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Intelligent System of Internet of Things-Oriented BIM in Project Management

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ABSTRACT

At present, edge computing is more and more widely used in the development process of various industries. With the stable development of social industrial structure, the development scale of enterprises is gradually expanding, the project production cycle is getting longer and longer, and the project information and project elements are also getting more and more. Under the traditional project management mode, the project elements are independent from each other, the participants are difficult to interact, and the information content is relatively dispersed, which has seriously hindered the improvement of the efficiency and level of enterprise project management. The emergence of intelligent the BIM (building information modeling) project management system provides technical support for the realization of the overall project management objectives, but there are still large limitations in actual use, mainly reflected in the poor flexibility of attraction and error prone. In order to solve the dilemma of enterprise project management, based on the analysis of the characteristics of project management and the functional requirements of the system, this article proposes an intelligent system of BIM in project management oriented to the internet of things. In order to verify the effectiveness of the system, this article conducts system tests from the aspects of project management efficiency, system security, and user experience. The results show that the average intelligent system error level of internet of things-oriented BIM in project management is about 0.310. It can be seen from this result that, on the basis of internet of things technology, various project elements and information within the system have achieved effective integration and promoted the deep intelligent development of project management.

KEYWORDS

Building Information Modeling, Intelligent System, Internet of Things, Project Management

INTRODUCTION

With the development of information technology such as edge computing, enterprise project management has also undergone tremendous changes. At present, most enterprises have got rid of the previous single organizational structure and management model and started to develop towards the direction of informatization. In this context, the application value of BIM (Building Information Model) has been fully exploited and played an important role in project management. As a new information management mode, it can effectively improve the traditional enterprise management situation, thereby

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effectively improving the business efficiency and efficiency of enterprises. However, the development environment of various industries is complex and changeable, and the enterprise projects are gradually showing the characteristics of large quantity and wide range. The intelligent project management system based on BIM is difficult to effectively coordinate and interact with each project; it is also difficult to scientifically control the cost, progress, and quality of it, which has a great impact on the subsequent development of the enterprise. With the continuous development of electronic information and media industry, Internet of Things technology has made considerable achievements and progress and has been widely used in various fields, such as in intelligent transportation, medical, agriculture, home furnishing, and other industries. In the intelligent project management system of BIM, Internet of Things technology can conduct macro-control on the project and balance and coordinate the system modules, so that all projects can complete the project objectives under the limitations of resource scope and time scope. It provides effective real-time data management, which is of great significance to the rational and orderly development of enterprise management.

With the complexity of project management, more and more scholars pay attention to the research of intelligent system of BIM in project management. To determine the potential of intelligent project management system based on 5D BIM, Pakhale and Prale (2020) conducted unstructured interviews, discussions, and questionnaires among various stakeholders in its actual work. The final results show that the digital project management system based on 5D BIM integrates all processes and improves the efficiency and effectiveness of project management (Pakhale & Prale, 2020). Kocakaya (2019) proposed a project management system based on BIM and tested it in complex building projects. The results show that the system can use effective resource management methods to plan and manage projects. It improves productivity efficiency and work coordination (Kocakaya, 2019). Ghannadpour (2019) believed that BIM had unique advantages in project management and prioritizes the parameters of the collected results by using the fuzzy hierarchical decision-making method. This showed that the project management intelligent system based on BIM has the ability of conflict detection and plane correction (Ghannadpour, 2019). Liao et al. (2017) proposed an intelligent system for project management to improve the productivity of Singapore's construction projects. He quantified the project through BIM and proved that the proposed system can improve productivity performance through case studies of local residential projects (Liao et al., 2017). The research on intelligent system of BIM in project management makes some achievements in practice, but with the deep development of enterprise management, the operating efficiency of the current system still needs to be constantly improved.

Internet of Things technology can effectively optimize the management process and improve the operating efficiency of the system. Siountri et al. (2020) believed that Internet of Things-oriented BIM can realize end-to-end communication, data exchange, and information sharing among project participants in the intelligent system of project management and bring more intelligent results to the community. She took the actual construction project as an example and tested the system's connectivity and interoperability and proved that the system can achieve security management and operation (Siountri et al., 2020). Ghimire (2017) has established an effective system for project management through the Internet of Things technology and achieved this goal by dynamically establishing situational awareness based on the existing manufacturing process. Finally, he verified the good effect of the system in the actual industrial scenario (Ghimire, 2017). Internet of Things-oriented BIM has high application value in the intelligent system of project management. From the current development, most research only discusses its practical significance from the theoretical level and does not provide more objective data.

This paper makes a deep research on the intelligent system of BIM in project management based on Internet of Things technology and tests its actual use from the aspects of project management efficiency, system security, and user experience. The test results show that in terms of project management efficiency, the average of intelligent system error level of Internet of Things-oriented BIM in project management was about 0.310. The average error level of the traditional system was

about 0.418. In terms of system security, the average security degree of this system under different traffic conditions was 89.29%. The change of traditional system under different traffic was more significant, and the average safety result was about 79.22%. In terms of user experience, the system in this paper scored more than four points in the six categories of test items, while the traditional system scored low in the six categories of test items, with an average user rating of about 3.15 points. From the perspective of data comparison, the IOT-oriented BIM in this paper is more operable in the intelligent system of project management.

INTELLIGENT SYSTEM OF BIM IN PROJECT MANAGEMENT

System Overview and Demand Analysis

Project management refers to the process of planning, layout, adjustment, and control of projects to achieve management objectives in the environment and conditions defined by the enterprise (Lee et al., 2020). From this concept, project management is not the product of enterprise development in the new era. Among them, project refers to the work carried out to achieve a specific purpose under the restriction of specific resources and needs, while management has a clear purpose and standard. It must be realized under limited resources, time, and cost conditions, and the final results generated by management can be expected services or specific products.

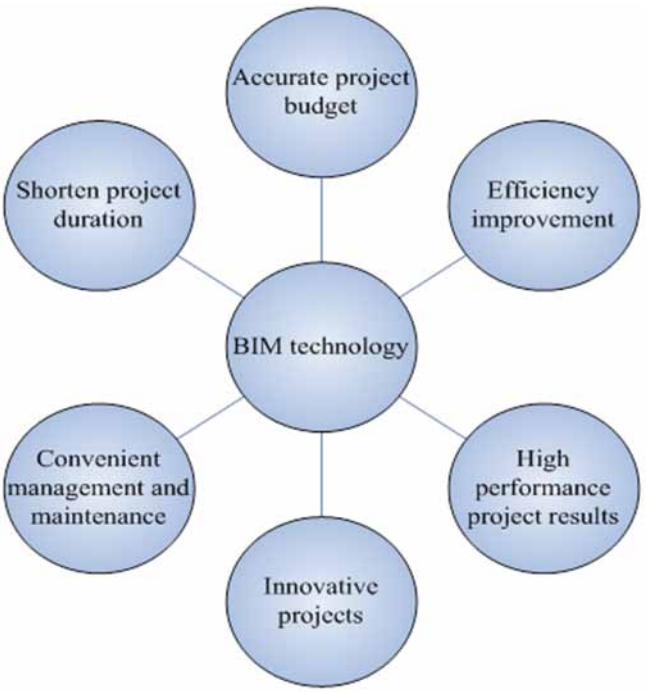
In the actual development, project management has some significant characteristics, which are divided into four aspects in this paper: First, project management is deterministic. It is mainly reflected in the management results. Any project would achieve a specific purpose after completing the overall management process. In the planning process, once the project management objectives are established, they shall not be replaced or changed at will except for major changes in the project management environment. If there are major changes in the internal and external environment of the project. Then, the management objects of the project would be adjusted accordingly and the objectives would change accordingly. Second, project management is unique. Its uniqueness is very different from the manufacturing of products. The same products can be manufactured and processed many times, while the management of large projects basically occurs one time. According to different projects, the management methods and conditions have their own particularity and limitations. Third, it is constrained by resources and time. To achieve the management objectives of each project perfectly, it is necessary to use multiple resources within a limited time. Resources consist of different types, mainly human, material, and financial. All projects should be carried out under the constraints of these resources, and the smooth implementation of the project cannot be separated from the cost of various resources consumed. The fourth is the standardization and normalization of project management. Project management is a very complex technical activity. With the development of society, the demand of enterprises for high-level management has gradually increased, the number of projects has been increasing, and the management difficulty has also been increasing, which requires an intelligent system adapted to the development of the times to solve this problem.

BIM Technology

BIM is a digital representation form of project entity and functional characteristics and is also a specific process of interactive transmission of information resources in the overall process of project management (Olawumi et al., 2017; Pezeshki & Syed, 2018). In the process of project management, all participants can find and correct relevant information through the BIM platform and can cooperate within different permissions. Its main advantages are shown in Figure 1.

The intelligent system of BIM in project management refers to the system for overall planning of projects. It can provide the basis for the formulation of the management plan of each link of the project and is the planning integration of project management (Chan, 2018). To establish this system, it is necessary to integrate relevant information in various fields of project management, including time

Figure 1. BIM technical advantages



constraints of project planning, participants and equipment, subsequent control, and implementation standards. According to the differences in project types and management needs, the management tasks of the system can be divided into scope management, schedule management, and among others. The intelligent management of BIM in project management is a comprehensive plan integrating project types, levels, and management contents.

Compared with the traditional management system, BIM has three significant characteristics in the intelligent system of project management. First, the management object observed by the participants is no longer an independent element but an entity formed by the integration of elements. BIM is an object-oriented technical form that regards the project as a group of entity objects. Second, in addition to the role of visual 3D modeling, BIM also covers the detailed information generated in the management process; for example, detailed data such as the progress of the management process and the expenses incurred in the management process. In addition, the information it contains can also specify the purpose and model of the entity object. If people select specific information as the keyword to search, the information will be automatically displayed in the system interface. Third, it supports open management standards, and BIM facilitates the integration of information of all participants. In the whole life cycle of the project, the information at each stage is diverse, and the managers involved are also complex. With the support of BIM, information can not only be exchanged and shared at various stages and among any subjects, but it can also effectively prevent duplicate records.

However, with the improvement of the complexity of the enterprise management environment, the previous intelligent project management system has become increasingly difficult to adapt to the actual development requirements, which is also a development dilemma in the current project management situation. That is, the traditional project management intelligent system cannot be adjusted and optimized in time according to the development needs, and its flexibility is low, so that the management results gradually deviate from expectations. In the process of consumer use, due to the independence of each participant, it is difficult for the system to effectively organize and

coordinate the implementation of the project, leading to their inability to exchange information and hindering the smooth implementation of the management process. Under the current management mode, the system cannot integrate project progress, cost, quality, and other information. Enterprise project management includes various project management schemes, such as schedule scheme, cost scheme, and quality control scheme. These project management schemes are related to each other to some extent. Once one party changes, it can affect the management schemes of other projects. Therefore, in a system, the balance degree of each project management scheme will directly affect the effect of the whole project. The current intelligent system is difficult to integrate the planning of each project, and it is easy to affect other goals due to excessive pursuit of one goal, thus affecting the overall benefit of the entire project.

Demand Analysis

At present, some representative intelligent project management systems have appeared in the market. Their functional focus is different, and they also have their own advantages and scope of application in practical applications. However, as far as the development trend of project management in most enterprises is concerned, the system needs to provide support for project planning, resource management, and project implementation (dynamic control and adjustment). Project planning is not only the basis of project management, but is also the first link in the project implementation process, including project planning and arrangement, management task definition, and allocation. Resource management mainly includes the creation of resource sets, resource scheduling, and resource use records, among other functions. Project implementation mainly includes project startup, implementation of management tasks, and related information collection and data processing. In this link, the internal and external management environment may change due to the development of the enterprise. At this time, the corresponding management tasks and contents need to be adjusted in a timely manner. In addition, the system also needs to provide different project participants with the monitoring of the project status, so that they can grasp the project progress in time and prepare for the subsequent management.

INTERNET OF THINGS TECHNOLOGY AND SYSTEM IMPLEMENTATION

Internet of Things Technology

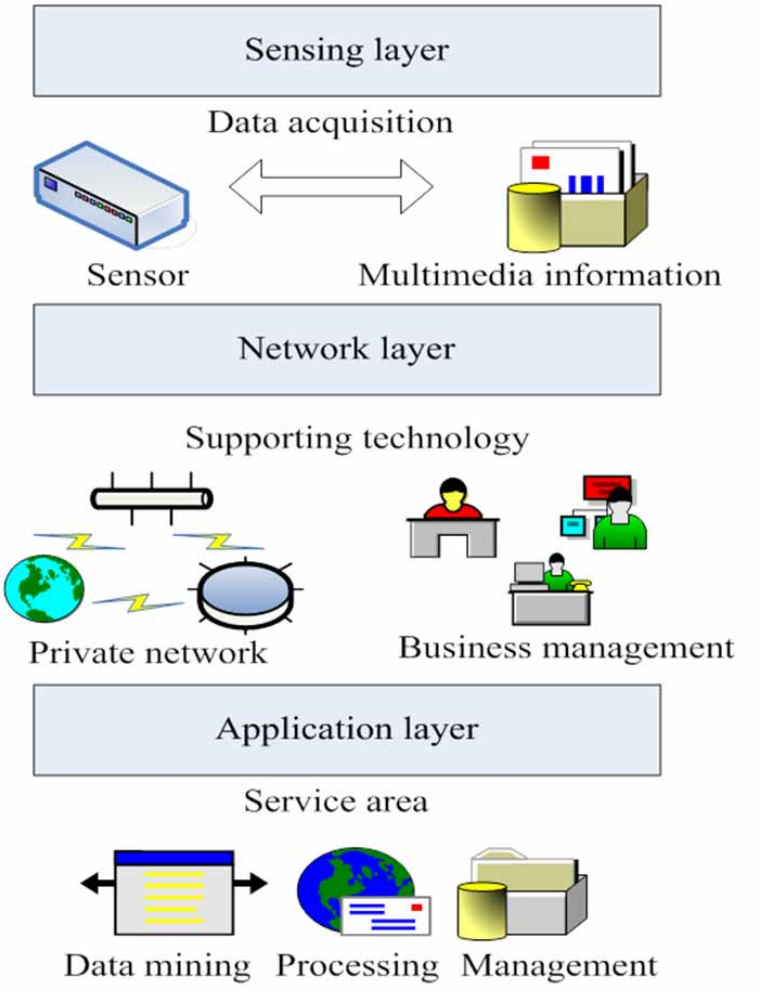
With the development of the times, Internet of Things has become an emerging technology with key influence (Kumar et al., 2019). Generally speaking, Internet of Things refers to a network of objects connected with each other (Dai et al., 2019; Abdel-Basset et al., 2018). Intelligence, interactivity, and innovation are the three main characteristics of the Internet of Things. Its technical framework can be divided into three levels: The first level is the sensor level, which is composed of sensors, multimedia information technology modules such as infinite smart cards, two-dimensional readable bar codes, among other things. Its main function is to identify objects and intelligently collect information. The second level is the network layer, which is mainly used to transmit and calculate the information of the perception layer in a specific area. The third layer is the application layer, which is mainly used to transmit information and data from the network layer to the operating system for processing and to interact with user groups on different clients, as shown in Figure 2. (Ng & Wakenshaw, 2017; Saleem & Chishti, 2019).

System Realization

From the development status and demand analysis of the project management intelligent system, readers can understand that there are still many problems in the construction and application of the current system. In order to effectively solve this dilemma and improve the system operation efficiency, this paper proposes an intelligent system of BIM in project management oriented to the Internet of Things.

In the operation of the intelligent project management system, there are generally large operating errors, which are mainly caused by strong pulse interference and sudden changes in the environment.

Figure 2. Technical Framework of the internet of things



The most prominent feature is that the error level is high and the range is large. Significant errors are irregular and would greatly affect the management efficiency of the system. It is obvious that this paper adopts the criteria often used in Internet of Things technology and Grabbs Criterion to eliminate this error. Assuming that the sampling value of the received signal from a fixed wireless access node collected at a sampling point is $\left(s_1, s_2, \cdots, s_n\right)$, the residual is defined as:

$$e_i = s_i - \overline{s} \tag{1}$$

Among them:

$$\overline{s} = \frac{1}{n}\sum_{i=1}^{n} s_i \tag{2}$$

The root mean square error A is expressed as:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} e_i^2} \tag{3.}$$

In the offline sampling stage, there are many times to sample, so the 3Ã criterion is used to eliminate the gross error. If the residual error is:

$$\left|e_i\right| > 3\sigma \tag{4.}$$

then the sampling value corresponding to $e_i = s_i - \overline{s}$ would be rejected, as s_i has gross error.

In the online positioning stage, the number of samples is relatively small, so Grabbs criterion is used to eliminate gross errors. The sampling value $\left(s_1, s_2, \cdots, s_n\right)$ is arranged into statistics $\left(s_{(1)}, s_{(2)}, \cdots, s_{(n)}\right)$ in ascending order. Assuming the significance is ′ (generally 0.01 or 0.05), the critical coefficient $C_0\left(n, '\right)$ is calculated and derived:

$$C_1 = \frac{\overline{s} - s_{(1)}}{\sigma} \tag{5.}$$

$$C_n = \frac{s_{(n)} - \overline{s}}{\sigma} \tag{6.}$$

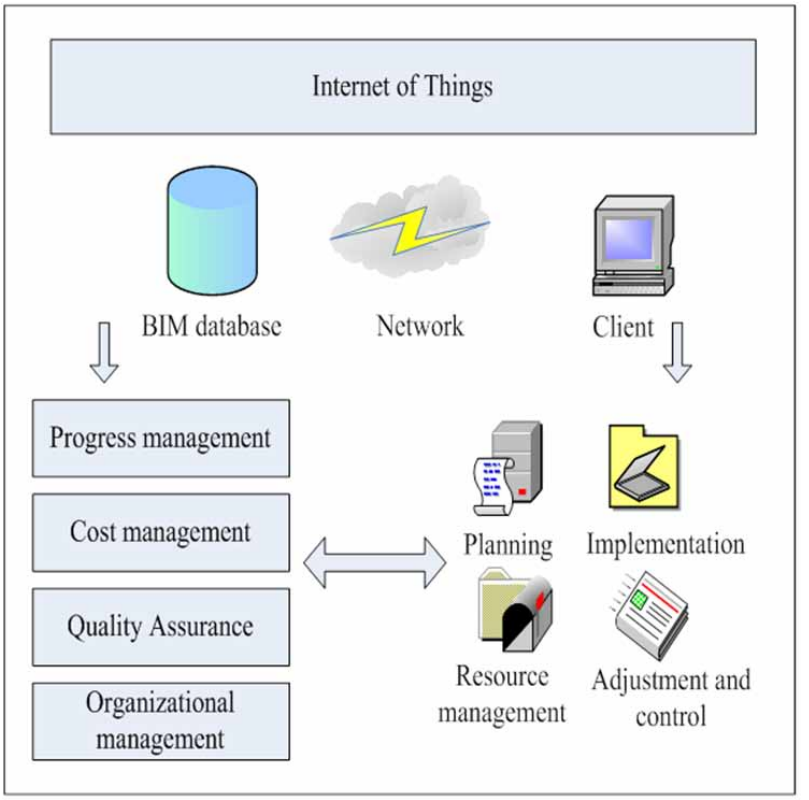
After the processing in the previous step, it can significantly reduce the interference of different errors in the system management process and effectively improve the efficiency of system project management. This paper integrates this algorithm idea into the implementation process of the system and constructs the overall framework of the intelligent project management system, as shown in Figure 3.

From the perspective of the development requirements of the project management intelligent system, in addition to improving its functionality, it is also necessary to improve the scalability and maintainability of the system. Therefore, in the process of system construction, in order to achieve good control and reasonable business logic of the system, this paper uses Dbutils technology and conducts data exchange in JavaScript Object Notation format.

The object of project management is the project elements involved in all aspects of the project from production to completion. In the management process, each element or management content is related to one another, and the change of one element will change the overall management content, which will lead to the failure to achieve the goal smoothly. In this respect, it is very important for the system to integrate the project management. This paper constructs an integrated system of project management from the four aspects of process, cost, quality, and organization for research and uses BIM, Internet of Things, and other information technologies to manage the entire project, as shown in Figure 4.

The management process of the system is mainly divided into three parts, including planning, implementation, and control adjustment. In terms of planning, the system has established a complete resource base based on BIM technology, which is convenient for relevant personnel to quickly determine the resource cost and quantity required for the project. In terms of implementation, it is to use the Internet of Things technical model and various functional modules in BIM integrated management to calculate the specific error between the expected value and the actual value of each management parameter of the project and make real-time and dynamic correction to the specific error so as to restrict the error level within the expected range. The key point of the control and

Figure 3. Overall framework of intelligent project management system



adjustment link is to search for the specific causes of errors and control and improve the factors that cause errors. Through Internet of Things technology, multiple factors in each link of the project can achieve effective information exchange and transmission. This not only enables the user community to better observe the project management dynamics, but it can also promote the enterprise to achieve more ideal integrated management effects.

INTELLIGENT SYSTEM TEST OF PROJECT MANAGEMENT

In order to verify the effectiveness of the Internet of Things-oriented BIM in the intelligent system of project management, this paper tests it from the aspects of project management efficiency, system security, and user experience. In order to intuitively reflect the test results, this paper compares it with the traditional project management intelligent system, and the test environments of the two systems are consistent, as shown in Table 1.

Project Management Efficiency

The project management efficiency test mainly tests the level of sampling error of the system for project management cases. The lower the error level, the higher the efficiency. In order to reduce the test complexity, this paper randomly selects eight samples in the Sakila sample database for testing, and the task amount of different samples is different. According to the order of tasks from small to large, this paper uses numbers to represent them in the test. The error level results of the two systems are shown in Figure 5.

Figure 4. Project management process

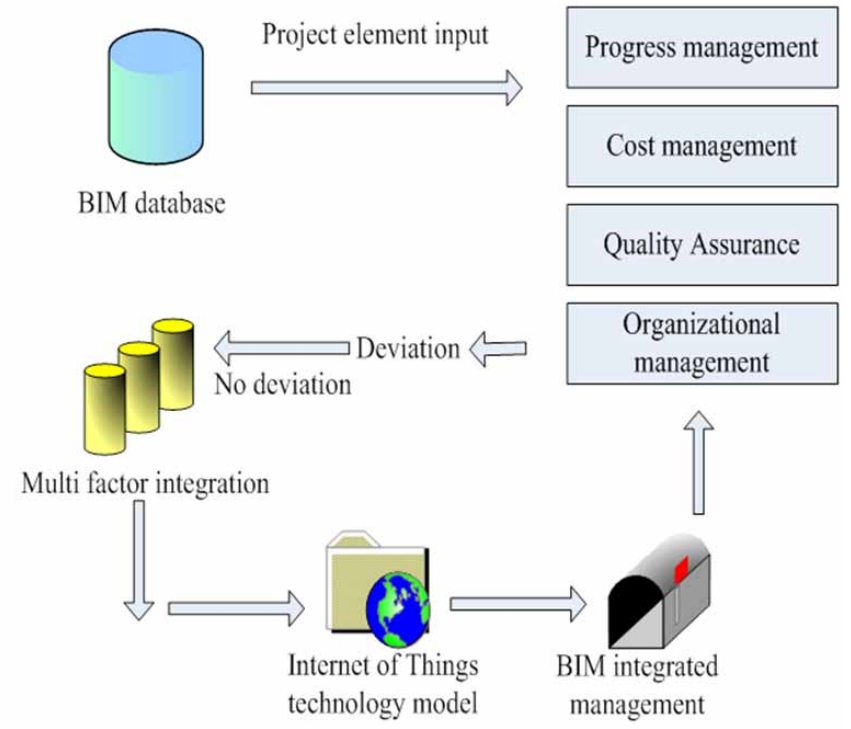


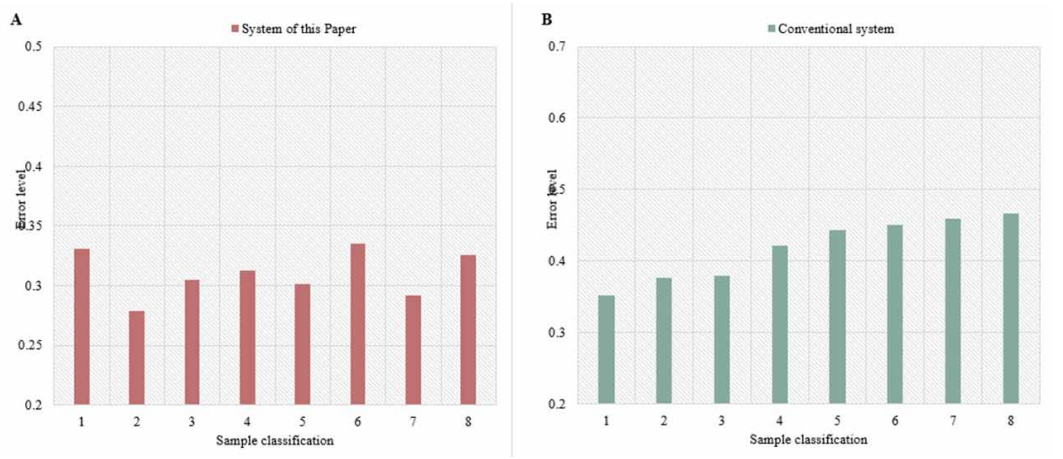
Table 1. System test environment

Scope	Equipment	Specifications
Hardware	Central Processing Unit	Intel core i9 11900 k
	Memory	4G
	Hard Disk	256G
	Network Card	1000M bit/s
Software	Operating System	Windows Server 2016
	The Server	Apache2.4.39
	Sample Database	Sakila

It can be seen from the test data in Figure 5 that the sampling error levels of the two systems under the same example conditions are significantly different. In Figure 5a, the intelligent system of Internet of Things-oriented BIM in project management is less affected by the amount of example tasks, and its error level is generally low and stable, with an average error level of about 0.310. In contrast, the error level of the traditional project management system, demonstrated in in Figure 5b, increases with the increase of the number of tasks, which shows that it is vulnerable to the impact of the number of example tasks. The highest error level is 0.467, and the average is about 0.418. From this data comparison, it can be clearly seen that when the project scale is large and the information resources are abundant, it is difficult to ensure a high operating efficiency in the traditional system, which would be a greater obstacle to the subsequent management level and progress control. The system in this paper, supported

Figure 5. System error level

Note. Figure 5a shows the systematic error level of this paper.
Note. Figure 5b shows the traditional system error level.



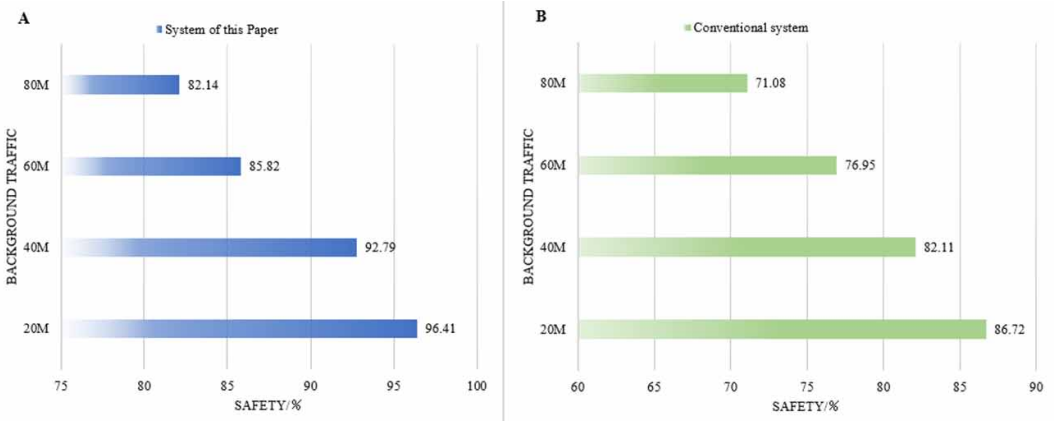
by the Internet of Things technology and BIM integrated management, is not easily affected by the difference in project workload, and it can also ensure high stability and operational efficiency in the case of a large workload, which will achieve orderly management and control.

System Security

In addition to ensuring high management efficiency, the system also needs to ensure the security of various items within the system and user information privacy. In order to verify the system security, this paper tests the system security under different background traffic. The background traffic setting conditions are 20M, 40M, 60M and 80M respectively. The higher the background traffic, the greater the challenge to system security. The security results of the two systems are shown in Figure 6.

Figure 6. System security

Note. Figure 6a shows the system security of this paper.
Note. Figure 6b shows the traditional system security.



In Figure 6, the security of both systems shows a downward trend with the increase of background traffic. In Figure 6a, the system security results under 20M, 40M, 60M, and 80M traffic are 96.41%, 92.79%, 85.82%, and 82.14%, respectively, with an average of 89.29%. From the specific data changes, it can be seen that although the security degree presents a decreasing trend, the security degree is still high, and when the traffic reaches 80M, the security degree is still more than 80%. It can be seen that Internet of Things-oriented BIM has strong reliability in the intelligent system of project management and is not easily affected by the use environment. With the support of Internet of Things technology, its security risks would be greatly reduced, ensuring the security of project information. In Figure 6b, the range of changes of traditional systems under different flows is relatively large. The safety results are 86.72%, 82.11%, 76.95%, and 71.08%, respectively, with an average of 79.22%. When the traffic condition is set to 60M, the security level starts to drop below 80%, which is caused by the fact that the traditional system did not take into account the differences between the use environments of different users when it was established. From this aspect of the test, we can see that the project management security of this system is stronger.

User Experience

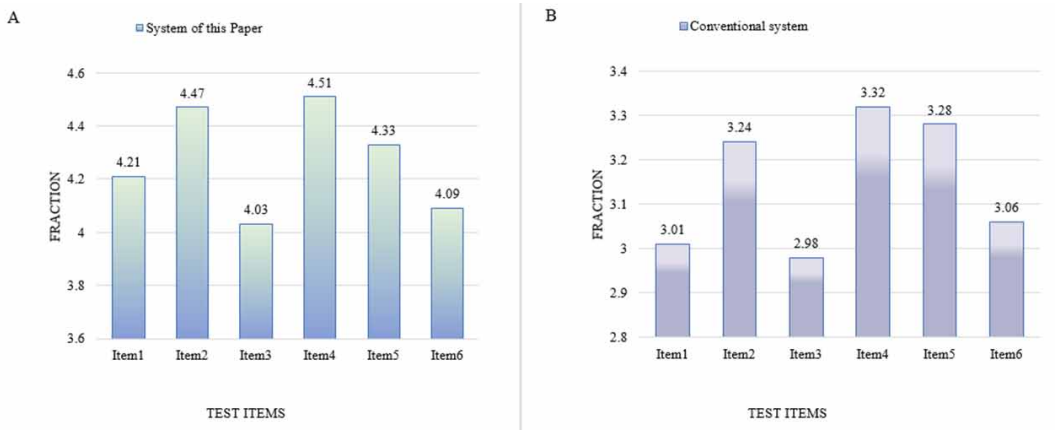
The user experience of this paper mainly focuses on the user's sense of use of the user interface of the two systems. The contents are mainly divided into six types of test items: echo of data items, function play, interface element status, rationality of project layout, logical judgment, and error handling (set as items 1 to 6, respectively). This phase of the test is scored by users and implements a range of 1-5 points; the higher the score, the better the user experience. The evaluation results of the two systems are shown in Figure 7.

From the overall test results in Figure 7, the evaluation scores of this system are generally higher than those of traditional systems. As demonstrated by Figure 7a, the system in this paper scored more than 4 points in six types of test items. Among them, the play of system functions and the rationality of project layout scored higher, reaching 4.47 points and 4.51 points, respectively. In Figure 7b, the scoring results of the traditional system in the six categories of test items are generally low, and the interface element state score is the lowest. The specific result is 2.98 points, and the average user rating of the six types of test items is about 3.15 points, which can be seen from this scoring result. The traditional system still has great limitations in user experience, which not only affects the actual use, but also has a negative impact on the planning and management of the later stage of the project.

Figure 7. User experience of the system

Note. Figure 7a shows the user experience of this system.

Note. Figure 7b shows the user experience of the traditional system.



With the support of Internet of Things technology, BIM's project management intelligent system performs better in terms of functionality and project planning, and the system's data item echo, logical judgment, and error handling are also ideal. This shows that each mechanism of the system operates in a coordinated and orderly manner, which can greatly improve the user's sense of experience and project management effect in actual use.

CONCLUSION

With the development of edge computing, project management is becoming more and more important in the management organization of enterprises. With the fierce development of enterprise competition, the efficiency and effect of project management would directly affect the subsequent survival of enterprises. With the change of market environment and project production cycle, the intelligent system of BIM in project management needs to be improved more and more. In order to improve the efficiency of the system, this paper optimizes the role and effect of BIM in the intelligent system of project management with Internet of Things technology and improves the project management level of the system. At the same time that it ensures the security of the system, it improves the user experience of the system and improves the intelligent system from different angles. However, in the process of research, there are still some areas that need to be improved. Although the system in this paper has an ideal performance in terms of operating efficiency, some functional modules still need to be upgraded. In the future research process, the author will continue to improve the research quality in the main direction of system function improvement to provide more objective guidance for enterprise management.

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THE COMPETING INTERESTS STATEMENT

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