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Relationship between Information Quality, System Quality, Service Quality and Building Information Model（BIM) User Satisfaction in Construction Industry of China

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Abstract

In recent years, more and more Chinese enterprises have adopted BIM technology, which is not only applied to construction projects, but also expanded to highway projects, rail transportation projects, airport projects and so on. In the era of big data, it is also combined with new technologies such as cloud technology, Internet of Things, RFID and other new technologies to broaden the scope of application of BIM technology. Academics and the industry are focusing on the BIM application areas and at the same time are beginning to pay attention to the satisfaction of the users during and after the implementation of BIM. Analyzing clearly what affects BIM user satisfaction and how these causes interact with each other is directly related to the success or failure of BIM technology information system projects and is a more important concern for researchers and corporate executives. This study investigates the factors affecting BIM user satisfaction and the mechanism of inter-factors from the user's point of view, to gain a deeper understanding of the user's thoughts and to improve BIM user satisfaction in order to accelerate the pace of BIM application. A large number of scholars at home and abroad have studied the satisfaction of information system users, and this study focuses on the study of user satisfaction of BIM system in the field of information system. The main research contents are the conceptual model of BIM user satisfaction and the system of observational variables; the influencing factors and the mechanism of BIM user satisfaction. This study is based on the actual situation of BIM and combines the existing research results and related theories to conduct an empirical study.
Keywords: Building Information Modeling (BIM); User satisfaction; Influencing factors; Mechanism of action

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Introduction

Building Information Modeling (BIM) has become an important technology and methodology in the field of construction engineering today. Its ability to digitally represent and manage data has made it useful in all phases of a construction project, including design, construction, facilities management, and project delivery.The application of BIM not only allows for individualization and customization of needs with a customer-centric approach, but also provides numerous advantages in terms of reducing costs, reducing time consumption, improving quality, increasing productivity, and ensuring that projects are delivered on time (Sibenik, G., et al, 2022; Venkrbec, V., et al, 2018). However, despite the great potential of BIM technology, its application still faces challenges and barriers, which may vary somewhat from country to country and region to region.

In New Zealand, a study by Hall et al. (2022) found that small and medium-sized enterprises (SMEs) face a number of barriers to BIM adoption, including interoperability issues between different software platforms, failure of the government to promote the use of BIM at the project level, the cost of expensive software, and lack of demand for BIM in customer requirements. Similarly, in China, Wu et al. (2021) identified finance-related factors and lack of full support from owners as the main factors limiting the adoption of BIM in construction projects. Whereas, in India, Ahuja et al. (2020) examined the factors affecting the adoption of BIM by construction firms, which include hesitation in learning and adapting to the BIM process, lack of a national-level BIM push, varying levels of BIM readiness among project teams, and software sourcing, among other issues. In addition, Hire et al. (2021) highlighted the lack of understanding of the benefits of BIM, hesitation to learn the BIM process, reluctance to change from the traditional BIM approach, and significant barriers to the adoption of site safety that exist in the Indian construction industry.

Although scholars and organizations have begun to focus on the satisfaction of BIM users and their related research on the behavior and effects of BIM adoption, the current research is still in its preliminary stages. Most studies have focused on assessing the relationship between BIM user satisfaction and BIM sustained use behaviors as well as application effectiveness without delving into BIM user satisfaction itself. Therefore, this study aims to build on existing research to further explore the factors associated with BIM user satisfaction in Chinese construction projects. Particular attention will be paid to the relationships between information quality, system quality, and service quality and BIM user satisfaction in order to gain insight into the application of BIM technology in the Chinese construction industry. This research will help to reveal how BIM technology can be maximized to meet client needs, improve project efficiency, and address the challenges faced by the construction industry. In the next sections, we will discuss in detail the impact of information quality, system quality and service quality on BIM user satisfaction, as well as the methodology and framework of this study.

Literature Review and Hypothesis Development

In this section, we provide a comprehensive literature review and develop our hypotheses by grounding them in the DeLone and McLean Information Systems Success Model, hereafter referred to as the D&M model. The D&M model is a widely recognized and influential theoretical framework for assessing the success of information systems. Our study utilizes this model to conceptualize and explain the relationships between BIM User Satisfaction, System Quality, Information Quality, and Service Quality.

DeLone and McLean Information Systems Success Model (D&M Model)

The D&M model, proposed by DeLone and McLean in 1992, offers a structured framework for evaluating information system success based on six key dimensions: System Quality, Information Quality, Service Quality, Use, User Satisfaction, and Net Benefits. The model originally emerged in the context of traditional information systems, but its applicability extends to emerging technologies like Building Information Modeling (BIM) due to its foundational focus on the quality and satisfaction of system users.

System Quality

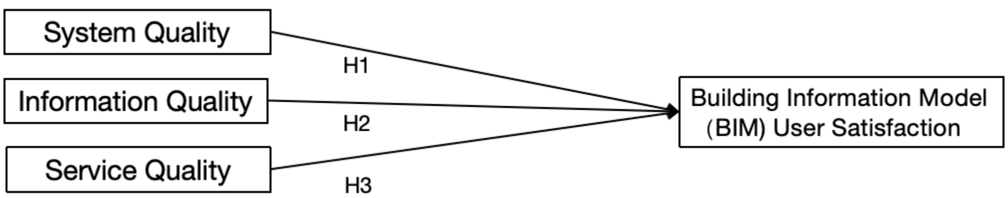
In the context of the D&M model, **System Quality** pertains to the technical aspects of an information system, including its functionality, reliability, and efficiency. Empirical studies, such as Mohammadi (2015) and Liang Wei et al. (2020), have consistently demonstrated the significant impact of System Quality on user satisfaction. System Quality is considered a critical factor in

determining whether users adopt and are satisfied with a particular information system (Wentao Wang et al., 2014).
H1: System Quality positively affects BIM user satisfaction. This hypothesis is grounded in the well-established relationship between System Quality and user satisfaction documented in prior research.

Information Quality
Information Quality, as outlined in the D&M model, signifies the extent to which the information provided by the system is accurate, relevant, and useful to users. Empirical studies, like Xie Peihong et al. (2011) and Wang Wei and Liu Yu (2014), have highlighted the positive influence of Information Quality on user satisfaction in various contexts, underlining its significance in evaluating IT satisfaction.
H2: Information Quality positively affects BIM user satisfaction. This hypothesis aligns with prior research indicating the pivotal role of Information Quality in shaping user satisfaction.

Service Quality
Service Quality, as defined in the D&M model, involves the quality of interactions between users and system support personnel. In the context of BIM, this encompasses the timeliness and competence of support provided to users. Service Quality has been assessed using dimensions such as responsiveness, reliability, competence, and attitude of the system support department (Teo et al., 2008). Ensuring a high level of Service Quality is essential for users to derive benefits from BIM technology.
H3: Service Quality positively affects BIM user satisfaction. This hypothesis draws from the understanding that the quality of support and assistance provided by system personnel can significantly influence user satisfaction, a concept supported by literature such as Lijun Deng and Wenjian Yang (2016).

By grounding our hypotheses in the D&M model, we establish a solid theoretical foundation for examining the relationships between BIM User Satisfaction, System Quality, Information Quality, and Service Quality in the context of the construction industry. The model's applicability to emerging technologies, like BIM, underscores its utility for assessing the success and impact of innovative information systems. This theoretical framework guides our research design and analysis, allowing us to investigate the intricate interplay between these dimensions and their implications for BIM adoption and user satisfaction.



D&M IS Success Theory
Figure 1: Proposed Research Framework

Research Methodology and Data Analysis

Research Methodology
In this paper, literature research method, questionnaire survey method and statistical analysis method are used to carry out the research, as follows:

Literature research method
Collect relevant literature about user satisfaction and its influencing factors, methods of satisfaction measurement, and success model of D&M information system. Understand the current status and

results of research at home and abroad, and provide the theoretical basis for the next step of the research and the method for unfolding the analysis.

Questionnaire Survey Method

On the basis of analyzing the relevant studies in the literature, the questionnaire is obtained by combining the D&M information system success model. The questionnaire is improved after preliminary analysis, and the questionnaire survey is carried out with the research objects of design units, construction units, consulting units and people who use BIM in construction units. After organizing the collected numbers, the data are used in the research of the influence mechanism of BIM user satisfaction.

Statistical analysis method

Statistical analysis method is to statistically and analytically analyze the data and information obtained from the survey with the help of mathematical theories or some analysis software.

The data and information are statistically and analytically analyzed with the help of mathematical theories or some analytical software, so as to achieve a correct understanding of the research object and draw relevant conclusions (Ke Huixin, 1992). In analyzing the data of this study, EXCEL, and SPSS27.0 were used to analyze the sample data back from the research basically, and then the reliability and validity were tested to verify the validity and reliability of the data from the BIM user satisfaction survey. Path analysis was performed with structural equation modeling and with the help of Smartpls 4.0, and then the BIM user satisfaction model was fitted, tested and corrected.

Descriptive Analysis

The target of this questionnaire survey mainly focuses on the practitioners of enterprises in the field of construction engineering, and a total of 384 valid samples were obtained.A total of 384 valid samples were obtained, and the statistical analysis of the basic information of the samples was the preliminary assessment of the samples, mainly from the six aspects of gender, year age, education level, type of participant, position, and BIM experience, and the specific statistical results are shown in Table 1.

Table 1: Demographic Profile of the Respondents

Variable	Category	Frequency	Percentage
Gender	Male	197	51%
	Female	187	49%
Age (years)	25 and below	40	10%
	26-30	193	50%
	31-35	91	24%
	36-40	51	13%
	Over 40	9	2%
Education level	Bachelor’s	211	55%
	Specialist or below	153	40%
	Master’s and above	20	5%
	Others	6	2%
Parties	Designer	111	29%
	Constructor	150	39%
	Owner	45	12%
	Consultant	72	19%

	Others	10	3%
Position	Project/site manager	40	10%
	Professional and technical staff (general staff)	216	56%
	BIM engineer	118	31%
BIM experience (years)	1-2	116	30%
	0–1	156	41%
	2-4	85	22%
	4-8	21	6%
	8 years and above	6	2%

Based on the statistics in Table 1, the following points can be drawn: In terms of gender, the ratio of men to women is relatively close. In terms of age group, the survey included both young practitioners and experienced seniors.

The survey covers both young practitioners and seniors with rich working experience. Among them, the proportion of the sample population aged 26-30 is the highest, at 50%, followed by the sample population aged 31-35, more than one-fifth of the sample population, and the cumulative percentage of the sample population under 35 years old is more than 80%, which shows that the young practitioners are more willing to learn and use BIM technology with computer thresholds.

From the point of view of education, the respondents are the highest percentage of bachelor's degree (55%) education, specialties and below (40%), master's degree and above (5%) accounted for a relatively small proportion of the overall distribution is more reasonable, indicating that with the use of information technology, such as BIM, the architectural and engineering industry on the educational requirements have also increased.

In terms of participant categories, the construction side accounts for the highest percentage at 39%, followed by the design side at 29%. This indicates that the current application of BIM technology is still more in the construction phase.

In terms of positions, this questionnaire divides practitioners into three categories, namely, technology-related technical professionals and BIM engineers, and management-related project/department managers. and BIM engineers, and project/department managers related to management. This is a more comprehensive inclusion of BIM-related technical and management personnel. Among them, the proportion of professional and technical staff (general staff) is the highest, 56%, and the overall distribution is in line with the actual situation.

In terms of the BIM experience of the survey respondents, practitioners with more than 1 year of BIM-related experience accounted for about 60%, which ensures that the respondents understand BIM technology and have enough actual project work experience.

PLS-SEM

We assess and provide the findings of the Partial Least Squares Structural Equation Modeling (PLS-SEM) path analysis in this study using a two-step procedure. This approach follows the suggestion made by Henseler, Ringle, and Sinkovics (2009). There are two primary phases to the process:

Measurement Model Assessment

When assessing a measurement model, ascertain the following: discriminant validity, convergent validity, internal consistency reliability, hair, Hult, Ringle & Sarstedt, 2014; Heenseler Ringle & Sinkovics,2009; Individual item reliability.

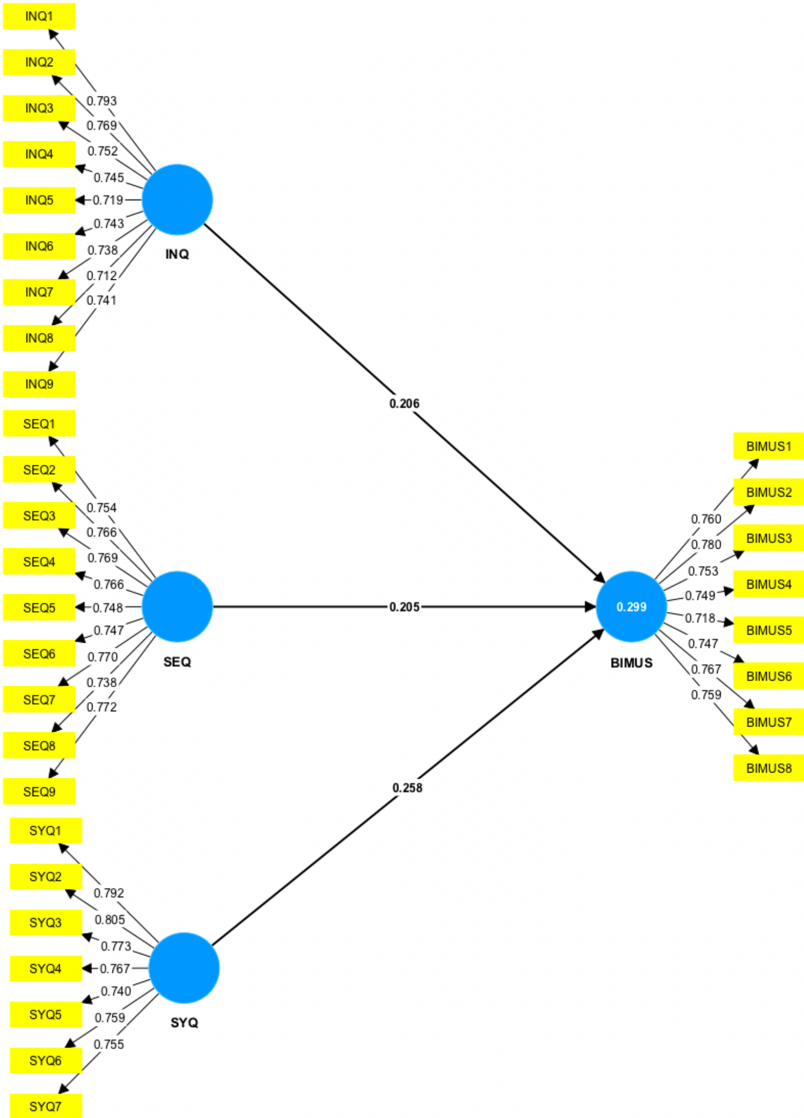


Figure 2: Measurement Model

Indicator Reliability and Multcollinearity

According to Hair et al. (2010), the measurement model is deemed to have dependable indications if the loading estimate for every item is within the range of 0.5 and 0.7.

Construct reliability and validity

Most reliability tests make use of CR and Cronbach Alpha. According to Hair et al. (2011), both reliability indicators are higher than 0.70. Build dependability is seen in Table 2. The agreement between various measurements of the same concept is known as convergent validity. When items converge to evaluate the underlying construct and the AVE value is more than 0.50, convergent validity is demonstrated (Fornell & Larson, 1981).

Table 2: Construct Reliability and Validity Analysis

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BIMUS	0.892	0.893	0.913	0.569
INQ	0.9	0.902	0.919	0.557
SEQ	0.908	0.91	0.924	0.576
SYQ	0.886	0.89	0.911	0.594

Assessment of Discriminant Validity

The degree to which assessments of various ideas are distinct is measured by discriminant validity. Valid evaluations of each notion should not significantly correlate if two or more are unique (Bagozzi et al., 1991, p. 425).

Fornell and Larcker (1981) show discriminant validity when a construct's square root of AVE is higher than its correlation with all other constructs. According to this study, a construct's square root of AVE (bold and italicized) was more strongly correlated with it than with other constructs (Table 3). offering compelling proof of discriminant validity.

Table 3: Discriminant Validity - Fornell and Larcker Criterion

	BIMUS	INQ	SEQ	SYQ
BIMUS	0.754			
INQ	0.451	0.746		
SEQ	0.422	0.5	0.759	
SYQ	0.462	0.549	0.442	0.77

Note: Bold and Italics represent the square-root of AVE

Heterotrait-Monotrait Ratio (HTMT)

HTMT is based on an evaluation of construct correlation. Discriminant validity is determined by the HTMT ratio.Regarding the HTMT threshold, current literature is divided. Kline (2011) proposed a substantial range of 0.85 or less. the accommodating standard proposed by et al. (2008) of 0.90 or less. The HTMT ratio is less than 0.85, as Table 4 demonstrates.

Table 4: Discriminant Validity - HTMT

	BIMUS	INQ	SEQ	SYQ
BIMUS				
INQ	0.499			
SEQ	0.466	0.552		
SYQ	0.513	0.613	0.494	

Structural Model Assessment

The following topics would be covered in a structural model assessment: path coefficients, R-squared values, effect sizes (f square), structural collinearity, and predictive capacity (Q square).

Assessment of the Structural Model for Collinearity Issues

Collinearity is more likely to occur at VIF levels more than five than at VIF values between three and five (Becker, Ringle, Sarstedt, & Volckner, 2015; Mason & Perreault, 1991). Table 5 demonstrates that every VIF value is less than 3. Since the structural model is unlikely to raise significant issues with cross-predictor component collinearity, we can continue analyzing the outcome report.

Table 5: Collinearity statistics(VIF) for Structural Model

	BIMUS	INQ	SEQ	SYQ
BIMUS				
INQ	1.625			
SEQ	1.409			
SYQ	1.513			

Assessment of the Path Coefficient

In accordance with Hair, Hult, Ringle, and Sarstedt's (2017) guidelines, any hypotheses or relationships with p-values greater than 0.05 were disregarded. Three out of the three path coefficients in the structural model had positive and statistically significant connections, as demonstrated by hypothesis testing and direct connection analysis in Table 6. The structural model using T-statistics is displayed in Figure 3.

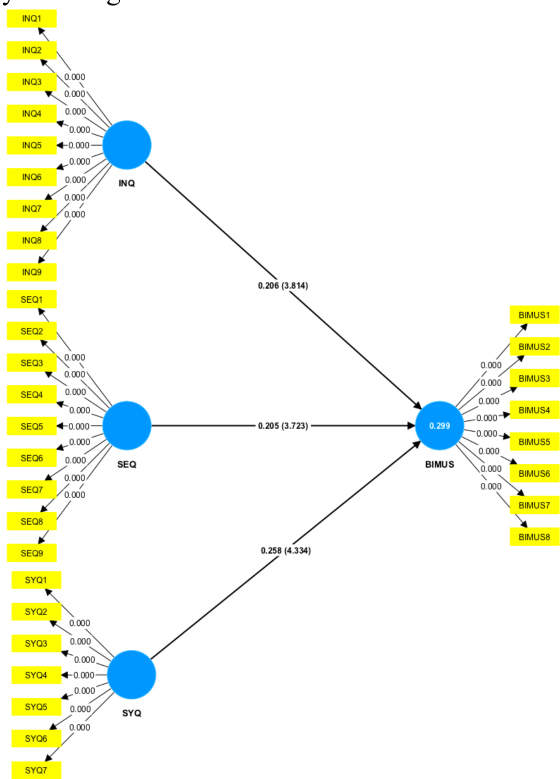


Figure 3: Structural Model with T-statistics

Table 7: Direct Relationships

NO	Hypothesis	Beta Coefficient	STDEV	T values	P values	Result
H1	SYQ -> BIMUS	0.258	0.06	4.334	0.000	Supported
H2	INQ -> BIMUS	0.206	0.054	3.814	0.000	Supported
H3	SEQ -> BIMUS	0.205	0.055	3.723	0.000	Supported

H1 evaluates whether System Quality significantly and positively affects BIM User Satisfaction. The results indicate that System Quality has a significant and positive impact on BIM User Satisfaction (β = 0.258, t = 4.334, p = 0.000). Therefore, H1 is supported.

H2 assesses whether Information Quality significantly and positively influences BIM User Satisfaction. The findings reveal that Information Quality has a significant and positive effect on BIM User Satisfaction (β = 0.206, t = 3.814, p = 0.000). Thus, H2 is supported.

H3 examines whether Service Quality significantly and positively impacts BIM User Satisfaction. The results demonstrate that Service Quality has a significant and positive influence on BIM User Satisfaction (β = 0.205, t = 3.723, p = 0.000). Consequently, H3 is supported.

Assessment of the Level of R Square (R^2)

The squared correlation between an endogenous component's observed and predicted values is represented by R^2. For endogenous latent variables, Cohen (1988) suggested evaluating R2 values as follows: 0.26 (substantial), 0.13 (moderate), and 0.02 (weak). Because a construct's size is influenced by the number of paths leading to it, comparing R2 values across models can be difficult. This problem is addressed by the adjusted R2 value, which considers the sample size and the quantity of exogenous components (Hair Jr. et al., 2016). Table 8 shows that the adjusted R2 values of all endogenous constructs are more than 0.26. This suggests that the model provides a good explanation (Cohen, 1988).

Table 8: R2 and adjusted R2 values

	R-square	R-square adjusted
BIMUS	0.299	0.293

Assessment of the Effect Size ($f2$)

The degree to which the removal of an exogenous construct from the model affects an endogenous construct is quantified by the f^2 impact size. An f2 value that falls between 0.02 and 0.14 indicates a slight effect. A moderate influence is indicated by a value between 0.15 and 0.34, and a large effect is suggested by a value of 0.35 or higher. According to Hair et al. (2016), there is no discernible influence on the endogenous construct when the f2 value is less than 0.02. The f2 effect size in Table 9 indicates that System Quality, Information Quality, and Service Quality have a significant influence on BIM User Satisfaction.

Table 9: f2 Effect Size

	BIMUS	INQ	SEQ	SYQ
BIMUS				
SYQ	0.063			
INQ	0.037			
SEQ	0.043			

Assessment of the Predictive Relevance (Q2)

The model's ability to predict outcomes beyond the sample data used for estimation is indicated by the Q^2 number. The ability of the model to predict an endogenous component is shown by a Q^2 score greater than zero (Hair Jr et al., 2016). As recommended by the literature, an omission distance of 10 was used to evaluate the model's prediction performance. Endogenous construct Q2 values were above 0, indicating predictive relevance, as Table 10 demonstrates.

Table 10: Q2 Values

	Q^2predict(D=10)
BIMUS	0.278

Results and Discussions

Results of statistical analysis based on hypotheses are presented in this chapter. It begins by outlining the variables and participant demographics for the descriptive analysis. Structural equation modeling and the Pearson product-moment correlation coefficient were used to validate the hypotheses. Three hypotheses were supported by the SEM study. BIM User Satisfaction has a positive and significant correlation with System Quality, Information Quality, and Service Quality. Below is a summary of the findings:

Table 11: Summary of results and hypotheses testing

NO	Hypothesis	P values	Results decision
H1	There is a significant and positive relationship between System Quality and BIM User Satisfaction.	Significant	Supported
H2	There is a significant and positive relationship between Information Quality and BIM User Satisfaction.	Significant	Supported
H3	There is a significant and positive relationship between Service Quality and BIM User Satisfaction.	Significant	Supported

Now, let's delve into the comparative discussion of our findings with previous studies. Understanding how our results align with or differ from earlier research is essential for gaining a more comprehensive perspective on the topic.

Comparative Discussion

Our findings indicate a positive and significant relationship between BIM User Satisfaction and each of the three quality dimensions (System Quality, Information Quality, and Service Quality), consistent with prior studies in the field. To establish this consistency, it is essential to acknowledge previous research findings through proper citations and then discuss how our findings align or diverge from them.

For instance, Wu Kunfeng (2023) reported a similar positive relationship between BIM User Satisfaction and the quality dimensions, in a study conducted in China. Our results support and reinforce their findings, demonstrating the universality of these associations. Additionally, Umaapathy and Sundarrajan (2023) found analogous results in their research on the Indian construction industry, further validating the transnational relevance of these relationships.

However, it is valuable to recognize both the similarities and potential differences in the context of our research compared to previous research. While prior studies have also reported positive associations between BIM User Satisfaction and the various quality dimensions, our findings might shed light on certain nuances or variations. Regional variations, industry-specific practices, and technological advancements, which have evolved since the previous studies, may contribute to discrepancies in the strength or specifics of these relationships.

For example, in our Chinese construction industry context, we observed a particularly strong positive relationship between BIM User Satisfaction and System Quality. This could be attributed to the rapid adoption of advanced BIM technology within the Chinese construction sector in recent years, leading to a more pronounced impact on user satisfaction compared to regions with slower BIM integration. While this strengthens the overall consensus about the importance of these quality dimensions, it also highlights the need for future studies to delve into the contextual factors influencing these associations.

In conclusion, our study confirms the positive relationships between BIM User Satisfaction and the quality dimensions of System Quality, Information Quality, and Service Quality, aligning with the findings of Wu Kunfeng (2023) and Umaapathy and Sundarrajan (2023) in different contexts. These findings provide empirical support for the importance of these quality dimensions in enhancing BIM User Satisfaction in the Chinese construction industry. By acknowledging the consistencies and potential differences in our findings compared to previous research, we contribute to a deeper understanding of the complex dynamics between BIM and user satisfaction in construction projects, emphasizing the need for context-specific research in this evolving field.

Conclusion & Future Recommendation

Findings of the study

This paper identifies a conceptual model of BIM user satisfaction based on theoretical and literature research, drawing on the D&M Information Systems Success Model. The four latent variables included in the model are service quality, system quality, information quality and BIM user satisfaction. The main conclusions drawn from this study are as follows.

System quality, information quality and service quality play a direct role in influencing BIM user satisfaction. Through the structural equation modeling analysis method based on questionnaire research and partial least squares, it can be seen that the BIM user satisfaction analysis model proposed in this paper based on the success model of D&M information system for construction projects has a good explanation of BIM user satisfaction ($R2=0.293$). Therefore, it can be shown that factors such as system quality, information quality and service quality are important factors affecting BIM user satisfaction. However, their degree of role and the mechanism and extent of their role are not the same, specifically, in terms of the degree of role, system quality has the greatest degree of influence on BIM user satisfaction, service quality has the second greatest degree of role, and information quality has the least degree of role.

Research limitations

Given the length of the article and the limitations of the author's ability, there are still many shortcomings in this study as well as research points that can be further deepened and expanded.

First, from the point of view of the study, the sample of this study only collected cross-sectional data once, and did not collect sample data several times at different points in time, so as to analyze the influence relationship between model variables longitudinally based on the time dimension. Therefore, subsequent studies can use dynamic tracking surveys to examine the dynamic changes in the role relationships among the factors influencing BIM user satisfaction based on a long period or for different time periods for a group of projects.

Second, in terms of variable definition and scale measurement, to ensure the content validity of variables, this study refers to existing and mature measurement scales and designs each variable scale with the research results of rooted theory. From the results of empirical analysis, the scales of this study have good reliability and validity, but it does not exclude the existence of other measurement methods, which can get the same or even better analysis results.

Future Recommendation

First of all, the sample data is based on the subjective evaluation of the user, which may have some bias. Statistical analysis is based on data with subjective awareness, which affects the accuracy of the final results. This study only examined the effect of factors extracted from D&M model on BIM user satisfaction. However, there may be more factors that can be affected, such as return on investment in the economic dimension, cost of use, and the ability of the individual may affect the user satisfaction of BIM. Therefore, future research could investigate the impact of these additional variables to facilitate a deeper inquiry into BIM user satisfaction. Secondly, this paper only considered the satisfaction of individuals as the object of study, but the satisfaction of enterprises as large users using BIM technology is indeed unknown, therefore, future research could explore BIM satisfaction from an organizational perspective. This study analyzed satisfaction during the period of BIM use, but satisfaction changes over time. Therefore, changes in satisfaction can also be analyzed from the time dimension, such as changes in satisfaction before and after BIM implementation.

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