~90	90~95	≥95

$$\mu(x \in c_2) = \begin{cases} \dfrac{80 - x}{80 - 70} & 70 < x \le 80 \\[2mm] \dfrac{x - 60}{70 - 60} & 60 < x \le 70 \\[2mm] 0 & \text{others} \end{cases},$$

$$\mu(x \in c_3) = \begin{cases} \dfrac{90 - x}{90 - 80} & 80 < x \le 90 \\[2mm] \dfrac{x - 70}{80 - 70} & 70 < x \le 80 \\[2mm] 0 & \text{others} \end{cases},$$

$$\mu(x \in c_4) = \begin{cases} \dfrac{95 - x}{95 - 90} & 90 < x \le 95 \\[2mm] \dfrac{x - 80}{90 - 80} & 80 < x \le 90 \\[2mm] 0 & \text{others} \end{cases},$$

$$\mu(x \in c_5) = \begin{cases} 1 & x > 95 \\[2mm] \dfrac{x - 90}{95 - 90} & 90 < x \le 95 \\[2mm] 0 & x \le 90 \end{cases}. \tag{11}$$

Through the evaluation by experts' score, we can get secondary index measure vector; then, this secondary index measure matrix is as follows:

$$I_1: \bar{\mu}_1 = \begin{bmatrix} 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0.1 & 0.9 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0.3 & 0.7 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.8 & 0.2 & 0 \end{bmatrix},$$

$$I_2: \bar{\mu}_2 = \begin{bmatrix} 0 & 0.2 & 0.8 & 0 & 0 \\ 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0.6 & 0.4 \end{bmatrix},$$

$$I_3: \bar{\mu}_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0.7 & 0.3 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0 & 0.9 & 0.1 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix},$$

$$I_4: \bar{\mu}_4 = \begin{bmatrix} 0 & 0 & 0.3 & 0.7 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0.6 & 0.4 \end{bmatrix},$$

$$I_5: \bar{\mu}_5 = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0 & 0 & 0.8 & 0.2 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0.2 & 0.8 & 0 & 0 \\ 0 & 0 & 0.2 & 0.8 & 0 \end{bmatrix},$$

$$I_6: \bar{\mu}_6 = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0.6 & 0.4 \end{bmatrix}. \tag{12}$$

The corresponding index measure vectors are shown in Table 4.

6.2. Weight Calculation of Secondary Index. Classification of secondary index calculated is weighted by information entropy. Below is the calculation of weight of organization management system of safety risk (X_1):

$$I_1: \bar{\mu}_1 = \begin{bmatrix} 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0.1 & 0.9 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0.3 & 0.7 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.8 & 0.2 & 0 \end{bmatrix}. \tag{13}$$

Using equation (4), $V_{11} = 0.7428$, $V_{12} = 0.8329$, $V_{13} = 0.7428$, $V_{14} = 0.6861$, $V_{15} = 0.7428$, $V_{16} = 0.6541$, $V_{17} = 0.7428$.

Using equation (5), $\omega_{11} = 0.1444$, $\omega_{12} = 0.1619$, $\omega_{13} = 0.1444$, $\omega_{14} = 0.1334$, $\omega_{15} = 0.1444$, $\omega_{16} = 0.1272$, and $\omega_{17} = 0.1444$.

Thus, level indexes can be obtained under the X_1 category weights:

$$
\begin{aligned}
\overline{\omega_1} &= \begin{pmatrix} 0.1444 & 0.1619 & 0.1444 & 0.1334 & 0.1444 & 0.1272 & 0.1444 \end{pmatrix}, \\
\overline{\omega_2} &= \begin{pmatrix} 0.2051 & 0.2457 & 0.3210 & 0.2161 \end{pmatrix}, \\
\overline{\omega_3} &= \begin{pmatrix} 0.1414 & 0.1414 & 0.1414 & 0.999 & 0.1193 & 0.0957 & 0.1193 & 0.1414 \end{pmatrix} \\
\overline{\omega_4} &= \begin{pmatrix} 0.3430 & 0.3285 & 0.3285 \end{pmatrix}, \\
\overline{\omega_5} &= \begin{pmatrix} 0.1201 & 0.1554 & 0.1386 & 0.1866 & 0.1221 & 0.1386 & 0.1386 \end{pmatrix}, \\
\overline{\omega_6} &= \begin{pmatrix} 0.3019 & 0.3019 & 0.1929 & 0.2032 \end{pmatrix}.
\end{aligned}
\tag{14}
$$

6.3. The Measure Calculation of First-Grade Index. Using equation (6), the measurement vector of first-grade index under organization management system of safety risk (X_1) is

$$
\mu_1 = \overline{\omega_1} \times \overline{\mu_1} = \begin{bmatrix} 0.1444 \\ 0.1619 \\ 0.1444 \\ 0.1334 \\ 0.1444 \\ 0.1272 \\ 0.1444 \end{bmatrix}^T \begin{bmatrix} 0 & 0 & 0.2 & 0.8 & 0 \\ 0 & 0.1 & 0.9 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0.3 & 0.7 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0.6 & 0.4 \\ 0 & 0 & 0.8 & 0.2 & 0 \end{bmatrix} = \begin{pmatrix} 0 & 0.0562 & 0.3835 & 0.2785 & 0.2819 \end{pmatrix}.
\tag{15}
$$

Similarly, we know that X_2, X_3, X_4, X_5, X_6 measure vector corresponding to $\mu_2 = \begin{pmatrix} 0 & 0.0410 & 0.1887 & 0.3510 & 0.4076 \end{pmatrix}$, $\mu_3 = \begin{pmatrix} 0.2113 & 0.0874 & 0.1576 & 0.2607 & 0.2828 \end{pmatrix}$, $\mu_4 = \begin{pmatrix} 0 & 0.1971 & 0.2343 & 0.4372 & 0.1314 \end{pmatrix}$, $\mu_5 = \begin{pmatrix} 0.0601 & 0.0878 & 0.1541 & 0.6215 & 0.0766 \end{pmatrix}$, $\mu_6 = \begin{pmatrix} 0 & 0 & 0 & 0.1605 & 0.8394 \end{pmatrix}$.

Thus, the measurement matrix of the first-grade index is

$$
\overline{\mu} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{bmatrix} = \begin{bmatrix} 0 & 0.0562 & 0.3835 & 0.2785 & 0.2819 \\ 0 & 0.0410 & 0.1887 & 0.3510 & 0.4076 \\ 0.2113 & 0.0874 & 0.1576 & 0.2607 & 0.2828 \\ 0 & 0.1971 & 0.2343 & 0.4372 & 0.1314 \\ 0.0601 & 0.0878 & 0.1541 & 0.6215 & 0.0766 \\ 0 & 0 & 0 & 0.1605 & 0.8394 \end{bmatrix}.
\tag{16}
$$

6.4. Determining the Classification Weight of First-Grade Index. The first index judgment matrix is established using Saaty's 1–9 scale, and AHP is applied to calculate the weights as the final results: $\overline{W} = \begin{pmatrix} 0.2668 & 0.1308 & 0.3916 & 0.0661 & 0.0408 & 0.1038 \end{pmatrix}$. According to the weight calculation results, the total order of the evaluation index weight in the criterion layer is as follows: site civilized construction > safety risk organization management system > safety education and training > subcontract management > machinery, equipment, material management > occupational health protection. Therefore, it is necessary to pay more attention to the analysis of the safety factors in the construction process of construction projects and the development of construction safety protection measures.

$$B = w_i^0 \times \overline{u} = \begin{bmatrix} 0.2668 \\ 0.1308 \\ 0.3916 \\ 0.0661 \\ 0.0408 \\ 0.1038 \end{bmatrix} \begin{bmatrix} 0 & 0.0562 & 0.3835 & 0.2785 & 0.2819 \\ 0 & 0.0410 & 0.1887 & 0.3510 & 0.4076 \\ 0.2113 & 0.0874 & 0.1576 & 0.2607 & 0.2828 \\ 0 & 0.1971 & 0.2343 & 0.4372 & 0.1314 \\ 0.0601 & 0.0878 & 0.1541 & 0.6215 & 0.0766 \\ 0 & 0 & 0 & 0.1605 & 0.8394 \end{bmatrix} = \begin{pmatrix} 0.0852 & 0.0712 & 0.2105 & 0.2932 & 0.3382 \end{pmatrix}. \quad (17)$$

Thus, the score is calculated as

$$S = B \times A = \begin{bmatrix} 0.0852 & 0.0712 & 0.2105 & 0.2932 & 0.3382 \end{bmatrix} \times \begin{bmatrix} 1 & 3 & 5 & 7 & 9 \end{bmatrix} = 6.4475. \quad (18)$$

The calculation results show that the overall score of No. A residential building contains 8 projects is 6.4475, and the sustainable evaluation result is good.

6.5. Calculation of Comprehensive Measure Vector. Confidence level recognition is performed using equation (10) and the calculated comprehensive measurement vector. Here, λ is set as 0.6 [42–45].

When $\lambda = 0.6$, $k_0 = \min \sum_{l=1}^{k} \mu_{il} \geq 0.6$, $k = 4$, it shows that the confidence level recognition is good.

The result safety risk evaluation of construction site shows that No. A residential building contains 8 projects is relatively security condition, which is consistent with the objective reality.

In this paper, the unascertained measure theory and AHP are combined to establish a building construction risk assessment model, and a set of scientific and systematic building construction safety risk assessment index systems is established. The reliability of the index weight determined by information entropy calculation is improved, while avoiding the subjective bias. Using this model to evaluate the safety risk of building construction, its principle is clear and simple, and the operability is strong. When dealing with the uncertain influencing factors, the model is more practical and reliable than fuzzy mathematics, the operation is simple, and the loss of information is less. The security risk evaluation of "No. A Residential Building Contains 8 Projects" shows that the evaluation result is basically consistent with the actual situation in the construction, indicating the scientific nature of the model.

7. Conclusions

(1) On the basis of analyzing the characteristics and types of safety risks in construction site, the evaluation index system is established from six aspects: safety risk organization management system, safety education and training, site civilized construction, machinery, equipment, material management, occupational health protection, and subcontract management. The unascertained measure theory is used for comprehensive evaluation, which solves the objective basis of safety risk assessment on construction site, and is beneficial to government supervision departments and enterprise managers to find and solve problems in time.

(2) Using the analytic hierarchy process (AHP), the risk factors were analyzed, as well as the safety of the construction site to build judgment matrix to calculate the weight, after consistency check, it is concluded that the weight of six indicators in the rule layer is as follows: site civilized construction > safety risk organization management system > safety education and training > subcontracting management > machinery, equipment, materials management > occupational health protection.

(3) This paper applies the unascertained measure to comprehensively evaluate the safety risk of the construction project. The overall score of the project is 6.4475, and the evaluation result is good, which is consistent with the actual situation, and the feasibility and effectiveness of the evaluation index system and evaluation model are verified, which provides a reference for safety risk management in the construction stage of construction projects. It has certain practical application value.

(4) Although the safety risk assessment of construction site based on the unascertained measure analytic hierarchy process can improve the efficiency of safety management, it is difficult to identify and manage hazard sources, and the analysis and design of unknown hazard sources require the participation of many people in the enterprise and the project department. In addition, when doing theoretical research and practical application, we can learn from the advanced experience at home and abroad, but we should do a good job in the investigation of the project safety situation and avoid blindly and one-sided compulsory use of the research results.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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