Primljen / Received: 7.7.2022.
Ispravljen / Corrected: 21.9.2022.
Prihvaćen / Accepted: 10.11.2022.
Dostupno online / Available online: 10.4.2023.

BIM Adoption for effective interface management in Indian construction industries

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Research Paper

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BIM Adoption for effective interface management in Indian construction industries

The contribution of the construction industry towards the development of the economy of an economy is inevitable. Building Information Modelling (BIM) is an emerging information tool that supports interface management in construction projects based on intellectual digital illustration that provides a maximum number of benefits throughout the lifecycle of projects. A country like India has recently adopted the BIM tool, but it is not widely adopted by construction companies. Therefore, comprehensive and systematic analyses are essential for determining the factors influencing BIM adoption. In this study, a proposed model is employed using seven significant factors, namely, Organizational support (OS), Information Quality (IQ), System Quality (SQ), Service Quality (SRQ), usage (U), User Satisfaction (US), and Net Benefits (NB), to analyse the influence of these factors on BIM adoption. An experimental analysis was conducted based on the developed success model and the fitness of the model was estimated. The results of this model suggest that system quality plays a major role in BIM usage. Furthermore, a hypothesis test was performed to analyse the impact range of each independent factor over the dependent factors.

Key words:

Building Information Modelling (BIM), interface management, information system success model, user satisfaction (US), net benefits (NB)

Prethodno priopćenje

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Usvajanje BIM-a za učinkovito upravljanje sučeljem u indijskoj građevinskoj industriji

Doprinos građevinarstva razvoju gospodarstva je neizbježan. Informacijsko modeliranje gradnje ili BIM novi je informacijski alat koji podržava upravljanje sučeljem u građevinskim projektima na temelju intelektualne digitalne ilustracije koja pruža maksimalan broj prednosti tijekom trajanja projekata. Države poput Indije nedavno su usvojile BIM alat, ali građevinske tvrtke nisu započele s njegovom primjenom. Stoga su sveobuhvatne i sustavne analize nužne za određivanje čimbenika koji utječu na primjenu BIM-a. U ovom se radu primjenjuje predloženi model koristeći sedam čimbenika značajnosti, točnije, organizacijsku podršku (OS), kvalitetu informacija (IQ), kvalitetu sustava (SQ), kvalitetu usluge (SRQ), korištenje (U), zadovoljstvo korisnika (US) i neto korist (NB), kako bi se analizirao utjecaj tih čimbenika na usvajanje BIM-a. Na temelju razvijenog modela uspješnosti provedena je eksperimentalna analiza te je procijenjena prikladnost modela. Rezultati tog modela pokazuju da kvaliteta sustava ima glavnu ulogu u primjeni BIM-a. Nadalje, provedeno je testiranje hipoteze kako bi se analizirao raspon utjecaja svakog nezavisnog čimbenika u odnosu na zavisne čimbenike.

Ključne riječi:

Building Information Modelling (BIM), upravljanje sučeljem, model uspješnosti informacijskog sustava, zadovoljstvo korisnika (US), neto korist (NB)

1. Introduction

The management of construction projects is a critical aspect as it involves multidisciplinary teams that require proper communication and coordination among them. Building Information Modelling (BIM) represents the digital illustration of physical and functional features of a construction that are integrated with reliable information regarding the lifecycle of a building (i.e., planning, design, construction, operations, and facility management) and provides construction data. BIM is the most common and optimal tool for applying construction based on Architecture, Engineering, and Construction (AEC) [1]. To develop rich data, construction projects utilise BIM to support the shift of the AEC industry from vision to realisation [2]. Therefore, BIM can assist in the more significant applications of a customer-centric approach, including customisation and personalisation in the AEC industry. Similarly, it can demonstrate the merits like cost reduction, reduced time consumption, quality increment, greater productivity and on-time delivery [3, 4]. Furthermore, the digital representation of data from the complete lifecycle of the building till the final delivery to stakeholders can be managed. In addition, interacting policies, visualisation, construction planning, cost estimation, facility management, forensic analysis, project management and collision detection support throughout the entire project lifecycle can be managed in a similar way [5].

From early 2000s, the BIM has been used in many countries and various institutes have attempted to analyse the status of BIM adoption. Also, several studies have been conducted to determine the factors that promote the adoption of BIM in construction industries in various countries. Hall *et al.* [6] analysed the barrier for the adoption of BIM in the Small and Medium Sized Enterprises (SMEs) in New Zealand and found that interoperability between software platforms, absence of government mandate on BIM utilization at the project level, high expense for software and lack of client demand for adopting BIM are significant barriers to BIM adoption. Rakib *et al.* [7] determined that the BIM training for existing non-BIM professionals, efficiency of BIM software and cost are the most factors influencing the BIM adoption in all phases of construction projects in Bangladesh. Nasila & Cloete [8] studied the factors influencing the BIM adoption in the construction industry of Kenya and reported that high cost of buying and updating of software is the main barrier for the adoption of BIM in construction projects. Hatem *et al.* [9] reported that the lack of governmental initiative, resistance to change and poor knowledge on the advantages of BIM are the primary barriers for the adoption of BIM in construction projects of Iran. Wu *et al.* [10] reported that the capital-related factors and lack of owner support are the major barriers for the BIM implementation among the construction projects in China. Ahuja *et al.* [11] explained the status of BIM adoption in the Indian construction industry using the multi-level social construct. However, this study [11] does not report the barriers for BIM adoption. Ahuja *et al.* [12] studied the factors that affect BIM adoption among the Indian architectural firms. Hire *et al.* [13] reported that the absence of knowledge about the advantages of BIM, hesitance to learn the process and change from conventional techniques, absence of a national driver for BIM adoption, variation in BIM readiness among project teams and purchase of software are the significant barriers in the Indian construction industries with the aspect of site safety applications. Kolaric *et al.* [14] analysed the utilization of BIM in the Croatian construction industry and reported that the high cost of software and hardware, lack of consultant's assistance and inadequate BIM knowledge of civil engineers are barriers for the BIM adoption. An existing literature on the BIM adoption is very extensive; however, still some deficiencies exist. It is evident from the past studies that that they analysed the barriers of BIM adoption from a particular point of view. Although, the BIM has been introduced for a considerable time, the depth of its popularization is not enough in developing nations like India. Likewise, there is a lack of comprehensive research on barriers to BIM adoption in the Indian construction industry. In recent days, the Indian construction industry is facing various difficulties. The lack of guidelines and low utilization of technology are some of the shortcomings, as described by Planning Commission of the country. The Indian construction sector is confronted by numerous issues, including time overruns, cost overruns, misunderstanding among stakeholders and skill deficit. Generally, design in the construction sector has consistently depended on 2D drawing. Because of the complexity in design, construction and operation, this outdated technique is not viable any more. The projects often experience adversarial relationship, high inefficiency rate and low productivity rates resulting in increased cost and time overruns. BIM is expected to improve the circumstances for the betterment of project delivery. Despite the potential advantages of the BIM, its implementation rate was slow owing to various barriers. Therefore, a comprehensive and systematic analysis was conducted to determine the factors influencing BIM adoption in the Indian construction industry. Also, a fitness model was developed to discover the impact of various factors on adopting BIM tools for better interface management. Here, the OS, SQ, IQ, SRQ and U parameters over the US and NB are analysed. Then, the various benefits of the BIM in construction projects with the help of model fitness by attaining different metrics such as GFI, NFI (Normed Fit Index), AGFI (Adjusted Goodness of Fit Index), RMSEA (Root Mean Square Error of Approximation) and RMSR (Root Mean Square of Residuals) are analysed. Furthermore, the performance analyses of adoption of the BIM tools in the construction industries are performed.

The management of construction projects has become more complex and larger in scale owing to advances in technologies, work culture and operations. The projects are outsourced to numerous parties with different backgrounds and work-culture. Each party is answerable to develop one or more project components or systems. Although these systems and components have been developed independently, many share a standard interface. Therefore, proper integration is essential. Poorly managed interfaces result in several interfacial issues, such as coordination problems, design errors, system failures, and other construction conflicts. Interface management is the inspiration for organising a fancy project into various interface points, thus managing all the responsibilities, communication and coordination of the project. Lin Yu-Cheng [15] identified the utilisation of a BIM approach to reinforce construction interface management through a case study. This research aimed toward tracking and managing interface events using 3D interface maps integrated into BIM. In addition, the event of a BIM-based interface management system for engineers boosts interface information sharing and efficiency tracking in construction projects. The results indicate that the proposed Con BIM-IM system is an efficient and user-friendly platform for construction interface management, such that users can track and manage interfaces virtually.

2. Material and methodology

2.1. Information system success model

An ISS model (Information System Success Model) is an information system approach that explains the details of different dimensions of various success factors with the help of the evaluation by the information system. McLean and DeLone developed this method in 1992 [16]. The feedback of the system has been gradually improved by various researchers. The ISS model has been used in several research papers for contemporary analyses. Notably, in 2003, the authors McLean and William DeLone modified their old model and formulated an improved ISS model that focused on service quality, information quality and user satisfaction.

2.1.1. Organizational support

The organizational support represents support from the construction industry for BIM tool usage. Shang and Shen [17] presented an emerging Information Communication Technology (ICT) that enhances collaboration in various project extensions in BIM. The authors described the development of the Building Information Modelling accomplishment of association from technical, organizational support, process, and legal objectives, and identified the critical success factors (CSFs) of BIM based on recent releases. Ruoyu *et al.* [18] presented the BIM implementation scenario from developed countries to other developing countries as a global movement. The research roughly selected 94 Chinese BIM experts to examine BIM practice and its related concepts for performing the survey using the questionnaire method. Errors in design and consequent construction restoration were considered the best advantages of using BIM. Beliz and Karahan [19] investigated the CSFs of BIM implementation, identified 16 factors under five categories, and analysed BIM implementation based on project characteristics.

2.1.2. Information quality

Information quality (IQ) refers to the status of information, which means that the system can reserve, reform, and generate information. Evaluated using information systems, IQ is one of the furthermost mutual dimensions. IQ influences user satisfaction with the design and intentions of the user to customise the system. Davis [20] suggested that information technology explains perceived benefits, perceived comfort of practice, and user acceptance. The study proposed and confirmed new scales for two specific variables: perceived usefulness, ease of use of perceived and user approval. Magid *et al.* [21] developed an integrated conceptual model using a microcomputer approach. Using the technology acceptance model, they examined the influence of external factors on the user acceptance of microcomputer technology. Zuppa *et al.* [22] explained the shortcomings of many solutions in the construction industry and suggested building information modelling (BIM). This study proposed a broad definition of BIM through a survey of AEC experts by identifying the perceived effect of BIM on the success of building projects. BIM has been continuously perceived as a tool in the survey results for AEC work to remove errors and increase the productivity, safety, schedule, quality, and cost of construction projects. Papadonikolaki [23] researched BIM connected to the internal and intermediate organizational conditions of BIM operations. Based on this study, cross-cultural case sampling can be performed, which increases the global gains of traction. It is to be noted that the functionality of BIM is continuously transitioning.

2.1.3. System quality

In an information system, an organisation's overall quality is one of the most commonly evaluated dimensions, along with information quality. The system quality indirectly affects the extent to which the system can deliver benefits through intermediate relationships, use of intentions and user satisfaction structures. This paper proposes the development of CSFs for BIM adoption that can be further developed in the AEC industry. Seongah *et al.* [24] suggested the favourable conditions for AEC participants in Korea by assessing BIM. An effective BIM adoption strategy was developed by gathering the actual BIM user intentions for critical projects in the Korean AEC. AEC companies worldwide are still developing BIM to increase competition. Tsai *et al.* [25] presented a CSFs development method for evaluating BIM adoption.

2.1.4. Service quality

According to the quality of service, information systems can be provided along with the quality of the information and system. The application objectives and user satisfaction with the system are directly affected by the quality of service, which affects the net benefits of the system. Jiule *et al.* [26] presented the quality of information, system quality, and external services on the BIM satisfaction of the user. They explored the influence of these factors on BIM adoption. The main contributors to this work were the quality of information, top management support, and external services, which have an evocative influence on the BIM satisfaction of the user. Yaakob *et al.* [27] classified CSFs of BIM usage into four categories: technology, organisation, process and legal. The technology category showed the factors that included software and service compilations and various protection models for information and data.

2.1.5. User satisfaction

Information systems are directly related to the net benefits from user satisfaction. User satisfaction denotes the degree to which a user is happy or satisfied with an information system, and is instantly concocted by system usage. Structural equation modelling (SEM) with an acceptance model for BIM was proposed. Roky and Meriouh [28] formulated a user-evaluated industrial information system (XPPS) for IS success depending on the Mclean and Delone model. They tested that model through a quantitative study using data collected in a questionnaire, following a hypothetical-deductive method. Their study revealed that the response rate was less than 30 %, the number of responses was low, and the success of XPPS for a sub-evaluation. Seulki *et al.* [29] presented an acceptance of BIM in construction, and 114 questions were retrieved. The hidden meaning of non-significant hypotheses must be investigated by identifying the sub-factors of the hypotheses and sub-factor relationships.

2.1.6. Net benefits

The net benefits of an information system can provide a significant worth of the technology to its users or the base company. The net benefits of the system are concocted by its usage and user satisfaction with the system in the ISS success model. The benefits of the system are related to user satisfaction and the application of a user's purpose. Liao and Teo [30] analysed the adoption of BIM in construction projects in Singapore, and their CSFs were analysed. The main objective of this research is to identify the implementation of BIM by identifying critical success factors and exploring the relationship among the essential elements of success. Based on the research-specific activity for the enhancement of BIM implementation, evidence for PLS-SEM analysis, CSF groupings, and a project management team need to be identified. Memon *et al.* [31] presented a novel method for BIM for construction design. They described that BIM provides all essential information for any project before it is constructed and designed digitally. The low-rate value of the BIM process in the construction industry was revealed. Applications of BIM include improving schedules, drawing coordination, controlling time, cost reduction, and a single detailed model. The limitations of BIM include enhanced collaboration, which requires coordinated drawing and interoperability. Khosrowshahi and Arayici [32] presented a BIM implementation to create a road map for the construction industry in UK. They failed to clear something that prevented or simplified the enhancement of maturity, and the other side needed to streamline their work.

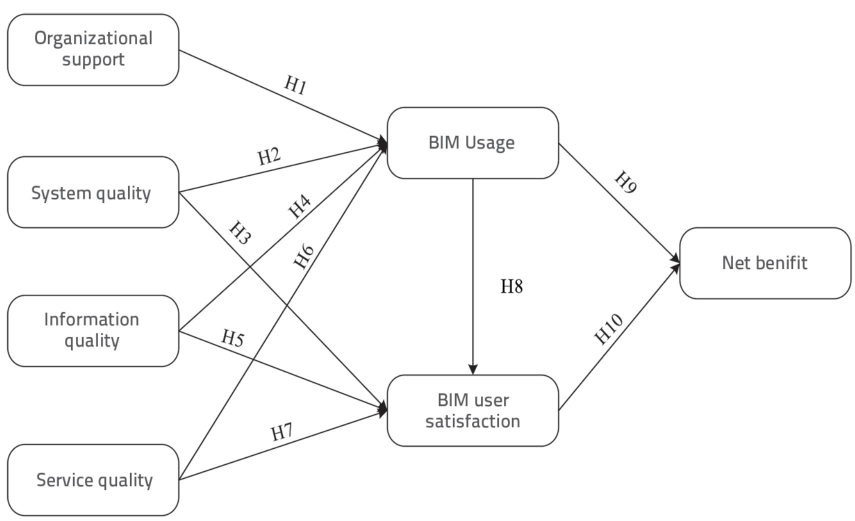

Figure 1. Hypothesis diagram of the proposed structural model

2.1.7. Usage

The purpose for which an information system is used and the usage of the existing system are well-determined structures in the information system literature. System usage and usage intention in the ISS Model are affected by information, organisation and quality of service. System usage is intended to affect user satisfaction with the information system and their usage intentions. Along with user satisfaction, system use directly affects the net benefits it can provide. Zhikun *et al.* [33] suggested that building adoption by architects by crucial factors in a Chinese study by giving increased attention to BIM through the benefits of various stages of building life cycles. This effectively simplifies the implementation of BIM. The main objective of this study is to consider the mechanism of BIM adoption by designers. The group stated the failure of their paper was that owing to time and resource limitations, only one AEC architect was selected as a research participant. Wang and Chien [34] presented the planning and scheduling of projects using BIM in the Australian construction industry. BIM has also been widely used to discover the most common purposes of utilising BIM tools for simulations, visualisations and progress tracking. It is easy to create and manage BIM models, cheap software, and better software. Improved management, interoperability enhancement, and facile user interaction are essential for improving project planning and scheduling efficiency using BIM tools. Ireneusz & Pękala [35] compared the traditional design with the design of the modern building information tools. They explained the definitive design history and development of civil engineering. The model was developed based on DeLone and McLean's updated ISS model [16]. However, the proposed framework depends on the organizational support, quality of service, system quality, information quality, user satisfaction, usage and net benefits of BIM. Based on the study by Jiule *et al.* [26], the role of the organisation and its support plays a vital role in the usage of BIM. Hence, organisational support was included in the model to identify the impact of OS on BIM usage. The conceptual framework of the factors affecting BIM user satisfaction and net benefits is shown in Figure 1.

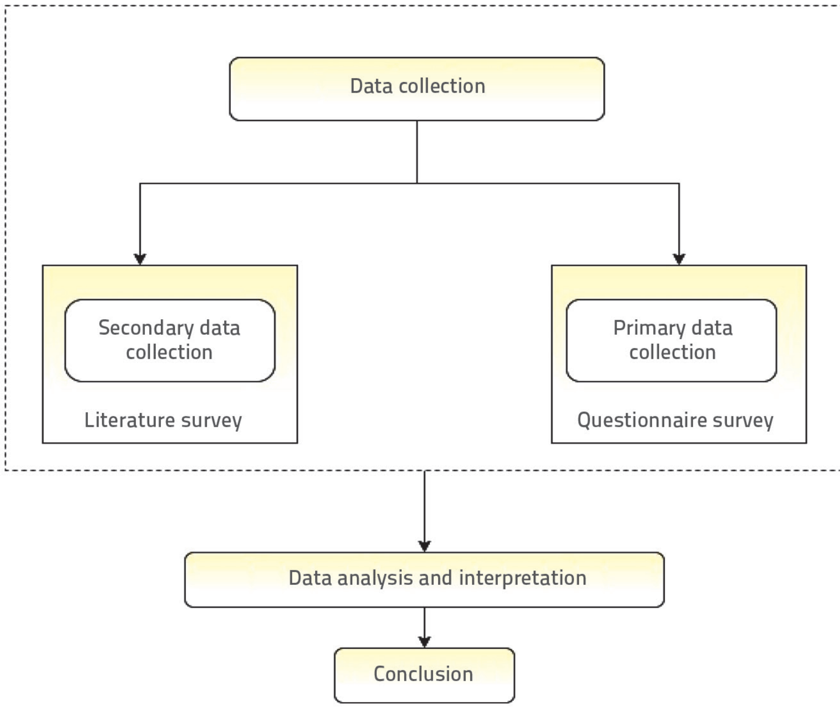

Figure 2. Methodology

2.2. Methodology

Figure 2 presents the methodology used in this study. The data were collected using primary and secondary data collection methods. A questionnaire-based survey was used to collect primary data, and the questionnaire was developed using published research articles such as those by Rouibah *et al.* [36], Memon *et al.* [37], Mom *et al.* [38], Lee *et al.* [39], Seongah *et al.* [24], Liao *et al.* [40], and Ozorhon & Karahan [41] as secondary data. First, the initial questionnaire was prepared based on factors such as Organizational Support (OS), System Quality (SQ), Information Quality (IQ), Service Quality (SRQ), BIM usage (U), BIM User Satisfaction (US), and the Net Benefit (NB) of BIM tools. The collected questionnaires were shortlisted and placed on the sheet to analyse the effectiveness of the BIM tools. This form contains four categories with respect to experience years: 1–3, 3–5, 5–10, and above ten years. The respondents included the client, contractor, consultant, architect, and others. BIM-based works are categorised as residential buildings, industrial buildings, Roads & Bridges, and Others. The number of projects that utilised BIM tools was classified as less than 10, 10–25, 26–50, and above 50. The choice of BIM tool was based on market pressure, future requirements, client interest and realisation of actual benefits. This form was shared with various construction industries based on individual visits and the Google form format was shared via email to collect their responses. Individual visits are applied to three companies: Studio Parametric, L&T and SPCL. These three organisations primarily utilise BIM 360, Revit and Navisworks as BIM tools for construction.

Table 1. Research hypothesis

Hypothesis	Definition
H1	Organizational Support will positively impact the BIM usage
H2	System quality will positively impact the BIM usage
H3	System quality will positively impact the BIM user satisfaction
H4	Information quality will positively impact the BIM usage
H5	Information quality will positively impact the BIM user satisfaction
H6	Service quality will positively impact the BIM usage
H7	Service quality will positively impact the BIM user satisfaction
H8	BIM usage will positively impact the BIM user satisfaction
H9	BIM usage will positively impact the net benefit
H10	BIM user satisfaction will positively impact the net benefit

36 construction companies responded by filling up the Google form. These construction industries utilise BIM tools such as Revit, Navisworks, sp3D, Modelling, Sketchup, Review, Virtual and Augmented reality, BIM 360, ArchiCAD and Tekla. A total of 257 responses were received from the individual visits and Google Forms. Of these 257 responses, 88 (34 %) were from individual visits, and 169 (66 %) were from Google Forms. ANOVA was used to analyse the variance between different variables. In the ANOVA, QS, SQ, IQ, SRQ and BIM U were the independent variables, and BIM US and NB were the dependent variables. The hypotheses investigated are shown in Table 1. The demographic characteristics of the respondents are shown in Table 2.

Table 2. Demography of the respondents

Variable	Category	Frequency	Percent
Destination	Contractor	188	73.2
	Consultant	24	9.3
	Consultant architect	19	7.4
	Architect	13	5.1
	Others	13	5.1
Experience	1-3	38	14.8
	3-5	61	23.7
	5-10	99	38.5
	above 10	59	23.0

2.2.1. Measurements

This section explains the measurements obtained from the questionnaire analysis and the scale of each factor. Here, factors such as OS, SQ, IQ, SRQ, U, US, and NB were estimated by utilising reflective indicators with five scale points: strongly disagree, disagree, neutral, agree, and strongly agree. Factors such as OS, SQ, IQ, SRQ, U, US, and NB contain one to five sub-factors which are denoted as OS1–4, SQ1–4, and others. The factor OS was developed based on the existing related work by Shang and Shen [17] and Ruoyu *et al.* [18]. The factor SQ was developed by Seongah *et al.* [24], and the related work by Davis *et al.* [20] was helpful in creating the factor IQ. Similarly, SRQ and BIM usage (U) elements were developed by Jiule *et al.* [26] and Wang and Chien [34]. BIM user satisfaction was obtained from the study by Seulki *et al.* [29]. Finally, the factor NB was taken from the related work by Liao and Teo [30], and the formed factors were altered to be applicable to the field of BIM adoption. The seven factors were constructed against the 0.4 thresholds and the element which qualified against the loading requirement was also investigated by utilising data from 257 valid questionnaire responses.

3. Results and discussions

3.1. Data analysis and results

The data analysis process was performed based on structural equation modelling with the help of AMOS. There is no assumption of data distribution and a small sample size, and the evaluation and hypothesis test is performed by utilising SPSS-AMOS. A total of 257 valid questionnaire responses were used for the data analysis process, gathered from individual visits and Google Forms.

Structural model goodness of fit analysis

The factors utilised for the proposed work were formed as a confirmatory factor analysis with the help of SPSS-AMOS and validated the goodness of fit of the structural model. Here, the integrity of the model fit is validated by seven standard model-fit measures: goodness-of-fit index (GFI), degrees of freedom (*df*), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), normalised fit index (NFI), root mean square error of approximation (RMSEA) and root mean square residual (RMSR). The recommended values for these model-fit measures and the model-fit values obtained are listed in Table 3.

Table 3. Model-fit values of the structural model

Model-fit measures	Recommended value	Structural model
X^2/df	≤ 3.00	1.224
GFI	≥ 0.90	0.906
AGFI	≥ 0.80	0.872
NFI	≥ 0.90	0.774
CFI	≥ 0.90	0.946
RMSR	≤ 0.10	0.036
RMSEA	≤ 0.08	0.03

The results obtained for the model-fit measures of the structural model achieved the recommended values, except for the NFI value. The recommended value for the NFI must be greater than 0.9, and the obtained value is 0.774. However, the structural model was a fit because other model-fit measures achieved their recommended values.

Convergent validity

Convergent validation was performed by determining the value of composite reliability (CR) and factor loading. The value of composite reliability for the validation of convergence must be above 0.7, and the average variance extracted (AVE) must be above 0.5. The obtained factor loadings, composite reliabilities, and t-values are listed in Table 4.

The obtained CR values are presented between 0.72 and 1.08, proving that the model has good convergent validity. Similarly, the AVE values are between 0.3 to 1.17 and the Factor OS is only obtained below 0.5 in AVE.

Table 4. Convergent validity of each construct and item

Construct and Item	Factor Loading	T Value	Composite Reliability (CR)	Average Variance Extracted (AVE)
Organizational support			0.72	0.30
OS1	0.427	69.019		
OS2	0.356	76.484		
OS3	0.305	82.684		
OS4	0.290	72.291		
System quality			0.99	0.97
SQ1	0.447	85.374		
SQ2	0.230	63.361		
SQ3	0.110	53.678		
SQ4	0.443	91.802		
Information quality			0.97	0.87
IQ1	0.549	77.328		
IQ2	0.591	88.291		
IQ3	0.484	91.518		
IQ4	0.496	84.308		
Service quality			0.95	0.84
SRQ1	0.515	76.816		
SRQ2	0.336	87.208		
SRQ3	0.414	87.174		
SRQ4	0.365	83.818		
BIM Usage			1.01	1.03
U1	0.475	88.248		
U2	0.395	79.621		
U3	0.288	80.980		
U4	0.492	84.198		
User satisfaction			1.08	1.17
US1	0.548	80.952		
US2	0.478	85.271		
US3	0.572	89.937		
US4	0.463	86.431		
Net benefit			1	1
NB1	0.490	81.970		
NB2	0.538	86.781		
NB3	0.505	91.871		
NB4	0.463	92.686		
NB5	0.375	89.085		

Discriminant validity

The discriminant validity of the latent constructs is examined by investigating the cross-loading values given in Table 5, and the correlations of the constructs are compared in Table 6.

From table 5, the dependent construct variables US-4 and NB5 have the highest mean values, and it is clear that the respondents accept user satisfaction (US4). Similarly, the independent construct variable OS3 has the highest mean value that attributes the necessary organizational support [17, 23].

IQ3 has the highest mean value, which indicates the necessary information quality of the data.

Table 5. Cross loading

Code	OS	SQ	IQ	SRQ	U	SAD	NB	Mean	Std. Deviation
OS1	0.26	-0.002	0.023	0.009	-0.014	0.01	0.026	3.83	0.89
OS2	0.176	-0.018	0.025	0.006	-0.01	0.011	0.014	3.88	0.81
OS3	0.089	-0.007	0.001	-0.014	-0.01	0	0.003	4.09	0.79
OS4	0.212	0.015	0.023	0.005	0.003	0.013	0.021	3.90	0.86
SQ1	-0.006	-0.029	0.026	0.128	-0.06	0.031	0.055	3.91	0.73
SQ2	0.087	0.014	-0.011	0.039	-0.021	0.003	0.011	3.86	0.98
SQ3	-0.035	0.002	0.008	0.016	0.01	0.002	0.006	3.58	1.07
SQ4	0.041	0.055	0.047	0.266	-0.073	0.083	0.065	3.98	0.70
IQ1	0.076	0.016	0.12	0.016	0.108	0.014	0.059	3.93	0.81
IQ2	0.055	0.02	0.136	0.017	0.127	0.019	0.064	3.96	0.72
IQ3	-0.041	0.005	0.046	-0.057	0.081	-0.013	0.009	4.07	0.71
IQ4	-0.021	0.048	0.073	0.001	0.101	0.014	0.01	4.01	0.76
SRQ1	-0.022	0.133	0.006	0.074	0.028	0.022	0.036	3.82	0.80
SRQ2	-0.006	0.096	0.029	0.056	0.042	0.018	0.033	3.93	0.72
SRQ3	-0.011	0.096	0.003	0.052	0.019	0.013	0.026	3.99	0.73
SRQ4	-0.011	0.054	0.012	0.006	0.032	-0.022	0.017	3.99	0.76
U1	-0.02	-0.074	0.091	0.058	-0.034	0.04	0.068	3.89	0.71
U2	-0.009	-0.068	0.079	0.043	-0.033	0.035	0.058	3.88	0.78
U3	0	-0.04	0.049	0.035	-0.022	0.022	0.039	4.07	0.80
U4	0.003	-0.05	0.064	0.05	-0.029	0.03	0.052	3.96	0.75
US1	0.041	0.137	0.096	0.116	0.137	0.093	-0.107	3.92	0.78
US2	0.005	0.02	0.009	0.003	0.024	0.068	0.092	3.97	0.75
US3	0.011	0.041	0.023	0.01	0.052	0.155	0.147	4.07	0.73
US4	0.005	0.023	0.011	0.008	0.025	0.053	0.065	4.14	0.77
NB1	0.006	0.02	0.016	0.002	0.03	0.124	0.045	4.03	0.79
NB2	0.015	0.048	0.036	0.029	0.056	0.125	0.001	3.99	0.74
NB3	0.014	0.047	0.035	0.028	0.055	0.123	0.001	4.09	0.71
NB4	0.015	0.051	0.038	0.031	0.06	0.133	0.001	4.10	0.71
NB5	0.017	0.042	0.035	0.027	0.055	0.145	0.024	4.12	0.74

Table 6. Correlation of each construct

Construct	OS	SQ	IQ	SRQ	U	SAD	NB
OS	1						
SQ	0.377	1					
IQ	0.504	0.825	1				
SRQ	0.332	1.371	0.792	1			
U	0.458	0.659	1.15	0.98	1		
SAD	0.412	0.89	0.76	0.761	0.947	1	
NB	0.48	1.021	0.903	0.895	1.102	1.159	1

From the above tables (Table 5 and 6), the pre-determined factor loading values were greater than the loading values of the other factors. Therefore, the discriminant value of the proposed model was derived.

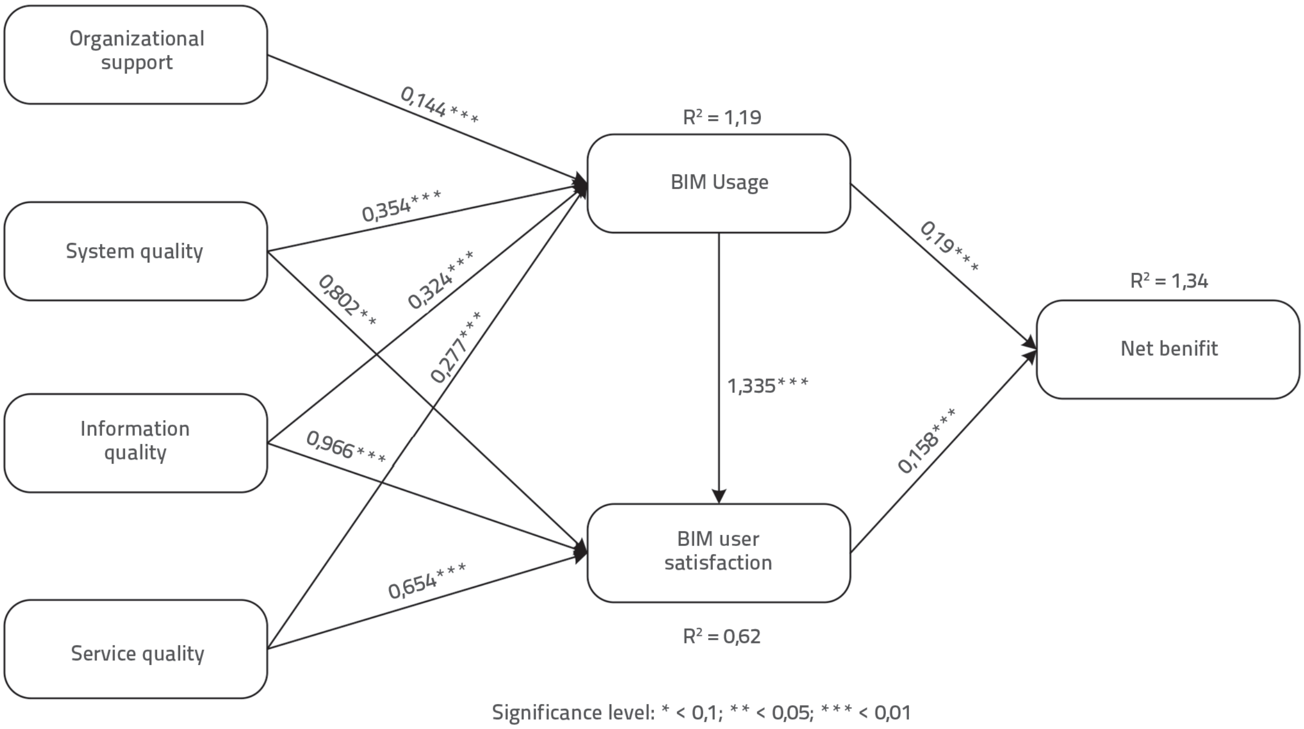

Figure 3. Results of Hypothesis testing

Table. 7 Obtained results for hypothesis testing

Relationship	Results			
	β - value	p - value	Hypothesis	Support
U < --- OS	0.144	0.000	H1	Yes
U < --- SQ	0.354	0.000	H2	Yes
U < --- IQ	0.324	0.000	H4	Yes
U < --- SRQ	0.277	0.000	H6	Yes
US < --- SQ	0.802	0.003	H3	Yes
US < --- IQ	0.966	0.000	H5	Yes
US < --- SRQ	0.654	0.000	H7	Yes
US < --- U	1.335	0.000	H8	Yes
NB < --- U	0.19	0.000	H9	Yes
NB < --- US	0.158	0.000	H10	Yes

Hypothesis testing

Hypothesis testing was analysed using SPSS-AMOS, and the obtained R^2 value for BIM Usage was 1.19, BIM user satisfaction was 0.62, and net benefit was 1.34. The hypothesis-testing results obtained from SPSS-AMOS are shown in figure 3. The obtained β-values and p-values are listed in Table 7.

The results show that all paths in hypothesis testing are significant. Figure 2 demonstrates that the impact of OS on U is mathematically significant ($\beta = 0.144$, $p < 0.01$), and this hypothesis supports the model. The impact of SQ on U was mathematically significant ($\beta = 0.354$, $p < 0.01$), and the impact of IQ on U was also mathematically significant ($\beta = 0.324$, $p < 0.01$). The impact of the SRQ on U was significant ($\beta = 0.277$, $p < 0.01$). Similarly, the impacts of SQ, IQ, and SRQ on US are significant, and the values are $\beta = 0.802$, $p < 0.05$, $\beta = 0.966$, $p < 0.01$, and $\beta = 0.654$; $p < 0.01$, respectively. The impact of U on the US and NB is also significant, with $\beta = 1.335$, $p < 0.01$, and $\beta = 0.19$; $p < 0.01$, respectively. Furthermore, the impact of the US on NB is significant ($\beta = 0.158$, $p < 0.01$), and all hypotheses (H1, H2, H3, H4, H5, H6, H7, H8, H9, and H10) support the structural model.

3.2. Discussions

From the analysis, OS, SQ, IQ, SRQ and BIM U played a significant role in BIM US and NB. Here, all factors significantly impact the dependent facets. SQ highly influences BIM U compared to OS, IQ and SRQ. This outcome was in line with Zhang *et al.* [42], who reported that system quality affects BIM U in construction organisations in China. For instance, utilising high-quality employees and selecting projects requiring BIM is helpful in enhancing the competitiveness of the organisation. It can further improve production efficiency, increase organizational income, and promote the BIM adoption process better and faster. BIM U highly affects BIM US compared to SQ, IQ and SRQ. This will increase the confidence in the application of US as a factor for BIM success. BIM U have both negative and positive effect on the user satisfaction [26, 43]. High user satisfaction may be accomplished with a high BIM U and low complexity. It was found that the effect of BIM U on NB was greater than that of BIM US on NB. Overall, BIM U strongly affects BIM user satisfaction and net benefit. It is demonstrated that the use of BIM software increases BIM user satisfaction and net benefits. Therefore, the proposed method for obtaining BIM usage strongly affects BIM user satisfaction and net benefit.

4. Conclusion

Demand for BIM and related software has gradually increased worldwide. The adoption of BIM is in the beginning stage in developing countries as compared to developed countries. In some countries, BIM implementation does not yet exist at the national level, whereas EU countries have been utilising BIM for more than 10 years. The growth rate of BIM adoption in India is much lower than that in Europe and other Western countries. Despite its positive effect on productivity, BIM adoption still experiences some barriers. This study analysed the factors influencing the adoption of BIM software in the construction industry using an extended model developed by Wang and Liao [44]. The factors affecting BIM software adoption were derived, and a background survey was conducted on the adoption of BIM software. The seven significant factors– organizational support, system quality, information quality, service quality, BIM usage, BIM user satisfaction, and net benefit– were considered and framed as questionnaires to validate user responses. Finally, 257 responses were collected from various construction industries through individual visits and the Google form. Based on these answers, confirmatory factor analysis was performed using SPSS-AMOS. The experimental results prove that users are satisfied with the adoption of BIM using the proposed model. From the final hypothesis results, we concluded that the usage of BIM strongly affects BIM user satisfaction and net benefit. These net benefits have a significant impact on the proper management of various interfaces in a project. Hence, the adoption of BIM significantly influences the interface management of construction projects for better project performance in terms of time, cost, quality, safety and productivity. The major limitation of this study is that the model was applicable only to the Indian context. Furthermore, this study will be extended to European and Western countries.

Acknowledgement

The author expresses sincere thanks to the Civil Engineering Department of Kumaraguru College of Technology for their support in completing this research.

REFERENCES

[1] Qingsheng, X., Zhou, X., Wang, J., Gao, X., Chen, X., Liu, C: Matching real-world facilities to building information modeling data using natural language processing, IEEE Access, 7 (2019), pp. 119465-119475, https://doi.org/10.1109/ACCESS.2019.2937219

[2] Cerić, A., Završki, I., Vukomanović, M., Ivić, I., Nahod, M.M.: BIM implementation in building maintenance management, Građevinar, 71 (2019) 10, pp. 889-900, https://doi.org/10.14256/JCE.2730.2019

[3] Sibenik, G., Kovacic, I., Petrinas, V., Sprenger, W., Bubalo, D., Ruzičić, N.: Automated preprocessing of building models for structural analysis, Građevinar, 74 (2022) 3, pp. 211-226, https://doi.org/10.14256/JCE.3259.2021

[4] Venkrbec, V., Galić, M., Klanšek, U.: Construction process optimisation – review of methods, tools and applications, Građevinar, 70 (2018) 7, pp. 593-606, https://doi.org/10.14256/JCE.1719.2016

[5] Ozturk, G.B.: Interoperability in building information modeling for AECO/FM industry, Automation in Construction,113 (2020), pp. 103122, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000505

[6] Hall, A.T., Durdyev, S., Koc, K., Ekmekcioglu, O., Tupenaite, L.: Multi-criteria analysis of barriers to building information modeling (BIM) adoption for SMEs in New Zealand construction industry, Engineering, Construction and Architectural Management, (ahead-of-print), 2022.

[7] Rakib, M.F.H., Howlader, S., Rahman, M.: Factors affecting the BIM adoption in the construction industry of Bangladesh, Goedert & Meadati, (2018), pp. 19-21

[8] Nasila, M., Cloete, C.: Adoption of Building Information Modelling in the construction industry in Kenya. Acta Structilia, 25 (2018) 2, pp.1-38

[9] Hatem, W.A., Abd, A.M., Abbas, N.N.: Barriers of adoption building information modeling (BIM) in construction projects of Iraq, Engineering Journal, 22 (2018) 2, pp. 59-81

[10] Wu, P., Jin, R., Xu, Y., Lin, F., Dong, Y., Pan, Z.: The analysis of barriers to BIM implementation for industrialized building construction: A China study, Journal of Civil Engineering and Management, 27 (2021) 1, pp. 1-13

[11] Ahuja, R., Jain, M., Sawhney, A., Arif, M.: Adoption of BIM by architectural firms in India: technology–organization–environment perspective, Architectural engineering and design management, 12 (2016) 4, pp. 311-330

[12] Ahuja, R., Sawhney, A., Jain, M., Arif, M., Rakshit, S.: Factors influencing BIM adoption in emerging markets–the case of India, International Journal of Construction Management, 20 (2020) 1, pp. 65-76

[13] Hire, S., Sandbhor, S., Ruikar, K., Amarnath, C.B.: BIM usage benefits and challenges for site safety application in Indian construction sector, Asian Journal of Civil Engineering, 22 (2021) 7, pp. 1249-1267

[14] Kolarić, S., Vukomanović, M., Bogdan, A.: Analysis of the use of BIM in Croatian construction industry, Građevinar, 72 (2020) 3, pp. 205-214, https://doi.org/10.14256/JCE.2774.2019

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

[16] DeLone, W.H., McLean, E.R.: Information systems success: The quest for the dependent variable, Information systems research, 3 (1992)1, pp. 60-95, https://doi.org/10.1287/isre.3.1.60

[17] Shang, Z., Zhigang S.: Critical success factors (CSFs) of BIM implementation for collaboration based on system analysis, Computing in Civil and Building Engineering, (2014), pp. 1441-1448, https://doi.org/10.1061/9780784413616.179

[18] Ruoyu, J., Hancock, C., Tang, L., Chen, C., Wanatowski, D. Yang, L.: Empirical study of BIM implementation–based perceptions among Chinese practitioners, Journal of management in engineering, 33 (2017) 5, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000538

[19] Beliz, O., Karahan, U.: Critical success factors of building information modeling implementation, Journal of management in engineering, 33 (2017) 3, pp. 04016054

[20] Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology, MIS quarterly, (1989), pp. 319-340, https://doi.org/10.2307/249008

[21] Magid, I. Guimaraes, T., Davis, G.B.: Testing the determinants of microcomputer usage via a structural equation model, Journal of management information systems, 11 (1995) 4, pp. 87-114, https://doi.org/10.1080/07421222.1995.11518061

[22] Zuppa, D., Issa, R.R., Suermann, P.C.: BIM's impact on the success measures of construction projects, Computing in Civil Engineering, (2009), pp. 503-512, https://doi.org/10.1061/41052(346)50.

[23] Papadonikolaki, E.: Loosely coupled systems of innovation: Aligning BIM adoption with implementation in Dutch construction, Journal of management in engineering, 34 (2018) 6, pp. 05018009, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000644

[24] Seongah, K., Park, C.H., Chin, S.: Assessment of BIM acceptance degree of Korean AEC participants, KSCE Journal of civil engineering, 20 (2016) 4, pp. 1163-1177, https://doi.org/10.1007/s12205-015-0647-y

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

[26] Jiule, S., Migliaccio, G.C., Wang, G., Lu, H.: Exploring the influence of system quality, information quality, and external service on BIM user satisfaction, Journal of Management in Engineering, 33 (2017) 6, pp. 04017036, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000549

[27] Mazri, Y., Wan Ali, W.N.A., Radzuan, K.: Identifying critical success factors (CSFs) of implementing building information modeling (BIM) in Malaysian construction industry, AIP Conference Proceedings, 1761 (2016) 1, pp. 020105, https://doi.org/10.1063/1.4960945

[28] Hanae, R., Al Meriouh, Y.: Evaluation by users of an industrial information system (XPPS) based on the DeLone and McLean model for IS success, Procedia Economics and Finance, 26 (2015), pp. 903-913, https://doi.org/10.1016/S2212-5671(15)00903-X

[29] Seulki, L., Yu,J., Jeong, D.: BIM acceptance model in construction organizations, Journal of management in engineering, 31 (2015) 3, pp. 04014048, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000252

[30] Longhui, L., Teo, E.A.L.: Critical success factors for enhancing the building information modelling implementation in building projects in Singapore, Journal of Civil Engineering and Management, 23 (2017) 8, pp. 1029-1044, https://doi.org/10.3846/13923730.2017.1374300

[31] Memon, A.H., Rahman, I.A., Memon, I., Aqilah Azman, N.I.: BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level, Research Journal of Applied Sciences, Engineering and Technology, 5 (2014), pp. 606-614

[32] Khosrowshahi, F., Arayici, Y.: Roadmap for implementation of BIM in the UK construction industry, Engineering, construction and architectural management, 19 (2012) 6, pp. 610–635, https://doi.org/10.1108/09699981211277531

[33] Zhikun, D., Zuo, J., Wu,J., Wang, J.Y.: Key factors for the BIM adoption by architects: A China study, Engineering, Construction and Architectural Management, 22 (2015) 6, pp. 732–748, https://doi.org/10.1108/ECAM-04-2015-0053

[34] Wang, C.C., Chien, O.: The use of BIM in project planning and scheduling in the Australian construction industry, Proceedings of the ICCREM 2014: Smart Construction and Management in the Context of New Technology, 2014., pp. 126-133, https://doi.org/10.1061/9780784413777.015

[35] Ireneusz, C., Pękala, A.: Traditional design versus BIM based design, Procedia Engineering, 91 (2014), pp. 210-215, https://doi.org/10.1016/j.proeng.2014.12.048

[36] Rouibah, K., Hamdy, H.I., Al-Enezi, M.Z.: Effect of management support, training, and user involvement on system usage and satisfaction in Kuwait, Industrial Management & Data Systems, 2009.

[37] Memon, A.H., Rahman, I.A., Memon, I., Azman, N.I.A.: BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level, Research Journal of Applied Sciences, Engineering and Technology, 8 (2014) 5, pp. 606-614

[38] Mom, M., Tsai, M.H., Hsieh, S.H.: Developing critical success factors for the assessment of BIM technology adoption, Part II.: Analysis and results, Journal of the Chinese Institute of Engineers, 37 (2014) 7, pp. 859-86

[39] Lee, S., Yu, J., Jeong, D.: BIM acceptance model in construction organizations, Journal of management in engineering, 31 (2015) 3, pp. 04014048.

[40] Liao, L., Teo, E.A.L.: Critical success factors for enhancing the building information modelling implementation in building projects in Singapore. Journal of Civil Engineering and Management, 23 (2017) 8, pp. 1029-1044

[41] Ozorhon, B., Karahan, U.: Critical success factors of building information modeling implementation, Journal of management in engineering, 33 (2017) 3, pp. 04016054.

[42] Zhang, R., Tang, Y., Wang, L., Wang, Z.: Factors influencing BIM adoption for construction enterprises in China, Advances in Civil Engineering, 2020.

[43] Bryde, D., Broquetas, M., Volm, J.M.: The project benefits of building information modelling (BIM), International journal of project management, 31 (2013) 7, pp. 971-980

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

[45] Vigneshwar, R.V.K., Shanmugapriya, S., Sindhu Vaardini, U.: Analyzing the Driving Factors of BIM Adoption Based on the Perception of the Practitioners in Indian Construction Projects, Iran J Sci Technol Trans Civ Eng, 46 (2022), pp. 2637–2648 https://doi.org/10.1007/s40996-022-00834-9

APPENDIX: Obrazac korišten u istraživanju

SECTION-1

1. Name of organization:
Dr/Mr/Mrs:

2. Designation of respondents:
- ○ Client
- ○ Contractor
- ○ Consultant
- ○ Architect
- ○ Others

3. Working Experience (in years)
- ○ 1-3
- ○ 3-5
- ○ 5-10
- ○ >10

4. Name of BIM software used:

5. Types of the work done using BIM:
- ○ Residential building
- ○ Roads & Bridges
- ○ Industrial building
- ○ Others

6. Number of project executed using BIM so for (in years)
- ○ Manje od 10
- ○ 10-25
- ○ 26-50
- ○ Above 50

7. Choice of BIM based on:
- ○ Market pressure
- ○ Client interest
- ○ Future requirement
- ○ Realizing actual benefits

SECTION-2

FACTORS INFLUENCING ADOPTION AND IMPLEMENTATION OF BIM

Please indicate the significance of each factor by selecting the appropriate boxes. Add any remarks relating to each factor in the last column, for example, for reasons, critical factors, or solutions.

SD - strongly disagree
D - disagree
N - neutral
A - agree
SA - strongly agree.

MAIN FACTORS	ID	SUB FACTORS	SD	D	N	A	SA
ORGANISATIONAL SUPPORT [OS]	How do you personally agree with the influence of ORGANISATIONAL SUPPORT for the adoption of BIM in construction projects?						
	OS1	Our organization is aware of the benefits of implementation BIM tools in the project phases					
	OS2	Our organization provides education and training on BIM software					
	OS3	Our organization encourages and motivates us in utilizing the BIM software in all the phases of the					
	OS4	project					
SYSTEM QUALITY [SQ]	How do you personally agree with the influence of SYSTEM QUALITY for the adoption of BIM in construction projects?						
	SQ1	BIM software provides accurate and definite output of the project data					
	SQ2	BIM provides a well-structured and an user friendly interface for the people under various disciplines					
	SQ3	BIM software can be easily integrated with the existing software in our organization					
	SQ4	BIM tools are stable and acceptable					
INFORMATION QUALTIY [IQ]	How do you personally agree with the influence of INFORMATION QUALTIY of the organization for the adoption of BIM in construction projects?						
	IQ1	BIM provides secured information sharing among our project participants					
	IQ2	The information presented by BIM is accurate and efficient.					
	IQ3	BIM utilization improves information accessibility					
	IQ4	BIM software helps in better understanding of the activities of the project by providing necessary					
SERVICE QUALITY (SRQ)	How do you personally agree with the influence of SERVICE QUALITY of the vendors offering BIM services?						
	SRQ1	Maintenance and up-gradation is provided by software vendors whenever necessary					
	SRQ2	Quick response is offered by the software vendors whenever required					
	SRQ3	The staff of technical support for the BIM software is empowered to resolve user problems					
	SRQ4	The staff of technical support for the BIM software is available when I need it.					
USE (U)	How do you personally agree with the USE of BIM software in construction projects?						
	U1	I use BIM software for planning and scheduling for project phasing simulations					
	U2	I use BIM software for designing and drafting for easy visualization of the existing model					
	U3	I use BIM software for costing and estimation for better quantity extraction					
	U4	I use the documents and drawings obtained from the BIM software for better IM throughout the project life cycle					
USER SATISFACTION (US)	How do you personally agree with YOUR SATISFACTION of BIM software in construction projects?						
	US1	I am satisfied with task processing speed and accuracy of BIM					
	US2	I am satisfied with the Decision making process throughout the project					
	US3	I am satisfied with the outcomes accomplished by BIM and it is better than expected					
	US4	I am satisfied with the systematic management of the information and high quality documentation of the project					
NET BENEFITS (NB)	How do you personally agree with the NET BENEFITS of BIM software for enhancing the interface management in construction projects?						
	NB1	Overall improvement in project performance (in terms of time, cost, safety and quality) is enhanced throughout the project life cycle					
	NB2	Effective communication and co-ordination among the stakeholders is established					
	NB3	Clash detection and resolution throughout the project life cycle is achieved					
	NB4	3D Visualization and Walkthrough for better understanding of the project design is framed					
	NB5	Effective action to risks in the project is developed					