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APPLICABILITY OF BIM TECHNOLOGY FOR ENHANCING THE LEAN CONSTRUCTION PROCESS IN SRI LANKA

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ABSTRACT

Building Information Modelling (BIM) is widely implemented in construction industries around the world, providing many benefits. BIM has brought significant improvements in productivity, accuracy, and efficiency. Lean is an innovative construction management method that is closely linked to the overall lifecycle of a project to ensure its success. Lean and BIM are two different concepts used to enhance the value and quality of overall construction projects. The combination of these two concepts has been used to eliminate waste and encourage a streamlined workflow ensuring the delivery of value to the customers. But still, there is a lagging that can be identified in the applicability of BIM for enhancing the lean construction process in local scenarios. Therefore, the study explored the applicability of BIM technology for the lean construction process in Sri Lanka. Accordingly, a comprehensive literature survey and three case studies were conducted to collect data. Subsequently, the collected data were analysed using content analysis with the use of NVivo software. The study indicates that 12 lean techniques which have been implemented in local construction projects and 9 BIM-related software encourage the establishment of lean principles. The study further revealed, 7 common challenges while integrating of Lean-BIM and 9 solutions to overcome the challenges identified. Finally, a framework was developed based on the research findings to identify the current situation of the applicability of BIM technology for enhancing the lean construction process in Sri Lanka.

Keywords: *Building Information Modelling; Construction Industry; Collaboration; Lean Construction.*

1. INTRODUCTION

The construction industry is one of the key industries which contributes to the country's economy (Onyango, 2016). In a developing country, construction is crucial because it creates a path for the country's economic growth and is also very complex in its nature (Aljahdali & Alsulami, 2017). Hence, it has become a very challenging task to achieve the project requirements and constraints (Cheung & Yiu, 2006). According to Issa (2013), lean construction is a philosophy oriented toward construction administration which was developed from Toyota`s production system. Also, it sets productive flows in motion to

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develop and control systems to reduce losses throughout the construction process. Reduced cost of implementation, improvement of continuity, minimising waste, and finishing the output within the agreed period are some of the advantages of lean construction (Li et al., 2020). According to Johansen and Walter (2007), lean principles have been used in developed countries such as Australia, Denmark, Finland, Singapore, the United Kingdom, and the USA, to get the best value for their projects. With the technology development, the concept of Building Information Modelling (BIM) came into place. BIM helps to minimise wastage, and errors to carry out the construction process effectively and efficiently as well as reduce the life cycle cost and gain the quality of the output (Epasinghe et al., 2018). BIM is used for this lean construction process in parallel (Guerriero et al., 2017). Most European countries and the United States have obtained progressive popularity in BIM technology. Over the last few years, BIM usage has risen dramatically over the world, particularly in industrialised countries such as Australia, China, Denmark, Finland, and Singapore, Sweden, the United Kingdom (Ullah et al., 2019). However, it has previously been observed that the Sri Lankan construction industry has poor records in completing projects within the given time, allocated cost, and expected quality targets (Halwatura & Ranasinghe, 2013; Perera et al., 2021). Sri Lanka is still in the initial stage of lean practice and BIM technology. Based on the "Bew-Richards UK BIM Maturity Model," the Sri Lankan construction industry is classified as being in "Phase 0.". Hence, this research paper identifies the significance of BIM's applicability to the lean construction process in Sri Lanka.

2. LITERATURE REVIEW

2.1 LEAN MANUFACTURING

The lean process involves adding value to the production to get a high return on investment in manufacturing (Salem et al., 2006) and combines both workflows of the organisation with the organisational techniques to achieve a higher quality outcome by using minimum resources (Katayama & Bennett, 1996). The lean manufacturing system has encouraged by five principles which are identifying value, mapping the value stream, creating flow, establishing pull, and seeking perfection. Lean production principles were successfully used for TOYOTA product manufacturing in 1950 in Japan (Abdelhamid & Salem, 2005). Those principles boost creating better production flow and improve the culture continuously. According to Kelendar (2020), there are three main concepts in lean thinking including eliminating waste, creating values, and continuous improvement which can be used to identify value-adding activities, non-value-adding activities which can be eliminated, and non-value activities which cannot be eliminated in the process. Those non-value activities which can be eliminated are called 'waste'.

2.2 LEAN CONSTRUCTION

Even though lean was developed for the manufacturing industry, it has had a significant impact on many other industries all over the world (Abdelhamid & Salem, 2005). There are significant differences between the construction industry and other manufacturing industries. According to Salem et al. (2006), the construction industry deals with larger units in which end products cannot be transported whereas the manufacturing industry deals with the end products which can be moved as a whole. Further, the researchers have highlighted that some of the other differences are on-site production: productions are site position manufacturing, One-of-a-kind production: customer decides the final output, complexity: completion of construction projects are very complex, unique, and dynamic systems (Koskela & Howell, 2002). Even though there are differences between the construction industry and other manufacturing industries, the objectives of every project are the same. According to Howell (1999), it is a common scenario when it comes to the goal of delivering a project meeting specific customer requirement in zero time. According to Koskela (1992), lean construction techniques have become a foundation for project management because it views the construction process without focusing on individual activities. According to previous studies, the countries such as Australia, Brazil, Chile, Denmark, Ecuador, Finland, Peru, Singapore, South Korea, the UK, the USA and Venezuela are the leading countries which have adopted lean construction (Albalkhy & Sweis, 2021; Ballard & Howell, 2003; Johansen & Walter, 2007; Jørgensen & Emmitt, 2008). With time, many instruments have been created to materialise the application of the lean construction philosophy more systematically, they are minimising waste, maximising value, and continuous improvement.

According to Marhani et al. (2013), the implementation of lean construction has a profound impact on construction schedules and overall project performance. It effectively enhances workforce productivity, fosters effective coordination and communication, and reduces defects and rework. One of the most significant positive outcomes of embracing lean principles in construction projects is the timely delivery of completed projects to clients. Furthermore, the adoption of lean principles has led to an increased rate of innovation within the construction industry (Meng, 2019).

2.3 BUILDING INFORMATION MODELLING

Like all the other industries, the construction industry also gets benefited from a range of information and communication technology (ICT) solutions in the project delivery process (Bui et al., 2016). It has proved that the construction industry is more productive with ICT applications (Bryde et al., 2013). The most prominent example of an effective ICT application using in the construction industry is BIM (Eadie et al., 2013). BIM is widely seen as a stimulant for innovation and productivity in the global construction industry. In the current industry practices, BIM is commonly used to design, construct, and maintain approaches for projects (Bryde et al., 2013). BIM integrates people and technology to reduce time and costs and increase efficiency in projects. Unlike other ICT applications used in the construction industry, BIM can create realistic models of the building. In the design, construction and operation process, BIM is used to create and manage the data and represent it in a cloud-based real-time collaboration platform. IFC enables the interoperability between BIM software and uplifts collaboration with the professionals involved in the construction industry (Tse et al., 2005). It enables data visualisation, rapid generation of alternative designs, automated assessment of model reliability, generation of comprehensive reports, and accurate forecasting of building performance (Ullah et al., 2019; Sacks et al., 2010). Further, in the construction phase, a project team can monitor the progress, coordinate meetings, integrate RFIs, change orders and punch list information using the BIM models (Al-Yami & Sanni-Anibire, 2021).

As Ullah et al. (2019) demonstrate, in recent years, there is a significant increase in the adaptation of BIM in developed countries, whereas most Asian countries have used BIM for all their public projects. However, whether it was used the BIM technology for numerous purposes, and individually use the BIM and lean concepts competitively for construction industry development, no research has been conducted to investigate the applicability of BIM technology for enhancing the lean construction. Thus, the following methodology has been taken to find out the applicability of implementing BIM technology to enhance the lean practices in the Sri Lankan construction industry.

3. METHODOLOGY

In this study, a comprehensive literature survey was conducted to identify the lean construction principles in the construction industry and then, BIM and its uses in the construction industry. Correspondingly, the case study approach was followed under the qualitative research method to identify the application and practical issues of implementing BIM and lean applications in the Sri Lankan construction industry. Due to the limited number of BIM projects in the Sri Lankan context, a purposive sampling method was used to select individuals who were most relevant to the research objectives. It enables to increase the accuracy of the data by allowing the researcher to gather in-depth and focused information from the selected sample. Accordingly, three case studies which used BIM-related software applications were selected, and under each case study, nine respondents were interviewed. Then the collected data were analysed using content analysis with the use of NVivo software. The profiles of the case study projects are summarised in Table 1.

Table 1: Case study profiles

Description	Case A	Case B	Case C
Project Type	Educational	Infrastructure	Office
Contract Sum	LKR 1.6 billion	USD 550 million	LKR 5 billion
Project Duration	2 years	3 years	3 ½ years
Procurement Type	Measure & Pay	Measure & Pay	Design & Build
LOD level	LOD 350	LOD 350	LOD 400
BIM Maturity Level	Level 2	Level 2	Level 2
Used BIM Software	CubiCost, Sketchup	SketchUp, Revit, CubiCost	BIM 360, Revit, CostX, Navisworks
Other Software	Zoom, MS Project	Zoom, MS Project	Asana, MS Teams, MS Project

From three case studies, each case was interviewed by three professionals. All nine respondents' details are shown in table 2.

Table 2: Respondents' Profile

Respondent	Title	Type of Org.	Experience (years)		Professional Qualification	Scope of Work
			Industry	BIM		
A1	Quantity Surveyor	Consultant	3	2 ½	BSc QS	Quantification, communication, collaboration, cost management
A2	Director (Quantity Surveyor)	Consultant	16	5	Charted QS	Reduce cost & manpower, cost estimates, communication & collaboration

Respondent	Title	Type of Org.	Experience (years)		Professional Qualification	Scope of Work
			Industry	BIM		
A3	Project Quantity Surveyor	Contractor (CS2)	3	2	BSc. QS	Quantification, Managing the team, Checking the models & drawings, Collaboration
B1	External BIM Advisor	Consultant	3	1	BSc (Hons) QS	Introduce BIM to the project, Identify LOD in the Pre-contract stage
B2	Director (QS)	Consultant	30	5	Charted QS	Pre-Tendering works, Cost Estimation, Cost Planning
B3	Quantity Surveyor	Consultant	4	2	BSc. QS	Quantification, Cost estimates
C1	Senior QS (BIM Team Leader)	Consultant	10	5 ½	Charted QS	Construction and rectification of defects, Quantification, Managing the team
C2	Senior Architect	Consultant	15	5	Charted Architect	Modelling
C3	Engineer	Consultant	8	3	BSc (Hons) Electrical	Modelling electrical drawings

4. ANALYSIS AND FINDINGS

4.1 IDENTIFICATION OF LEAN WASTES IN THE CONSTRUCTION INDUSTRY

Respondents were asked to provide information about the lean wastes which they have experienced during their past projects. All nine respondents mentioned that they had identified all eight lean wastes during their past projects. According to A1, most sites don’t have a proper waste disposal system. They had to transport materials to another land from the construction site to dispose of, which results in additional costs for the project. Supporting this argument, B2, B3, and C3 also highlighted the presence of waste in construction and transportation. C3 further explained that in cases where low-quality materials are ordered or inadequate storage facilities are available, particularly in MEP sections, the replacement has to be done due to damages. B1 states *“the motion waste comes up with poor coordination, miscommunication, and poor documentation. Labours’ carelessness and the supervisors’ ignorance make more motions in the site. To find specific equipment site labourers have to walk through the site and waste time”*. Not only in the sites but also in the consultancy firms motion waste can be identified.

According to C1, *“most architects' workspaces and equipment tend to be messy, and it makes very difficult in locating documents and tools”*. This lack of organisation can lead to wasted time and delays. Another form of waste identified in lean construction is excessive inventory. C3 expressed that the ordering and purchasing of materials to address damages can result in an accumulation of excessive inventories, which ties up capital and contributes to waiting waste. C1 specifically highlighted that waiting waste is most commonly observed in MEP sections. Additionally, B1 and A1 identified that delays in drawings also lead to waiting waste. While A2, B1, and C1 mentioned that waiting waste can be caused by client decisions. B2 emphasised that it can also occur within the team itself. C1 further explained *“when purchasing orders are not placed in a* *timely manner as per a procurement plan, it results a considerable time waste"*. Delays can occur if purchasing orders and requests are not submitted promptly. A1 further stated that most of the defects can be identified from the site due to poor quality of work, damaged material, rework, or punch list items.

As reinforcement is one of the major materials, which has a high-cost, waste of reinforcement is a major issue in the construction industry. A3 mentioned that since labours who are in the bar bending yard cut reinforcements according to the schedule provided, changes in these schedules result in material waste. B2 and C3 also mentioned that overproduction can happen on the sites. According to the data collected, over-processing was highlighted only by respondents B2 and B3. However, B3 stated that poor communication, coordination, and task management will lead to over-processing waste.

Moreover, the drawing changes were highlighted as common in the construction industry. B1 and B2 explained that these drawing changes often require a reassessment of quantities, resulting in wasted skills. A2 further illustrated that variations in the project also contribute to the misuse of skills, estimating it to be around 7% of his experience.

According to the data analysed, waste occurs throughout the entire project in the Sri Lankan construction industry. Most of the waste identified by the respondents is related to waiting, such as waiting for approvals, waiting for drawings, and sub-contractors waiting for others to finish their tasks. These waiting periods significantly impact project efficiency. However, the analysis reveals that the construction industry experiences all eight lean wastes during the construction process.

4.2 LEAN PRACTICES WITH BIM-RELATED SOFTWARE IN SRI LANKA

Respondents were asked about the software and the lean techniques that they have used for their projects. According to their opinions in Sri Lanka, there has no 100% BIM or lean projects. They have used other software and techniques to implement lean in their organisation. Table 3 shows the techniques which have been used with BIM software.

Table 3: Lean techniques with BIM software

Lean Technique	BIM Software
Visual Management	Revit, CubiCost, BIM 360, Viskar, CostX, Navisworks, SketchUp
Integrated Project Delivery	MS Project
Target Value Cost	CostX, CubiCost
Pull Approach	MS Project, Primavera
Effective Analysis	Primavera
Last Planner System	MS Project, Primavera, Navisworks
Just in Time	Navisworks
Value Stream Mapping	Navisworks
Target Value Design	Primavera
Line of Balance	Primavera

In addition, companies implemented lean techniques using other software. Table 4 presents the non-BIM software used to implement lean.

Table 4: non-BIM software with lean techniques

Lean Technique	Non-BIM Software
Kanban	Asana
Daily Huddle Meetings	Zoom, MS Teams

4.3 CHALLENGES OF BIM TECHNOLOGY FOR LEAN CONSTRUCTION IN SRI LANKA

In case A, A1, A2 and A3 expressed that since the BIM technology is still not established in Sri Lanka, the knowledge and practice regarding the adaptation of lean using BIM technology are relatively low here. They have identified a lack of professional knowledge and the influence of the traditional education system as significant factors affecting this situation. A3 also points out that the unwillingness to embrace change is a challenge, as many traditional professionals are reluctant to adopt new technologies. A2 specifically mentioned the absence of a BIM culture in Sri Lanka, while A3 emphasises the resistance towards technological advancements.

A1 has highlighted the lack of expertise and limited commitment to research and development regarding lean practices and BIM technology in Sri Lanka as another barrier. As a developing country, one significant obstacle in Sri Lanka in implementing BIM technology is the high initial costs associated with BIM-related software applications, which are often difficult to afford for most contractors, consultants, and employers in the country. Further, the limited availability of resources and financial constraints make it difficult for the construction industry in Sri Lanka to fully embrace BIM due to the high upfront investment required. A1 mentioned that *"Government involvement in the advancement of modern technology is very poor"*. Further, A3 stated that Denmark, Finland, and the UK have better BIM implementation because of the strong involvement of their government. As the respondents emphasised, compared to those countries, Sri Lankan government involvement is significantly lower. It can be inferred that the limited government involvement in imposing guidelines and the absence of adequate standards and protocols for BIM contribute to the challenges faced by Sri Lanka in effectively implementing BIM in the construction industry.

Consequently, in case B also, B1, B2 and B3 emphasised the lack of experience in the use of BIM technology and lean as a key barrier. Additionally, there is a common perception among professionals that tasks performed using BIM can be accomplished using traditional methods as well. This mindset hinders the adoption of BIM and prevents the exploration of its full potential. Furthermore, if organisations aim to implement BIM alongside lean practices, the need to invest in staff training and provide opportunities for hands-on practice were recognised as demotivating factors. Alongside software expenses, the requirement for high-performance computers further adds to the financial burden. Additionally, it was found challenging for more experienced professionals to adapt to new technologies like BIM as they are not familiar with computer technologies.

4.4 MEASURES TO OVERCOME CHALLENGES FOR IMPLEMENTING BIM TECHNOLOGY FOR LEAN CONSTRUCTION IN SRI LANKA

When considering the lack of knowledge and less commitment to education among construction professionals in Sri Lanka, A1 suggested to engage foreign experts to increase the awareness of them. This could involve organising continuous professional development (CPD) programs, webinars, and seminars. Additionally, A1 proposed that universities should incorporate comprehensive educational programs for undergraduates right from the beginning. Consequently, B3 stated that open BIM centres will help to get education about BIM and lean.

Additionally, government support emerged as a significant factor, as suggested by the respondents. A2 emphasised that "*one way the government could support the industry would be to establish specific organisations to provide education, training, and resources to professionals in the industry*" This would facilitate the dissemination of knowledge and expertise in BIM technology and lean principles. In contrast, B2 recommended encouraging the use of BIM technology and lean principles by providing funding for pilot projects which demonstrate their benefits in the Sri Lankan context. The third suggestion put forward by the respondent A1 was the introduction of guidelines and regulations that either mandate or incentivise the use of BIM technology and lean principles in specific construction projects. Such measures would promote their integration and create a standardised approach within the industry. In addition, B1 proposed offering tax incentives to encourage investment in necessary machinery and provide a trademark or recognition to organisations who are implementing BIM technology. As the same respondent explains, *"this could be similar to the rating system in sustainable construction, where organisations receive grades such as gold or platinum based on their performance"*. This grading system could be extended to include BIM and lean construction, providing a clear evaluation framework.

As the respondents mentioned they had to spend the high cost of the computers and the purchasing software. Other than that, organisations must train their staff and they have to hire those who have knowledge about BIM and lean practices, and after purchasing software they had to renew their licences and maintain the cost of computers. C1's opinion about the cost of purchasing items was *"if you want to use BIM, you have to buy the software and machines which are required"* or he suggested, *"we can charge from it from the client"*. To do that A2 and B2 mentioned that they must promote BIM and lean technologies among the clients.

Figure 1 represents the identified wastes in the construction sector, the lean tools that can be used, and the BIM application for each lean technique to minimise construction waste in Sri Lanka. Further, the above-discussed challenges and solutions to overcome those in BIM technology and lean implementation are discussed in Figure 1.

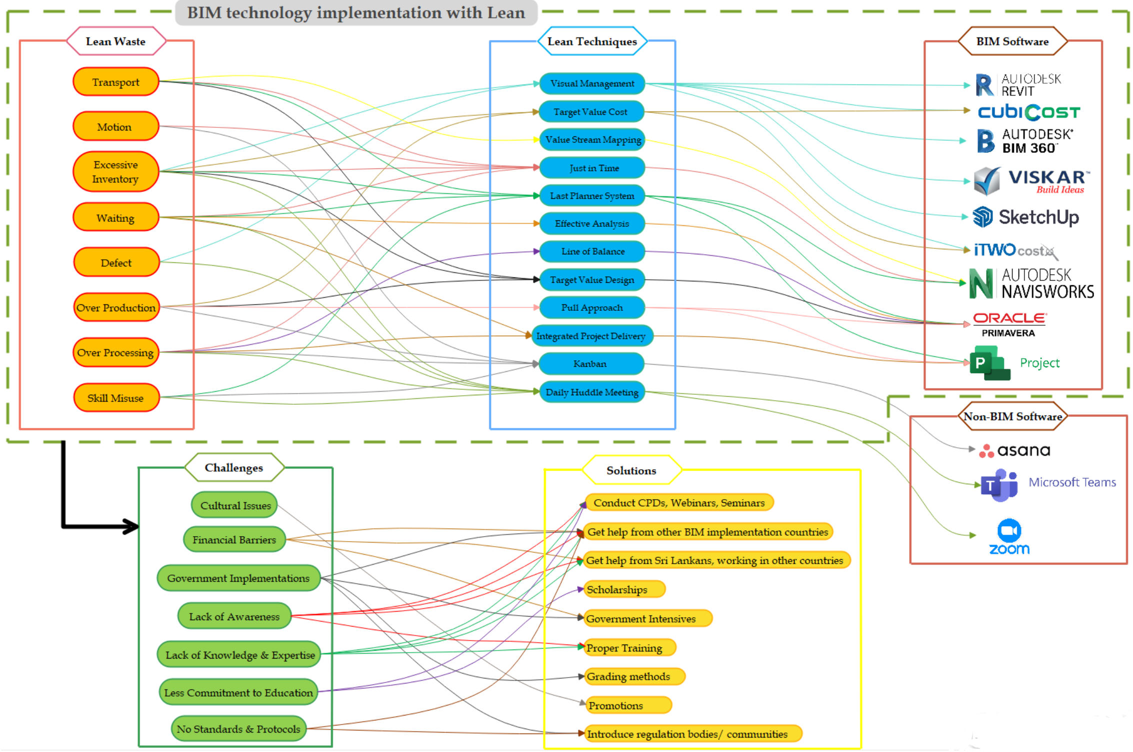

Figure 1: Framework of applicability of BIM technology to enhance lean construction in Sri Lanka

5. CONCLUSIONS

In conclusion, numerous lean techniques, such as just-in-time, the last planner system, Kanban, target value cost, daily huddle meetings, and pull approaches, can be applied directly and indirectly in the construction industry. By adopting these techniques, most countries could achieve significant benefits. The study identified how Building Information Modelling (BIM) technology is utilised in the construction industry and the purposes it serves. Standards and protocols for creating, managing, and using BIM models offer rules and best practices throughout a building or infrastructure project's lifecycle. BIM software enables collaboration on a project and real-time information sharing between architects, engineers, and construction workers, enhancing communication, and lowering errors. Subsequently, combining lean construction and BIM models is an approach that seeks to enhance productivity, minimise waste, and improve quality in the construction sector. The study conducted interviews with three industry professionals who are currently utilising BIM technology and lean practices in their projects. The data collected highlighted how BIM technology can be used to identify and minimise lean waste. For a developing country like Sri Lanka, integrating BIM and lean project management practices can lead to high-quality project outcomes in the minimum possible time.

The study further identified the challenges of implementing BIM technology to enhance lean construction in Sri Lanka. Accordingly, financial barriers, government implementation, lack of awareness, and lack of knowledge were identified as the most critical challenges. Therefore, it is recommended to get the support of other countries, and Sri Lankans working in other countries who have engaged in BIM practices to overcome the challenges and to enhance lean construction through BIM in Sri Lanka.

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