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BIM IMPLEMENTATION BY INTEGRATING LEAN CONSTRUCTION AND IDT (LCIDT)

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ABSTRACT

The construction industry, which makes a significant contribution to the country's GDP, continues to grapple with rising costs and project delays. While multiple factors contribute to such overruns one contributing factor is the underutilization or limited deployment of new innovative technologies and procedures. BIM is one such technology/process which have numerous benefits throughout the lifecycle of a project. However, the construction sector is still behind the rate at which innovation should be adopted due to many barriers and a heavy reliance on frameworks based on innovation adoption theories (IDT, TAM, etc.). The study utilized a systematic literature review (SLR) and a document analysis approach to seek answers for the current status of BIM and the hurdles faced by Indian construction stakeholders in its implementation. The shortlisted articles and documents underwent quantitative and qualitative content analysis. The study found that the BIM maturity in India is still very low due to various barriers, which can be eliminated by using a combination of theoretical and practical strategies. Hence, the study proposes a framework ("LCIDT") based on an integrated approach of lean construction (LC) and innovation diffusion theory (IDT) for enhancing BIM implementation. IDT can primarily help in eliminating technical and cost-related barriers, whereas LC can overcome organizational, people, and government-related barriers affecting the utilization of BIM. This framework significantly provides stakeholders with a new perspective on the barriers and integrates theoretical guidance with practical LC applications. However, future research should focus on validating the developed framework across different organizations and geographical locations.

Keywords: *Building Information Modelling (BIM); Innovation Diffusion Theory (IDT); Lean Construction (LC).*

1. INTRODUCTION

The Government of India (GOI) initially allocated ₹111 trillion towards infrastructure development between 2020 and 2025, which further increased substantially to ₹168.93 trillion indicating expanded scope and ambition (Ministry of Finance Government of India, 2020), resulting in huge demand for infrastructure construction as well as maintenance in the country due to the increasing population (Machnoor, 2021). However, as of March 2025, projects worth ₹31.1 trillion have been completed, achieving 28% of the original target. Though pace of construction in the country has tremendously increased with the applications of advanced tools and techniques, however recent studies show that a considerable number of projects overshoot budgets and anticipated timelines (Pal & Nassarudin, 2020; Shendurkar et al., 2022) and encounter difficulties with

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cooperation and coordination among the stakeholders throughout the process (Shendkar & Patil, 2017). A significant number of construction projects in India have higher cost-overruns amounting to 63%–141% of the initial budgeted cost and delays up to 79% of preliminary project milestones as compared to the worldwide average (Rajan et al., 2014). As per the June 2024 report by the Ministry of Statistics and Programme Implementation (MoSPI), among a total of 1,817 projects (with a value exceeding INR 150 crores), 458 projects have overshot the initial cost budgets, whereas 831 projects were experiencing time overruns. Some of the most common and important factors for such delays include failure to share relevant project information, lack of collaboration and communication, low productivity of people involved, disagreements among stakeholders, and lack of use of innovative technology, dearth of research on delay factors that are specific to the sector, the impact of delay factors, and the absence of standardization of innovative technologies (PMI and KPMG India, 2019; Saxena et al., 2023).

The increased need for an intelligent and environmentally friendly constructed environment only adds to the complexity of the task (Gupta et al., 2022). Utilization of novel and innovative construction techniques, including digitalization and automation are specific way to enhance the efficiency, value, and administration of construction projects and should be adopted to unleash the industry's enormous potential (Gao et al., 2019). Building Information Modelling (BIM) has been introduced with this objective from the perspective of the construction industry. However, the industry has been slower than other industries in adopting these technologies (Sepasgozar et al., 2019). BIM is widely recognized as a crucial facilitator for effectively identifying risks and achieving the intended construction management objectives among various stakeholders (Aghimien et al., 2022). BIM is revolutionizing the way in which various stakeholders in the construction industry collaborate on projects as a diverse array of BIM software applications is employed during the design, construction, operation & maintenance, and demolition phases (Patel et al., 2021). BIM has been integrated more deeply into various lifecycle phases of construction projects, further facilitating greater digitized industrialization (Gavali & Halder, 2020; Singh et al., 2021) and enhanced project delivery conditions. This has resulted in a notable enhancement in the overall performance of construction projects, from their delivery to management throughout their lifecycle (Raya & Gupta, 2022). Therefore, the Indian construction industry should embrace BIM to reduce project delays and achieve cost-effectiveness in project delivery (Shendurkar et al., 2022).

2. RESEARCH PROBLEM

The adoption of BIM has significantly transformed the processes involved in designing, constructing, delivering, and operating building projects on a global scale. BIM has seen widespread adoption in developed nations, whereas it is rarely put into practice in the context of developing nations (Arokiaprakash & Aparna, 2018). Regarding developing nations, specifically India, it can be observed that the implementation of BIM is still in its initial stages (Ahuja et al., 2020). BIM has been in circulation for a significant duration; however, its level of dissemination is inadequate (Arunkumar et al., 2018), and its application is restricted to visualization (Mohanta & Das, 2022), design management, clash detection, and automatic generation of bill of quantities (BoQs), resulting in low BIM maturity in India (Ahuja et al., 2017; Koul et al., 2023; Sood & Laishram, 2022). Nevertheless, a limited number of studies have endeavoured to leverage BIM tools beyond traditional applications. These studies have focused on techniques such as integrating linear structures with 3D geometric surfaces to enhance the precision and efficiency of 3D reconstruction in smart city initiatives, thereby streamlining construction and maintenance procedures (Kurup & Bhise, 2024), and a framework to mitigate geometric discrepancies during segmental casting alignment of bridge elements (Babanagar et al., 2023). Additionally, the use of BIM in India is restricted only to urban and large-scale megaprojects, with rare implementation in rural or low-budgeted residential projects (Raya & Gupta, 2022; Surya & Tom, 2022). There have been few studies of BIM implementation in India at different project levels (Bhat et al., 2018; Charlesraj & Dinesh, 2020; Gaur & Tawalare, 2022; Gavali & Ralegaonkar, 2019; Mohanta et al., 2019; Pakhale & Pal, 2020; Rafi & Chari, 2019; Ralegaonkar et al., 2017) and the implementation rate is found to be very low in comparison to other countries owing to various barriers (Dhopte & Daga, 2022; Saxena et al., 2023). Therefore, it can be inferred that even after conducting various studies, BIM implementation among construction firms in India is very low and is attributable to inadequate investigation into the barriers impeding its adoption, as well as the absence of frameworks to address them.

It is recommended that the adoption of BIM in different construction organizations be handled through the lens of innovation (Murphy, 2014). There have been studies across the globe that developed and utilized frameworks based on Innovation Diffusion Theory (IDT) and Technology Acceptance Model (TAM) to understand the process of implementation of such novel and innovative technologies in the construction sector (Fakhimi et al., 2021; Gledson, 2022; Hosseini et al., 2016; Kim et al., 2016). However, even after utilizing such frameworks, the construction sector is still behind the rate at which innovation should be adopted, as these integrations are constrained to the creation of theoretical frameworks that primary stakeholders do not fully comprehend. Therefore, to address the limitations of theoretical models and improve the implementation of BIM through a practical approach, this study attempts to modify the existing frameworks by integrating them with Lean Construction (LC) principles. This approach draws inspiration from the conclusions of a few of the studies that lean construction principles, tools, and techniques can be used to enhance BIM implementation (Barkokebas et al., 2021; Demirdöğen et al., 2021; Mahalingam et al., 2015; Michaud et al., 2019; Piroozfar et al., 2019; Weerasinghe et al., 2023). Few studies that have integrated lean and BIM, with a specific emphasis on BIM as a means to achieve lean goals, have been carried out (Andújar-Montoya et al., 2020; Bhattacharya & Mathur, 2023; Ismail et al., 2023; Moballeghi et al., 2023; Tezel et al., 2020; Uvarova et al., 2023) but these studies lack a holistic framework. Hence, to address these gaps and enhance BIM implementation, the study conducted a systematic literature review to understand the current level of BIM implementation, barriers in its implementation by considering the case of the Indian construction sector and proposed a framework that combines LC and IDT.

3. RESEARCH METHODOLOGY

The research employed a combination of systematic literature review (SLR) and document analysis approach to shortlist academic literature and other documents, respectively, to gain answers to our research problem.

3.1 SYSTEMATIC LITERATURE REVIEW

The systematic review protocol is essential for the identification, screening, and critical assessment of pertinent studies. This procedure also entails the gathering and examining data that will be integrated into a review led by specific research inquiries and explicit methodologies. To organize the literature, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method is used (Moher et al., 2009), which involves evidence-based (minimum set) items for conducting systematic reviews and meta-analyses. The aforementioned methodology was instituted in the year 2009 and has gained traction across various research domains in science and technology, owing to its replicability and efficacy in enabling the development of superior processes (Sidani et al., 2021). It involves a four-step process (Shahruddin & Zairul, 2020) and has been adopted by various studies (Charef et al., 2018; Safikhani et al., 2022; Shahruddin & Zairul, 2020; Sidani et al., 2021).

3.1.1 Stage 1: Identification of Database and Keywords

Scopus database served as the primary source of data due to its free accessibility for the authors through their university and is widely recognized as a reputable database engine for academic data. This is because Scopus has indexed a greater number of journals in comparison to other data sources: PubMed, WOS, and Google Scholar (Chadegani et al., 2013). Scopus encompasses a range of data structures, such as keywords, abstracts, article types, authors, journals, institutes, languages, countries, and references, which facilitate the execution of four fundamental search techniques (Khan et al., 2021). Based on our research problem, different keyword blocks such as “BIM”, “barrier”, and “critical success factor”, and their synonyms, the following search syntax was adopted by utilizing Boolean operators "AND" and "OR":

[TITLE-ABS-KEY (“BIM” OR “Building Information Model”) AND (“Barrier” OR “Challenge” OR “Hurdles” OR “Driver” OR “CSF” OR “critical success factor*”)] AND [LIMIT-TO (AFFILCOUNTRY, “India”)].

3.1.2 Stage 2: Screening

Following the database search, 94 articles were retrieved and were further filtered by language and document type. Only journal and conference articles written in the English language were kept for the next stage, as conference papers serve as a convenient means to enhance an inclusive knowledge of the latest developments in a particular field, thereby facilitating the acquisition of up-to-date knowledge. This step resulted in a list of 78 articles which were downloaded into an MS Excel file.

3.1.3 Stage 3: Eligibility using Inclusion and Exclusion Criteria

The abstracts of the articles from the previous stage were analysed to determine their eligibility based on inclusion and exclusion criteria. The study revealed that a total of 20 articles were sourced from disciplines outside of the construction industry, while 8 articles were deemed irrelevant to the investigation of BIM in India.

3.1.4 Stage 4: Included

During the final stage, an analysis of full-text availability was conducted, revealing that four articles were not present in the database. Therefore, a finalized list of 46 articles was selected to undertake both quantitative and qualitative content analysis.

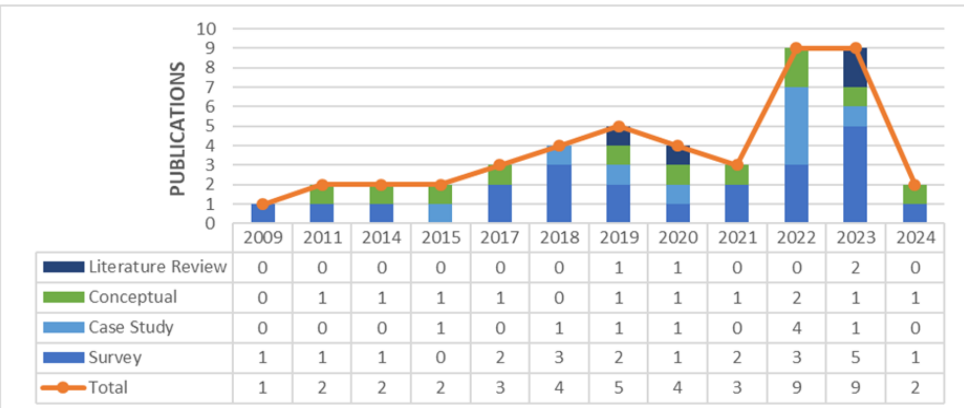
3.2 DOCUMENT ANALYSIS

Document analysis is a qualitative research methodology that involves the evaluation of many types of documents, including printed and electronic archives (Bowen, 2009). The primary objective of this approach is to generate empirical information and foster a comprehensive understanding of a specific topic. After establishing the study's background and shortlisting academic papers, further analysis was conducted on different documents obtained from online sources (such as blogs, webpages and reports) to enhance the existing knowledge about BIM implementation in India as well as validate the findings of the shortlisted papers (Bagalkotkar & Narain, 2022; Machnoor, 2021; Shetty & Narain, 2021; Verma, 2023).

4. CONTENT ANALYSIS

4.1 QUANTITATIVE ANALYSIS

The quantitative analysis classified the articles based on the year of publication as well as the method of research opted for (Figure 1). The graphical representation illustrates that the emergence of publications about BIM in India commenced in 2009 and has exhibited a favourable upward trend. The year 2009 saw the minimum number of publications, with only one article being published, while the maximum number of publications, with nine articles being published, was observed in the years 2022 and 2023. This indicates a growing interest in BIM-related studies among various researchers in the Indian construction sector. However, the aggregate quantity of BIM-centric scholarly articles published in the years 2020 and 2021 has exhibited a decline in comparison to the corresponding figure for 2019 which could potentially be due to COVID-19 impact. The articles were also classified based on the methods adopted by the authors and are classified into literature review, conceptual, case study, and survey based. The result shows that survey-based methodology that involves online/offline questionnaires, as well as interviews with construction experts, is the most preferred methodology that has been opted for by Indian researchers. Additionally, these 46 selected articles, were also classified based on the type of publications (journal/conference). It was found that 28 articles (61%) were published in various journals whereas the remaining 18 articles (39%) were part of national and international conferences. Among these journal publications, the top 3 journals with a total of 11 articles include Asian Journal of Civil Engineering



	2009	2011	2014	2015	2017	2018	2019	2020	2021	2022	2023	2024
Literature Review	0	0	0	0	0	0	1	1	0	0	2	0
Conceptual	0	1	1	1	1	0	1	1	1	2	1	1
Case Study	0	0	0	1	0	1	1	1	0	4	1	0
Survey	1	1	1	0	2	3	2	1	2	3	5	1
Total	1	2	2	2	3	4	5	4	3	9	9	2

Figure 1: Publications based on year and research method

having 5 articles followed by Buildings having 4 articles, and Institution of Civil Engineers with 2 articles.

4.2 QUALITATIVE ANALYSIS

The qualitative analysis helps to conduct the content analysis of the selected articles and other documents. Three different themes/categories for in-depth analysis have been identified.

4.2.1 Geographical Location

A study in Rajasthan (a Northern state of India) modified the BIM based on the needs of rural infrastructure development (Raya & Gupta, 2022). Based on a case study of a rural water management (RWM) project, a rural BIM (R-BIM) model was developed. This model delved into multiple facets, with particular emphasis on the BIM cloud operations, incorporating the active involvement of pertinent stakeholders. In another study conducted in Kerala (a Southern state of India), a methodology that advocates for the integration of Indigenous architectural features into the structural framework was proposed (Surya & Tom, 2022). This approach aims to facilitate the uptake of BIM within the context of residential construction projects. In addition, (Kalidass et al., 2023) conducted a questionnaire survey-based study to investigate the state of occupational safety, health, and environmental standards within the construction sector of Chennai, a major city in southern India. The study aimed to comprehend the existing conditions and assess the integration of BIM for regulatory compliance in these domains. Additionally, various infrastructure projects such as personal rapid transit in Amritsar, Bangalore international airport, Mumbai international airport, Chenab bridge in Kashmir, metro rail in Delhi, and Nagpur have witnessed successful BIM implementation in India (Shetty & Narain, 2021; Verma, 2023).

4.2.2 N-Dimensional BIM

The research on adopting BIM was further refined by incorporating multiple dimensions of BIM into the analysis. In a study conducted in Eastern India, it was determined that BIM was predominantly confined to creating 3D BIM models, primarily due to a variety of technical barriers (Mohanta et al., 2019). Similarly, Charlesraj and Dinesh (2020) surveyed to explore the prevailing level of 4D BIM usage in Indian construction projects. The results revealed that the practical implementation of 4D is very low due to the absence of in-house trained staff, reliance on traditional construction management and contracts, and scarcity of 4D BIM experts. Pakhale and Pal (2020) analyzed the Nagpur Metro Rail Project through a case study approach, with specific attention directed towards assessing both the challenges and benefits entailed in the deployment of a 5D integrated BIM system. The researchers identified the absence of a proficiently trained team, difficulties in converting from 2D drawings to 3D models, and the initial lack of a BIM contract at the project's outset. Similar conclusions have also been drawn by Gaur and Tawalare (2022) from their study of a large-scale project in India that utilized 5-D BIM technology, whereas Sood et al. (2025) emphasizes the importance of sustainability within the construction industry and the potential of 6D BIM for attaining sustainable design for buildings.

4.2.3 Barriers and Action Plans

One of the studies on barriers and action plans influencing Indian construction stakeholders' preference to adopt BIM has investigated the technological, organizational, and environmental factors affecting BIM adoption among different architectural organizations in India (Ahuja et al., 2020). The findings indicate that these firms are currently in the experimentation stage of BIM implementation, primarily due to their inability to identify critical BIM capabilities (Ahuja et al., 2017). Among the most recent studies, Gaur and Tawalare (2022) identified eight primary challenges affecting the implementation of the 5D BIM, Srikanth et al. (2023) identified cultural, legal, financial, lack of skill sets and competence, and management-related factors, whereas Umaapathy & Sundarrajan (2023) did a systematic study based on seven significant factors influencing BIM adoption in India. In another study by Mohanta & Das (2022), an online and interview survey approach was used to rank and find the significance of 14 BIM applications and 12 BIM adoption challenges. Additionally, cost-based factors (such as high costs for software, licenses, hardware, security, staff training, etc.) were found to be major barriers in the majority of studies conducted in India (Arokiaprakash & Aparna, 2018; Gaur & Tawalare, 2023; Sreelakshmi et al., 2017; Verma, 2023). However, a few other significant barriers were related to a lack of collaboration among stakeholders, insufficient resources, limited awareness and knowledge of BIM and ISO 19650 standards, cultural reluctance to adopt new technologies, legal barriers, and dependence on conventional methods (Gaur & Tawalare, 2023; Hire et al., 2021; Machnoor, 2021; Malla et al., 2024; Sawhney, 2014; Singh & Kumar, 2023; Srikanth et al., 2023; Verma, 2023).

Furthermore, a few studies have also suggested various action plans to enhance the adoption and implementation of BIM. To foster broader adoption and implementation of BIM in India, it is imperative to undertake a comprehensive analysis of both the advantages and disadvantages linked to the incorporation of BIM capabilities within organizational frameworks, along with the formulation of ways to overcome the barriers through significant adaptations at both the individual and disciplinary levels (Ahuja et al., 2016). Few studies have suggested that academic measures through BIM education at the university level (Hire et al., 2021), corporate staff training (Patel et al., 2021), organizational support (Umaapathy & Sundarrajan, 2023), social media campaigns (Surya & Tom, 2022), forming BIM groups such as the Indian BIM association (Machnoor, 2021), policy recommendations (Roy & Pawar, 2022), enhanced collaboration and transparent communication between the stakeholders (Gaur & Tawalare, 2022; Singh & Kumar, 2023) can enhance BIM implementation. Moreover, the adoption of BIM in India is often propelled by government mandates, governance models, and standards (Patel et al., 2021; Singh & Kumar, 2023; Verma, 2023), alongside the aspiration of stakeholders to get a tangible return on their investments (Bagalkotkar & Narain, 2022; Charlesraj & Dinesh, 2020; Umaapathy & Sundarrajan, 2023). Few studies have also tried to examine the role of lean construction (LC) principles, tools, and techniques as one of the most suitable strategies for mitigating coordination and collaboration-related challenges, particularly concerning metro projects (Mahalingam et al., 2015) and off-site housing construction in India (Sreeja et al., 2023).

5. CONCEPTUAL FRAMEWORK INTEGRATING LC AND IDT (“LCIDT”)

A novel conceptual framework utilizing the “concept mapping” approach has been proposed based on the six-step methodology: preparation, generation of statements, structuring of statements, representation of statements through a concept map, interpretation, and utilization (Kane & Trochim, 2007). This methodology entails the use of visual representations, such as diagrams or pictorial maps, to convey concepts and ideas. The framework incorporates five categories of barriers and demonstrates the role of IDT and LC in eliminating various categories of barriers, as highlighted in Figure 2.

According to academic literature, the diffusion of an innovation approach refers to the transmission of a novel idea disseminated through targeted communication channels within a social system over a defined timeframe, whereas adoption is distinguished by a conscious choice to completely accept an innovation as the best feasible course of action (Rogers, 2003). Innovation Diffusion Theory (IDT) delves into understanding the workings, motivators, and trends of the dissemination of novel ideas and advancements in technology within different societal contexts (Rogers, 2003). The utilization of this concept has been extensive within the realm of Information Technology (IT) research, as it offers valuable perspectives on the uptake, execution, integration, and expansion of IT innovations (Fakhimi et al., 2021). The methodology offers a comprehensive set of quantitative and qualitative instruments to evaluate the probable pace of technology diffusion, while also identifying the factors that either promote or hinder the acceptance and deployment of a given technology. There exist apprehensions regarding the potential assimilation of BIM within the industry, as novel technologies do not invariably yield their anticipated transformative impact and may exhibit a slower-than-expected adoption rate or fail to gain traction altogether (Gledson, 2022). The diffusion of innovation is a phenomenon that is observed throughout society; however, the construction industry experiences a relatively low rate of innovation. As per Rogers (2003), within a given population, the initial 50% of individuals who reach a critical point of innovation adoption are comprised of innovators (2.5%), early adopters (13.5%), and the early majority (34%), while the remaining are composed of the late majority (34%) and laggards (16%). Several scholarly investigations have employed these theoretical frameworks to comprehend the BIM implementation in diverse nations. The utilization of IDT in investigating the BIM adoption among SMEs in Australia (Hosseini et al., 2016), Oil, Gas, and Petrochemical Industry in Iran (Fakhimi et al., 2021), and the UK industry (Gledson, 2022) was observed, whereas, Xu et al. (2014) and Kim et al. (2016) employed an integrated approach that combined the Innovation Diffusion Theory with the Technology Acceptance Model (TAM-IDT), to investigate BIM adoption in China and Korea, respectively.

However, in contrast to the above theoretical perspectives, Lean construction (LC) serves as an overarching term encompassing a blend of operational research and practices customized for the AEC industry, with its origins traced back to the lean production system pioneered by Toyota, a leading Japanese automobile manufacturer (Ballard, 2000; Koskela, 1992; Sacks et al., 2010). The main goal of LC is to eliminate various forms of waste from a process, thereby maximizing the value delivered to the customer (Heigermoser et al., 2019). By leveraging the principles of LC, construction processes can undergo continuous improvement and standardization (Zhang et al., 2016). This suggests that integrating principles from lean concepts can also elevate the maturity level of BIM within organizations. There have been various studies that consider the use of various lean tools such as the Last Planner System (LPS), Integrated Project Delivery (IPD), Value Stream Mapping (VSM), and the Big Room concept as potential techniques to enhance innovation acceptance across various construction projects (Mahalingam et al., 2015; Michaud et al., 2019; Piroozfar et al., 2019).

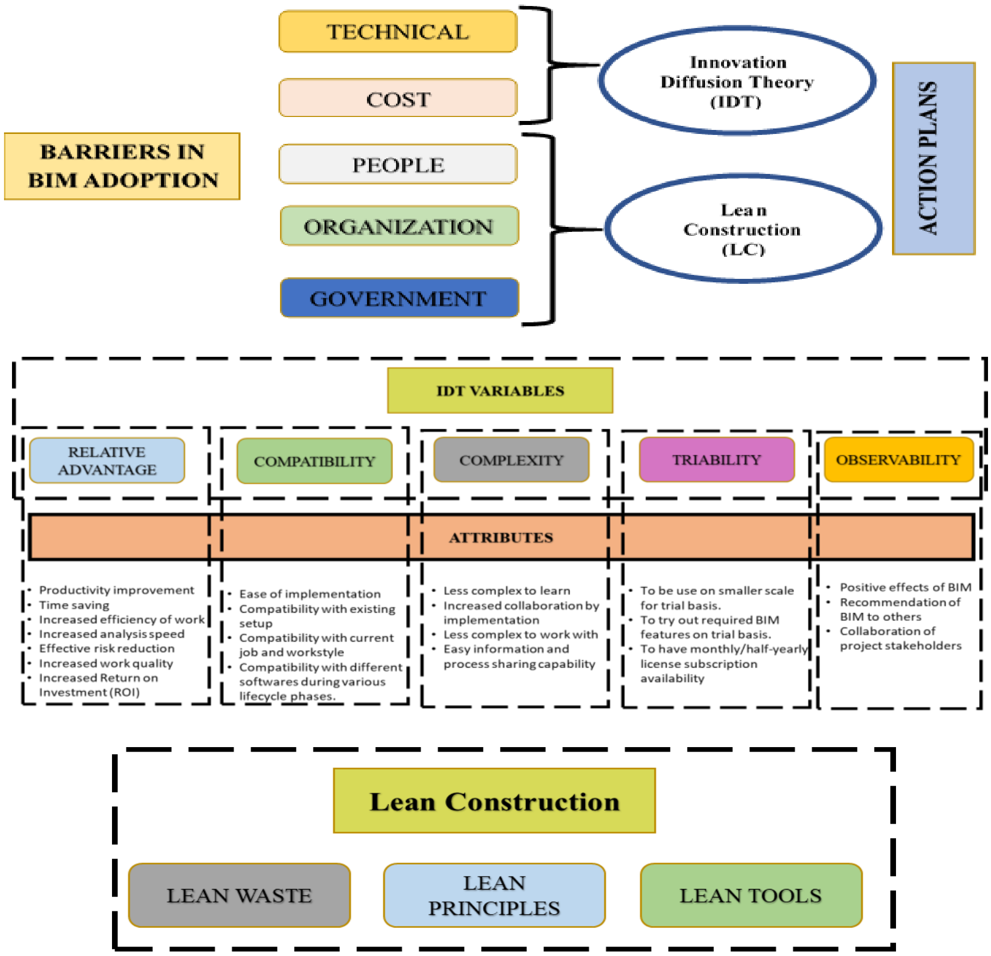


Figure 2: LCIDT - A conceptual framework

Hence, "LCIDT" has been formulated by integrating LC with IDT to demonstrate effective strategies to overcome the barriers. The barriers are classified into five different categories: Technical, People, Organization, Cost, and Government barriers, based on similar other studies (Ahuja et al., 2020; Gaur & Tawalare, 2022, 2023) and demonstrates the role of IDT and LC in eliminating various categories of barriers. As shown in the framework, IDT involves five categories of variables including innovation's relative advantage (perception of the innovation's superiority above current practice), compatibility (extent to which an innovation aligns with prior concepts, and/or perceived necessity.), complexity (level of understanding associated with the utilization or comprehension of an innovation), trialability (the extent to which the innovation can be tried intermittently) and observability (extent to which prospective adopters can perceive the outcomes of an innovation). These five variables include different attributes related to the technical and cost aspects of BIM-related software and can be utilized to select multiple BIM software during various lifecycle phases of a project, depending upon varying levels of necessity. Hence, the IDT variables can be a useful method for stakeholders to select appropriate BIM software based on their technical requirement and purchasing power, hence eliminating technology (interoperability issues, data privacy/security issues, availability of multiple BIM software, etc.) and cost-related barriers (high cost of software, hardware, risk of low ROI, etc.).

On the other hand, LC cultivates a philosophy of improved coordination and collaboration among different project teams, further establishing a new cultural environment which will consequently amplify the adoption of BIM (Mahalingam et al., 2015). It helps in enhancing organizational learning, which aids companies in value addition through the promotion of innovations (Salehi & Yaghtin, 2015), training and standardization of processes (Schimanski et al., 2021). Furthermore, it improves the early involvement of key participants and increases the level of trust among influential stakeholders (Piroozfar et al., 2019). Additionally, few studies have suggested that enhanced BIM maturity level, as well as integrated BIM implementation (called Level 3 BIM), would not have been achievable without a thorough comprehension and use of LC principles (Barkokebas et al., 2021; Hamdi & Leite, 2012; Koseoglu et al., 2018). Hence, it can be inferred that LC can help in eliminating various organizational (lack of top management support, resistance to change, etc.), people (lack of collaboration, lack of knowledge and BIM training, etc.) and government (lack of standards and mandatory BIM contracts, lack of involvement and initiatives).

6. CONCLUSION

The study developed a framework to enhance the adoption of BIM by integrating the theoretical and practical lenses of IDT and Lean construction, respectively. In this regard, a systematic review of 46 papers (using the PRISMA technique and the SCOPUS database) along with an analysis of various online available documents was done. The authors identified 46 articles that underwent quantitative analysis based on their year of publication, research method employed, and type of article (journal or conference). Based on the qualitative analysis, the studies were analysed based on different geographical locations in India as well as various dimensional applications of BIM. It was found that BIM and other digital technologies have not yet been fully adopted by the Indian construction sector, shedding light on the current status of BIM development as well as the barriers affecting its successful implementation. It was also ascertained from the study that there is a paucity of research on the deep understanding of BIM implementation in India due to various socio-cultural and geographical factors. Furthermore, no prior investigation has employed Innovation Diffusion Theory (IDT) to analyse BIM adoption in the Indian context. Additionally, no framework has depicted the impact of Lean Construction (LC) on improving BIM implementation. Thus, the novelty of this study arises from the development of the framework "LCIDT" by integrating LC with IDT. The IDT can deal with technology and cost-related barriers by comprehending and selecting the necessary BIM tools required for different project trades and applications. Similarly, LC can help to eliminate people, organizations, and government-related barriers through the engagement of lean principles and tools. Utilizing the conceptual framework can help in the pragmatic execution of diverse emerging technologies across different infrastructure domains. Moreover, the framework can be customized according to the specific technology being considered and can be beneficial for implementing different innovations in the AEC Industry. Although the stakeholders are reluctant to deviate from conventional construction approaches, existing literature strongly supports the implementation of LCIDT in the construction industry for effective technology adoption.

The study focuses on the implementation of LC within project organizations. However, LC applications are presently being utilized by designers, contractors, and consultants, whereas client organizations, which are one of the primary stakeholders for BIM use, remain largely unaware of its potential benefits and implementation. In addition to the contribution of this study to the body of knowledge, as part of future work, the framework can also be further enhanced by categorizing the barriers into distinct lean waste categories, and appropriate lean tools, techniques, and principles can be applied to eliminate them. Additionally, empirical research and surveys can be conducted with different lean implementing organizations and stakeholders to enhance the understanding of the applications of LC for improving the digitalization of the global construction sector. Lastly, the study selected articles from a single database, and to increase the study's comprehensiveness and validity, document analysis from other sources such as webpages, blogs, and reports was also performed. However, the study recommends the use of multiple databases as part of future studies to enhance data reliability.

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