

Retraction

Retracted: Research on Site Safety Management by BIM Technology Based on Fuzzy Intuition Set

Security and Communication Networks

Received 11 July 2023; Accepted 11 July 2023; Published 12 July 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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] P. Liu, "Research on Site Safety Management by BIM Technology Based on Fuzzy Intuition Set," *Security and Communication Networks*, vol. 2022, Article ID 7289440, 9 pages, 2022.

Research Article

Research on Site Safety Management by BIM Technology Based on Fuzzy Intuition Set

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Received 7 May 2022; Revised 20 June 2022; Accepted 5 July 2022; Published 31 July 2022

Academic Editor: Mukesh Soni

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The application of building information modeling technology on a smart site can take advantage of the coordination, visualization, and simulation capabilities of this technology, allowing the engineering design and construction of the site to be based on a BIM model. In the construction of any engineering project, an accurate BIM model can be created using engineering information and data gathered at an early stage. Even though the “smart site” management system and BIM technology have some positive effect on safety production management, there is still room for improvement. This paper introduces the characteristics of safety and security management through the analysis of BIM big data and then selects evaluation indices. Using administrator experience and fuzzy inference tools, inference rules are then established and inference models are designed. Lastly, example validation and comparative analysis verify the method's rationality and efficacy, providing a basis for the administrator's deployment decision for the safety production command. Experiments show that the method proposed in this paper can be better applied to site safety management.

1. Introduction

With the wave of Internet development, construction safety management has also taken flight on the wings of informationization, and the “smart site” management system and BIM technology can assist enterprises in enhancing management means, optimizing management strategies, and enhancing management level, thereby accelerating the production of construction safety [1]. As a transformation and upgrade of traditional safety management, the smart site utilizes various advanced information management technologies, such as the Internet of Things, the Internet, and BIM, to collect, analyze, and process data and information at the construction site in order to achieve collaborative and efficient management of the work site [2]. However, in the process of applying information technology in the construction industry, the majority of businesses are still in the preliminary exploration and practice phase, and many smart sites apply information management, but the application of information technology equipment is still singular and unsystematic, and the majority of businesses do not make full use of information resources [3].

This paper introduces the concept of essential safety in the field of smart site, defines the definition of essential safety management of smart site, establishes the theoretical structure model and application architecture of essential safety management of smart site, and constructs the essential safety management system of smart site, which includes “human, material, environment, and management,” as well as other safety production elements, and provides theoretical guidance for future researchers. It provides theoretical guidance for safety management and references for implementing safety management information systems in construction projects.

In BIM technology, the subjective assignment method, the objective assignment method, and a combination of subjective and objective assignment methods [4] are the primary methods for evaluating the safety level comprehensively. Most existing subjective assignment methods, such as AHP and Delphi, are based on expert experience and are overly subjective, whereas objective assignment methods, such as entropy method and principal component analysis, are based on a large amount of sample data and are

therefore unsuitable for evaluation of objects that lack information.

In this paper, we first adopt an intuitionistic fuzzy language set to characterize the evaluation preferences of experts, which helps to compensate for the difficulty of obtaining information about evaluation objects and the lack of precise sample data. Considering that the interrelationship between evaluation indexes also affects the final evaluation results, the power average operator [5] is introduced and extended to the intuitionistic fuzzy linguistic set. This operator can not only objectively reflect the interrelationship among the assembled data, but also reduce the subjective preference error of experts' linguistic evaluation. To make the dynamic evaluation more comprehensive, the evaluation base value growth and growth trend are measured and modified by defining the stratified incentive factor by global information, and the growth factor by stage information, and a dynamic evaluation model is constructed based on the evaluation base value, change state, and development trend three-dimensional evaluation index. Through quantitative analysis of evaluation indices, it objectively evaluates the intrinsic safety status of the smart site, clarifies the deficiencies in the construction process of the smart site intrinsic safety management, assists managers in formulating specific improvement measures, and achieves the continuous optimization and improvement of the intrinsic safety management level.

2. Related Work

2.1. BIM Technology. The initial concept of BIM was proposed by the "father of BIM" Eastman in the 1970s, and then Autodesk proposed the concept of "Building Information Model" to the International Institute of Architects (IIA) for the construction industry [6]. "In 2006, the United States developed a national BIM standard, which clearly defined the deeper meaning and practical content of BIM technology. With the continuous development of the world's construction industry, BIM has become an important tool in the field of construction engineering to provide bidding support, guide on-site construction, and list out drawings and other whole process services. BIM is based on 3D modeling and gradually developed into BIM-nD model carrying schedule and cost information, which has become an important carrier containing multidimensional engineering information of construction projects and can meet the whole process cycle of the project. It is a comprehensive platform for extracting, updating, and modifying information among different professions, as shown in Figure 1, which summarizes the functions of each stage of the project [7].

Models in BIM-3D are displayed as follows: The introduction of BIM technology has become a "milestone" in the evolution of the construction industry. First, it converts the traditional 2D perspective of the construction industry into a 3D perspective, allowing for the visualization of the completed building's effect. Second, it can process and update the project's component properties in real time to ensure the accuracy of the construction information.

Thirdly, it can provide real-time data reporting information. Fourthly, it is able to efficiently generate drawings of the required building perspectives and issue lists based on construction specifications. Fifth, it is organically compatible with other collaborative software, allowing for secondary development [8]. Sixth, the technology can be coupled organically with construction project enabling safety information visualization management and risk warning.

2.2. Security Management. Mike Steven's team creates large building BIM models using Bentley software and expands the Bentley sample library to lay the groundwork for later modeling by people in related fields. The extensive sample library reduces much workload and demonstrates the necessity and inevitability of sample library development.

The research team of Zhanglu Tan and others classified the smart mine information system according to the service oriented objects into three categories based on the overall mine architecture and the application layer: engineering digitalization system, comprehensive automation information system, and management information system [9]. This intelligent information system combines mine safety and other information standards with the operation and maintenance management platform, based on personnel, equipment, and environment, and realizes real-time monitoring and reporting of parameters for mine staff, personnel location sharing, and determination of basic parameters for staff in the work area, thereby producing a comprehensive application result of safety information visualization utilizing current generation technology.

The team of Yang [10] proposed a semantic Focus + Context human-computer interaction technology for information visualization and built a dynamic visualization instance based on the semantic focus of the topic with nested fisheye views in conjunction with the safety human-computer theory. The application example demonstrated that the proposed technology can effectively support the user in the information visualization interface for intelligent visualization.

Wang et al. [11] constructed a "smart construction site" by leveraging the advantages of 5G network and the flexible computing and storage capabilities of MEC edge cloud to ingeniously combine advanced technologies such as AI video analysis, IoT, edge computing, and construction site safety production management, aiming for construction. It is a comprehensive solution to the most difficult safety management problems, such as real-time monitoring of safety production risks and scientific decision-making, by implementing all-round monitoring from the three dimensions of managing people and things and by comprehensively and effectively resolving the common problems and confusions in safety production.

A Hammad team [12] investigated the use of advanced agent technology and multiagent systems, real-time simulation, and automated machine control in the "smart construction" process, which combines 3D design models (e.g., highway models) with the management and operation

Planning Stage	Design Phase	Construction Phase	Operation and maintenance phase
Visual analysis of building safety information			
Building BIM models for buildings			
Construction planning, scheme design, site planning, comprehensive factor analysis			
	Safety information visualization		
	Visualization platform field application		
		Identify target equipment and key components	
			System operation management
			System maintenance management
Testing in extreme conditions			

FIGURE 1: Stage function summary of BIM safety information visualization.

processes of large-scale construction to enhance the productivity and safety of large-scale construction projects.

The team of Liu et al. [13] has used the interisland project of the Hong Kong-Zhuhai-Macao Bridge as an example to realize collaborative work and information sharing by constructing a “smart site” that integrates various computer technologies, such as BIM, big data, and cloud computing, into the construction process and alters the behavior and management mode of the construction site.

2.3. Basic Definitions and Theorems of Fuzzy Intuition

Definition 1. Let U be a theoretical domain and call the mapping [14].

$$\begin{aligned} \mu_A: U &\longrightarrow [0, 1], \\ x &\longrightarrow \mu_A(x) \in [0, 1]. \end{aligned} \quad (1)$$

A fuzzy set A on U is determined, the mapping μ_A is called the affiliation function of A , and $\mu_A(x)$ is called the degree of affiliation of x to A .

Definition 2. For a given nonempty theoretical domain X , define an intuitionistic fuzzy set on the theoretical domain X as

$$A = \{ \langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X \}, \quad (2)$$

where $\mu_A(x)$ and $\nu_A(x)$ denote the fuzzy subordination and nonsubordination of x to the set A , respectively, and $\mu_A(x)$ and $\nu_A(x)$ satisfy the relation $0 < \mu_A(x) + \nu_A(x) < 1$ for $x \in X$. For each intuitionistic fuzzy subset in the given

theoretical domain, $\pi_A = 1 - \mu_A(x) - \nu_A(x)$ is said to be the hesitancy of x to the fuzzy set A , sometimes also called x subordination to A the intuitionistic fuzzy index. Clearly there is $x \in X$ when $0 < \pi_A(x) < 1$. When $\pi_A = 0$, the intuitionistic fuzzy set becomes a conventional fuzzy set.

Definition 3. Let $A = \{ \langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X \}$ and $B = \{ \langle x, \mu_B(x), \nu_B(x) \rangle \mid x \in X \}$ be two intuitionistic fuzzy sets on a given domain X . Then define the basic operations of A and B as

$$\begin{aligned} (1) \quad A + B &= \{ \langle x, \mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x), \nu_A(x)\nu_B(x) \rangle \mid x \in X \} \\ (2) \quad \lambda A &= \{ \langle x, 1 - (1 - \mu_A(x))^\lambda, (\nu_A(x))^\lambda \rangle \mid x \in X, \lambda \in R^+ \} \end{aligned}$$

Definition 4. Let $A = \{ \langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in X \}$ and $B = \{ \langle x, \mu_B(x), \nu_B(x) \rangle \mid x \in X \}$ be two intuitionistic fuzzy sets on a given domain X . $\pi_A = 1 - \mu_A(x) - \nu_A(x)$ and $\pi_B = 1 - \mu_B(x) - \nu_B(x)$ are the intuitionistic fuzzy indices of the fuzzy intuitionistic sets A and B , respectively. Then the distances of A and B are defined as

$$D(A, B) = \frac{1}{2} (|\mu_A(x) - \mu_B(x)| + |\nu_A(x) - \nu_B(x)| + |\pi_A - \pi_B|). \quad (3)$$

It is easy to prove that the following properties exist for the distances of the above direct fuzzy sets.

$$\begin{aligned} (1) \quad D(A, B) &> 0 \\ (2) \quad D(A, B) &= D(B, A) \end{aligned}$$

- (3) $D(A, A) = 0, D(A, B) = 0$, when and only when $A = B$
- (4) $D(A, C) \leq D(A, B) + D(B, C)$, where A, B , and C are fuzzy intuitionistic sets
- (5) Let X be a nonempty set on a given domain and A, B , and C be fuzzy intuitionistic sets, B is closer to A than C when and only when $D(A, B) \leq D(A, C)$

3. Method

3.1. Safety Management Evaluation Indexes. In this paper, through the problems reflected in the safety management of the actual site, combined with the actual needs of safety management, using statistical questionnaires as show in Figure 2 it is finally selected as the final set of safety management performance evaluation indicators [15].

3.2. Determination of Evaluation Index Weights. The Analytic Hierarchy Process (AHP) [16], which combines qualitative and quantitative methods, can be used to determine the weights of enterprise safety management performance evaluation indicators, taking into account the uncertainties in the process of determining the weights of safety management evaluation indicators and making full use of experts' personal experience. Using the AHP method to determine the weights of safety management performance evaluation indicators is primarily based on the experts' personal knowledge and experience to make a two-by-two comparison of the importance between the indicators affecting safety management performance, and according to the importance between the indicators by using the values shown in Table 1 to reflect the importance between the indicators in order to construct a mutual inverse judgment matrix.

In the process of determining the weights of safety management performance evaluation indexes using the AHP method, the main thing is to determine the mutual inverse judgment matrix $R = (r_{ji})$ with satisfactory consistency. After constructing the mutual inverse judgment matrix, the consistency of the judgment matrix needs to be verified, mainly by calculating the maximum eigenvalue λ_{\max} of the mutual inverse judgment matrix $R = (r_{ji})$ and the eigenvector $V = [v_1, \dots, v_n]^T$ corresponding to the maximum eigenvalue, and calculating the random consistency index $CI = (\lambda_{\max} - n)/(n - 1)$ based on the maximum eigenvalue. Combined with the average random consistency index RI given in Table 2, the index $CR = CI/RI$ can be calculated to verify whether the mutual inverse judgment matrix satisfies consistency, and if $CR \leq 0.1$, only then the constructed mutual inverse judgment matrix satisfies satisfactory consistency and can be used to determine the weights of the safety management performance evaluation index.

The AHP method is used to compare the importance of safety management performance evaluation indicators between two, and finally the eigenvalue method is used to obtain the weight vector of each indicator affecting the safety management performance evaluation.

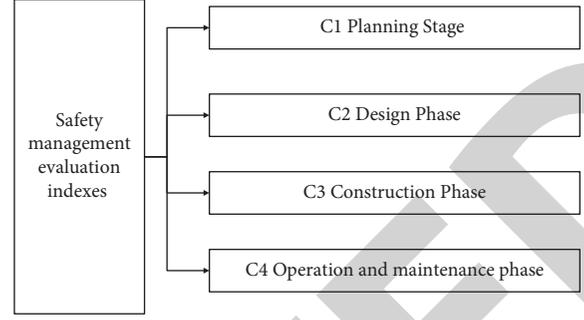


FIGURE 2: Safety management evaluation indexes.

$$W = (w_1, \dots, w_5). \quad (4)$$

3.3. Safety Management Performance Evaluation Method Based on the Ideal Solution Method. We let the selected personnel engaged in safety management-related personnel jointly constitute the evaluation expert group, and each expert, by examining the safety and evaluation methods of the subordinate enterprises, finally uses the intuitionistic fuzzy set to give the evaluation results, and let the intuitionistic fuzzy evaluation results of the group experts under the j evaluation index of the i subordinate enterprise be $x_{ji} = (p_{ji}, q_{ji})$, then we finally get the n safety management performance evaluation results of the enterprises, which are shown in Table 3.

Considering the importance of each indicator, the indicator weighting is applied to the intuitionistic fuzzy set to obtain the weighted evaluation information, which is shown in Table 4.

$y_{i,j} = w_i x_{ij} = (u_{ij}, v_{ij})$ denotes the indicator-weighted value of the intuitionistic fuzzy evaluation value under the j indicator of i subordinate enterprise.

Based on the indicator-weighted evaluation value, the positive ideal state and negative ideal state of the comprehensive evaluation value are selected, where the intuitionistic fuzzy positive ideal state is

$$z_i^+ = (\delta_i^+, \eta_i^+) = \begin{cases} \delta_i^+ = \max_{k=1,2,\dots,n} u_{ki} \\ \eta_i^+ = \min_{k=1,2,\dots,n} v_{ki} \end{cases}, \quad i = 1, 2, \dots, 4. \quad (5)$$

The intuitionistic fuzzy negative ideal state is

$$z_i^- = (\delta_i^-, \eta_i^-) = \begin{cases} \delta_i^- = \min_{k=1,2,\dots,n} u_{ki} \\ \eta_i^- = \max_{k=1,2,\dots,n} v_{ki} \end{cases}, \quad i = 1, 2, \dots, 4. \quad (6)$$

Based on the distance between the intuitionistic fuzzy numbers, the distance between the weighted vector of safety management performance indicators of each subordinate secondary enterprise and the positive ideal state is calculated in turn, where the distance between the safety management performance evaluation value of the i th subordinate enterprise and the positive ideal state is

TABLE 1: Scaling of AHP construction of mutual inverse judgment matrix.

Scale	Mean
1	Indicator A is equally important as indicator B
3	Indicator A is more important than indicator B
5	Indicates that indicator A is strongly more important than indicator B
7	Indicates that indicator A is very much more important than indicator B
9	Indicates that indicator A is extremely more important than indicator B
2, 4, 6, 8	Intermediate value

The reciprocal of each number in the above column is compared, i.e., indicator i is compared with indicator j to obtain the judgment b_{ji} , and then $r_{ji} = 1/r_{ij}$.

TABLE 2: Average random consistency index.

Matrix order	0	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.21	1.26	1.32	1.38	1.41

TABLE 3: Site safety management performance evaluation information.

Site/indicators	C_1	C_2	C_3	C_4
A_1	X_{11}	X_{21}	X_{31}	X_{41}
A_2	X_{12}	X_{22}	X_{32}	X_{42}
...
A_n	X_{1n}	X_{2n}	X_{3n}	X_{4n}

TABLE 4: Weighted evaluation information of safety management performance indicators.

Site/indicators	C_1	C_2	C_3	C_4
A_1	Y_{11}	Y_{21}	Y_{31}	Y_{41}
A_2	Y_{12}	Y_{22}	Y_{32}	Y_{42}
...
A_n	Y_{1n}	Y_{2n}	Y_{3n}	Y_{4n}

$$S(A_i, Z^+) = \frac{1}{4} \sum_{i=1}^4 D(A_{ij}, z_j^+). \quad (7)$$

Similarly, the distance between the safety management performance evaluation value of the i th subordinate enterprise and the negative ideal state is calculated as

$$S(A_i, Z^-) = \frac{1}{4} \sum_{i=1}^4 D(A_{ij}, z_j^-). \quad (8)$$

Then the closeness of the final subordinate secondary enterprises' safety management performance evaluation values to each ideal state is

$$\sigma_i = \frac{S(A_i, Z^-)}{S(A_i, Z^-) + S(A_i, Z^+)}. \quad (9)$$

In the process of safety management performance evaluation, it is generally hoped that the closer the safety management performance evaluation value is to the positive ideal state, the better, while the closer it is to the negative ideal state, the better. Therefore, the principle in achieving

the merit of safety management performance evaluation is: the greater the closeness index, the better the safety management performance evaluation result of the corresponding enterprise [17].

4. Experimental Results and Analysis

4.1. Technical Comparison of Safety Monitoring Function in Smart Site. BIM fusion information technology can provide scientific and reasonable solutions for real-time control, data management, and auxiliary decision-making in construction, and provide a decision basis for all participants. However, the construction characteristics of specific projects vary, and BIM fusion with different information technologies can achieve a variety of functions, as well as varying degrees of efficiency and effectiveness in resolving identical construction problems. The issues to be considered are whether "BIM+" technology is required and what type of technology is required to achieve what function in order to solve the problems encountered during the actual project construction process. On the basis of existing research and engineering application examples, we analyze the current state of research and application of BIM integration information technology, and Table 5 summarizes the functions of BIM integration with various information technologies.

4.2. Safety Visualization System. The safety information visualization system based on BIM technology is able to monitor the safety equipment in the smart safety site in real time, upload the parameters and indicators of the monitoring items of the smart safety site to the cloud safety platform, and implement the operations of detector data integration of monitoring equipment, data comparison and analysis, early warning under hazardous conditions, monitoring equipment scheduling, and automatic generation of a combustible gas report.

As depicted in Figure 3, intelligent safety site safety management personnel can view equipment and critical component information in real time, allowing for the timely discovery of equipment operation safety hazards and the dispatch of relevant technical personnel to the designated location for instrument maintenance operations to prevent safety events, thereby protecting the site staff's personal safety and property.

4.3. Statistics of High Accident Types. Through the statistics of accident types in 2017–2021, it can be seen that fall from height is the accident type with the highest accident

TABLE 5: Comparison of functions achieved by BIM integrating different information technologies.

Type of information technology	Main functions of information technology	Integration of BIM in engineering projects
UAV, GIS, BeiDou, remote sensing, and UWB	Two-dimensional electronic maps, three-dimensional topography, satellite positioning	Construction materials, construction surveys, equipment management, and personnel management
Big data, cloud technology, and blockchain	Storage, calculation, management, and mining, etc., of massive data	Construction quality, safety, and business management
Bionic intelligence algorithms, machine learning, and expert knowledge base	Prediction, image recognition, event decision-making, and multiobjective optimization	Construction progress, resources, and safety management
Internet of Things (RFID, QR codes, sensors, etc.), internet	Instant communication, sensing, remote management, and control	Construction quality, progress, safety, material, and business management
Integrated applications	Sensing, analysis, decision-making, and execution	Intelligent construction site, intelligent construction management platform (human, machine, material, law, and environment)

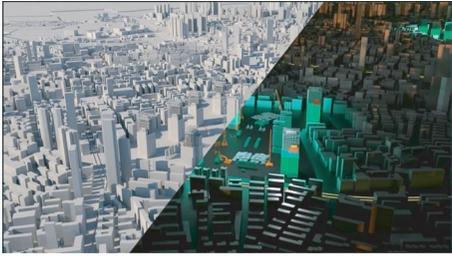


FIGURE 3: Immersive visualization of the site.

probability, occupying about 56% of the total number of accidents each year. Falls from height, collapses, object strikes and lifting injuries are the main accident types, occupying more than 80% of the total number of accidents, while other accident types including vehicle injuries and mechanical injuries occupy about 10% in total, and the ranking and distribution of the percentages do not change much each year [18], as shown in Table 6 and Figure 4.

4.4. Empirical Analysis of Safety Management Performance Evaluation. We chose a large publicly traded company in order to evaluate the safety management performance of subordinate sub-sites, hired experts to evaluate the safety management performance of four subordinate sites based on the uncertainty and fuzziness in the process of safety management performance evaluation, using intuitionistic fuzzy set for evaluation, evaluation results using a group of experts respectively based on their own experience to give evaluation values, and analyzed the results. As depicted in Table 7, the group's final evaluation of the performance of safety management is obtained.

A two-by-two comparison of the importance of the safety management performance evaluation indicators using hierarchical analysis was performed, and the reciprocal inverse judgment matrix was obtained as

$$R = \begin{bmatrix} 1 & 3 & 2 & 7 & 9 \\ 1/3 & 1 & 1/3 & 2 & 6 \\ 1/2 & 3 & 1 & 3 & 5 \\ 1/7 & 1/2 & 1/3 & 1 & 2 \\ 1/9 & 1/6 & 1/5 & 1/2 & 1 \end{bmatrix}. \quad (10)$$

The importance of the safety management performance evaluation indexes is compared between two using hierarchical analysis, and the mutual inverse judgment matrix is obtained as.

The maximum eigenvalue of the mutual inverse judgment matrix is calculated as $\lambda_{\max} = 5.1453$, and the consistency index is calculated as $CR = 0.0300 < 0.1$, so it satisfies the satisfactory consistency requirement, and it is feasible to determine the weights of the safety management performance evaluation indexes using this mutual inverse judgment matrix, then the weight vector of the safety management performance evaluation indexes finally obtained is

$$W = (0.4586 \ 0.1541 \ 0.2708 \ 0.0758 \ 0.0407). \quad (11)$$

The indicator weighting of the safety management performance evaluation information is obtained as shown in Table 8.

Then the corresponding positive and negative ideal states are

$$\begin{aligned} Z^+ &= \{(0.7125, 0.1336), (0.1963, 0.6487), (0.2822, 0.6616), (0.1232, 0.8452), (0.0744, 0.8970)\}, \\ Z^- &= \{(0.2308, 0.3856), (0.0739, 0.8514), (0.1419, 0.7911), (0.0438, 0.9421), (0.0154, 0.9572)\}. \end{aligned} \quad (12)$$

TABLE 6: 2017–2021 main types of construction safety accidents distribution table.

Accident type	2017 NUM	2018 NUM	2019 NUM	2020 NUM	2021 NUM	Total	Percentage
Fall from height	235	333	331	383	415	1697	51.8
Collapse	59	67	81	54	69	330	10.1
Object strikes	66	97	82	112	123	480	14.7
Injuries from crane machinery	32	56	72	55	42	257	7.8
Other	50	81	126	130	124	511	15.6
Total	442	634	692	734	773	3275	100

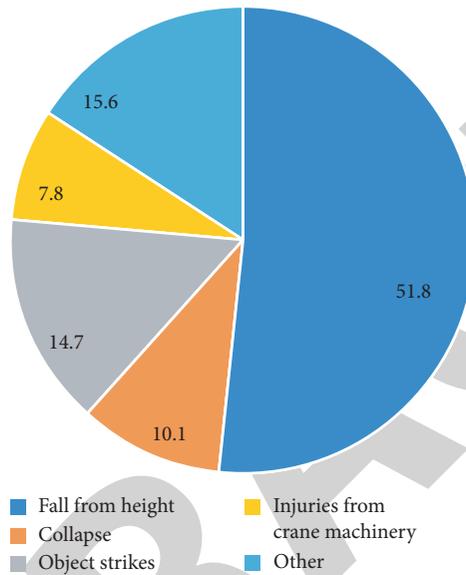


FIGURE 4: Site accident type statistics.

TABLE 7: Four site safety management performance evaluation information.

Site/indicators	C ₁	C ₂	C ₃	C ₄
A ₁	(0.6557, 0.0945)	(0.4357, 0.0745)	(0.8491, 0.1252)	(0.9340, 0.0124)
A ₂	(0.6787, 0.0603)	(0.7577, 0.2033)	(0.7431, 0.2228)	(0.3922, 0.3520)
A ₃	(0.6555, 0.4210)	(0.5712, 0.2175)	(0.7060, 0.2611)	(0.4318, 0.2278)
A ₄	(0.6769, 0.3821)	(0.4462, 0.4555)	(0.4971, 0.3403)	(0.8235, 0.1087)

TABLE 8: Weighted evaluation information of indicators for safety management performance at four sites.

Site/indicators	C ₁	C ₂	C ₃	C ₄
A ₁	(0.3867, 0.3390)	(0.2308, 0.3040)	(0.5799, 0.3856)	(0.7125, 0.1336)
A ₂	(0.1605, 0.6487)	(0.1963, 0.7823)	(0.1890, 0.7934)	(0.0739, 0.8514)
A ₃	(0.2507, 0.7911)	(0.2049, 0.6616)	(0.2822, 0.6951)	(0.1419, 0.6699)
A ₄	(0.0821, 0.9297)	(0.0438, 0.9421)	(0.0508, 0.9215)	(0.1232, 0.8452)

Then the similarity between the evaluated values of safety management performance of each site to be evaluated and the positive and negative ideal states is calculated.

$$\begin{aligned} S(A, Z^+) &= (2.9889 \ 2.8551 \ 3.1511 \ 3.1653), \\ S(A, Z^-) &= (3.2033 \ 3.1532 \ 3.2922 \ 3.2147). \end{aligned} \quad (13)$$

Then the closeness is, as shown in Figure 5.

$$\sigma = (0.5173 \ 0.5248 \ 0.5109 \ 0.5039). \quad (14)$$

By comparing the magnitude of the closeness of the safety management performance evaluation of the four sites according to the principle of merit, the final ranking results of the safety management performance evaluation of the four secondary sites of the publicly traded company are as follows:

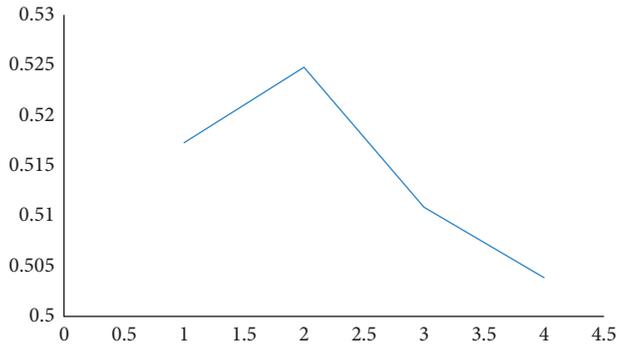


FIGURE 5: Diagram of the closeness of the safety management performance evaluation of the four sites.

$$A_2 > A_1 > A_3 > A_4. \quad (15)$$

Despite the fact that the safety management performance of the four sites varies according to their proximity, a comparison of the closeness's magnitude reveals that the level of safety management performance of the four sites is identical, and the difference between them is insignificant. The method in this paper has a large amount of calculation and is not suitable for large-scale management decision-making problems.

5. Conclusion

With the gradual and widespread application of smart site system in project construction management, as well as the continuous development of BIM technology and intelligent system, future smart site system technology will be more advanced, more functionally applicable, and more intelligently managed. Through the application of a smart site cloud platform, the information data related to project safety management, quality management, and schedule management can accurately and comprehensively demonstrate the management efficiency of a construction site. Using administrator experience and fuzzy inference tools, we establish inference rules and design inference models based on the comprehensive analysis of big data. Lastly, the method's rationality and efficacy are validated through example validation and comparative analysis, providing a basis for the administrator's deployment decision regarding the safety production command. Experiments demonstrate that the method proposed in this paper is applicable to site safety management. In the future, we will devote ourselves to studying large-scale management decision-making problems and propose corresponding rapid management methods.

Data Availability

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

Conflicts of Interest

The author declares that he has no conflicts of interest.

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