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Potential of Lean to Minimise Implementation Costs of Building Information Modelling (BIM): A Conceptual Framework

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Abstract

Building Information Modelling (BIM) is a combination of technological processes in which the design, construction, operation, and maintenance of any construction project can be digitally managed. Even though BIM's promising nature has been appraised in scholarly works, it is not yet being fully implemented in the construction industry. Many scholarly works have identified cost headings of the BIM implementation as the major barriers for a successful BIM implementation. As a come-up strategy, Lean Construction Principles (LCP) can be used to minimise the wastes which do not add value to the construction. Therefore, the aim of this research to develop a lean integrated BIM framework to minimise the cost headings of BIM implementation. Accordingly, an extensive literature survey was conducted to develop a conceptual framework by identifying the cost headings and the possible expectations with the BIM implementation and identifying the applicable lean construction principles to optimise the value of BIM implementation with respect to each cost heading as the objectives of this study. So that, this study has identified the BIM implementation with the expectations of the stakeholders and the associated cost headings. Further, BIM implemented projects have been compared with the traditional projects to identify the major benefits. Addition to that, LCP were discussed with the benefits of its usage. Therefore, this framework lays down the guidance for construction industry-related firms to find their capabilities and competence to implement BIM with the integration of lean construction principles. Hence, this research will be effective for the construction industry as the major barrier for the BIM implementation has been recovered with the strategy of lean construction principles.

Keywords
Building Information Modelling (BIM), Lean Construction Principles (LCP), BIM Implementation Cost, Construction Industry

1. Introduction

Building Information Modelling (BIM) is a modern technology that affects the life cycle of a construction project. BIM replaces all the traditional and conventional methods of Architecture, Engineering, Construction, and Operations with modern digitalised methods (Epasinghe et al., 2018; Fosse et al., 2017). Therefore, BIM is a modern approach that recreates the construction industry in an efficient and effective manner (John D. D., 2016). According to Epasinghe et al. (2018), the construction industry is not yet ready to implement BIM for construction activities. Several types of research have been conducted to find the barriers that can be affected by the implementation of BIM in the construction industry (Abeyratne and Jayasena, 2013; Jayasena and Wedikkara, 2012; Gnanarednam and Jayasena, 2013; Kulasekara et al., 2013). However, only a limited number of research have been conducted to overcome those identified barriers (Gunasekara and Jayasena, 2013; Rathnayake, 2017). As a result, various strategies have been implemented to overcome those barriers. Even though, still, BIM is in the infant stage within the construction industry. The excessive cost is identified as the major barrier for BIM implementation, where the stakeholders are willing to use BIM at a low cost or without a cost (Gunasekara and Jayasena, 2013; Jayasena and Wedikkara, 2012; Kulasekara et al., 2013).

Lean construction can be identified as a novel concept that can affect the effectiveness of the construction industry. Lean construction is clear that lean principles have been implemented for the construction industry to reduce wastages and improve efficiency (Tzortzopoulos and Formoso, 1999; Huovila and Koskela, 1998; Aziz and Hafez, 2013). Numerous research have been done by integrating lean principles with various aspects like civil constructions, challenges in waste reductions, and challenges in sustainable construction (Nikakhtar et al., 2015; Huovila and Koskela, 1998; Hosseini et al., 2012). As well as many types of research have been done to overcome the BIM barriers through lean principles (Sacks et al., 2009; Elmaraghy et al., 2018). However, any of these studies have not implemented those two concepts together to overcome the barriers found with the BIM implementation.

Many waste activities can be identified depending on the real goals of BIM implementation which is subjective on the context and adopter. Since lean construction has been found to have effective principles to optimise cost by avoiding unnecessary costs, such principles could help in minimising such wastes. The rationale is two-folds. First, BIM is primarily about virtual construction, and it has some resemblance to the construction process. Second, the LCP are widely developed and adopted in the industry. Consequently, a research gap could be found between lean construction principles and BIM to support overcoming BIM implementation barriers. Structured knowledge on how lean principles can minimise different cost headings of BIM implementation would be of high significance in receiving the expected outcomes of BIM implementation along with minimum implementation cost.

2. Literature Review

An in-depth literature review was conducted as the data collection method of this study. So, this section included about the major findings that covered through the literature survey.

2.1 Building Information Modelling (BIM)

BIM can be identified as a revolution in the modern construction industry to manage and design construction projects throughout their building lifecycle (Ullah et al., 2019). Moreover, Ullah et al. (2019) asserted that BIM offers the potentials to tackle problems among project stakeholders, such as low productivity, rising cost, inadequate quality, construction waste, delays, and lack of knowledge management. Further, BIM can be identified as a tool for enhancing the efficiency of the construction industry (Azhar S., 2011). Over the last two decades, the performance of the construction industry has been enhanced and transformed with the capacity of BIM by increasing efficiency, improving productivity, and increasing the corporation between stakeholders (Abanda et al., 2018).

BIM is identified as a change in the process and not only just being a change in technology (Eastman et al., 2011). Physical and functional characteristics of the construction projects have been digitally represented by the BIM while sharing the project information and making reliable decisions from the conception to demolition of a project (Abanda et al., 2018; Abeyratne and Jayasena, 2013). BIM is a novel approach for the construction industry which deviates from the traditional approaches of architecture, engineering, construction, and operations (Epasinghe et al., 2018). Epasinghe et al. (2018) further asserted that the basic outcome of the implementation of BIM is to increase the collaboration of the project partners who have been involved in the construction at the distinct stages without creating any interoperability issues. As a result, a continuous flow of information throughout the lifecycle of the construction will be created between the BIM project stakeholders and BIM acts as a mechanism to rectify the issues that occurred due to the exchange of the information (Epasinghe et al., 2018).

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2.1.1 Implementation of BIM in the Construction Industry

BIM is a modern modelling technique, machine-readable parametric objects that can be used to compile virtual models to show the needs of designing, analysing, and testing (Sacks et al., 2004). According to Eastman et al. (2011), BIM helps to complete building projects of higher quality at a lower cost and shortened project length. Further, BIM reinforces the core construction process (Sacks et al., 2010). According to Sacks et al. (2010), when implementing BIM for a BIM infant industry, it will increase the knowledge of construction while making detailed designing processes than in the traditional methods. Moreover, by forming new teams, BIM will introduce new positions, such as BIM managers or consultants (Sacks et al.,2010). Fung et al. (2014), said that technical and labour-intensive aspects based on the traditional roles can be replaced with the implementation of BIM for the construction to improve efficiency and productivity.

The construction industry has been strengthened by design, construction, and management due to the powerful set of tools provided by BIM (Ahmed, 2018). The author has further said that BIM technology should be successfully implemented for construction projects to gain the benefits of BIM even after the lifecycle of construction projects. Virtual building models with qualitative and quantitative characteristics can be created through BIM implementation (Fakhimi et al, 2016). In the construction industry, BIM-related tools and processes have been implemented to achieve effective management of information generated throughout the life cycle of the construction project (Khosrowsnani and Arayici, 2012). BIM can be applied for each stage in the project design as illustrated in Table 1.

Table 1: Implementation of BIM in the project design phase

Schematic Design	**Detailed Design**	**Construction Detailing**
• Options Analysis (to compare multiple design options) • Photo Montage (to integrate photo-realistic images with its existing conditions)	• 3D exterior and interior models • Walk-through and fly-through animations • Building performance analyses (e.g., energy modelling) • Structural analysis and design	• 4D phasing and scheduling • Building systems analysis (e.g., clash detections) • Shop or fabrication drawings

2.1.2 Expectations of BIM implementation

BIM is a developed technology and process that can be used for construction projects to improve productivity in terms of design, construction, operation, and maintenance (Love et al., 2013). The expectations of BIM implementation have been widely spread throughout the construction industry to make reductions in construction cost, integrate the project systems, improve the quality of design information, assess the life cycle of construction projects, improve the accuracy, and make collaboration between the participants (Howard and Björk, 2008; Barlish and Sullivan, 2012; Aranda-Mena et al., 2009; Love and Edwards, 2011). Love et al. (2014), said that the contractors can visualise the expectations of implementation of BIM at the stage of design and construction in terms of costs and time schedules. Further, the author has mentioned on the speed of getting expectations from BIM implementation is higher during the design and construction stages than in the operation and maintenance. According to Ullah et al (2019), expectations of the BIM implementation can be tabulated according to the phases of construction as the bellow Table 2.

Table 2: Expectations of BIM implementation

Phases	**Expectations from BIM**
Pre-Construction	• Improve the accuracy and the effectiveness • Improve the design reviews in terms of sustainability • Reduce the design clashes through visualisation • Prepare most accurate cost estimates • Effectively analyse the site to manage the resources and the environment • Faster the process effectively
Construction	• Allow better utilisation of the site • Improve the safety of the site

	• Effectively manage the project procurement • Evaluate the construction of complex buildings • Fabrication of offsite building components effectively
Post Construction	• Efficiently manage the maintenance schedules • Easy access for the information during maintenance • Helps to make decisions related to the operation, maintenance, repair, and replacement

2.1.3 Comparison of BIM integrated projects with traditional projects

Architects and Engineers have stopped the usage of traditional drawings and calculation tools in the 20th century with the usage of Computer-Aided Design (CAD) systems (Czmoch and Pękala, 2014). Further Czmoch and Pękala (2014) have been described that the traditional documentations which are consisting of details of architectural designs, landscape designs, construction, and installation designs have been replaced with a one 3D model having all the details with the adoption of BIM. The major issue that occurred in the traditional projects can be identified as cost overrun and delays due to the inefficient flow and the ineffective sharing of the information between the participants of the project (Al Hattab and Hamzeh, 2013). Accordingly, Al Hattab and Hamzen (2013), told that those issues can be reduced in the BIM-based projects due to the transparency of the information shared between the participants and the visualisation of the project as a live version in the real environment.

Manual practices such as excel spreadsheets and 2D CAD systems are still used by Quantity Surveyors which can be caused human errors and reduced the performance of the Quantity Surveyors due to the dissatisfaction of the Employer (Fung et al., 2014). According to Fung et al. (2014), such tedious time-consuming activities are eradicated with the implementation of BIM in construction projects. Moreover, BIM-based projects have been automated the tedious tasks of quantity Surveyors such as take-off measurements, feasibility studies, cost plans, preparation of schedules, and prepare bills of quantities (Perera et al., 2012). Schedules are prepared with the 4D dimension of BIM by visualising the 3D models and all cost estimates are prepared by extending the construction schedules (4D) in the application of the 5D dimension of BIM while managing the time-consuming activities in the traditional construction projects (Czmoch and Pękala, 2014; Fung et al., 2014). Further, 6D and 7D dimensions will be applied for the sustainable concepts and facilities management activities respectively to improve the performance of the constructions (Czmoch and Pękala, 2014).

2.1.4 Cost headings in BIM implementation

The implementation of BIM for the construction industry will be affected to gain many advantages while facing various challenges. Many researchers have found distinct types of barriers that will cause the BIM implementation in the construction industry. The major barrier for BIM implementation is the deficiency of capital in the industry (Elmualim and Gilder, 2013). According to Elmualim and Gilder (2013), the industry has been practiced for conventional methods and the participants are unwilling to change their workflow with innovative methods. However, to gain the benefits from BIM to the construction industry, significant attention is needed to the challenges and the barriers of BIM implementation (Ismail et al., 2017; Hallberg and Tarandi, 2011). Table 3 will illustrate the cost headings of the BIM implementation during the design and construction phases.

Table 3: Cost headings during design and construction phase

Design Phase	Construction Phase
Technologies	Technologies
Labour training	Labour training
Added coordination	Added coordination
Ensuring the data accuracy	BIM-based decision review
BIM-based decision review	Organisation costs
Added more design details	Repurposing BIM design
Premature decision making	Developing as-built BIM
BIM consultant	BIM ownership determination
Space requirement	BIM Consultant
CAD rework costs	Contractual costs
Contractual cost	Risk of using modern technology

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2.2 The Concept of Lean

Lean is a term used to boost the construction industry's efficiency by reducing waste that does not add value to clients (Binh, 2013). According to Binh (2013), the performance of the construction industry is at an unsatisfactory level and productivity has been declined when compared with other industries due to waste. However, lean construction is a concept that can be used to manage production with the aim of achieving significant improvements in terms of time and resources that do not add value to the product or service delivered to the customer, dropping all waste (Droste, 2007). The concept of lean has been identified as a management philosophy that has been widely used in both the manufacturing and construction industries (Gao and Low, 2013).

2.2.1 Lean construction principles

The dramatic performances have resulted from the lean concept in the construction because of the principles behind the concept (Binh, 2013). Lean principles have been applied for the processes such as project delivery system, production control, work structuring, design, supply chain, and project control including overall construction project management by the project managers (Hosseini et al., 2012). Moreover, Hosseini et al. (2012) contended that lean construction principles have been based on time-based management and value-based management with the aim of reducing the cycle time and increasing the output value, respectively. According to Koskela (1992), there are eleven construction principles that are centred on one main principle called flow, and some of them are fundamentally oriented while others are application oriented. The further author told that these eleven principles can be applied to the total flow process with its sub-processes with the aim of resolving the problems related to flow processes such as complexity and transparency.

Koskela (1992) has stated the eleven construction principles as "reducing the share of non-value adding activities, increase output value through systematic consideration of customer requirements, reduce variability, reduce the cycle time, simplify by minimizing the number of steps, parts, and linkages, increase output flexibility, increase process transparency, focus control on the complete process, build continuous improvement into the process, balance flow improvement with conversion improvement and benchmark". Even though all the principles are not at the same abstraction level while they are closely related to each other (Pollesch et al., 2017).

2.2.2 Benefits of lean construction

The misconception in the construction industry was theoretically believing that lean concepts can be applied successfully only in the manufacturing industry (Ruan et al., 2016). However, according to the authors, the application of the lean concept into the design and construction industry was slow due to the conflation of reasons such as the disinclination of making capital investments. Even though Vilasini et al. (2011) have been told that lean construction philosophy modernised and value the construction industry as a key driver which reorganised the construction industry. The implementation of innovative, effective, and efficient concepts like lean construction into the construction industry makes changes in the industry by driving it to focus on the value for money (Jørgensen and Emmitt, 2009). Further, the authors said that the discussion on construction improvement has embraced lean construction as a modern construction process that has the potential to achieve substantial changes in the construction industry in terms of project success with Employer satisfaction.

The construction industry believes that the application of lean principles in the industry is a concept that has no bearings to make variations as it can create more waste in the industry (Koskela et al., 2013). Accordingly, lean construction principles supply great support to reduce wastage to speed the construction process by reducing rework and non-value adding activities (Yahya and Mohamad, 2011). Moreover, the implementation of lean construction principles into building construction projects has been identified as an innovative solution for challenges like rehabilitation and replacement in terms of minimising environmental impacts, construction time, and the design processes (Barros Neto and Alves, 2007). The reduction of rework due to less integration between parties is a major benefit that can be gained by the implementation of lean construction principles (Common et al., 2000). Apart from that, cost savings, less management cost, reduce project duration, increase completion of the present plan and fewer inventories have been identified as the major benefits of the implementation of lean construction principles in building construction projects (Mohan and Iyer, 2005; Yahya and Mohamad, 2011; Ruan et al., 2016).

3. Research Method

This research intends to answer the problem of "how does the cost headings of BIM implementation can be minimised by integrating lean construction principles?" through a qualitative approach, as qualitative methods subsidies to implement systematic analysis on evolving beliefs and is more suitable when the study has a trifling base of literature background (Saunders et al.,2019). Further, the Sha and Coreley (2006) have asseted that the qualitative method can be used to create new relationships with the variables to understand the complex processes and to illustrate the influence of society. Accordingly, the extensive literature review was supplemented by books, journal papers, conference proceedings, and electronic sources to investigate BIM implementation and the application of lean construction principles for the construction industry and develop the conceptual framework to guide the main research as presented in this paper.

4. Research Findings and Analysis

The findings about the implementation of lean concept in the construction industry has addressed through this section with the findings about integration of both lean and BIM in the construction industry. Further, a conceptual framework has developed by analysing the collected data from the literature.

4.1 The success of the application of the lean concept in the construction industry

Lean construction which is an innovative concept for the construction industry has been applied for various instances in construction. Both civil and building construction projects have gained many benefits with the implementation of concept lean construction. According to the research conducted on the application of lean concept into the drainage operations and maintenance crews, researchers have proved that 4% of improvement can be seen in the drainage construction sector in Edmonton, Canada (Agbulos et al., 2006). Agbulos et al. (2006) have proved the improvements using two case studies and crews have been divided into six categories according to their duties. Similar research has been conducted in Edmonton by applying the lean concept to the water and sewer service installation and has concluded that productivity has been increased by 5%-10% (Kung et al., 2008). Al-Sudairi (2007), has been conducted research to evaluate the construction processes with the applicability of lean construction principles by selecting the projects in Dammam metropolitan area, Eastern Saudi Arabia focusing on the block laying and plastering. As a result, Al-Sudairi (2007) has concluded that the efficiency of the block laying and plastering processes has been increased by 21% and 50% respectively following the data collected through interviews and field surveys.

The eleven construction principles have been applied for the design process by Tzortzopoulos and Formoso (1999) and find some gaps between the application of knowledge about the principles into designs when concerning two case studies based on small-sized house building companies. Apart from that, lean principles have been applied for sustainable development to achieve the best quality products through sustainability (Huovila and Koskela, 1998). Accordingly, many types of research have been conducted on the implementation of the concept of lean construction for both building and civil constructions in every stage of the life cycle to reduce the lifetime, reduce non-value activities, improve efficiency and productivity (Agbulos et al., 2006; Al-Sudairi, 2007; Amaral et al., 2012; Binh, 2013; Nikakhtar et al., 2015).

4.2 Integration of Lean Principles with BIM

Lean and BIM have been identified as two major developments that affect the architecture, engineering, and construction industries where lean is a conceptual approach for construction and project management and BIM is a transformative information technology (Sacks et al., 2010). Even though lean and BIM are two separate independents that create impacts on the construction industry, there appeared to be coaction between them to make the construction industry more effective by integrating both approaches (Sacks et al., 2010). However, both approaches are in their infancy, and both are developing their adoption in the construction industry (Sacks et al., 2009). Higher cost has been acted as a barrier for the implementation of both approaches and the benefits of the implementation can outweigh the costs (Reger, 2003). Further Fox (2008) describes key problems for BIM adoption as underutilisation and interoperability while lack of conceptual understanding is a barrier for applying lean construction principles.

Sacks et al. (2010) have prepared a framework by making the interaction between BIM and lean construction principles and have concluded that the implementation of both approaches together will reduce the issues caused in the construction industry by making benefits in terms of time and quality. Further. Bhat et al. (2018) have made a matrix by addressing the BIM functionalities and lean construction principles to increase the efficiency of the construction industry by adding value to the final outputs. The collaboration of two concepts into complex building projects creates more advantages as the owner can visualize the greater returns from the investments by implementing it from the first stage (Tuan, 2019). Accordingly, many types of research have conducted based on the integration of

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BIM and lean concept in the construction projects to gain more benefits throughout the construction life cycle by adding value to the project in terms of time and quality (Bhat et al., 2018; Tuan, 2019; Sacks et al., 2010).

However, many types of research have been conducted on the application of BIM for the implementation of lean principles to the construction industry (Bhat et al., 2018; Bolpagni et al., 2017; Elmaraghy et al., 2018; Gómez-Sánchez et al., 2019; McHugh et al., 2019). No literature has been found on the application of lean construction principles for the implementation of BIM in construction projects. As a result, this research is conducted to apply lean construction principles to minimise the cost headings of implementing BIM in the construction industry. Therefore, the collaboration will be helping to mitigate the non-value activities and the misconceptions between the stakeholders and make the projects of high quality within a lesser duration in a more effective manner. So that, lean principles will reduce non -value concepts and will be increased flexibility with the aim of mitigating the barriers of BIM implementation.

4.3 Conceptual Framework

BIM is an innovative approach used in the construction industry to reduce the challenges and issues that occurred in the construction industry. Accordingly, BIM can visualise the construction projects as in the real environment from the design stage of the projects by making better coordination between the information flow and the stakeholders. However, due to the barriers like high initial cost, lack of knowledge about the benefits, lesser training, and resistance to change, BIM is at the infant stage in the Sri Lankan construction industry. Accordingly, those barriers must be overcome to gain the benefits from BIM. Therefore, cost headings of BIM implementation which act as the major barrier must be minimised to promote BIM for the benefit of the construction industry in Sri Lanka. As a result, lean construction principles are going to be applied to minimise the cost headings of BIM implementation.

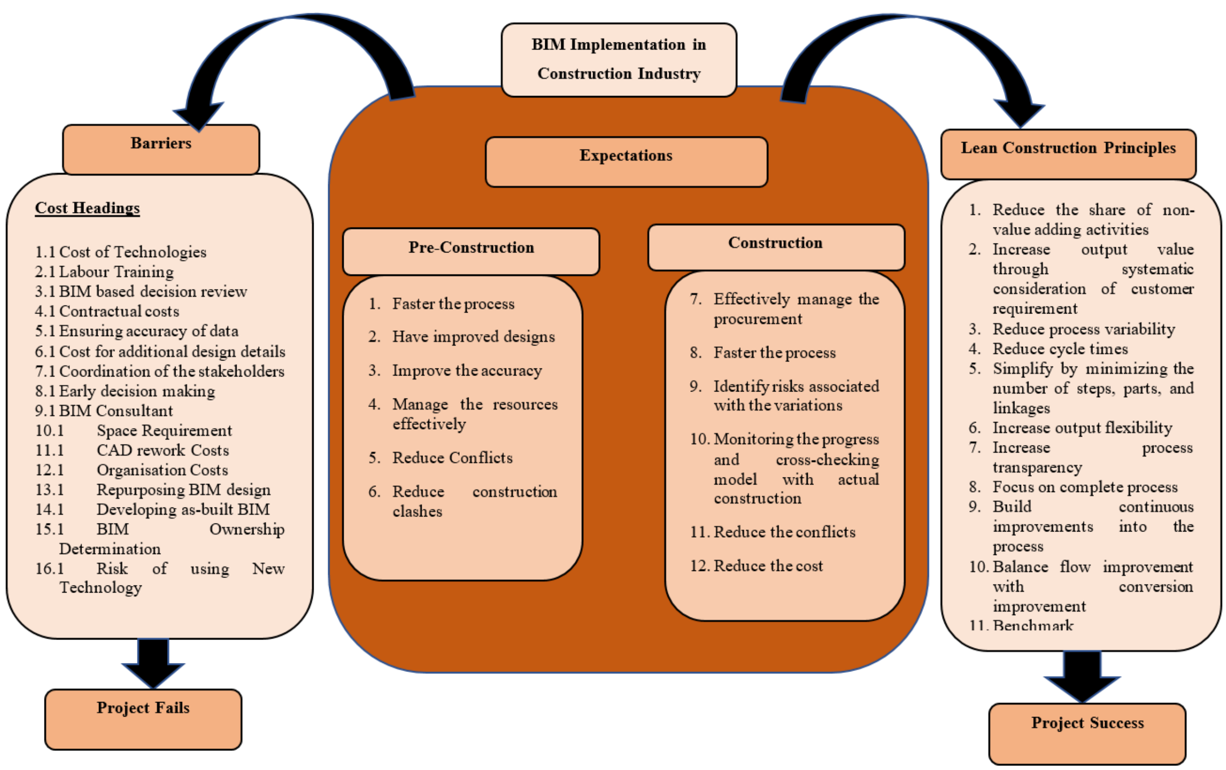

Figure 1: Conceptual Framework

According to the following Figure 1, there are various types of cost headings associated with the BIM implementation. Reference to that, it is clear those cost headings are consisting with the numerous waste activities which do not add value to the construction. Hence, the BIM implementation cost has been increased in a range which cannot be carried by a developing contractor. Therefore, as in Figure 1, LCP can be integrated with the BIM implementation cost headings as a strategy to minimise non-value adding activities which are associated with those cost headings. Hence, it is clear that if we integrate the BIM implementation cost headings with the identified LCP, non-value adding activities can be reduced and value adding activities can be improved with the aim of achieving the expectations of BIM implementation as in the following Figure 1.

5. Concluding Remarks

Literature synthesis has been developed to summarise the existing knowledge on BIM implementation and the lean construction principles. Moreover, the availability of new applications specifically for the construction industry and the global interest in widening the implementation of BIM and lean construction principles due to enhanced benefits can be a great movement compared to the traditional methods in the construction industry. The conceptual framework has been developed by highlighting the cost headings of the BIM implementation and the identified LCP. Hence, BIM implementation costs have contained waste activities which do not add values to the construction industry. As a result, LCP can be used as a strategy to add value to the BIM implementation by removing and reducing the non-value adding activities associate with the BIM implementation. Accordingly, LCP can be integrated to minimise the cost headings of the BIM implementation to achieve a successful BIM implemented projects. The outcomes of this study can be further proved in the construction industry through a detailed validation of the proposed conceptual framework in the view of field experts' opinions, which will be the next phase of the research.

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