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Research Article

Evaluating the effective factors of BIM for enhancing the construction interface management

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Abstract: Maintaining the proper interface management among the construction stakeholders is becoming more crucial due to the interconnected nature of construction work. Adopting and implementing building information modelling (BIM) technology can aid in the proper execution of construction projects. Therefore, the main goal of this study is to evaluate the effective factors of BIM using DeLone and McLean's (DM) model. The DM model's factors evaluate the system or technology in terms of system quality, information quality, service quality, and most importantly, the system's net benefits and user satisfaction. The questionnaire was developed with the expert's opinion and the survey was conducted. As mega-projects have more complicated and various levels of information sharing, this study targeted collecting responses from industrial project practitioners in India. From the survey, a total of 166 responses were obtained. Using these data, the frequency test, reliability test, and the relative importance index (RII) were performed. These effective factors of BIM contribute significantly to project performance improvement through proper interface management and communication among stakeholders. The findings of the study emphasized the importance of user satisfaction and the net benefits of BIM. Thus, this study provides further insights to increase the adoption and implementation of BIM technology.

Keywords: Building information modelling (BIM), interface management, BIM adoption and implementation, megaprojects, DeLone and McLean's model.

1. Introduction

Building information modeling (BIM) is a relatively new IT (Information Technology) tool that facilitates collaboration between the construction stakeholders (Zuppa et al., 2009; Vilutiene et al., 2021) and it is an important part of the construction industry's digital transformation (Papadonikolaki, 2018). Because of its benefits at various stages of a building's life cycle, BIM is gaining popularity around the world (Ding et al., 2015; Loyola and López, 2018). BIM spreading its implementation from developed to developing countries (Jin et al., 2017). Moreover, BIM has the potential to be a solution to construction problems, but its implementation is not without risks and difficulties (Ozorhon and Karahan, 2017; Datta et al., 2023). On the other hand, the complicated projects are broken down into interface points that are then managed for accountability, communication, and coordination. Each project participants (i.e., architects, engineers, consultant, contractors, and clients) are accountable for the development of at least one project component or system (Matoseiro Dinis et al., 2024). Since mega-construction projects are inherently complex and large in scope, there is a major requirement for supporting the smooth project management processes (Daniels et al., 2014). Furthermore, poorly managed interfaces result in design flaws, system failures, and other construction problems. Therefore, Interface management (IM) has evolved into the most critical component of an effective project management approach.

The widespread adoption of BIM technology is largely due to the perception that it enables the sharing and collaboration of information throughout a project's life cycle (Lee et al., 2015). Although many researchers and practitioners agree on the practical application and advantages of BIM in the construction industry, it is still undefined why BIM is supported and what factors contribute to its implementation (Lee et al., 2015). Similarly, proper communication and information sharing can reduce the significant proportion of rework in the projects. Thus, the proper interface management can help in determining the project cost, scheduling, and quality that affect the construction projects both directly and indirectly (Lin, 2015). By considering these statements, this study concentrates on measuring the effectiveness of BIM utilization in construction projects. Similarly, there is currently no comprehensive approach or methodology for evaluating the industrial adoption of BIM technology (Tsai et al., 2014).

This study introduces a novel application of the DeLone and McLean (DM) model to evaluate the effective factors of Building Information Modeling (BIM) in enhancing construction interface management. While previous research has explored BIM's impact on various aspects of construction, this study is distinct in its focus on how the DM model can be specifically applied to assess BIM's influence on interface management within construction projects. Thus, the objectives of this study are: 1- to identify the effective factors of BIM through the literature review, 2- to evaluate the factors based on the construction industrial project practitioners' perception, 3- to determine the most influencing factors of BIM, and 4-to suggest the solution for construction improvements. The paper is organized as follows: Section 2 provides a literature review of BIM and interface management. Section 3 outlines the methodology used in the study; Section 4 presents the results and discusses the findings in relation to the research objectives. Finally, Section 5 concludes the study, highlighting the implications for practice and suggesting areas for future research.

2. Literature review

2.1. BIM adoption, implementation, and utilization

Zuppa et al., (2009) surveyed architecture, engineering, and construction (AEC) professionals to evaluate the most widely accepted definition of BIM and its influences on project performance metrics. According to the survey findings, BIM is considered a tool for visualizing and coordinating AEC work, avoiding errors and omissions, and enhancing the productivity, schedule, safety, cost, and quality of construction projects. Khosrowshahi and Arayici (2012) established the concept of BIM maturity for enhancing its implementation in the UK construction industry.

The result of this study is a road map for BIM implementation in the United Kingdom, which lists the issues that need to be solved as organizations' concerns. Hameed Memon et al., (2014) said that BIM allows for the multi-dimensional visualization of designs as well as the provision of all project-related information prior to construction. Additionally, they examined the advantages and disadvantages of BIM, as well as implementation barriers, and proposed effective strategies for increasing BIM adoption in the construction industry. From the survey results, 95 completed questionnaires were analyzed using the average index and the relative importance index methods. BIM's primary benefits include improved scheduling, improved drawing coordination, cost control, and a single detailed model.

As a result, the lack of qualified staff capable of operating the software, unfamiliarity with the technology, and an absence of parametric libraries are found to be the primary impediments to poor BIM implementation. Tsai et al., (2014) examined the influential and key factors of BIM adoption to predict the critical success factors (CSFs) using a survey method and data analysis. The findings suggested that the key factors "defining project goals before forming teams" and "coordination and integration among professions" were found to be very essential among the "top management support" and "functionality and design validation" of BIM tools. Wang and Chien, (2014) studied the use of BIM in the project planning and scheduling processes of the Australian construction industry. The findings of the study show that BIM awareness is not as widespread as previously thought, but the technology acceptance is increasing among the young population.

Thereby incorporating BIM into project planning and scheduling will enhance the interfaces, data exchange, and an efficient change management system. Ding et al., (2015) examined a better understanding of how practitioners such as architects adopt BIM in order to implement it effectively in the construction industry. The study results proposed that motivation, BIM technical defects, and BIM capability had significant effects on architects' BIM adoption but the knowledge and structure management support had no effect. Additionally, they said that AEC firms and project managers need to provide BIM training to architects to increase their likelihood of using BIM on future projects. Lee et al., (2015) proposed a BIM acceptance model using Structural Equation Modeling (SEM). Through the review of the literature on technology acceptance and behavioral theories, they identified the key components using this BIM acceptance model (BAM). Kim et al., (2016) result suggested that examining the differences in participants' use intentions and attitudes toward BIM will support the development of more suitable and efficient strategies for activating BIM adoption. Yaakob et al., (2016) proposed that BIM had the potential to enhance the construction industry's actual performance in terms of cost-effectiveness, project quality, and time to market. Apart from that, the benefits of BIM in industrialized construction are far more advantageous to the majority of stakeholders when it comes to project implementation.

As a result, the paper concludes that the low adoption rate is also a result of issues with readiness, a lack of prior BIM experience, a lack of BIM knowledge, and a lack of market demand for BIM. Ozorhon and Karahan, (2017) conducted a questionnaire survey among Turkey's public and private sectors participants. From the results, the three most critical factors identified are (1) qualified personnel availability, (2) effective leadership, and (3) information and technology availability. LIAO and TEO, (2017) identified critical success factors (CSFs) for improving BIM implementation and examined their interrelationships. A total of fifteen CSFs were determined through factor analysis and classified as integration and model accuracy, commitment and training from management, and benefits and implementation support. The proposed framework, which defines the CSFs and their relationships, enables a thorough understanding of BIM implementation and can assist firms in committing to project-wide BIM adoption.

Song et al., (2017) attempted to study the BIM's success in terms of user satisfaction while accounting for the mediating effect of top-management support. It is based on the user satisfaction literature for information systems and enterprise resource planning. A survey among the BIM users in China examined the effects of four factors (system quality, information quality, external service, and top-management support) on user satisfaction. And the result concluded that other than system quality all the factors had a considerable impact on BIM user satisfaction. Papadonikolaki, (2018) conducted three case studies for the qualitative analysis using the loosely coupled systems theory to determine the relationship between BIM adoption drivers and project implementation of BIM. According to the empirical data results, there is a need for enhancing the compatibility, inter-firm knowledge mobility, and inter-firm power dynamics. Won and Lee, (2019) aimed at highlighting the importance of CSFs in determining the success of projects (i.e., software selection criteria).

2.2. Interface management

Siao and Lin, (2011) said that construction interface matrix (CIM) is used to represent information about interface issues among the project participants. This technique allows the project managers and participants to quickly access information necessary for efficient interface management. The testing results imply that the CIM system is capable of assisting with interface management during the construction phase. According to the findings of Tian, (2013), a new interface categorization was proposed into four categories: time interfaces, relational interfaces, information interfaces, and environmental interfaces. The term "time interfaces" refers to the connections between project stages, the connections between various processes, and the connections created by the numerous connected factors in a project. Maintaining a smooth information exchange throughout the duration of the project is critical to its success, and thus the project management of the informational interface should be strengthened. Lin, (2013) suggested that the participants in IM can identify and track interface or changed events, which enables them to optimize construction processes, minimize rework, and reduce the overall duration. This research established a practical methodology for tracking and managing interface events by utilizing network-based interface maps (NBIM). NBIM enables practitioners to obtain a comprehensive view of previous and current interface events occurring within a selected project, as well as to exercise appropriate advanced control and management of interfaces. The goal of this study is to propose and develop a web-based construction network-based interface management (CNIM) system to facilitate the monitoring and sharing of interface information. The CNIM system is used to validate the proposed methodological approach and illustrate the efficacy of interface management through a case study of a Taiwanese building project.

Daniels et al., (2014) said that due to the complexity and scale of mega-construction projects, managing them requires additional effort. Interface management systems have been investigated as a possible solution for managing complex mega-projects. It describes a megaproject that resulted in the development of an interface management system to manage the project's numerous organizational interfaces. The focus of this article is to evaluate the management plan's compliance with current interface management system models and the management plan's implementation by participants. As a result, interface management is still being studied as a means of increasing construction efficiency. Megaprojects are large-scale construction projects that include highways, bridges, airports, tunnels, and utility systems. Much of the research into how to implement interface management in the construction industry has been concentrated on large-scale projects. Ju et al., (2017) examined the supply chain management for complex construction projects that are characterized by multidisciplinary participants, adversarial short-term relationships, and fragmentation of project delivery procedures.

Due to the lack of shared values, there is a lack of understanding regarding how the behaviors of one discipline affect the behaviors of related disciplines. As a result, they concluded that Improving procurement processes is critical for resolving interface conflicts. The construction industry institute (CII, 2014) defines an interface point in engineering and construction (E&C) as "a soft and/or hard contact point between two interdependent interface stakeholders in a construction project". Ahn et al., (2017) evaluated the efficacy of information management practices in E&C projects. The importance of communication has been emphasized in order to facilitate organizational integration in complex projects. Formal procedures for interacting between parties have been developed, as well as more efficient information management practices.

Various major engineering and construction (E&C) projects have recently adopted formal interface management methodologies (IM). However, there exists a deficiency in understanding the role and effectiveness of Information Management (IM) practices in engineering and construction (E&C) projects. To address this, data were collected from 45 large-scale E&C projects regarding project complexity and IM practices. These data were then subjected to quantitative analysis techniques such as principal component analysis and linear regression. The findings of this analysis indicate that the formal IM practices currently employed in E&C projects are indeed effective in managing information.

Throughout the construction phase of a project, numerous interface events and problems occur, making it critical to track and control them. By utilizing IM, interfaces and changed events can be identified and tracked for the improvement of construction processes by minimizing rework and shortening overall project duration (Lin, 2015). Though BIM act as a significant change management operation that involves a variety of risk areas (Khosrowshahi and Arayici, 2012). Moreover, BIM enables the collection of all necessary data for a project prior to its construction and effective recommendations for enhancing BIM implementation in the construction industry are needed (Hameed Memon et al., 2014). Mostly BIM is used for visualization and simulation and to further enhance the use of BIM in project planning and scheduling the improvements in software application interfaces, data exchange, and a change management system had to be focused on (Wang and Chien, 2014). Furthermore, Song et al., (2017) examined the effects of four factors on BIM user satisfaction in the AEC industry system quality, information quality, external service, and top-management support. Adding to this, in India, the acceptance of BIM by the practitioners had explored by Vigneshwar et al., (2022). Therefore, the evaluation of BIM technology in terms of interface and change management will provide better insights. Thus, industrial projects are complicated and require the involvement of many practitioners. This study focuses on evaluating the efficient factors of BIM among industrial practitioners in India.

To evaluate the IS Success model, Wang and Liao, (2008) proposed a framework based on the DeLone and McLean's (DM) model. Adding to this, Roky and Meriouh, (2015) studied an empirical evaluation of information systems (IS) based on the DM model and the result suggested that system quality has a significant impact on user satisfaction. Therefore, to evaluate the effectiveness of the BIM, the factors of the DM model had been followed. Additionally, Song et al., (2017)established that the organization's role and support are critical in the implementation of BIM. Moreover, Shang and Shen, (2014) developed a framework for BIM implementation by involving the factors in terms of technical, organizational, process, and legal perspectives. Thereby, support from the organization is a predominant factor and it plays a major role in the BIM adoption and implementation. In accordance with existing literature, the chosen criteria for assessing the efficacy of building information modeling (BIM) include organizational support, quality of service, system quality, information quality, user satisfaction, usage, and the net benefits of BIM technology as outlined in Table 1.

Table 1. Factors and source references

Factors	ID	Factors	Source reference
Organizational support [OS]	OS1	Our organization is aware of the benefits of implementing BIM tools in the project phases	(Jin et al., 2017)
	OS2	Our organization provides education and training on BIM software	(Ozorhon and Karahan, 2017;Won and Lee, 2010;Won and Lee, 2019;LIAO and TEO, 2017;Tsai et al., 2014;Lee et al., 2015;Shang and Shen, 2014)
	OS3	Our organization encourages and motivates us in utilizing the BIM software in all phases of the project	(Won and Lee, 2010;Ding et al., 2015;Jin et al., 2017)
	OS4	Our organization provides necessary financial resources and continuous investment for BIM usage	(Jin et al., 2017)
System quality [SQ]	SQ1	BIM software provides an accurate and definite output of the project data	(Lee et al., 2015;Kim et al., 2016)
	SQ2	BIM provides a well-structured and a user-friendly interface for the people under various disciplines	(Shang and Shen, 2014)
	SQ3	BIM software can be easily integrated with the existing software in our organization	(Won and Lee, 2010;Lee et al., 2015;Kim et al., 2016)
	SQ4	BIM tools are stable and acceptable	(Shang and Shen, 2014;Tsai et al., 2014)
Information quality [IQ]	IQ1	BIM provides secured information sharing among our project participants	(Shang and Shen, 2014;Tsai et al., 2014;Won and Lee, 2010)
	IQ2	The information presented by BIM is accurate and efficient.	(Tsai et al., 2014;Lee et al., 2015)
	IQ3	BIM utilization improves information accessibility	(Davis, 1989;Igbaria et al., 1995)
	IQ4	BIM software helps in better understanding of the activities of the project by providing necessary information	(Lee et al., 2015;Kim et al., 2016;Jin et al., 2017;Davis, 1989;Zuppa et al., 2009;Papadonikolaki, 2018)
Service quality [SRQ]	SRQ1	Maintenance and up-gradation are provided by software vendors whenever necessary	(Song et al., 2017;Yaakob et al., 2016;Tsai et al., 2014)
	SRQ2	Quick response is offered by the software vendors whenever required	(Song et al., 2017;Yaakob et al., 2016;Tsai et al., 2014)
	SRQ3	The staff of technical support for the BIM software is empowered to resolve user problems	(Song et al., 2017;Yaakob et al., 2016;Tsai et al., 2014)
	SRQ4	The staff of technical support for the BIM software is available when I need it.	(Song et al., 2017;Yaakob et al., 2016;Tsai et al., 2014)
Use [U]	U1	I use BIM software for planning and scheduling project phasing simulations	(Wang and Chien, 2014;Sindhu Vaardini and Shanmugapriya, 2018)
	U2	I use BIM software for designing and drafting for easy visualization of the existing model	(Czmoch and Pękala, 2014;Sindhu Vaardini and Shanmugapriya, 2018)
	U3	I use BIM software for costing and estimation for better quantity extraction	(Sindhu Vaardini and Shanmugapriya, 2018;Vitasek and Žák, 2019)
	U4	I use the documents and drawings obtained from the BIM software for better IM throughout the project life cycle	(Sindhu Vaardini and Shanmugapriya, 2018;Lin, 2015)
User satisfaction [US]	US1	I am satisfied with the task processing speed and accuracy of BIM	(Davis, 1989;Lee et al., 2015;Kim et al., 2016)
	US2	I am satisfied with the Decision-making process throughout the project.	(Davis, 1989)
	US3	I am satisfied with the outcomes accomplished by BIM and it is better than expected	(Roky and Meriouh, 2015)

	US4	I am satisfied with the systematic management of the information and high-quality documentation of the project	(LIAO and TEO, 2017;Lee et al., 2015;Khosrowshahi and Arayici, 2012)
Net benefits [NB]	NB1	Overall improvement in project performance (in terms of time, cost, safety, and quality) is enhanced throughout the project life cycle	(Zuppa et al., 2009;Roky and Meriouh, 2015; Lee et al., 2015;Kim et al., 2016)
	NB2	Effective communication and coordination among the stakeholders are established	(Lee et al., 2015;Khosrowshahi and Arayici, 2012)
	NB3	Clash detection and resolution throughout the project life cycle are achieved	(Lee et al., 2015;Khosrowshahi and Arayici, 2012;LIAO and TEO, 2017;Hameed Memon et al., 2014)
	NB4	3D Visualization and walkthrough for a better understanding of the project design are framed	(Lee et al., 2015;Khosrowshahi and Arayici, 2012;LIAO and TEO, 2017)
	NB5	Effective action to risks in the project is developed	(Kim et al., 2016)

3. Methodology

The factors are chosen in accordance with the DM model and literature review of this study. As a means of examining the effective factors of BIM adoption, a questionnaire survey was utilized for this investigation. Consequently, the questionnaire was formulated following expert consultation and consists of two distinct sections. A pilot study of the questionnaire was undertaken by examining a sample of ten questionnaires. The survey instruments were disseminated among professionals with expertise in the domain of construction, encompassing project managers, BIM engineers, and planning engineers. The responses offered by these pilot survey participants were integrated into the primary survey. On a Likert scale of 1 to 5, respondents were requested to rate the significance of the given statement: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree). The data for evaluating the effectiveness of BIM were gathered through interviews and emails among the BIM users throughout India. From the questionnaire survey, the type of respondents such as number of consultants, contractors, clients and architectural firms can be obtained. The respondent participated in this survey and their demographics were shown in Table 2.A total of 166 responses were received and the data were analyzed using frequency, RII relative importance index, and reliability test using SPSS software. Therefore, the following section presents the test results and findings obtained from the analysis.

4. Results and findings

The respondents involved in this study and their information were shown in Table.2. Cronbach's alpha test was used to determine the internal consistency of survey items in order to assess the survey's reliability. Similarly, as shown in Table.3, the Cronbach's alpha test result is 0.783 and it showed that the factors are 78.3 % reliable.

Table 2. Respondents' information

Respondents' information	Frequency	Percentage
Designation of the respondent		
Architect	6	3.6
Consultant	5	3
Contractor	155	93.4
Working experience years		
Below 3 years	8	4.8
3-5 years	44	25.9
6-10 years	66	39.8
Above 10 years	48	28.9
Choice of BIM		
Realizing actual benefits	81	48.8
Client interest	70	42.2
Future requirement	4	2.4
Others	11	6.6
Total	166	100

Table 3. Reliability test

No of items	Cronbach's alpha
166	0.783

The relative importance of effective BIM factors is determined using the relative importance index (RII) (Shanmugapriya and Subramanian, 2013) presented in equation (1).

$$RII = \Sigma W / (A x N) \quad (1)$$

Where, W denotes the weights assigned by respondents to each factor (i.e., ranging from 1 to 5 in this case), A denotes the highest weight (i.e., 5 in this case), and N denotes the total number of respondents (i.e., 166 in this study). Based on the RII results, the individual sub-factors ranking and the overall all factors ranking are shown in Tables 4 and 5 respectively.

Table 4. RII ranking.

ID	Overall		Consultant		Architect		Contractor	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
OS1	73.38	29	80	3	70	23	73.3	29
OS2	79.4	15	72	17	76.67	9	79.75	15
OS3	82.66	2	76	10	76.67	9	83.1	2
OS4	77.11	27	76	10	83.34	1*	76.91	27
SQ1	78.32	22	76	10	70	23	78.71	22
SQ2	80.37	8	80	3	80	5	80.39	10
SQ3	75.43	28	60	29	73.34	19	76	28
SQ4	79.28	17	84	1*	76.67	9	79.23	17
IQ1	78.2	23	68	23	80	5	78.46	23
IQ2	78.8	18	68	23	76.67	9	79.23	17
IQ3	80.61	6	72	17	80	5	80.91	7
IQ4	79.4	15	76	10	80	5	79.49	16
SRQ1	77.47	26	64	28	73.34	19	78.07	24
SRQ2	80.13	11	80	3	73.34	19	80.39	10
SRQ3	79.64	13	72	17	76.67	9	80	13
SRQ4	80.61	6	68	23	76.67	9	81.17	5
U1	77.72	24	80	3	83.34	1*	77.42	26
U2	77.72	24	72	17	73.34	19	78.07	24
U3	81.81	4	72	17	83.34	1*	82.07	4
U4	79.76	12	68	23	66.67	27	80.65	8
US1	78.8	18	76	10	76.67	9	78.97	20
US2	78.44	21	68	23	70	23	79.1	19
US3	80.37	8	80	3	76.67	9	80.52	9
US4	82.05	3	76	10	66.67	27	82.84	3
NB1	78.8	18	80	3	76.67	9	78.84	21
NB2	79.52	14	76	10	70	23	80	13
NB3	80.25	10	72	17	83.34	1*	80.39	10
NB4	80.97	5	80	3	76.67	9	81.17	5
NB5	82.9	1*	84	1*	66.67	27	83.49	1*

* Indicates the top-ranking factors, RII values in percentage

To denote the various perception differences according to the respondent's designation, the ranking based on the designation was performed as shown in Table 4. The results had shown that the top factors are NB5, OS3, US4, U3, NB4, and SRQ3 with the RII values of 83.49, 83.1, 82.84, 82.07, and 81.17 respectively. These attributes denote the effective factors such as risk elimination, organization motivation, information quality, better cost and quantity estimation, three-dimensional visualization, and technical staff availability.

The net benefit factor NB-5 "effective action to risk in the project is developed" is found to be the top factor with RII value of 82.9. The findings of Isaac et al. (2009) and Shibani et al. (2021) support this outcome, indicating that taking proactive measures to mitigate risk at the very beginning of a project will avoid unnecessary risks. The organization support factor OS-3 "encouragement and motivation for utilizing the BIM software in all the factors of project phase" is found to be the top factor with RII value of 82.66. This result is supported by Lee et al (2015) and Kim et al (2016) that encouragements/ motivation forms the organization for utilizing BIM place an effective role in its adoption. The factors US4 "I am satisfied with the systematic management of the information and high-quality documentation of the project" was found to be the most important factor in User Satisfaction with RII value 82.05 which was supported by Rajalakshmi (2019) where the users were satisfied with the systematic management of the information and the high-quality documentation of the project.

Similarly, this study can contribute to the development of more efficient and realistic strategies for BIM adoption by examining differences in user preferences and attitudes among BIM participants. For comparing the two or more elements or groups based on a variety of attributes, the radar charts are used. Thereby using the values in Table 4, the radar graph was created as shown in Fig.1.

Table 5. Total RII ranking

Factors	RII	Rank
OS	78.13	7
SQ	78.34	6
IQ	79.25	4
SRQ	79.46	3
U	79.25	4
US	79.90	2
NB	80.48	1

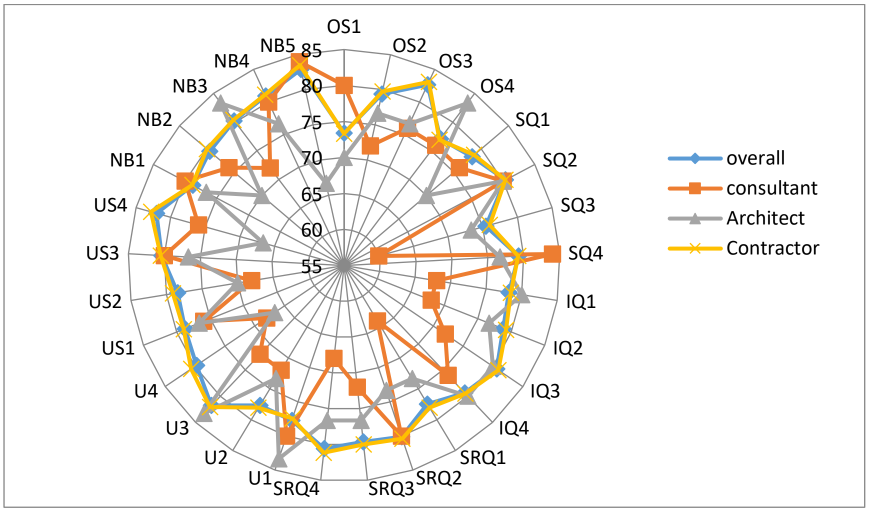

Figure 1. Radar graph using RII values.

In this survey, the participation of architects and consultants was low. Thereby from Fig.1, the varied response can be seen in the graph. From table 5, the overall group ranking had highlighted that the practitioners are agreeing with the net benefits and user satisfaction of BIM with high RII values. The net benefits deal with the overall improvement in project performance (in terms of time, cost, safety, and quality), effective communication and coordination among the stakeholders, Clash detection, and risk reduction. Similarly, user satisfaction assesses the satisfaction of the practitioners in terms of task processing speed and accuracy of BIM, Decision-making process, systematic management of the information, and high-quality documentation. Similarly, from Table 5, the organization support seemed to be with the least value (i.e., 78.13). Especially, the organization's awareness about BIM and providing regular training to the practitioners were founded to have less impact.

5. Discussion and conclusion

Many studies had highlighted the benefits and barriers of BIM adoption, but this multi-dimensional BIM technology is not been widely used in the construction phases. Some researchers had suggested BIM as an effective tool for interface management. Moreover, due to the different levels of information sharing, the performances of megaprojects are becoming more complicated than other construction projects. Since, interface management systems had been studied as possible solutions for effective management of complex megaprojects (Daniels et al., 2014).

First objective of this study is to identify the effective factors of BIM through the literature review. To analyze the effectiveness of BIM in terms of quality, net benefits, and user satisfaction the factors of this study were framed based on the DM model. The questionnaire was framed using the factors shown in Table 1 and the survey was conducted. Second objective is to evaluate the factors based on the construction industrial project practitioners' perception. This study focused on collecting the response among the construction practitioners involved in industrial projects. From Table.2, in this survey, the percentage of the contractors and practitioners with 6-10 years of experience seems to be greater. Regarding the choice of BIM, most of the respondents had agreed with the actual benefits of BIM and the second-highest value highlights the importance of clients' interests. This suggests that the client's interest plays a major role in BIM utilization in India.

Third objective of this study is to determine the most influencing factors of BIM. The predominant importance of the DM model is to evaluate the system or technology in terms of system quality, information quality, and service quality. The net benefits and user satisfaction measures reflect the overall combination of these factors as project performance improvement, and satisfaction of the practitioners while utilizing the software. According to the findings of this study, the net benefits of BIM and practitioner satisfaction appear to be more valuable. This refers to the greater practitioners' assessment and contentment with the software or technology in comparison to other software or technology. The evaluation of BIM using the DM factors among the industrial project practitioners highlighted those practitioners are more satisfied with the BIM and utilizing the benefits of BIM.

Thereby, the BIM system quality, information quality, and service quality are found to be more significant. Thus, increasing the organizational support through improved BIM training and execution among all practitioners will result in improved interface management. From Tables 4 and 5, all the effective factors of BIM in NB and US emphasize the practitioners' fulfillment and the enhanced possibilities for interface management by utilizing BIM in the projects. Thereby, BIM enables the proper management of interface events, the sharing of information among practitioners during the planning, scheduling, and costing phases, and the reduction of problems during the construction phases.

Following are some recommendations: 1) although the importance of BIM is widely recognized within the Indian construction organization, there is a significant lack of a common and operationalize understanding of the BIM concept. Therefore, existing education and training programs must be readjusted. Also, in construction organizations, they should incorporate BIM into the curriculum of educational institution taking construction-related courses to address the lack of well-trained professionals who can use BIM tools. 2) Recent developments in digital technology present great opportunities for the Indian construction industries looking to transform into a digital business environment. The Indian government, therefore, needs to develop and implement a policy framework to successfully implement its digital strategy. It is important to pay attention to capacity building on digital business concepts, strategies and processes relevant to the construction sector. Education and training programs must be dynamic and adaptable to the ever-changing needs of business, society and the public. 3) Indian construction stakeholders, including government and specialized regulatory agencies, should work together to ensure that prerequisites for BIM adoption are met and empowered, including provisions of regulations and industry standards to guide implementation recommended.

6. Limitations and future work

Evaluation of the BIM factors highlighted that BIM can be an effective tool for proper interface management and it will benefit the proper execution of mega projects in the interconnected nature of construction work. The data analyzed for this study was obtained from the BIM users and especially from the practitioners involved in an industrial project. There were no data obtained from the practitioners involved in residential, commercial, and others. Therefore, future work can extend to collected data from all the project practitioners (residential, commercial, infrastructural and industrial projects). Future studies will evaluate the DM model using the structural equation model by involving these effective BIM factors to analyze the direct and indirect impacts.

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References

Ahn, S., Shokri, S., Lee, S., Haas, C. T., Haas, R. C. G. (2017). Exploratory Study on the Effectiveness of Interface-Management Practices in Dealing with Project Complexity in Large-Scale Engineering and Construction Projects. Journal of Management in Engineering, 33(2), 04016039. https://doi.org/10.1061/(asce)me.1943-5479.0000488

CII (Construction Industry Institute). (2014). RS302-1 interface manage- ment, Austin, TX.

Czmoch, I., Pękala, A. (2014). Traditional design versus BIM based design. Procedia Engineering, 91(TFoCE), 210–215. https://doi.org/10.1016/j.proeng.2014.12.048

Daniels, C., Farnsworth, C. B., Weidman, J. (2014). Interface Management on Megaprojects : A Case Study. 50th ASC Annual International Conference Proceedings, 2006. http://ascpro0.ascweb.org/archives/cd/2014/paper/CPGT166002014.pdf

Datta, S. D., Sobuz, M. H. R., Mim, N. J., & Nath, A. D. (2023). Investigation on the effectiveness of using building information modeling (BIM) tools in project management: a case study. Revista de la construcción, 22(2), 306-320. Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly, 13(3), 319. https://doi.org/10.2307/249008Ding, Z., Zuo, J., Wu, J., Wang, J. (2015). Key factors for the BIM adoption by architects: a China study. Engineering, Construction and Architectural Management, 22(6), 732–748. https://doi.org/10.1108/ECAM-04-2015-0053

Hameed Memon, A., Abdul Rahman, I., Memon, I., Iffah Aqilah Azman, N. (2014). BIM in Malaysian Construction Industry: Status, Advantages, Barriers and Strategies to Enhance the Implementation Level. Research Journal of Applied Sciences, Engineering and Technology, 8(5), 606–614. https://doi.org/10.19026/rjaset.8.1012

Igbaria, M., Guimaraes, T., Davis, G. B. (1995). Testing the Determinants of Microcomputer Usage via a Structural Equation Model. Journal of Management Information Systems, 11(4), 87–114. https://doi.org/10.1080/07421222.1995.11518061

Isaac, S. and Shimanovich, M., 2021. Automated scheduling and control of mechanical and electrical works with BIM. Automation in Construction, 124, p.103600.

Jin, R., Hancock, C., Tang, L., Chen, C., Wanatowski, D., Yang, L. (2017). Empirical Study of BIM Implementation–Based Perceptions among Chinese Practitioners. Journal of Management in Engineering, 33(5), 04017025. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000538

Ju, Q., Ding, L., Skibniewski, M. J. (2017). Optimization strategies to eliminate interface conflicts in complex supply chains of construction projects. Journal of Civil Engineering and Management, 23(6), 712–726. https://doi.org/10.3846/13923730.2016.1232305

Khosrowshahi, F., Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management, 19(6), 610–635. https://doi.org/10.1108/09699981211277531

Kim, S., Park, C. H., Chin, S. (2016). Assessment of BIM acceptance degree of Korean AEC participants. KSCE Journal of Civil Engineering, 20(4), 1163–1177. https://doi.org/10.1007/s12205-015-0647-y

Lee, S., Yu, J., Jeong, D. (2015). BIM Acceptance Model in Construction Organizations. Journal of Management in Engineering, 31(3), 04014048. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000252

LIAO, L., & TEO, E. A. L. (2017). CRITICAL SUCCESS FACTORS FOR ENHANCING THE BUILDING INFORMATION MODELLING IMPLEMENTATION IN BUILDING PROJECTS IN SINGAPORE. Journal of Civil Engineering and Management, 23(8), 1029–1044. https://doi.org/10.3846/13923730.2017.1374300

Lin, Y. C. (2013). Construction network-based interface management system. Automation in Construction, 30, 228–241. https://doi.org/10.1016/j.autcon.2012.11.025

Lin, Y. C. (2015). Use of BIM approach to enhance construction interface management: A case study. Journal of Civil Engineering and Management, 21(2), 201–217. https://doi.org/10.3846/13923730.2013.802730

Loyola, M., & López, F. (2018). An evaluation of the macro-scale adoption of Building Information Modeling in Chile: 2013-2016. Revistade la Construcción. Journal of Construction, 17(1), 158–171. https://doi.org/10.7764/RDLC.17.1.158

Matoseiro Dinis, F., Rodrigues, R., & Pedro da Silva PoçasMartins, J. (2024). Development and validation of natural user interfaces for semantic enrichment of BIM models using open formats. Construction Innovation, 24(1), 196-220.Ozorhon, B., Karahan, U. (2017). Critical Success Factors of Building Information Modeling Implementation. Journal of Management in Engineering, 33(3), 04016054. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000505Papadonikolaki, E. (2018). Loosely Coupled Systems of Innovation: Aligning BIM Adoption with Implementation in Dutch Construction. Journal of Management in Engineering, 34(6), 05018009. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000644

Rajalakshmi, K., 2019. Building Information Modeling using Systems Integration in Construction Engineering and Management (CEM). Journal of Emerging Technologies and Innovative Research (JETIR), 6(1).

Roky, H., Meriouh, Y. Al. (2015). Evaluation by Users of an Industrial Information System (XPPS) Based on the DeLone and McLean Model for IS Success. Procedia Economics and Finance, 26(0), 903–913. https://doi.org/10.1016/s2212-5671(15)00903-x

Shang, Z., Shen, Z. (2014). Critical success factors (CSFs) of BIM implementation for collaboration based on system analysis. Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering, 1441–1448. https://doi.org/10.1061/9780784413616.179

Shibani, A., Bhavsar, A., Hassan, D., Saidani, M. and Agha, A., 2021. Investigating the Benefits of BIM for Mid-Rise Timber Buildings in Canada: A Qualitative Study. Journal of Mechanical And Civil Engineering, 7(1), pp.1-32.

Siao, F. C., Lin, Y. C. (2011). The development of construction interface information management system. Proceedings of the 28th International Symposium on Automation and Robotics in Construction, ISARC 2011, 1, 411–416. https://doi.org/10.22260/isarc2011/0075

Sindhu Vaardini, U., Shanmugapriya, S. (2018). ROLE OF BIM ADOPTION IN CONSTRUCTION PROJECTS. National Conference on Advanced Construction Materials and Techniques in Civil Engineering, CIT, Coimbatore.

Song, J., Migliaccio, G. C., Wang, G., Lu, H. (2017). Exploring the Influence of System Quality, Information Quality, and External Service on BIM User Satisfaction. Journal of Management in Engineering, 33(6), 04017036. https://doi.org/10.1061/(asce)me.1943-5479.0000549

Tian, X. (2013). Influencing factors for project interface management. ICCREM 2013: Construction and Operation in the Context of Sustainability - Proceedings of the 2013 International Conference on Construction and Real Estate Management, 448–456. https://doi.org/10.1061/9780784413135.042

Tsai, M. H., Mom, M., Hsieh, S. H. (2014). Developing critical success factors for the assessment of BIM technology adoption: Part I. Methodology and survey. Journal of the Chinese Institute of Engineers, Transactions of the Chinese Institute of Engineers,Series A, 37(7), 845–858. https://doi.org/10.1080/02533839.2014.888811

Vigneshwar, R. V. K., Shanmugapriya, S., Sindhu Vaardini, U. (2022). Analyzing the Driving Factors of BIM Adoption Based on the Perception of the Practitioners in Indian Construction Projects. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 0123456789. https://doi.org/10.1007/s40996-022-00834-9

Vilutiene, T., Kiaulakis, A., & Migilinskas, D. (2021). Assessing the performance of the BIM implementation process: a case study. Revistade la Construcción. Journal of Construction, 20(1), 26–36. https://doi.org/10.7764/RDLC.20.1.26

Vitasek, S., Žák, J. (2019). BIM for cost estimation. Advances and Trends in Engineering Sciences and Technologies III- Proceedings of the 3rd International Conference on Engineering Sciences and Technologies, ESaT 2018, September, 657–662. https://doi.org/10.1201/9780429021596-103

Wang, C. C., Chien, O. (2014). The Use of BIM in Project Planning and Scheduling in the Australian Construction Industry. ICCREM 2014: Smart Construction and Management in the Context of New Technology - Proceedings of the 2014 International Conference on Construction and Real Estate Management, November 2014, 126–133. https://doi.org/10.1061/9780784413777.015

Wang, Y. S., Liao, Y. W. (2008). Assessing eGovernment systems success: A validation of the DeLone and McLean model of information systems success. Government Information Quarterly, 25(4), 717–733. https://doi.org/10.1016/j.giq.2007.06.002

Won, J., Lee, G. (2019). Identifying the consideration factors for successful BIM projects. EG-ICE 2010 - 17th International Workshop on Intelligent Computing in Engineering.

Yaakob, M., Ali, W. N. A. W., Radzuan, K. (2016). Critical success factors to implementing building information modeling in Malaysia construction industry. International Review of Management and Marketing, 6(8Special Issue), 252–256.

Zuppa, D., Issa, R. R. A., Suermann, P. C. (2009). BIM's Impact on the Success Measures of Construction Projects. Computing in Civil Engineering (2009), 346(June), 503–512. https://doi.org/10.1061/41052(346)50