Duality of Lean Construction and Building Information Modeling into Digital Collaborative Scheduling in Qatar: A Conceptual Framework

Murat Gunduz
Professor of Civil Engineering, College of Engineering, Doha, Qatar
mgunduz@qu.edu.qa

Khalid Naji
Dean of College of Engineering, College of Engineering, Doha, Qatar
knaji@qu.edu.qa

Ayman Fahmi Naser
PhD Candidate, Engineering Management, College of Engineering, Doha, Qatar
an1401569@student.qu.edu.qa

Abstract

Long has the construction industry been chastised for its low production performance. Building Information Modelling (BIM) and Lean Construction (LC) are two of the most widely adopted concepts in the construction industry for improving project delivery performance. LC is a complex blend of project management principles and tools whose origins can be traced to the automobile manufacturing industry. BIM refers to the technologies and processes that allow for the effective management of project information from inception to deconstruction. There are significant positive synergies when LC and BIM are implemented together. Nonetheless, these two concepts are frequently managed and implemented by separate teams within client, design, and construction organizations. This is largely due to the LC and BIM teams' lack of awareness and incorrect biases. Collaboration between the LC and BIM teams is necessary for BIM to facilitate LC principles/tools and for LC to enhance BIM processes in order to maximize the synergy between these two concepts. Globally, this is also a major concern for the industry.

The objective of this research is to develop a collaborative digital model that facilitates the integration of BIM and LC teams in the construction industry. These objectives will comprise the proposed research on literature-based understanding of the collaboration dynamics between various teams. Document and map the two-way synergy between LC and BIM in design and construction management based on the literature, workshops and interview with expertise. Understanding the requirements for a digital, interactive, collaborative tool that will allow both LC and BIM teams to improve their processes. It is a conceptual and digital tool that may be referred to as a "LC and BIM translator."

Keywords: Lean construction; Building Information Modelling; Integration; BIM and Lean assessment; Visual and design management

1 Introduction

Qatar's efforts to modernise and attract investment in infrastructure projects have increased. The allocation of QAR 53.9 billion (US$ 14.8 billion) in infrastructure projects between 2021 and 2025 in conjunction with Ashghal, Qatar's public works administration, would contribute to the country's continued expansion. These projects consist of QAR 1.58 billion (US$ 440 million) for road and public area restoration and QAR 5.8 billion (US$ 1.59 billion) for infrastructure maintenance. As a result, a number of capital projects are supported, and the construction industry remains to be an integral part of the national plan. In the next years, Qatar will enhance to invest over $110 billion in infrastructure and mega-projects. Considered one of Qatar's most important industries, construction contributed 13.8, 16.7, and 18.7% of real Gross Domestic Product (GDP) in 2019, 2020, and 2021, respectively, and will continue to be the main contributor to economic growth over the next several years. Production in construction domain is often hampered by poor productivity, high labour turnover, low skill levels, and a lack of innovation. Estimates of building projects totaling billions of dollars over the next quarter-century have spurred the government and business to wonder, ***"Is the construction sector equipped to complete these projects?***"

Site construction teams spend an inordinate amount of time each week planning and monitoring non-systematic schedules, subcontractors do improper and stand-alone planning, absence of cooperation and communication between construction parties, and inefficient information sharing are all problems caused by the fact that traditional planning does not reflect the reality of the activities taking place on the construction site. These problems are usually overcome by assigning a skilled planning team to operate inside the project management structure (Heigermoser et al. 2019). However, the picture is different for the site teams, seldom is the theoretical knowledge provided in schedules digested and adapted to the reality of the site employees, resulting in a gap between theoretical information and worksite planning methods. In reality, having a planning staff as part of management just makes existing communication problems and silos worse. In the setting of a large-scale project with intricate management structures, this statement rings truer than ever (Heigermoser et al. 2019). To prevent the disconnection and meet the problems, an interoperable Lean-BIM model integrating BIM Operations and Lean techniques was designed. The framework is a product of merging action and design science research, which is tailored to service the different project planning stages and stakeholders. Duality with BIM is offered on this digital platform for collaborative planning of targets. The purpose of the article is to simplify the communication of schedules, support the understanding of planning-related challenges, optimise construction sequences, and guarantee that the schedule is updated in a smooth and efficient way for continual progress monitoring. The evaluation stated here is beyond the boundaries of this study and it will be investigated further in the future.

2 Literature Review

Few quantified and published outcomes of such collaboration on-site have been recorded yet, despite the fact that various studies over the previous decade have highlighted the advantages of combining Lean Construction and BIM. Numerous ways in which merging Lean concepts with BIM has improved construction are detailed in the literature (Sack et al. 2017; Maraqa et al. 2021; Evans et al. 2021). Lean construction practises allow for the enhancement of customer value and the maintaining of a steady work flow (Tezel et al. 2018). Planning is much more of a team effort when Lean construction concepts and Lean production processes are used to the building process instead of the more conventional approach of individuals working independently of one another. BIM may mean either "Building Information Modeling" or "Building Information Management." Construction experts such as architects, engineers, real estate developers, builders, manufacturers, and others may all work together in a single 3D model to plan, design, and construct a building or structure. The number of dimensions used by BIM in construction has expanded from 3D to 4D (scheduling), 5D (estimating), and 6D (facilities management) (Terreno et al. 2019; Evans et al. 2021). While one is often used separately, the other may enhance or diminish its benefits. It has been shown that there are a total of 56 interactions between Lean principles and BIM features (Sacks et al. 2010), with the authors concluding that the full potential of this connection can only be achieved via their completely integrated use. Although there is some evidence that Lean and BIM may enhance construction, no BIM-integrated planning, scheduling, and monitoring framework has been documented as of yet (Sacks et al. 2017). Guerriero et al. (2017) developed an intelligent construction planner as a software tool that promotes cooperative planning in line with the previous planner system. Their study also included a mapping of the planning stages to BIM 4D scheduling and the argument that the two should be used together in a single framework. Recent research into LCM and BIM, say Toledo et al. (2016), has focused too much on the theoretical synergy potential of both methodologies and too little on the creation of really usable methods and tools.

As a result, they suggest planning model, whereby a BIM model is integrated into the last planner system process, and its optimal utilisation across many stages is explained. With the approach suggested by Evans et al. (2021), project key stakeholders may prioritise addressing the critical problems and impediments to widespread use of LC and BIM in construction of megaprojects. The paper's results were limited to some suggested practical strategies for boosting the embracing of LC philosophies and BIM technologies in construction mega-projects, with the goal of encouraging key stakeholders in the construction industry to focus on overcoming the substantial challenges of integrating BIM and LC principles. In particular, Sbiti et al. (2021) performed a thorough literature assessment of the most recent advances on interconnection between BIM and lean construction, identifying key linkages between lean construction practices and BIM functional concerns. As an added bonus, the authors show how the existing BIM-based IT software used to assist Lean Construction has several serious automation flaws. Project management software that does not use BIM data continues to depend on manual operations including planning, evaluating limitations, measuring workloads, and managing site progress. As these two ideas are often led and implemented by different teams at client, design, and construction organizations in silos, these restrictions prevent an operable duality of BIM and Lean at the actual and actuate data level and make current lean IT tools extremely laborious, subjective, and prone to error. To maximise the synergy between LC and BIM, the authors were prompted by the preceding statement to develop a concrete recommendation to direct future researchers in forming a partnership between the two teams and looking into the mechanisms of automating construction schedule generation and progress monitoring.

3 Developing a Conceptual Lean-Bim Duality

In this article, we use a hybrid action research (Azhar et al. 2013; Naji et al. 2022b) strategy, which combines a systematic literature review with the Delphi technique and Design Science Research. The study identifies and builds a conceptual framework for simultaneous implementation of LC and BIM. The research strategy used in this study may be thought of as one in which an issue is tackled via the development of a fresh theoretical framework that adds to the existing body of work. Using a literature study and input from Lean and BIM specialists, we hypothesise a way forward that fills the current vacuum in the literature. As a result, the duality of Lean-BIM framework is at conceptual stage for this study and future research will address the assessment proposed in this publication, which is beyond the scope of the current investigation. The research strategy presented in the study is shown in Figure (1).

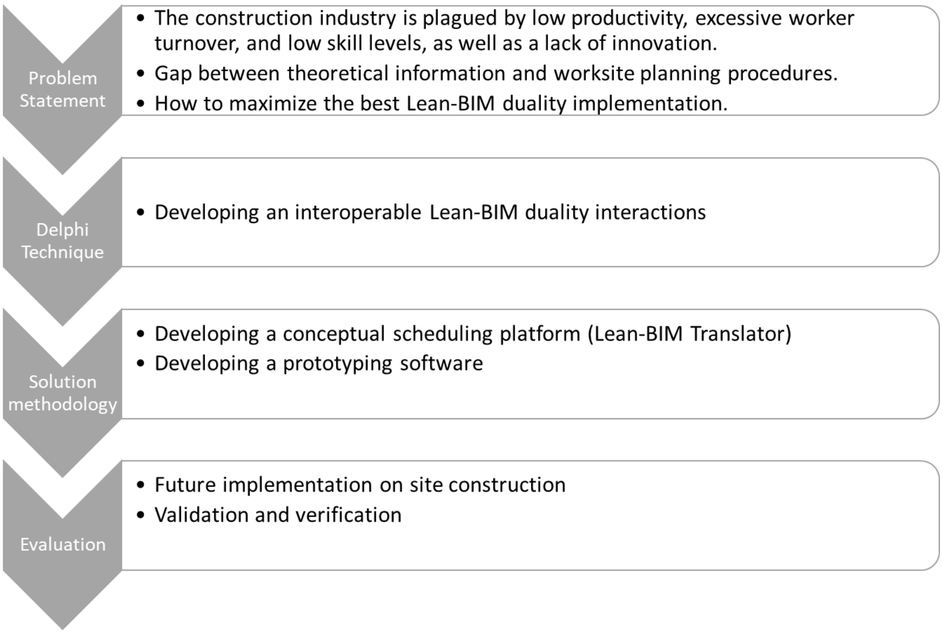

Fig. 1: Research methodology

3.1 Interoperable Lean-BIM interactions

Literature study and Delphi Method were used to uncover Lean-BIM Interaction variables based on Naji et al. (2022b) research's methodology. The variables with comprehensive measurements were established, studied, and evaluated using a three-step study approach. Step one is a thorough assessment of the literature on Lean techniques and BIM operations, with an emphasis on Lean-BIM interactions. Step two involves rigorous analysis of relationships between LC and BIM dual adoption. LC techniques and BIM activities that improve Lean-BIM duality are also from literature-review evaluations. Critical review, ten construction expert practitioners, and senior academic researchers were interviewed in face-to-face and semi-structured interviews to verify the Lean-BIM variables and interactions that would be used to construct the LEAN-BIM Duality Framework. As illustrated in Appendix A, ten lean construction practises (LC 1 to 10), ten BIM operations (BIM 1 to 10), and four dual LC-BIM interactions (LC-BIM1 to 4) were selected by literature analysis and conferences with ten construction experts. In the second stage, a two-round Delphi research with 25 construction professionals was undertaken to determine expert consensuses using advanced statistical analysis. Criteria for selection of experts was developed based on Naji et al. (2022a). Inter-rater agreement (IRA) analysis was used in the third phase to assess the strength of agreement, which was 96.8% for Lean practices and BIM operations and 100% for Lean-BIM dual interactions. Thus, a strong agreement was reached, and building specialists acknowledged the relevance of the highlighted parameters.

3.2 Developing a conceptual scheduling platform

Naji et al. (2022a) note that to accomplish construction project objectives often includes the optimization of the interdependent goal variables, time, costs and quality, for which avoiding the planning variabilities and maintaining process stability in execution are critical. Subsequently, approaches aimed toward achieving Lean and BIM aims, such as Collaborative Target Planning (CTP), become anchors for developing scheduling platform system. Four major potential factors were identified according to the interoperable Lean and BIM interaction that have significant room for potential improvement, and as a result, those areas will be added into the integration platform.

LC-BIM01, enhanced multi-dimensional visualization for evaluating design alternatives according to customer value and conformance with predictive analysis of performance and early cost prediction. After investigating, visual management, also known as "control by sight," Gunduz and Naser (2019) has emerged as an essential component of the Lean philosophical framework. Visual management is directed toward visual control in workplace organization, quality, cost, production delivery, people skills, and safety. Therefore, collaborations were realized within different construction life-cycle stages. At the design stage, design alternatives offer an admirable opportunity to the owner and designer to choose the best option to maximize their value. Simulation and modelling of construction sequences utilizing "4D" and "5D" software provides an amazing opportunity to view construction processes throughout the construction phase. This enables the detection of resource conflicts in time and place, as well as the resolution of constructability issues and their related cost implications. In addition, it encourages process improvement, so boosting efficiency and safety assists in identifying bottlenecks. The increased use of mobile devices with cloud databases (such as BIM 360/AutoCAD) adds to the widespread use of BIM visualization. In addition, the utilization of mobile devices and virtual reality improves the process transparency and visualization options accessible throughout the construction stages. Therefore, earned value analysis may be derived using earned value management (EVM) measures, such as Planned Value (PV) and Earned Value (EV). The CTP will outline the required effort and identify the "earning-value" used to determine the task accomplishment or not. Determining the actual costs (AC) and evaluating them to projected costs (EV) can ultimately provide insight into the current situation of overall spending (Gunduz and Fahmi Naser 2017).

LC-BIM02, enhanced collaboration throughout construction project lifecycle via the use of multi-user operating systems to modify and evaluate a single model. In collections of 2D drawings and relevant shop drawings, the exact same objects are depicted in a number of different locations. BIM operators are required to sustain consistency between the multiple illustrations and presentation views as the design process moves forward and modifications are made. By utilizing a singular representation of the information, from which all reports are automatically derived, BIM completely eliminates this problem. Even without producing drawings, sharing models among all team members is an effective way to improve communication during project construction phases.

LC-BIM03, Digital transformation and control with virtual transdisciplinary interaction and actual operating status for project during construction phases. As a 3D model captures all aspects of the design intent and relevant code of practices, BIM visualization features have been used to engage clients and stakeholders, as well as to enhance the collaboration during the construction phase during the CTP meeting sessions. Therefore, BIM based simulations of installation sequences and production can be digitized, which directs supervisors in how to carry out work in certain settings and is an effective tool for ensuring that standardized processes are adhered to. BIM models offer a centralized data repository for the entire life cycle of a project, which helps to decrease variability caused by problems with coordination and the transfer of project data between project phases.

LC-BIM04, Developing an integrated project construction stakeholder databases (i.e., material supply chains and sub-contractors)–Quantities that are automated and connected to BIM models provide more accurate results than those that are performed manually. In addition, modifying the design at a later stage causes corresponding modifications to be made in the connected quantity files. This further helps to guarantee that the amounts are always correct. In addition to this, any modifications that are made to a section or plan are instantly reflected in all of the other sections and plans, which helps to keep the design uniform and eliminate change orders. A BIM database enables construction teams to retrieve construction drawings as required, hence avoiding the traditional approach. With BIM adoption, the quantity take-offs, resource management, and suppliers' records, just-in-time material and consumable logistics for the construction site can be facilitated via timely coordination with suppliers.

4 The Scheduling Process via Lean-Bim Translator

Developing a master schedule that includes representations of key milestones is a point of commencing when planning out individual phases in accordance with the pull planning. The master schedule, actual material quantities, contractual documents, and the harmonised BIM model in the Issued for Construction (IFC) drawings are taken as input to the framework. Basically, Lean-BIM scheduling process follows the logic steps of pull planning as implemented in infrastructure projects, the State of Qatar as shown in Table (1) and Figure (2). The collaborative/pull planning was introduced as part of contractual enhancements to support project delivery and minimise programme disruption. The Lean-BIM translator is digital process interlinked with relevant BIM objects. During the planning phase and updating production performance, the construction team (last planners) can provide their individual input via cell phone. KANBAN Card application can be downloaded in the cell phone and linked to the Lean-BIM translator. Each kanban card includes a concise description of a work item, as well as its owner, due date, and status. The card may also contain references to source documents or a list of constraints impeding the item's completion.

12-Weeks Collaborative Target Planning (CTP), 4-Week Look Ahead Plan (4WLAP), Weekly Production Review (WPR), and Daily Huddles (DH) were set as an enhancement scheduling and controlling tools to evaluate and assess the performance of production and productivity in enhanced infrastructure projects. 12-week CTP is, master schedule, collaborative pull production planning session and including all relevant stakeholders to define and sequence tasks to manage interfaces, clarify requirements for handovers, and create/improve overall workflow and productivity for the following 12 weeks. In this session, phase planning can be developed collaboratively by construction and stakeholders' team. The CTP sessions are to eliminate waste, identify any missing approvals/key resources or materials etc. that are preventing maintenance of a continuous work flow i.e., design, resources, access, material, plant, permits, safety, and share understanding (DRAMPPSS). A written action plan shall be listed to ensure that the necessary activities to complete the works are correctly identified and required preparations are in place to ensure a successful on time completion. 4WLAP is a detailed work activity plan for the next 4 weeks, and should be aligned to the agreed CTP milestone dates. Relevant project construction team members visualize how best to set-up, organize and carry-out planned works. Then, verify DRAMMPSS –action as appropriate to support 4-WLAP, which is a rolling work plan updated every week as part of WPR. Percentage Planned Complete (PPC) may be calculated and recorded to assess the performance and effectiveness of the plan and study the way for improvement in next week. This can be monitored through DH to ensure continuous daily focus on the delivery of the CTP and weekly plan.

Table 1: Lean-BIM scheduling process

Step	Collaborative Pull Planning	Lean-BIM Translator
1	List of key milestones /activities for upcoming 12 weeks.	Select the BIM objects via IFC viewer to incorporate the milestone date.
2	Define the phase schedule works and relevant pre-requisites.	Select BIM items in IFC Viewer and click *Kanban Card* on mobile device or using digital board.
3	Estimate the time required to complete the phase and any significant intermediate releases from earlier or later phases.	Click on particular milestone and set completion date.

Step	Collaborative Pull Planning	Lean-BIM Translator
4	Conduct collaborative scheduling and post-it notes, construct the logic chain of construction events that are expected to accomplish the phase, and pull planning from the date of the milestone.	Link *Kanban Card* to accomplish the phase, starting from the milestone date via cell phone or using digital board.
5	Estimate time duration for each activity without contingency or float.	Set the duration using *Kanban Card*.
6	Double-check the duration of each activity to reduce the total duration and determine the earliest feasible phase start date.	The duration can be confirmed during 12 Week CTP meeting and 4WLAP.
7	Update the daily production data.	Update the *Kanban Card* via cell phone.
8	Evaluate the production performance via PPC, EV, KPI.	PPC, EV, and KPI values can be displayed in weekly production review meetings in order to evaluate and assess production performance.

4.1 Monitoring and Controlling via Project Performance Indicators

EVM's metrics PV, EV, and AV will enhance pull planning metrics including PPC, average cycle durations (CT), value added, non-value added (NVA), and lead times (LT). As an addition to the systematic CTP, the EV of each accomplished Kanban Card update will be pooled and utilized to assess project success each week. The BIM viewer may preserve each process's state as a query parameter for visual study of building progress, as illustrated in Figure (2).

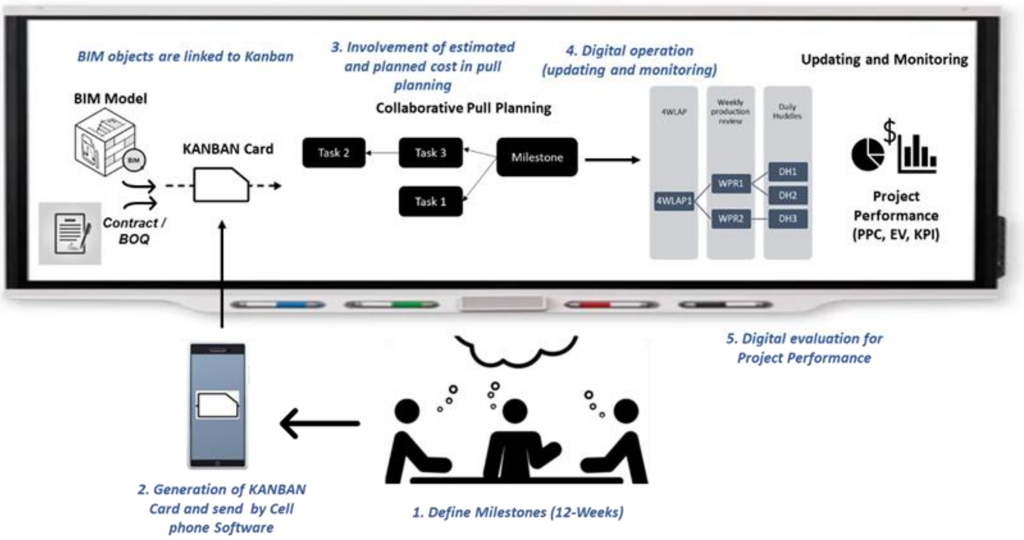

Fig. 2: Lean-BIM Process to develop a digital scheduling platform

5 Conclusion and Future Implementation

The conceptual production planning platform that has been presented integrates several different tried-and-true methods, including the following: EVM gives tools that may be used to assess whether or not a project is working efficiently, while CTP provides the methods to establish when and if value has been generated. In addition to this, it provides a basis for greater process stability as well as increased workflow dependability, which was expected. BIM, which gives the essential information to predict the costs and durations of construction activities, is the gap portion of this jigsaw. In contrast, it provides a more solid foundation for decision-making during 4WLAP, WPR, and DH sessions, in addition to serving as a platform for effectively depicting the project's current status. These qualities are able to be included into the digital Lean-BIM Translator board that has been developed.

For this reason, this paper proposes a conceptual framework for an operable Lean-BIM duality based on reality of planned activities and actual updating data on daily and weekly basis. This framework will be utilized as a departure point in the current research study to generate an operating system model for Lean-BIM Translator that is applicable for analysis of construction project models and, therefore, for assessment in the logic of the developed research design strategy. Consequently, this paper also assesses the developed research design approach. It was also considered the possible scope of the Lean-BIM Translator, as well as its guiding principles and the new roles that would be formed as a tribute to digital production monitoring system. In this manner, it has been demonstrated that the conceptual platform is a production system that not only fully represents the lean management principles, but also functional areas as a comprehensive construction management system that harmonises the project objectives of accurate planning, excellent deliverables, and minimizing a non-value added cost by imposing a digital planning platform integrating Lean-BIM viewpoint.

References

Azhar, S., Maulik, Y. L, & Ahmad, I. (2013). "An Investigation of Critical Factors and Constraints for Selecting Modular Construction over Conventional Stick-Built Technique." *International Journal of Construction Education and Research* 9, no. 3 (2013): 203-225.

Evans, M. et al. (2021). "Analysis Framework for the Interactions between Building Information Modelling (BIM) and Lean Construction on Construction Mega-Projects." *Journal of Engineering, Design and Technology*.

Guerriero, A. et al. (2017). "BIM-enhanced Collaborative Smart Technologies for LEAN Construction Processes." In *2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC),* pp. 1023-1030. IEEE.

Gunduz, Murat, & Naser, A. F. (2017). "Cost-based Value Stream Mapping as a Sustainable Construction Tool for Underground Pipeline Construction Projects." *Sustainability* 9, no. 12: 2184.

Gunduz, M., & Naser, A. (2019). Value stream mapping as a lean tool for construction projects. *International Journal of Structural and Civil Engineering Research, Issue*, *8*(1), 69-78.

Heigermoser, D. et al. (2019). "BIM-based Last Planner System Tool for Improving Construction Project Management." *Automation in Construction*, *104*, 246-254.

Maraqa, M. J., Sacks, R., & Spatari, S. (2021). "Quantitative Assessment of the Impacts of BIM and Lean on Process and Operations Flow in Construction Projects." *Engineering, construction and architectural management*, *28*(8), 2176-2198.

Naji, Khalid K., Gunduz, M., & Naser, A. F. (2022a). "The Effect of Change-Order Management Factors on Construction Project Success: A Structural Equation Modeling Approach." *Journal of Construction Engineering and Management* 148, no. 9: 04022085.

Naji, K. K., Gunduz, M., & Naser, A. F. (2022). Construction change order management project support system utilizing Delphi method. *Journal of Civil Engineering and Management*, *28*(7), 564-589.

Sacks et al. (2010). "Interaction of Lean and Building Information Modeling in Construction." *Journal of Construction Engineering and Management* 136, no. 9: 968-980.

Sacks, R., Korb, S., & Barak, R.. (2017). *Building Lean, Building BIM: Improving Construction the Tidhar Way*. Routledge.

Sbiti et al. (2021). "Toward BIM and LPS Data Integration for Lean Site Project Management: A State-of-the-Art Review and Recommendations." *Buildings* 11, no. 5 (2021): 196.

Terreno, S., Asadi, S., & Anumba, C. (2019). "An Exploration of Synergies Between Lean Concepts and BIM in FM: A Review and Directions for Future Research." *Buildings* 9, no. 6: 147.

Tezel, A., Koskela, L., & Aziz, Z. (2018). "Lean Thinking in the Highways Construction Sector: Motivation, Implementation and Barriers." *Production Planning & Control* 29, no. 3: 247-269.

Toledo, M., Olivares, K., & González, V. (2016). "Exploration of a Lean-BIM planning framework: A Last Planner System and BIM-based Case Study." In *24th Annual Conference of the International Group for Lean Construction*, vol. 7, no. 20, p. 2016.

Appendix A: Lean-Bim Interaction Factors

Lean Construction Practices (LC)	BIM Main Functions (BIM)
LC 1. Reducing project process variability and enhancing upstream flow.	BIM1. Superior visualizations for the assessment of the design's imaginary and functionality
LC 2. Reducing work in progress and cycle time	BIM2. Developing various design alternatives enhancing construction activities and minimizing change-orders
LC 3. Minimizing batch size and pursue single-item flow maintaining continuous output	BIM3. Developing predictive enhancement analysis evaluating the design and construction workflow performance
LC 4. Enhancing adaptability via multiskilling.	BIM4. Systematic cost and time estimate throughout the design and construction phases
LC 5. Standardizing procedures with user-friendly systems to manage production.	BIM5. Reviewing of client value conformity throughout the design and construction phases
LC 6. Improving visualization management controlling production flow.	BIM6. Collaborative modeling techniques based on different design disciplines, and automatic clash management
LC 7. Reliable lean technology enhancing the parallel workflow and line of balance.	BIM7. Collaboratively maintaining a single model throughout the design and construction phases
LC 8. Standardizing value streams via continually validating and verifying.	BIM8. Assessing the potential construction plans utilizing multi-dimensional visualization
LC 9. Collaborative problem-solving opportunities leveraging enhancement strategies.	BIM9. Virtual transdisciplinary collaboration and multi-dimensional visualizations throughout construction phase
LC 10. Enhancing construction stakeholders' networks to foster collaboration and sustain beneficial long-term connections with supply chains.	BIM10. Collaboration of project construction stakeholders and supply chains database
LC-BIM Translators (LC-BIM)	
LC-BIM1. Enhanced multi-dimensional visualization for evaluating design alternatives according to customer value and conformance with predictive analysis of performance and early cost prediction	
LC-BIM2. Enhanced collaboration throughout design and construction via the use of multi-user platforms to modify and evaluate a single model	
LC-BIM3. Digital transformation and control with virtual transdisciplinary interaction and actual operating status for projects during construction phases	
LC-BIM4. Developing an integrated project construction stakeholder databases (i.e., material supply chains and sub-contractors).	

Cite as: Gunduz M., Naji K. & Naser A.F., "Duality of Lean Construction and Building Information Modeling into Digital Collaborative Scheduling in Qatar: A Conceptual Framework", *The 2nd International Conference on Civil Infrastructure and Construction (CIC 2023)*, Doha, Qatar, 5-8 February 2023, DOI: https://doi.org/10.29117/cic.2023.0013