Enhancing Collaboration Efficiency in Building Construction: Exploring BIM-Based Lean Construction Management for Cost Estimate

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Abstract. The integration of Building Information Modeling (BIM) and lean construction holds promise for revolutionizing collaboration within the building construction industry. This article presents a comprehensive review of literature on lean construction, quantity surveying (QS) issues, and the collaboration between BIM and lean principles. Key challenges hindering the full realization of BIM-based cost estimation within lean construction are identified, including interoperability issues, technical expertise gaps, and organizational inertia. A proposed scheme outlines strategies for incorporating lean construction principles into BIM-based QS practices, emphasizing the importance of leadership and collaboration both internally within organizations and externally with government authorities. Furthermore, a collaborative behavior map is introduced to facilitate a deeper understanding of stakeholder roles and interactions, aiding in the assessment of lean construction adoption at various levels of the construction industry.

Keywords: lean construction, BIM, cost estimates, quantity survey.

1 Introduction

Nowadays, the integration of BIM and lean construction have the potential to enhance collaboration in the building construction industry. Many professionals and construction companies are exploring the integration of BIM and lean construction to improve collaboration efficiency [1] . Although researchers have applied BIM to lean construction in the project design phase, construction phase, maintenance phase, and operation phase [2,3]. The BIM-based lean construction management for cost estimate is not fully explored [4].

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2 Literature Review

2.1 Lean Construction

Lean principles, initially developed by Toyota in Japanese vehicle manufacturing, have evolved into lean construction over a period exceeding two decades. Lean construction theory incorporates advanced manufacturing concepts into engineering project management to reduce waste while maintaining quality and productivity [5,6]. The primary aim is to achieve effective project completion while prioritizing quality, minimizing construction time, and optimizing resource usage. BIM functions as an innovative and cohesive platform that supports lean construction management in various projects [7,8].

2.2 QS Issues

The main obstacles in traditional Quantity Surveying (QS) services within public and private sectors involve encountering clashes, uncertainties, ambiguities, and intricacies [9]. Traditional QS methods are often impeded by insufficient information during the design phase, inaccuracies in the transfer of building data, and erroneous deliveries resulting from the involvement of various disciplines like architects and different engineering fields [10]. Frequent alterations in design, inadequate drawings and specifications, delayed dissemination of drawings, and discrepancies among consultants all contribute to fragmentation, as well as time and cost overruns, conflicts, and compromised quality and productivity in projects [11,12].

2.3 BIM QS Lean Collaboration

The integration of visual processes, shared information, and convenient communication can enhance construction practices [8]. However, BIM-based quantity surveying (QS) or cost estimation has been slow to fully exploit the potential of lean construction [13]. There is limited focus on developing BIM-LEAN tools, and QS professionals lag behind architects and engineers in BIM and lean construction applications [14]. Many professionals and QS companies are still in the exploration and experimentation phase regarding the interaction between BIM and lean construction. Sacks et al. (2010) suggest that understanding production theory concepts can enhance the QS process [1].

QSs are hesitant about leveraging BIM-based cost estimates and insist on the conventional, less efficient working methods due to the absence of enough knowledge and confidence in the ability of BIM for QS practices, even though BIM has been proved that its capability to provide higher efficiency of cost estimate by combining graphical model and attributes data [15,16,17,18].

2.4 Issues and Barriers/Challenges

Factors such as compatibility and complexity influence the acceptance of BIM and LEAN interaction. Interoperability issues during data exchange between various applications pose challenges in ensuring data integrity, particularly in extracting quantity takeoff and generating Bills of Quantity automatically [19]. Barriers to the effective application of BIM-based cost estimation with LEAN construction concepts include technological, cost-related, managerial, personnel, and legal aspects, as identified by Zhan et al. (2022) through interviews and surveys.

Financial considerations, lacking technical expertise in BIM-Lean, lacking motivation and guidance from top management, behaviour and attitude of people to learn new technology, organizational inertia toward revolution, lacking government direction and standard guidelines, technical difficulties. In addition, Matthews et al. (2018) identified that the limited professional knowledge and practical experience are impeding the complete application of BIM-based cost estimates with LEAN construction [11].

3 Benefits

BIM-LEAN is still in its introductory phase within current Quantity Surveying (QS) services. However, studies have demonstrated the benefits of LEAN construction, including error reduction through interface and collision checking, shorter timescales, and decreased mistakes stemming from interpreting drawing-based designs [20]. Furthermore, LEAN construction has been associated with reduced instances of cost overrun and risk, along with enhanced accountability in information exchange among stakeholders, thus improving QS work quality and efficiency.

Traditional Quantity Surveying (QS) processes, which entail manual quantity takeoff and bill of quantity generation based on 2D drawings, are time-consuming and prone to errors. The implementation of BIM-LEAN methodologies can enhance the efficiency of QS workflows. Zhan et al. (2022) have highlighted new functionalities enabled by BIM-LEAN in QS, including life cycle costing, value and quality management, project management, facilities management, risk analysis, and dispute resolution. A proposed approach to applying lean construction in BIM-based QS involves leveraging lean construction features to facilitate full collaboration among various construction stakeholders, including clients, architects, engineers, and contractors, to enhance BIM-based cost estimation [19].

3.1 The Action of Adoption

The scheme can be divided into internal actions and external actions. Leadership from top tier leaders of an organization take a significant role in internal actions while government authorities are the external roles. Zhan et al., (2022) suggested that the top management's responsibility is to initiate the entire interaction between BIM-based cost estimate and lean construction in an internal context. From the external context, government authorities may cooperate with private sectors to provide public seminars and workshops and initiate the research or scheme to adopt BIM-based cost estimate with the LEAN construction concept for QS [19].

3.2 Analysis of Adoption Contents and Pressures

The external context comprises the social, economic, competitive, and political environment, while the internal context encompasses factors such as culture, organizational hierarchy, technical systems, and personnel

Aldrich (2008) argues that organisations have solid structural inertia that makes adaptive changes because organisational changes are considered disruptive. This structural inertia is divided into two aspects, internal and external pressures [21].

Internal pressures are regarded as imitations coming from the organisational itself:
1—previous choices made (equipment and specialised personnel)
2—the type of information that decision-makers receive
3—internal political constraints
4—history of the firm

External pressures are regarded as limitations outside the organisation
1—legal and fiscal barriers
2—information dissemination channels
3—legitimacy constraints
4—collective rationality problem [22].

3.3 Characteristics of Change or Adoption in the Organisation to Judge BIM-Lean Adoption for QS

The successful characteristics of new adoption in the organisation, which can guide organisations on how to adopt new management or techniques from four aspects: extent (global and partial), depth (disruptive and adaptative), rhythm (fast and slow), and base (imposed and negotiated) as shown in the table 1 below:

Table 1. characteristics of change and adoption

Extent	Global	Adoption affects all activities and units of organisation, strategy and culture developed
	Partial	Adoption affects a part of organisation, same as strategy and culture
Depth	Disruptive	Disruptive adoption marks an apparently difference with discontinuity. Strategy, working process, culture and performance are changed
	Adaptative	Adaptive adoption is moderate to disruptive. It lightly evolves the above division with continuity to previous situation.
Rhythm	Fast	Fast adoption is a redress against past situation, rapid change may be risky for organisation
	Slow	Slow adoption is a gradual process, slow change might not achieve the prospective effects
Base	Imposed	Imposed adoption acts decisively without negotiation
	negotiated	Resistance and negotiation of new adoption exist

This table has listed the specific features and contents to measure the extent of adoption, which may be applicable to judge the BIM-Lean adoption for QS [23].

3.4 Detailed Content Within Internal and External Environment

A Collaborative Behaviours 'B4C' Map delineates stakeholders' involvement across the entire process, spanning internal to external environments. As shown in figure 1 below, tt serves as a guide for professionals to cultivate collaborative behaviors, particularly during meetings. The map features maturity levels on the left column, indicating the extent of collaborative behavior. Across the top are stakeholders from the architecture, engineering, and construction industries. It's assumed that higher maturity levels encompass lower levels, making behaviors cumulative as maturity rises [24].

Role / Maturity	Project participant	Project leader	Group leader	Organisational leader	Industry leader
1	x				
2		x			
3			x		
4				x	
5					x

Fig. 1. collaborative behaviours map

Each row represents a role in the AEC industry: Project Participant, Project Leader, Group Leader, Organizational Leader, and Industry Leader. Each column represents a maturity level, ranging from 1 to 5. A checkmark (X) indicates the maturity level associated with each role. This graphic provides a clear visualization of the maturity levels for each role within the AEC industry. Adjust the placement of the checkmarks based on the specific characteristics and responsibilities of each role at different maturity levels.

In the architecture, engineering, and construction industry, various roles entail different levels of responsibility. The "Project participant" assumes a role within a project, including subcontractors. The "Project Leader" takes a leading role throughout the project, with potential changes as the project progresses through its phases. The "Group Leader" leads a section of an organization providing technical or managerial services, impacting beyond the project scope. The "Organization Leader" leads the organization strategically, shaping its operations comprehensively. The "Industry Leader" is a stakeholder driving industry initiatives to establish standards or policies [25].

4 Discussion

A collaborative behaviour map can specifically analyse the participants and stakeholders from every department to test the feasibility of lean construction adopted in a BIM-based quantity survey from industry to project level. Even though the specific requirements and contents of lean construction adopted in BIM-based quantity surveys are not identified yet on the collaborative behaviour map, each level should have the same effects and capabilities to ensure a fully collaborative working environment for quantity surveyors in the company. Once the requirements and contents are confirmed, the weakness and shortcomings can be identified based on the maturity level of the collaborative behaviour map from an overall perspective to improve the BIM-based quantity survey in the construction industry. Adopting internal or external pressure and characteristics of adoption can help explore and find specific requirements and contents for proper maturity level in the collaborative behaviour map above. Later, the level of collaborative maturity can be applied to test and adjust the actions of lean construction adoption in a BIM-based quantity survey.

5 Conclusion

The integration of Building Information Modeling (BIM) and lean construction methodologies presents a compelling opportunity to revolutionize collaboration and efficiency within the building construction industry. Significant progress has been made in applying BIM and lean construction individually across various phases of construction projects, such as design, construction, maintenance, and operation, there remains untapped potential in integrating these approaches for cost estimation and Quantity Surveying (QS) practices. The proposed Collaborative Behaviours 'B4C' Map provides a valuable framework for analyzing stakeholder involvement and identifying areas for improvement in collaborative behaviors. By aligning internal actions with external support, organizations can navigate the complexities of BIM-lean adoption and position themselves for long-term success in the evolving construction landscape. Overall, the findings of this research underscore the transformative potential of BIM-lean integration in the construction industry. By embracing collaboration, innovation, and strategic leadership, organizations can unlock new opportunities for efficiency, quality, and sustainability in construction projects.

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