Singhal, N., Ahuja, R. (2018). “Can BIM furnish Lean benefits- An Indian Case Study” In: *Proc. 26th Annual Conference of the International. Group for Lean Construction (IGLC), González, V.A. (ed.)*, Chennai, India, pp. 90–100. DOI: doi.org/10.24928/2018/0425. Available at: www.iglc.net.

CAN BIM FURNISH LEAN BENEFITS - AN INDIAN CASE STUDY

Nilay Singhal[1], Ritu Ahuja[2]

ABSTRACT

Building Information Modelling (BIM) is recognized as an enabler for proficient accomplishment of projects in construction industry at different levels. Various benefits have been achieved globally through BIM implementations including enhanced visualization, collaboration between stakeholders throughout the project life cycle, time and cost savings, value engineering, change management and many others. Harnessing the BIM capabilities efficiently to gain maximum benefits on the projects can be a major milestone for the Indian built environment sector. For this study, BIM has been identified as an effective process for achieving various lean benefits for construction projects in India.

The project envision BIM as a catalyst for improving the current scenario of Indian construction sector. The paper is based on exploration case based research methodology wherein, both literature review and semi-structured interview have been done. Relationship between BIM and lean by studying the use of various BIM capabilities on construction projects from initiation stage till operations and maintenance stage has been established. Lean benefits corresponding to each BIM capability has been reported upon validating in discussions with the industry experts and literature review.

KEYWORDS

BIM, Collaboration, lean construction, Indian Construction sector, Value.

INTRODUCTION

Indian construction sector is well known for its fragmented nature yet it is economically as viable as other sectors (More et al. 2016). From the past research, it is evident that construction impacts environmental, economic and social aspects of built environment (Rahman et al. 2013). Therefore, it becomes imperative for the stakeholders in this field to exercise effective pre-construction, construction, operations and maintenance strategies

[1] Post Graduate student, School of Construction, RICS School of Built Environment, Amity University, 5th Floor, F2 block, Sector- 125, Noida 201301 (UP) India; Phone +91-7042278991, nilays.mc16@ricssbe.edu.in

[2] Assistant Professor, School of Construction, RICS School of Built Environment, Amity University, 5th Floor, F2 block, Sector- 125, Noida 201301 (UP) India; Phone +91-120-6673038, rahuja@ricssbe.edu.in

and their subsequent implementations. Sustained growth in Indian economy has called for faster and quality construction practices by overcoming impediments—outdated technology, lack of training, poor planning, fragmentation, etc. Hence efforts are being made to yield quality products and services, benefits and assured return on investment (More et al. 2016). Lean construction is based on the underlying concepts and principles of the Toyota Production System (TPS) that focuses on waste minimization, enhanced delivery of value added product and services to customers, and continuous improvement (Sacks et al. 2009). BIM as defined by the National Building Information Modelling Standards (NBIMS) committee of USA is a digital depiction of physical and functional features of any infrastructural facility (Chougule and Konnur 2015). BIM also known as Virtual Design and Construction (VDC) has been reported to be in its experimentation stage in India (Sawhney 2014). Lean has helped in maximizing profits in Japanese manufacturing units. Thus, amalgamation of BIM and lean can bring surplus benefits to the construction industry (Bolpagni et al. 2017). There exists a synergy between lean and BIM (Sacks et al. 2009). BIM capabilities can be interpreted as potential characteristics resulting in functions or specific tasks that can be performed to accrue lean benefits on construction projects. This paper discusses the lean benefits of implementation of BIM on construction projects in India and reports a robust framework for case studies of the same.

LITERATURE REVIEW

Literature review acts as a foundation for this paper for which previous publications have been used to develop a BIM-Lean framework for case studies depicting BIM capabilities, their subsequent lean benefits. It has been reported that independently developed lean construction practices can be effectively leveraged by implementing BIM (Gerber et al. 2010). According to a UK based case study for design and construction of prison system, lean was the first deciding step on their path to BIM implementation (McGraw Hill Construction 2014). BIM directly contributes to lean goals by improving predictability, collaboration, discipline, learning and implementation (Koskela 2014). Reasons for such a close relationship between BIM and lean can be attributed to following BIM capabilities and lean benefits as identified through an extensive literature review in sections below—

BIM CAPABILITIES

BIM provides a common platform for stakeholders to work in a collaborative environment (Rokooei 2015). BIM helps in capturing reality, minimizing wastes and rework, conflict resolution, work sequencing, automation and customization (Ball 2014), value generation and improved workflow (Mollasalehi et al. 2016). Visualization of the proposed facility early in the design phase helps in realising what the proposed facility will look like upon completion (Mollasalehi et al. 2016). BIM simplifies quantity extraction, preparation of Bill of Quantities (BOQs) and accurate cost estimates (Raphael and Priyanka 2014). BIM capabilities such as Clash detection, 4D Scheduling, construction sequencing, collaboration and communication have been utilised extensively in previous projects (Sacks et al. 2009). Design coordination, Energy and performance analysis, digitised walkthroughs, Generation of "as-built" models help in value addition

(Muthumanickam et al. 2012). Integrated Site Planning, Change Management, Structural Analysis, BIM for Supply Chain Management (Ahuja et al. 2017), Code reviews, Fabrication/shop drawings, Forensic analysis, (Azhar et al. 2008) can be achieved to accelerate the project realization. Past researches have demonstrated that organizations are reluctant to adopt such innovative technological solutions due to scepticism (Premkumar and Roberts 1999). Identification and evaluation of risks and challenges at an earlier stage improves the effectiveness of technological advances (Chien et al. 2014). Availability of technical expertise will encourage BIM adoption (Ahuja et al. 2016). Favourable attitude towards BIM, availability of BIM based softwares on trial basis and consistent beliefs and values for BIM adoption catalyses the implementation of BIM in Indian scenario (Ahuja et al. 2018). At the same time BIM implementation faces challenges because of lack of standardization and complexity in processes (Ahuja et al. 2018). Capabilities of BIM facilitate the collaborative management of Construction and Demolition Wastes (CDW) (Akinade et al. 2018). However, at the same time it must be realized even though there a single model on which entire team of specialists works, yet there is loss of tribal knowledge because specialists are either shifted to new projects or they migrate to other firms (Barista, 2014). Such a turnover may lead to indirect form of waste in construction on account of loss of knowledge, skills and expertise. It is of utmost importance that the project management team should realize the benefits of BIM capabilities (Rokooei 2015) and disadvantages of disguised turnover of expert manpower (Barista, 2014).

LEAN BENEFITS

Increasing the customer satisfaction, flexibility, application of best working practises to gain competitive advantage over rivals propels lean adoption (Salonitis and Tsinopoulos 2016). Lean promotes continuous improvement at work places by creating an environment of mutual trust, respect and harmony (Banna 2017). It minimizes wastes, i.e. activities that do not add value to client’s demands (Skhmot 2017). Overproduction, delays/ waiting, over processing, unnecessary motion, inventory costs, knowledge scatter, wishful thinking and under realization of skills are identified as wastes (Larman and Vodde 2009). Lean processes help to improve worker’s safety and increase staff productivity by enhancing communication and collaboration within project teams (Karakhan et al. 2016). A survey conducted by McGraw Hill Construction reports lean practitioners achieved greater customer satisfaction and higher construction quality as key lean benefits (McGraw Hill Construction 2013). As per Construction Lean Improvement Programme (CLIP), organizations that adopted lean under its guidance achieved improved communication, team dynamics and waste minimizations which also saves money and effort (CIRIA 2003). Primary objective is to identify value addition from customer point of view and consider the interrelatedness and interdependence between the stages any project (Bade and Haas 2015). Proactive involvement of project team members and healthy competition leads to reduced project schedule (Riddell 2017). An interesting study regarding the BIM implementation and lean benefits resulted in formulation of a matrix which has been termed as BIM-Lean framework for case studies in this paper.

RESEARCH METHODOLOGY

Two projects were identified for conducting this study which helped in countering the following queries:

- What capabilities of BIM have been implemented on two of the construction projects in India?
- What potential lean benefits can be accrued by implementing BIM?
- What lean benefits have actually been accrued in the selected case studies?

In order to answer the above questions, an exploration based case study approach was adopted. (Yin) defined case study as an empirical investigation that examines an existing phenomenon within its real-life context especially when the boundaries between phenomenon and context are not distinctly obvious; and which uses either single or multiple sources of evidences. For this paper two case studies based on exploration of real life event are used to depict relationship between BIM and lean in order to specifically report various lean benefits which were obtained by effective implementation of different BIM capabilities. Following procedure as shown in Figure 1 has been adopted for the paper—

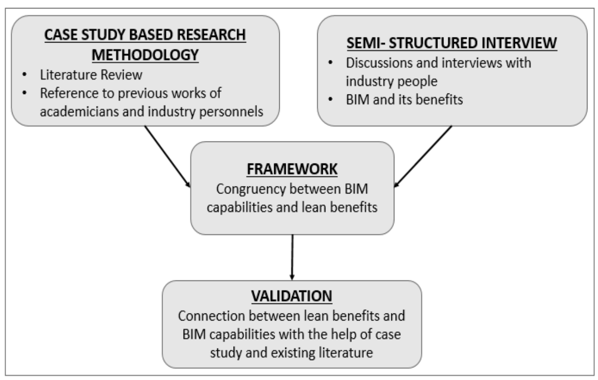

Figure 1: Research Methodology Flowchart

- Literature Review: As exploration based case study demands prior fieldwork and data collection to lay a concrete foundation for the study (Zainal 2007). Different BIM capabilities that are being utilized globally have been explored via existing literature and previous works of academicians and industry experts. Similarly, the lean benefits based on the principles of lean philosophy have also been identified.
- Framework: Based on extensive literature review and subsequent study and analysis, semi structured interviews with industry experts were conducted to identify what BIM capabilities have already been used and are being used in the selected Indian case study projects. There was specific interview and discussion with respect to each BIM capability with the expert working on that particular functionality of BIM. Subsequently, different lean benefits complementary to the accrued BIM capabilities were discussed with the experts via semi-structured interviews and reported in the form of a framework.

- Validation: The framework so developed upon the basis of literature review and semi-structured interviews was subsequently validated by the industry experts. There were series of detailed discussions held with the experts. Based on which analysis as to what, when and how each lean benefit was achieved while implementing or after having implemented a particular BIM capability. The experts are having an experience of more than fifteen years working in the construction and modelling industry and have been working on 5 dimensional BIM based projects both in India and abroad.

CASE STUDY PROJECTS

PROJECT 1

A commercial retail centre with a gross built up area of 35000 m^2 is being built in one of the cities of India. Client and General contractor mutually agreed for BIM based project implementation. A BIM consultant was thus hired BIM. Execution Plan (BEP) which is a contractual document that delineates roles and responsibilities of team members (Aungst 2017) and specifies guidelines for BIM implementation was prepared. Training sessions were organized by the BIM consultant to train the team on BIM based technologies for the project. Meetings and discussions were periodically conducted.

Preconstruction Phase:

Architectural, Structural, Mechanical, Electrical, Plumbing, Furniture and Fixture (MEPFF) drawings were prepared initially using 2D CAD in compliance with Level 1 (McPartland 2017) BIM implementation. Conceptual models were prepared using 3D CAD. Architects team developed Revit models with a maturity level of LOD 300 from Good for Construction (GFC) drawings and Enscape plug-in was then used with Revit to develop a Virtual reality (VR) model. MEPFF models were developed with maturity level of 400. Models were shared on a Common Data Environment (CDE) to enable real time discussions and coordination between team members. This improved transparency, information sharing, motivation, reduced rework and reduced duplicity of efforts. Walkthroughs helped in detecting clashes of services with the architectural and structural components to prevent time and cost overruns during execution stage. Material quantities were extracted directly from the Revit model and exported to excel file to prepare Bill of Quantities (BOQs). Construction schedule prepared on Microsoft Project (MSP) was imported on Navisworks Manage which was synchronized with previously imported Revit model to perform real time simulations for construction sequencing. Project Management Consultants (PMC) and contractors worked together to finalize the total duration of the project with the help of simulations.

Construction Phase:

Model was meticulously updated with the help of GFC drawings. Contractors at the site simultaneously updated the budget and schedule on the basis of progress to facilitate the development of pour schedules. Walkthroughs enabled planning and positioning logistics - materials, equipment, labour at site to improve safety and avoid irrelevant motions and work activities for increasing productivity at site. Construction Operation Building Information Exchange (COBie) data was updated on a excel file to build data for facility management.

Operations and Maintenance stage:

COBie and Revit models replaced the as-built drawings with rich and real time information. This information will be useful in maintaining and keeping the facility up and running with enhanced safety and minimized lifecycle costing.

The connections between BIM capabilities and various lean benefits reported has been presented in Table 1 below wherein, (•) means that the particular lean benefit was obtained to the corresponding BIM capability and (•) means that the particular lean benefit was not obtained to the corresponding BIM capability.

Table 1: BIM-Lean framework for Project 1

STAGE	BIM Capabilities	Worker safety	Increased staff productivity	Improved communication	Reduced project schedule	Reduced lifecycle cost	Continuous improvement	Better risk management	Waste minimization	High quality construction	Improved team dynamics	Greater Customer satisfaction
PRE-CONSTRUCTION (Project 1 and 2)	Design coordination	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Visualisation/ walkthrough	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Quantity take-off	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4D Construction Sequencing and Scheduling	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓
CONSTRUCTION (Project 1)	4D construction sequencing and tracking	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Cost Tracking	✗	✗	✓	✗	✓	✓	✓	✓	✗	✗	✓
	Safety Management	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓
	Collaboration and coordination	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OPERATIONS and MAINTENANCE (Project 1)	As- built drawings and models	✗	✗	✓	✗	✗	✓	✓	✓	✗	✗	✓
	Facility management	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓

The BIM capabilities and lean benefits listed in the table are based on findings from the literature review. However, the interrelationship between the two as depicted above has been thoroughly investigated and validated by discussions with industry experts.

PROJECT 2

A renowned Indian Public Sector Undertaking (PSU) has proposed the construction of—2 halls (500m^2) in the existing building, Bungalow (494.12 m^2), Guest house (1052.11 m^2) and a multipurpose hall (556.7 m^2) at its Northern region headquarter in Lucknow, India estimated close to INR 232 cr. A leading engineering and architectural firm situated in Noida, India has been awarded contract for design development and construction. Based on the project brief they presented to the client their intent for implementing BIM supported by their own BIM success stories in previous projects. The team impressed with the capabilities and advantages of BIM agreed for implementing it in the pre-construction stage.

Pre-Construction Stage:

A local architectural consultant in Lucknow was hired by the awardee to facilitate information exchange. The local architect created a CAD based conceptual design based on project brief which was subsequently revised and updated by the leading contractor for primary approval by the client. After approval REVIT based model was prepared which was used to estimate quantity, prepare BOQ and cost estimate, detect clashes, prepare site logistics plan, compliance with local and Indian standard codes. Client received a real time view of the proposed facility which encouraged active participation from their side. There was a reduction in efforts as any changes suggested by client was simultaneously updated on model which greatly enhanced information reliability and developed client’s trust and interest in BIM. Construction schedule, work sequencing was formulated to facilitate risk minimization and increase quality at minimized cost in a safer work environment during project’s lifecycle. Influenced by BIM capabilities and benefits client team is planning to implement the same in execution stage. The BIM capabilities adopted and the benefits reported at the preconstruction phase of this project are also similar to Project 1 preconstruction phase.

DISCUSION AND CONCLUSION

Preliminary findings for Project 1 and Project 2 are reported in the BIM-lean framework in Table 1. The lean benefits facilitated by BIM implementation has been discussed and compared with global literature. BIM synergises the entire project team working on the project. They can coordinate simultaneously while designing building elements- slabs, columns, beams, stairs, walls, fittings and fixtures, etc. of the same model and any changes made by one party are visible to the other to obtain holistic view of the facility and effective project documentation. Project team can leverage their skills, experience and expertise to devise risk management strategies while nourishing the design development with optimised resources to maximize value addition, customer satisfaction. A very important aspect of design coordination is clash detection. Previous studies also report that BIM enables visualisation of the building elements-MEP, architectural, structural to avoid any physical hindrance by one component to another (Dave et al. 2013). This saves time, money, material and human effort, because if clashes occur during execution, it will delay the work and leads to wastages. Project team members and client get a better understanding of the design. Walkthroughs helped the client to connect dots in design development. Thus lean benefits such as Worker safety, enhanced staff productivity, communication, waste minimization, customer satisfaction, improved team dynamics, construction quality and better risk management were achieved. This is in congruence with the case on Shanghai Tower in China that formally declared a total material savings of thirty two percent using Revit and Navisworks Manage by visualizing clashes and accelerated progress (Autodesk, 2012). During design development of its basement seven clashes were identified and during construction there were no clashes at all. 4D construction sequencing and scheduling implemented in the above projects is a combination of a BIM model and project schedule which enables visual analysis and simulations to prepare risk management strategies (Dawood et al. 2002). It also helps in preparing a site management plan. 4D model can be used to guide procurement of resources and positioning of equipments and temporary structures at site. BIM models facilitated automated quantity take offs. When we use BIM models we need not to measure each and every detail by entering commands as we used to do so while using AutoCAD, instead BIM authoring softwares such as REVIT provides the advantage to generate automated schedule of quantities from the parametric data of the model elements. In case there are any changes made in the properties of elements, the same gets easily updated in the revised schedule which allows savings in time and human efforts apart from assuring accuracy. Client gets quick access to cost estimates to help him finalise the project's scope. As per the case study by (Franco et al. 2015), during calculation of total quantity of dry wall using traditional CAD practise and BIM based model, BIM resulted in total savings of two percent on Drywall panels as it also considered the openings for doors and windows. BIM reduced total cost by fifteen percent. This incentivised increased confidence in documentations, collaboration, coordination, accuracy and productivity.

Storage and maintenance of 2D as-built drawings is a tedious task also it becomes difficult for the new members to understand the design in absence of the team that worked on it. Using BIM as-built models containing detailed information and history of changes regarding each element can be prepared. BIM is an enabler which helps to eradicate basic causes of waste generation— improper and unexpected design changes, poor procurement and control, planning, inefficiencies in material handling, residues of raw materials, and rework (Cheng et al. 2015). This is exactly in line with the collaborative approach between BIM benefits and Lean principles of construction.

UNESCO declared world heritage site Opera House, Sydney is managed using Industry Foundation Class (IFC) format for interoperability of BIM files. It has reported following advantages— contacting the concerned department in case of element failure, retrieve history of elemental revisions, maintenance, visualisations, simulations, security, improved customer service (CRC Construction Innovation 2007).

Findings in this paper are compatible with the previous works and evidences. BIM tends to yield lean benefits, increased confidence in project team and improved work flow. Societal demand, organizational acceptability, technical complexities are key factors to the implementation of BIM (Tulenheimo 2015). No prominent success stories of BIM are available with respect to the Indian context (Sawhney 2014). The same is evident in a model by (Ahuja et al. 2016) wherein entire project is categorized at macro-level, organizational team at meso level and its members at the micro level which places BIM adoption between micro and meso level. This suggests that BIM is majorly used in pre-construction stage for designing purposes which is in congruence with the project 2 as mentioned in this paper. Even though the project consultants are willing to implement

BIM yet, clients are quite reluctant to implement the same because of long lead time for scale implementation, lack of awareness and high training costs (Ahuja et al. 2018). One of the case study participant expressed the necessity for governmental initiatives to encourage and facilitate BIM adoption in India. India needs to develop expertise in BIM implementation and invest wisely for better Return on Investment as reported in the past projects.

ACKNOWLEDGEMENT

We are grateful to the SABS Architects & Engineers Pvt. Ltd. for providing us with the case studies related to BIM implementation.

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