BIM usage benefits and challenges for site safety application in Indian construction sector

Shalaka Hire¹ · Sayali Sandbhor¹ · Kirti Ruikar² · C. B. Amarnath³

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Abstract

Construction industry is highly exposed to accidents than other industries. Due to the multi-disciplinary nature of the construction industry, more than one task is required to be performed at the same time. If safety planning is improper, it may lead to serious accidents on-site, directly affecting overall productivity. Recent technologies such as Building Information Modeling (BIM) have the potential to manage safety on the construction site. This study deals with the status check of the awareness of BIM in Indian construction along with benefits, barriers faced in Indian construction. This study also presents the benefits that BIM implementation can bring for safety management. In this study, a questionnaire was designed to ascertain the level of awareness of BIM in the Indian construction industry. The questionnaire was distributed to construction professionals from all over India. A total of 171 valid responses were received from all the corners of India. Statistical Package for the Social Sciences analysis (SPSS) has been used for data analysis. The survey concludes that the Indian construction sector needs to work on the three main aspects that include awareness of BIM and its benefits for organizations, accumulation of BIM in the tertiary education system, and delivering corporate training in construction organizations for a successful realization of benefits by the implementation of BIM.

Keywords Building information modeling (BIM) · Indian construction industry · Construction safety planning · Benefits of BIM · Barriers

Introduction

The importance of the Indian construction industry to the Indian economy and the socio-economic growth of the country is significant. As after agriculture, the Indian construction industry is the second largest industry (Planning

Commission Government of India, 2013). The sector is labor-intensive and, including indirect jobs, employs a large number of people. India is going through significant urbanization and economic growth. Being the largest industry, proper management of all the construction activities including planning, scheduling, drawings, and information management is significantly necessary. Indian construction organizations need to overcome these problems, which will require construction firms to implement new and successful design, coordination, and documentation techniques. Building Information Modeling (BIM) is one of the widely used techniques in construction projects globally. BIM is one of the most promising developments in the Architecture, Engineering, Construction, and Operation (AECO) industries (Eastman et al., 2008). BIM refers to the digital representation of structure along with information management and information sharing with different stakeholders involved in the construction project. BIM has various dimensions and an associated set of functionalities contained within each dimension (Hire et al., 2021a, 2021b). These functions mainly include visualization, scheduling, cost

✉ Shalaka Hire
shalaka.hire@sitpune.edu.in
Sayali Sandbhor
sayali.sandbhor@sitpune.edu.in
Kirti Ruikar
K.D.Ruikar@lboro.ac.uk
C. B. Amarnath
amarnathcb@Intecc.com

¹ Civil Engineering Department, Symbiosis Institute of Technology (SIT), Symbiosis International (Deemed University) (SIU), Pune, India

² School of Architecture, Building and Civil Engineering, Loughborough University, Leicestershire, UK

³ Head-BIM Strategy, L&T Construction, HQ Chennai, India

management, energy management, facility management, and safety management (level 3D–8D) (Eastman et al., 2008). Despite knowing the potentials of BIM, its benefits are not fully explored by Indian construction firms (Ahuja et al., 2020). One of the major applications of BIM is safety management. The construction industry has a negative rep for its health and safety record, in comparison to other industries (Muzafar, 2020). Traditional strategies are labor-intensive, often time-consuming, and rely on the expertise of those involved in safety planning. BIM has started to be adopted by the global industry to assist with the development of safety protocols to mitigate these inefficiencies. Hence, this study deals with ascertaining the current status of BIM usage in India alongside an array of BIM for construction safety in particular through a questionnaire survey. This research would significantly contribute to the enhancement of knowledge about the integrated digital project management applied in infrastructure projects and will open doors for future research.

The section “[Literature review](#)” gives an overview of past surveys conducted in India by various authors and presents the key findings. This section also includes an estimate of the construction accidents given in existing research. The section “[Research Methodology](#)” describes the methodology adopted for the survey. It then discusses the design and theme of the section “[Questionnaire survey](#)”. It also includes sampling methods adopted and details of respondents. The analysis of responses in the form of results is described in the section “[Data analysis of results](#)”. The section “[Result and Discussion](#)” brings these strands together and includes an overview of the study. It also suggests future applications. Finally, the conclusion and future research directions are highlighted in the section “[Conclusion](#)”.

Literature review

The notion of BIM came from Professor Charles Eastman at the Georgia Tech School of Architecture at the end of 1970 (Latiffi et al., 2013). It has broadened in wide perspectives since its development. The development of BIM definitions which were developed based on the computer programs from 1975 to 2013 is studied (Latiffi et al., 2014). Researchers have defined BIM in different ways such as “a systematic process for managing and disseminating holistic information generated throughout the development and operation of building design” (Gerrish et al., 2017). BIM has its applicability that spans over the entire life cycle of a facility. Different construction phases can be procured with the utilization of BIM, such as stages of programming, design, pre-construction, development, and post-construction operations and maintenance. In the programming phase, BIM enables the project team to

evaluate space and appreciate the complexities of space standards and land legislation, saving time and allowing the team the ability to do more value-added activities. Besides, BIM advocacy can be found in various phases of project design, namely schematic design, detailed design, and detailed construction. BIM has the application of estimation, site coordination, and constructability analysis, in the pre-construction stage. Using 4D phase plans, trade planning meetings, change orders, and punch list details in the BIM models, BIM in the construction phase will track project progress. BIM is a single repository with total project data and these data can be leveraged by facility managers for downstream usage, thereby making operations and facility maintenance more effective (Azhar et al., 2012). Benefits of BIM or factors that affect BIM adoption, such as increasing teamwork within project teams to increase profitability, reduce costs, improve time management, and strengthen customer–customer relationships (Azhar, 2011), increase productivity and performance in the same way, and maintain synchronization of coordination are also identified by many researchers around the globe. This section overviews the past research on BIM especially the survey-based studies and their key findings are noted down to identify the gap and scope for future studies.

Looking at its benefits, countries such as Norway and Austria have open BIM standards. Countries such as the United States of America (USA), United Kingdom (UK), Singapore, Finland, Sweden, Russia, Denmark, Australia, Korea, and Dubai are leading in BIM adoption and exist with BIM mandates by their government for construction practices (Shimonti, 2018). Some countries are planning for mandates in near future. On the other hand, in some countries such as India, adoption of BIM is gradually increasing. Many researchers identified the challenges and obstacles for the effective adoption of BIM and clarify its mechanism (Hartmann et al., 2012). To date, some surveys on BIM adoption status, awareness status is conducted. Table 1 shows the BIM surveys conducted in India (limited to the Scopus database) and the key findings of the surveys. It can be stated that there is a significant growth of BIM surveys during 2009 and 2020.

India BIM Association (IBIMA)—the national society created to support the digital transformation of the Indian AECO Sector—has also surveyed BIM implementation in India. For the year 2022, it shows that improved productivity through interoperability, rising concern about energy and performance, and government mandates for BIM will be the top impacting factors for 2022. It also notes that the Indian population demography is that 65% of the population is below the age group of 35 years and half of the Indian population is around the age group of 35 years which represents India as an amazing young country. It is a good sign

Table 1 Number of BIM surveys in India

Year of survey	Authors	Key findings
2009	Kumar and Mukherjee (2009)	Focused on the scope of BIM in India and identified barriers to integrating BIM into their businesses. Barriers are: Difficulty of BIM, the inertia of pursuing emerging technologies, the absence of consumer and contractor support, the inability to reform conventional practice, and the confusion about the BIM framework
2013	Sawhney et al. (2014)	Presented the State of BIM adoption and outlook in India with drivers and barriers to the use of BIM in India. This study clarified that BIM's full scope for Indian construction projects has not yet been explored. A national BIM education and research agenda is needed
	Sawhney and Singhal (2014)	Reports that the use of BIM is still in its evolving phase and its implementation is facing major headwinds. Lack of knowledge among these experts and lack of rewards for adoption encouragement. To ensure the development of a strong value for the construction industry, a national BIM education and research agenda is needed
2014	Mathews et al., (2014)	Focused on the importance of an approach to system dynamics in understanding the implementation of information technology in construction projects
2016	Kushwaha and Adhikari (2016)	It addresses the adoption of knowledge building modeling in India in 2016 and the need for further implementation, noting that India must put into practice its globally recognized leadership in information and communication technology. If taken, BIM can do wonders for the AEC sector as a collaborative strategy for government and private sector businesses as well as for the Indian economy
2017	Sreelakshmi et al., (2017)	A report on the obstacles to the implementation of building knowledge modeling was conducted, exposing hurdles such as the cost of BIM implementation, high initial investments, fear of low performance, lack of top-level management support or senior leadership support, cost of implementation highly affect the BIM implementation in India
2018	Arunkumar et al., (2018)	A survey held in 2018 explored the feasibility study on the implementation of BIM from the architecture and engineer's perspective
2019	Charlesraj and Gupta (2019)	Analysis of the perceptions of beneficiaries and intermediaries on implementing Integrated Project Delivery (IPD) is carried out in Indian construction, which examines the adoption of IPD in Indian construction due to the challenges faced by different stakeholders in its formative stage
	Amarnath (2020)	India BIM Association (IBIMA)—the national society created to support the digital transformation of the Indian AECO Sector has also surveyed BIM implementation in India. For the year 2022, it shows that improved productivity through interoperability, rising concern about energy and performance, and government mandates for BIM will be the top impacting factors for 2022. It also notes that the Indian population demography is that 65 percent of the population is below the age group of 35 years and half of the Indian population is around the age group of 35 years which represents India as an amazing young country. It is a good sign that the rest of the world is aging, and we have more prospective people ready to work and improve the world who are active and dynamic young people
	Jagadeesh et al. (2019)	Investigation of BIM Adoption in India explored the current status of BIM adoption in India by the AEC and how it is implemented, and the challenges faced by BIM users, as well as indicating that government agencies need to modernize their legacy system and integrate BIM technology into their procurement processes and contracts
2020	Ahuja et al., (2020)	The study explored the factors impacting BIM adoption in India's emerging markets
	Pakhale and Pal (2020)	The Indian government has used BIM for a case study of the Nagpur Metro Rail Project. The aim of the infrastructure project is digital project management. It notes that all processes are incorporated into a 5D BIM-based digital project management framework, enhancing project productivity and effectiveness, right from design to operation and maintenance level

that the rest of the world is aging and we have more prospective people ready to work and improve the world who are active and dynamic young people (Amarnath, 2020).

It can be stated that researchers in India are actively working on implementing BIM in India and conducting BIM adoption surveys, in various areas of BIM application. Most of the surveys talk about the awareness of BIM, benefits of BIM, and barriers to adoption of BIM. It is also observed that there is a lack of survey data that mainly focus on BIM adoption

for safety in particular. This study not only focuses on BIM awareness but also deals with the benefits that BIM brings for safety management on construction sites. It explores the use of BIM for safety management. India is at a primitive stage of BIM adoption. For adopting any new process or technology, its awareness is essential. The initial part of this study focuses on awareness of BIM in the Indian construction industry along with its benefits and barriers to adoption. Furthermore, this study investigates current safety practices in Indian

construction, and moves towards the applicability of BIM for safety management and its possible future use.

Need of study

The Indian construction industry has undergone a steady decline in its labor productivity (India Ratings and Research, 2020). One of the major factors affecting productivity is labor safety (Gopal and Murali, 2016). As labors are involved in most of the activities and they have to deal with working at heights, handling heavy types of machinery, among other hazardous practices, so the risks of accidents are more. Also, planning construction site spaces to provide for safe and convenient working conditions is a multi-disciplinary and complex process that requires consideration of a wide range of circumstances (Kaveh & Vazirinia, 2019). Negligence of safety management can cause death, as well. Traditional safety practices involve the use of safety checklists, safety training, and safety audits. Somehow, these methods are not sufficient as the accident rate is still increasing. Occupational Safety and Health Administration (OSHA) in 2018 estimated that falling hazards are the leading cause of injury at building sites. About 48,000 workers in India die from work-related accidents, 38 of which occur every day in the construction sector (Indian Express, 2019). The minimum number of people who died annually in the construction sector in India between 2008 and 2012 was 11,614 (Patel & Jha, 2016). In the construction industry, the reduction of labor productivity requires more labor hours per contract number. This indicates that the building industry lacks the production of ideas to save labor (Marefat et al., 2019). This shows that traditional safety practices are not alone sufficient and there is a need for advanced safety management.

Based on the Scopus database, research on the adoption of BIM for safety are widely available in countries such as USA, China, UK, Australia, Germany, South Korea, and Italy. In contrast, research in India in this area is still in its infancy. India has adopted BIM, majorly for model development, 2D or 3D documentation services, and has not fully explored its potential for construction safety planning. Along with the awareness of BIM, this study focuses on the adoption of BIM for safety. It studies the current safety practices in Indian construction with a questionnaire survey. The next section explains the methodology employed for conducting the questionnaire survey.

Research methodology

BIM is transforming the global construction industry. Its effective applications are leading to its wider adoption. This survey deals with the adoption of BIM in India. Considering

the safety status of Indian construction sites, accident rates are still increasing. Hence, this study also focuses on BIM benefits for safety. This study is conducted to ascertain the level of awareness of BIM along with identifying the overall barriers, benefits, and benefits for safety in particular. The survey would help in understanding the current use of BIM, the benefits of using BIM, barriers to its adoption, its potential future use, and readiness of the construction project stakeholders in executing projects using BIM. Given that this research is a part of a wider research study that examines BIM adoption for site safety, the focus of the survey has also been on understanding current safety practices and exploring BIM benefits for safety management. These barriers and benefits are identified using an extensive literature survey. Furthermore, based on the literature survey and discussion with the experts, a questionnaire was designed and circulated among construction professionals all over India. Various online platforms have been used for conducting the survey. The next part of the methodology was to analyze the responses. As the questionnaire consisted of subjective and objective questions, descriptive statistics, and percentage statistics were used for analysis. An analysis of the responses gave an insight into the potential of BIM for safety management. The following section explains the design of the questionnaire in detail.

Questionnaire survey

A questionnaire is a study tool consisting of a set of questions to collect respondent data. It is a successful way to collect a large volume of data from a large range of individuals. Due to the familiarity with the current situation of the construction sector such as the status, need of the construction industry, construction professionals are the best suitable for responding to this survey. This survey brings out the opinion of Indian construction professionals about the use of BIM in India as well as safety practices with the use of BIM for safety in particular through questionnaires. In this study, respondents not only have special positions in their responses that are important to the study but also their respective voices are central to the evolution and results of the study. In this survey, a questionnaire was sent across all the corners of India to get responses from the construction professionals.

Design of questionnaire

The basis of designing the questionnaire is to analyze the current state art of BIM usage in India in general and the application of BIM in construction safety in particular. All the preliminary studies such as literature survey, type of questions (qualitative/quantitative) are studied for designing

the questionnaire. The questionnaire was designed with some themes to maintain the flow of the survey and for ease of understanding of respondents. The themes of the questionnaire are explained in the following section.

Questionnaire themes

A total of 6 themes are designed in the questionnaire, which is nothing but six different sections (Fig. 1). It initiates from basics and then moves towards technical and visionary themes. The first section of the survey deals with an introduction to the survey with its aim and personal details of respondents. This section discusses a brief survey with the surveyor's prologue. Also, as the survey was conducted all over India, it was necessary to know the demographical details of respondents and it helps to select valid responses.

The actual questionnaire concerning BIM commences with the second section which focuses on awareness and readiness of adoption of BIM. This section is included with the perspective of BIM awareness in India, or to know whether people from the construction industry are familiar with BIM or not. It also includes various use of various BIM-based software, the purpose of its adoption. Furthermore, the third section focuses on the benefits of BIM. BIM furnishes several benefits; however, which benefits are most appreciated are identified in this section. Fourth section deals with barriers faced by Indian construction organizations in adopting BIM. This section is included to identify the topmost barriers Indian construction is facing, so that focus can be given on them to enlarge its adoption. The fifth section deals with safety management and BIM. This section has two components. First, it deals with current safety practices in India, and second, it focuses on the benefits of BIM for safety management. This section is included to ascertain current safety management methods

and move towards identifying how BIM is beneficial in safety management. Finally, the sixth section focuses on the future scope and vision towards BIM in India. All these sections are explained in section data analysis and discussion of results.

Design of theme-wise questions

The questionnaire was combined with subjective and objective questions. Some of the sections were designed with an objective question comprised of Yes/No type questions or multiple-choice questions such as benefits/barriers of BIM and they are analyzed using descriptive statistics. Objective questions were designed using the Likert scale technique. The format of a typical level Likert item use for survey analysis is as follows:

- 0: Not Applicable/ Non-BIM User/ Unsure.
- 1: Strongly Disagree.
- 2: Disagree.
- 3: Neutral.
- 4: Agree.
- 5: Strongly Agree.

Based on this scale, respondents were asked to give their responses to objective questions. In this study, SPSS software is used for data analysis. It involves 3 main steps, starting with data collection and organization followed by data output file creation, and finally, statistical tests. All associated outputs are displayed in the output file. For subjective questions, respondents were asked to give in descriptive answers. Along with this, respondents were also given the freedom for sharing their views in each section of the questionnaire.

Fig. 1 Sequential sections of the questionnaire survey

Conduction of survey

Once after designing the survey, the very important task is to survey the selected location to collect appropriate responses. It is also important to consider the time required to reach the desired number of responses. This survey was live for 2 months to reach the desired number of responses. Details of sampling are explained in the section below.

Sampling technique and sample collection

The sampling technique adopted for this survey is judgmental sampling is often referred to as selective or subjective sampling, which relies on the researcher's discretion when determining who to ask to participate. The target groups were construction professionals such as owners of construction firms, project managers, deputy managers, and also BIM professionals such as BIM coordinators and BIM designers. The survey is conducted in the period of the COVID19 pandemic, due to which it was conducted via online mode. Various online platforms such as LinkedIn, emails, and Whatsapp were used for disseminating the questionnaire and connecting to representatives from all corners of India. Details of respondents are broadly explained in the following section.

Details of respondents

An India-wide online questionnaire survey was conducted. The questionnaire was sent out to 3254 experts via online mode. A total of 193 responses culminated in the initial and follow-up questionnaire requests. Out of these 193 responses, some responses were marked as invalid and eliminated due to missing data and discrepancy of answers, and hence, the total of 171 valid responses was eventually analyzed. The geographic details of respondents are illustrated in Fig. 2. The size of the bubble is proportionate to the number of responses. Bigger size bubbles denote a maximum number of responses received and smaller size bubbles represent the minimum number of responses. Out of 171 responses, the maximum responses were from Maharashtra. States such as Karnataka, Chennai, Delhi, and Kerala have also responded significantly. It can be said that the highest number of respondents is from Western India, followed by South India. Furthermore, Central India also has good respondents. It is observed that the very least number of the responses are received from Northern and Eastern India.

The majority of the respondents' designation belongs to BIM Professionals with 47.95%. The experience of the respondents is ranging from 0 to 35 years. The majority of the respondents' experience belongs to 10–20 years with 30.99%. This indicates that most respondents had a holistic view of the construction industry in India, as most of the

respondents had over 10 years of experience. The respondent's education level mainly includes 12.28% of diploma, 57.30% of engineering, 30.40% of master's degree, and 1% of doctorate level. The majority of the respondent's education belongs to a bachelor's level of 87%. From the findings and the current situation in the Indian AECO industry, it is evident that the Indian AECO industry is less focused on research-oriented BIM implementation. More and more innovative thinking and R&D work in the Indian AECO industry will help the development of the Indian construction sector. Working within this direction is very important for the Indian industry and academia. The demographical profile details of the respondents are discussed in Table 2.

Data analysis and discussion of results

Data analysis is carried out for a total of 171 valid responses. The questionnaire was consisting of subjective and objective types of questions. Analysis of each question of each section is carried out and discussed in depth below: The following section explains the third section of the questionnaire which is about BIM awareness and readiness.

BIM awareness and readiness

Awareness is fundamental for the adoption of any change. Before understanding the benefits and barriers, it is necessary to know about the awareness level of BIM in India. This section deals with the awareness and readiness of BIM in the Indian construction industry. The survey was initiated with questions regarding awareness of BIM. The survey reveals that 94% of respondents are aware of BIM, whereas 6% are not aware (Fig. 3a). The 2019 survey revealed that only 18% of respondents were aware of and using BIM, while 50% of experts were aware of BIM but did not use it (Jagadeesh et al., 2019). This shows that the awareness level of BIM has significantly increased and most of the construction professionals in India are aware of BIM. Furthermore, respondents were asked about the currently used BIM-based tools for their organization's work. This question was asked with multiple choices. Respondents were allowed to choose more than one response. 23% of respondents reported that Revit architecture and Navisworks are highly used tools followed by Revit MEP (Fig. 3b). The survey conducted in 2009 reported that 49% of the respondents used Revit as a major BIM tool (Kumar & Mukherjee, 2009). It can be stated that the Indian construction sector is widely using Revit as a BIM application for decades. Based on their current understanding and expectations, non-BIM users were asked to respond to the BIM adoption questions, where they mentioned that AutoCAD is the highly used tool, followed by MSP and Primavera. BIM has various applications, and

Fig. 2 State-wise geographical location of respondents

it can be utilized in most of the construction phases. When asked, 37.42% of respondents reported that design and drawing are the most common use of BIM in Indian construction organizations, followed by clash detection (Fig. 3c). India BIM Association surveyed BIM implementation in 2016 and it revealed that BIM maturity in India falls under the design stage. BIM applicability in India is limited to design and drawing purposes. It can be stated that Indian firms are not fully aware of the potential benefits of BIM.

Furthermore, when asked, 37% of respondents rated their knowledge of BIM as very good, while 33% rated themselves as good (Fig. 3d). This shows that maximum people are confident about their understanding of BIM. Thirty-eight

percent of respondents stated that the need to remain competitive is the most common reason for using BIM in India, whereas 36% of respondents stated that client demand is a common reason for adoption (Fig. 3e). Some of the respondents also stated that they use BIM, because BIM serves better information management during the project lifecycle, and it can identify the problems to face will be resolved before the construction starts. When it was asked about the provision of BIM training to the organization, 40.96% of respondents reported that they get 'In house training of BIM' and 34.50% reported 'self-learning using online platforms'. It is also observed that only 2.33% of respondents reported that they get trained for BIM in university coaching. It shows

Table 2 Details of respondents

Respondent information	Categories	Frequency	Percentage
Experience in the Construction industry	0–5 Year	45	26.31
	5–10 Year	61	35.67
	10–20 Year	53	30.99
	> 20 Year	12	7.015
Educational level	Diploma	21	12.28
	Bachelor's degree	98	57.30
	Master's degree	51	29.82
	Ph.D.	1	0.5
Discipline	Owner	08	4.67
	Contractors	10	5.84
	Construction manager	11	6.43
	Project manager	45	26.31
	Deputy manager	15	8.77
	BIM Professionals (BIM coordinator, BIM Designer, BIM MEP)	82	47.95
Total no. of valid questionnaire = 171			

that there is a lack of BIM training at the university levels in India and if BIM is introduced in the curriculum, the next generation of the practitioner (i.e., the current student population) will be BIM aware. Also, global BIM adoption has attained a level of maturity, to there is scope to actively engage international academics in advisory capacities to spearhead the process. In introducing BIM, they will bring about an enormous revolution and bridge the current knowledge gap. The need for including BIM in the curriculum of universities or colleges, as highlighted in (Fig. 3f).

Benefits of BIM

Many countries have commented that the adoption of BIM in practice leads to growth in their productivity due to the prominent advantages of BIM. A common benefit of BIM over CAD is that during the design phases, BIM can perform automated conflict detection, saving time, and resources (Elyamany, 2016). The advantages of BIM are studied in various research studies. Many researchers have identified the topmost benefits of BIM such as increased productivity and efficiency (Al-ashmori et al., 2020), visualization (Ebrahimi & Akhbari, 2015), clash detection, reduced rework during construction (Matarneh & Hamed, 2017), enhanced collaboration, and communication (Khosrowshahi & Arayici, 2012; Matarneh & Hamed, 2017), scheduling and sequencing coordination (Barlish & Sullivan, 2012). A total of 19 most relevant and significant advantages are selected for the survey and analysis of the results is carried out using descriptive statistics in SPSS. The mean values and standard deviation of each selected benefit are calculated and presented in Table 3. It is reported that the top five benefits of BIM are improved clash detection, better

visualization of work, effective collaboration communication and teamwork, better services to clients, and improved quality of completed project construction. It is also observed that cost-effective benefit is ranked lowermost as an advantage of BIM. It reflects that Indian construction firms find BIM as a less cost-effective. It is however important to note that the returns from BIM adoption are not always monetary, they can lead to efficiencies in processes, improved productivity through removal of redundant and repetitive practices, increased transparency, and accelerated spread of knowledge, among other benefits. Thus, simply hinging the decision on 'less cost-effectiveness' would be shortsighted.

Barriers to adoption of BIM

The Indian construction industry is adopting BIM at a leisurely pace. However, countries such as the USA, UK, and China are leading in the adoption of BIM. The purpose of this part of the survey is to uncover the challenges or barriers Indian construction firms are facing in BIM adoption. This can help construction practitioners to know the root causes of the lack of BIM adoption and to find ways to overcome the identified barriers. An extensive literature survey is carried out for finding different barriers to BIM adoption. Barriers, such as doubts about ROI, lack vision of benefits (Eadie et al., 2014). Lack of awareness about BIM, BIM industry standards, and codes are not available (Matarneh & Hamed, 2017), and social and habitual resistance to change, traditional methods of contracting (Ahmed, 2018) are frequently observed in most of the papers. Some researchers also examined factors influencing the adoption of BIM. A total of 18 number of frequently observed barriers are selected for this survey and results are analyzed. The

mean values and standard deviation of each selected barrier are calculated and presented in Table 4. The top six barriers are ‘no clear understanding of the benefits of BIM, reluctance to learn new processes or switch from conventional methods, lack of a national driver for BIM adoption, varying levels of BIM readiness among project teams, purchasing software and hardware to support BIM needs, and lack of BIM awareness.

BIM for site safety management

The construction industry in India involves large and complex construction projects and so the risk is also high. Site safety is one of the most important parameters affecting productivity. Safety on sites keeps a positive and healthy environment. International Labor Organization (ILO) found that 2.8 million worker deaths are reported worldwide each year, with over 6500 deaths from work-related diseases every day and 1000 from work-related accidents. Unfortunately, construction workers are not completely immune to these risks. Safety is an important issue for different projects in the construction industry pragmatically and conceptually (Gitinavard et al., 2020). Safety is the prime responsibility of all who are involved in the construction project. Most of the researchers have reported that current safety practices are insufficient, and with these practices, the accident rate has not reduced and still at a rapid pace. It shows that there is a need for advanced and automatic safety management techniques. However, before adopting any new process, it is necessary to study the existing processes. This section is included to realize the truth of current safety practices, on-site hazards, and safety management in India thoroughly. This part of the survey has two components. First, it deals with questions regarding current safety practices, and second, it moves towards the benefits of BIM for safety management. It reveals a level of agreement of respondents on the benefits of BIM for safety.

This part of the survey initiates with current safety practices on-site, and for this question, respondents were allowed to choose multiple answers from given options. It is reported that safety awareness programs and safety checklists are the most common safety practices reported by 23% and 21% of respondents. Safety training is also reported with a very close 20% of respondents (Fig. 4a). This shows that most construction organizations are following traditional safety methods for safety management. Furthermore, when asked 53% of respondents reported that Falls are the most common identified hazard on-site followed by struck by an object by 27 respondents (Fig. 4b). Falls are the highest observed hazards on most of the construction sites. OSHA also reported that 338 out of 1008 total deaths in construction in the year 2018 (33.5%) are due to fall hazards which are the highest (OSHA, 2018). Somehow, current safety methods are not

able to deal with fall hazards as falls are the topmost identified hazard for so long. It reflects that there is a need for strong and advanced fall prevention techniques or methods to mitigate fall hazards. The next question was asked regarding the person responsible for managing safety on-site, it is reported that 51% of respondents think the safety manager/safety inspector is responsible for safety management on-site, whereas 18% of respondents reported that the site in-charge/site supervisor is responsible for safety management. Some of the respondents stated that safety is the responsibility of everyone involved in the construction project.

Furthermore, when asked about the manner of the recording of safety incidents, multiple responses were expected and its most repeated answers are documentation or maintaining registers, safety checklists, and safety manuals. Some respondents also stated that CCTVs are provided on-site. Safety management on-site generates huge data of identified hazards, their type, their properties (location), people involved, measures are taken, and to name a few. It is observed that most of the record-keeping is done manually. The data generated in the form of paper-based documents can be misplaced or lost. In addition to this, it was also asked that who uses this recorded information and its purpose, and it is reported that most of the respondents said the project manager followed by the safety inspector keeps the record of this information. It is recorded for the lesson learned register for future safety assurance and to understand the root causes of issues to inform corrective action throughout the organization. Project Managers (PM) typically use the knowledge from previous projects to manage risks. The records help maintain a log for future reference, so lessons from previous projects can be applied to future projects to manage risks and adopt precautionary measures. Care would need to be taken to ensure that the lessons are applied in context.

Furthermore, when asked about the frequency of safety training and inspection, the spread of training and inspection practices vary from ad hoc (or not fixed practices 8%), at the lower end, through monthly training practice (23%) to weekly practices reported by 30% of the respondents (Fig. 4d).

It is illustrated that 71% of respondents use a safety checklist for inspection purposes (Fig. 4e). Furthermore, when asked 64% of respondents reported that they follow standard safety guidelines. The guidelines which are mostly followed are by OSHA and the second is ISO 45001.

Respondents were asked about the identification of accident-prone areas with their current safety practices, where 57% of respondents said no and 38% of respondents said yes, that their current safety practices can identify accident-prone areas. (Fig. 4g). When asked to elaborate on how their safety practices identify the accident-prone areas, it is reported that by safety inspections on-site and daily inspections to identify hazard areas and fix it on the spot by

(a): Awareness Status of BIM in India

(b): Most commonly used BIM tool

(c): Most common use of BIM in Indian construction firms

(d): BIM knowledge rating assessed by respondents

(e): Reasons for using BIM as stated by respondents

(f): Provision of training for BIM by construction firms

Fig. 3 **a** Awareness Status of BIM in India. **b**: Most commonly used BIM tool. **c** Most common use of BIM in Indian construction firms. **d** BIM knowledge rating assessed by respondents. **e** Reasons for using BIM as stated by respondents. **f** Provision of training for BIM by construction firms

providing recommendations to mitigate any risk; detailed review of the risk/hazard analysis in the work methodologies submitted by the contractor; (specific work methodology is required for any work activity; the safety and Environmental hazards are identified and a mitigation plan is also attached), Accident prone areas can be identified through a weekly walk down This shows the identification is done manually. It shows that there is a need for a process or technique that can automatically identify risk-prone areas prior to construction and accidents can be reduced.

Furthermore, respondents were asked about the provision of the probable cost of safety in total project cost; 72% of respondents stated that the cost lies between 0 and 5%, whereas 15% of respondents stated between 10 and 15% (Fig. 4h).

Advantages of BIM for safety

Safety has been always one of the highly ignored areas in the construction industry. Lack of safety on sites causes accidents which leads to financial loss as well as living loss. As discussed in Sect. 3.4, current safety practices are insufficient to manage safety on-site. Digitalization is rapidly increasing, and it has vast applications in construction safety, as well. Some advanced methods, such as the use of Ultra-Wide-Band (UWB) for tracing the position of a worker at the site (Giretti et al., 2009), Positioning sensors and router for gathering the real-time data of the workers (Naticchia et al., 2013), the adoption of a global positioning system for safety monitoring and control the work at the project site from a distance (Park et al., 2017), are studied. Development of an automatic safety checker model using BIM (Zhang et al., 2013) BIM-based automated scaffolding (Kim et al., 2018), BIM-based risk identification (Zhang et al., 2016), and BIM-based fall hazard identification (Zhang et al., 2015), are evident. In addition to that, the integration of BIM and Geographic Information System (GIS) are strong platforms widely used in the construction industry due to their various individual features and capabilities (Abd et al., 2020). It helps for providing safe construction zones (Khan and Park, 2021), linking BIM and GIS data for digital representation of the real world (Abd et al., 2020). Considering India, the utilization of BIM for safety, in particular, has been very limited. Very few studies such as BIM for site layout planning (Lota & Trivedi, 2020), BIM and GIS integration for site safety (Bansal, 2011), and BIM for form-work systems (Kannan & Santhi, 2013) exists. To spread the

awareness that BIM can be utilized for safety, this part of the survey has been included. It consists of the advantages of BIM for safety. The mean values and standard deviation of each selected advantage are calculated and presented in Table 5. It is observed that site layout planning, visualizing, and simulation of construction hazards and measures, rapid and efficient decision-making, early control of dangerous equipment and materials, on-site safety monitoring, and control are analyzed as the top five advantages. It is also reported that automatic safety checking has been marked as the lowermost advantage; this is indicative of a lack of understanding of the real benefits to be derived from BIM adoption. That BIM has the applicability of automatic safety checking and it is one of the most suitable methods of safety checking with time-saving and cost-saving quality, is not currently recognized.

Future use and vision towards BIM

Construction projects in India are rapidly increasing with the target of achieving maximum productivity. Advanced technologies can facilitate the growth of productivity. It encompasses a broad variety of current techniques and methods, including the latest advances in materials science, construction processes, quantity surveying, management of facilities, utilities, structural analysis and design, and studies of management. BIM has the potential to enhance existing practices and highlight major issues associated with cost and time overrun on projects. Countries such as the USA, UK, France, Germany, and Singapore all have a BIM mandate, and its implementation has shown significant growth in their construction productivity. Considering India does not have a BIM mandate yet, this is a significant hurdle to navigate in the short term if the projected long-term benefits are to be realized. This section opens up the views of construction professionals regarding BIM mandate, measures to be taken for BIM mandate, and the future scope of BIM.

It is reported that 83% of respondents agreed that BIM mandate is necessary to drive its wider adoption (Fig. 5a). It shows that majority of construction professionals willing to have BIM mandate as a standard set of rules and regulations can broadly affect its implementation in Indian construction. If the government can bring about BIM implementation, as a few foreign countries do, then the Indian AECO scenario can have a facelift and compete with construction industries around the world. Furthermore, when asked, 54% of respondents reported that it would take 5–10 years for BIM mandate in India, whereas 44% of respondents reported 10–20 years (Fig. 5b).

Furthermore, when respondents were asked to suggest measures that would have to be in place to get India ready for BIM adoption, it is reported that the maximum respondents said “Government mandate” must be there.

Table 3 Benefits of BIM

Benefits	Mean	Std deviation
Improved clash detection	4.6374	0.71751
Better visualization of work	4.6082	0.81439
Effective collaboration communication and teamwork	4.5205	0.74628
Better services to the client	4.4444	0.86167
Improved quality of completed project construction	4.4094	0.86550
Improved model-based cost estimation and quantity take-off	4.3918	0.86347
Sequencing of work and scheduling	4.3509	0.93603
Reduction in errors due to availability of up-to-date project information	4.3275	0.91285
Enhanced management of project knowledge	4.3275	0.79580
Single platform for project information management and sharing	4.2515	0.89504
Enhanced construction productivity	4.2398	1.02087
Increased global competitiveness	4.2339	0.91601
Improved verification guidance and tracking of construction activities	4.2222	0.95040
Single source of the truth with increased transparency	4.2047	0.91342
Reduced rework	4.1930	1.03080
A single repository of lifecycle project information	4.1813	0.87910
Increased speed of delivery	4.1520	1.00600
Move away from an organizational perspective to a project perspective	4.0000	1.08465
Cost-effective	3.9825	1.09799
Valid $N=171$		

Table 4 Barriers to the adoption of BIM

Barriers	Mean	Std. deviation
No clear understanding of the benefits of BIM	3.8246	1.33005
Reluctance to learn new processes and switch from conventional methods	3.6433	1.30438
Lack of national driver for BIM adoption	3.5848	1.28686
Varying levels of BIM readiness among project teams	3.5439	1.14384
Purchasing software and hardware to support BIM needs	3.5146	1.25725
Lack of BIM awareness	3.5146	1.22406
Lack of BIM knowledge	3.4327	1.26486
Advanced maturity of BIM adoption globally impedes India	3.3216	1.32689
Unavailability of BIM standards for India	3.3099	1.56538
Doubts about Return on Investment (ROI)	3.2924	1.41292
Lack of senior management support	3.2164	1.36983
The high cost of training	3.0175	1.33052
The current practice of working in silos	2.9825	1.32609
Legacy systems are not BIM compatible	2.8713	1.35727
The high cost of maintenance	2.8363	1.35780
Legal issues	2.8070	1.34740
Organizations view of considering current technology is enough	2.7368	1.49343
Unavailability of BIM training	2.6257	1.47139
Valid $N=171$		

Some respondents stated that a university education is needed. BIM should be included in the curriculum. Cost-effectiveness organizes free or low-cost awareness campaigns/conferences in every city where the construction sector is at its peak. Provide free or low-cost training so that many young talents will get attracted and the message

will be passed on to seniors and provide the training to the company personal of the engineering department strictly, so that the whole concept can be spread in the company. Due to the different descriptive opinions from respondents, a detailed word cloud is prepared which represents all

Fig. 4 **a** Current safety management practices. **b** Most common identified hazard on-site. **c** Responsible person for on-site safety management as stated by respondents. **d** Frequency of safety training and safety inspection held on-site. **e** Opinion on whether safety checklists are used for inspection purpose. **f** Use of any standard safety guidelines in the organization. **g** Identification of accident-prone areas with current safety practices. **h** Probable cost of safety provision out of total project cost (in percent)

Fig. 4 (continued)

Table 5 Advantages of BIM for safety planning

Advantages of safety	Mean	Std deviation
Site layout planning	4.1579	0.96020
Visualizing and simulation of construction hazards and measures	4.0643	0.95268
Early management of hazardous equipment and materials	3.9298	1.11976
Rapid and effective decision-making	3.9181	1.17035
On-site safety monitoring and control	3.8889	1.17044
Safety training and education	3.8187	1.13080
Safety assessment	3.8187	1.03861
Identification of risk-prone areas for future reference	3.7895	1.14897
Providing and communicating mitigation plans to the workers	3.7310	1.27793
Quantity take-off for safety equipment needed	3.6667	1.26025
Providing safety warnings for on-site workers when necessary	3.6374	1.30050
Automatic checking system for safety regulations and rules	3.4737	1.40300
Valid N=171		

measures reported by respondents in Fig. 5c. It states that words that appear bigger are mostly suggested measures.

BIM is regarded as the future of construction in many countries (Tahir et al., 2018). To check this statement and the opinions of Indian construction firms, a question was asked regarding their willingness to use BIM in the future. It is reported that 91% of respondents would like to use BIM

for their future projects (Fig. 5d). It shows that BIM has huge scope in India and people are willing to use it in the future.

It is also observed that 71% of firms are already using BIM and most of the respondents would adopt it in the next 5 years (Fig. 5e). From the survey, it is noted that the firms which are using BIM are mostly adopting it for drawing and design purpose. BIM adoption is not just about using tools, and it is about the process first and then the tool. It is a myth

Fig. 5 **a** Opinion on the mandate for BIM adoption in India is necessary to drive its wider adoption. **b** Years required for BIM to be mandated in India as per the respondents. **c** Key measures for wider adop-

tion of BIM. **d** Adoption of BIM for future projects. **e** Probable years to use BIM for the organization's work

Fig. 6: Thrust areas for successful BIM implementation in India

that BIM is just software. Using Revit does not confirm that they use BIM.

Finally, the survey reflects on persuading the BIM, it is observed that factors such as client demand, BIM learning courses, understanding of BIM, market demand, government mandate, time and cost management, advantages and effectiveness, BIM awareness session, reduced rework, better quality and project analyzing, cost efficiency, reduced license cost, ease and perfection, good standard, and long-term ROI are repeatedly reported as persuading for BIM.

Results and discussion

This study unfolds critical aspects of BIM in India involving its awareness level, benefits, and barriers at the initial part. Furthermore, the study focused on its adoption for safety in particular, where the current safety practices and benefits of BIM for safety are examined, leading towards the future and vision of BIM in the Indian construction industry. It is observed that design authoring tool like Revit from Autodesk is widely used as a BIM-based tool in Indian construction firms and also design and drawing are the topmost purpose for using BIM. It can be stated that BIM adoption in India is limited to design and drawing purposes. India needs to work on its awareness of the benefits of BIM along with its ROI. Construction sector professionals need to understand using software for design is not BIM, and it should be implemented for data management in the entire life cycle of

the project. BIM is a combination of processes and tools. Training, seminars, workshops, and knowledge of BIM for the effective and smooth running of projects must also be performed by industry professionals.

To understand the process as well as BIM-based tools and to get trained for BIM implementation, universities should include BIM hours in their curriculum. The number of people in the list of BIM users would increase if the academicians raised awareness among the students and Universities took active measures to include BIM in the curriculum. In introducing BIM, they would accelerate the bridging process between growing skills gaps due to 'emergent and imminent' industry needs and the supply of a competent workforce. This would lead to investing in the future due to a BIM-ready workforce. Of course, the need to train the existing workforce would remain, at least in the interim. With time, the need for incurring BIM training costs with an organization will be reduced.

BIM has been adopted widely in countries outside India. However, the results also reflect that most of the respondents are confident that BIM will go popular in the future, as proactive measures are taken to introduce it widely in the curriculum. The survey revealed that 85% of construction professionals believe the BIM mandate is necessary for the wider adoption of BIM in India. A national driver for BIM is required and if the government can bring about the implementation of BIM, as a few foreign countries do, India will be faster in implementing BIM. People believe that a standard set of rules for BIM can highly impact its adoption and implementation. Some organizations such as IBIMA are

taking initiative for wide-spreading benefits and awareness of BIM in India.

Based on the results and observations, a framework has been developed (Fig. 6). It illustrates the key thrust areas that need to be focused on by the Indian construction sector for the successful implementation of BIM.

In addition to this, the study also reports the top five benefits of BIM as improved clash detection, better visualization of work, effective collaboration communication and teamwork, better services to a client, and improved quality of completed project construction.

The top barriers identified in the adoption of BIM are ‘no clear understanding of the benefits of BIM, reluctance to learn new processes and switch from conventional methods, lack of a national driver for BIM adoption, varying levels of BIM readiness among project teams, purchasing software and hardware to support BIM needs’. In the past few years, amid all these challenges, the industry has seen an upward trend in BIM adoption. Indian construction projects, such as Personal Rapid Transit in Amritsar, Bangalore Airport, and Nagpur metro rail, have already implemented BIM in their construction works.

This study also deals with safety management on Indian construction sites and the benefits of BIM for safety. It is reported that current safety practices are mainly involved in traditional methods, such as safety checklists, safety inspections, and safety training. It is also observed that record-keeping is done manually on most of the sites. Considering the growing rate of on-site accidents, these methods are good but not enough to prevent the risks. It shows that there is a need for advanced methods for safety management on-site. BIM has several advantages for safety such as site layout planning, visualizing, and simulation of construction hazards and measures, early management of hazardous equipment and materials, rapid and effective decision-making, on-site safety monitoring, and control. Apart from these, BIM also has the applicability of automatic safety checking on-site, though this benefit has been ranked lowermost. The automatic safety checker model can identify the risk-prone areas prior to construction, which most of the respondents reported their current safety practices cannot identify.

It can be stated that Government bodies, educational institutes, and construction organizations together can yield enhanced results in implementing BIM.

Conclusion

The survey highlighted that the awareness level of BIM has increased, but the full potential of BIM has not been explored yet. In India, people are treating BIM as a drafting tool and not utilizing it for managing projects and data management, proper training should be delivered to make BIM

mandatory in projects to realize benefits. It is kind of important to understand BIM implementation in the construction process than just learning BIM-based software. Different set of software has different functionalities and BIM has the potential to combine and share that data, applicability through common data environment. In line with this, the data generated on construction sites are huge involving different kinds of data such as cost, quality, workmen, safety, and to name a few. These data need to be managed properly and BIM is a single repository where the data can be shared, managed, and stored in the digital platform.

As the industry is moving towards more complex and mega projects, the need for proper safety management on-site is equally important. The benefits of BIM for safety management are not limited to safety data management, site layout planning, and visualization, but also involve an advanced level of safety with automatic safety checking capability that can serve throughout the life cycle of the project.

The need for BIM implementation for safety in India has two main strands: first, its implementation can reduce the number of accidents on Indian construction sites, and second, the need shows the scope for Indian researchers to study in the domain of BIM for construction safety.

For finding to be truly representative of the widespread BIM adoption in India, especially for safety, sample would need comparable responses from states across India. However, currently, the responses are majorly concentrated from Maharashtra, Karnataka, Chennai, Delhi, and Kerala. Some questions in the survey required qualitative, opinion-based responses. As an example, of 171 responses, only 23–25% of respondents included their views. Thus, generalization of findings is not fully possible. For truly generalizable findings, the sample would need to be proportionately representative.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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