BIM and Lean for value generation in the built asset industry: an information management perspective

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Abstract. The built asset industry’s notorious productivity gap is being targeted through digitalization, operationalized through Building Information Modelling (BIM), and the application of Lean philosophy to the planning, design, delivery, maintenance, and management of the built environment. While both approaches grow in popularity, their development has remained largely on parallel tracks. Both approaches have existed, for the most part, as two independent initiatives aimed at improving performance and productivity. An increasing amount of work however is pointing to the significant potential that can be achieved through the integration of both approaches. This paper investigates the mutual relations and synergies between BIM and Lean from an information management perspective. The paper also presents the key similarities, differences, synergies, and interactions between these two main drivers of built asset industry reform, while providing an investigation into the principles guiding the application of both within the construction industry.

1. Introduction

The built asset industry plays an integral part in the global economy through its role in urbanization and enhancing quality of living. As Lee [1] states “projects in the construction industry are becoming increasingly large and complex, with construction technologies, methods, and the like developing rapidly”. Construction problems are well known and their impact on productivity and quality have been documented in the past [2]. Several solutions have been provided to relieve the chronic difficulties in construction. Two of the most recent and notable efforts to resolve these problems are considered in this paper. First is Lean Construction (LC) which involves the use of a conceptual approach to construction management borrowed from the manufacturing sector. Second are the transformative advancements in digitalization, operationalized through Building Information Modelling (BIM). Both are seen as a mechanism to increase efficiency, productivity, reduce project duration and lead times, enhance quality, and improve sustainability [3] The concepts of BIM and Lean have largely existed as two separate initiatives in the past. Research in the field is increasingly pointing towards the commonalities and synergies between both approaches. Yet, their implementation in tandem has been seen to cause confusion as explained by Sacks [5] “Their parallel adoption in state-of-the-art construction practice is a potential source of confusion when assessing their impacts and effectiveness”. While both Lean construction (LC) and BIM are bringing important changes to the industry in their own way, the integration of both principles promises to provide important benefits to the Architectural Engineering and Construction (AEC) sector. However, there is still significant work to be done to fully reap these benefits. Among this work, setting the proper theoretical foundations can help to better explain and
predict future outcomes as well as serve to better frame and understand how to effectively implement both approaches in tandem. Indeed, many researchers point to the lack of theoretical foundation in construction as an overall hinderance to progress [9].

The purpose of this paper is to investigate the synergies of BIM and Lean from an information management perspective. More specifically, it explores this question from a theoretical point of view through a review of past work in the field. The paper also provides a review of the background literature related to BIM and Lean principles to explore their likenesses and variances as well as potential integration and highlighting the existence of literature limitation and gap.

2. Literature Review

2.1. Theory of production as foundational theory of construction

The AEC industry suffers from poor quality and productivity due to problems related to a number of root causes which impact client decision making, design and construction management, among many others. Significant parts of these issues are initiated by limited view on production [6]. One of the main barriers to construction improvement is known as the lack of theoretical foundation as pointed out by several scholars (e.g., Koskela [7], [6] Ballard [11], Demirdöğen [13], Tauriainen [14]). Adopting the theory of production as a foundational theory of construction, can help in better framing pathways for improvement [7]. For instance, Sacks [8] propose “In the current context of lean construction and BIM, we propose that for comprehensive realization of benefits, not only should changes in information and material processes be coherently based on these two (IT benefits and understanding construction peculiarities), but that all three – process changes, BIM tools themselves, and of course lean construction principles – should be rooted in conceptual understanding of the theory of production in construction” which is explained in Figure [8].

Three different concepts of production have been developed. These exist as Transformation, Flow, and Value generation. None of these have been accepted as a generalized theory of production from either an industrial or a scientific point of view. Indeed:

- The Transformation (T) or conversion concept was dominant as a foundational theory of production, and it was formed based on Economic science. Two fundamental principles of the transformation model which view production as a conversion of inputs into outputs and dividing the total transformation into smaller, more manageable conversions known as analytical reductionism. Nevertheless, as transformation view is not particularly helpful in identifying how to avoid using unnecessary resources or how to certify that customer requests are met in the best approach, it tends to become ineffective and inefficient [9].
- The Flow (F) concept has its roots in Japan in the 1940s and challenged the transformation model, as the “Time” factor in transformation was neglected and it is identifying waste and non-value adding activities through the process [10]. The Lean production system was developed based on this theory. As such, the flow view is represented in lean production and lean construction. In the flow view, the essential thrust is to eliminate non-value adding or waste

![Figure 1 The dependence of benefits realization through process changes in construction on lean construction principles, BIM, and a theoretical understanding of production in construction [8].](image-url)
from processes. Consequently, such principles as lead time, variability reduction and simplification are endorsed.

- The Value generation (V) initiated in 1930’s where researchers debated that the value of a product can be determined only in reference to the customer, and the total goal of production is satisfying customer needs [11]. In the value generation view, the basic tenant is to achieve the best possible value from the point of view of the customer. The quality movement has attempted to translate this view into useful practices for the industry.

The fundamental goal guiding the development of a “theory of production” was to form a unified conceptualization of production, in lieu of three incomplete conceptualizations. The TFV theory of production developed by Koskela [9] proposes an integrated view of all three views of production. He suggested that the three views are all necessary for production management and they should be used simultaneously, in an integrated and balanced manner. The Integrated TFV view on production is shown in Table 1 [9]. The TFV theory of production enhances construction by improving performance through elimination of waste and increase value where possible through reduction of variability [2]. The TFV theory has demonstrated its potential to enhance construction performance, however it requires discipline integration that focus on design, control, and enhancement of production system.

| Transformation view | Flow view | Value generation view |
|---------------------|-----------|-----------------------|
| Conceptualization of production | As a transformation of inputs into outputs | As a process where value for the customer is created through fulfilment of his/her requirements |
| Main principle | Getting production realized efficiently | Elimination of waste (non-value adding activities) |
| Methods and practices | Work breakdown structure, MRP, organizational responsibility chart | Continuous flow, pull production control, continuous improvement |
| Practical contribution | Taking care of what has to be done | Making sure that unnecessary things are done as little as possible |
| Suggested name of practical application of the view | Task management | Flow management |

Table 1 TFV Theory of Production [9]

2.2. Conventional vs. Novel Project Management

Project management (PM) is a crucial factor in achieving the desired outcomes in the construction industry. Yet, conventional project management and its associated delivery systems follow a ‘task’-based rationale to project delivery. They largely ignore both value maximization and waste reduction. This approach confuses the ‘task’ view with managing the project. The new theoretical foundation of project management (PM) contains extended theory of project and theory of management. The theory of project consist of transformation, flow and value generation considers the factor of time, variability, and customer satisfaction into the transformation model. The theory of management on the other hand is comprised of three main constructs: planning, execution, and control. The theory of production (TFV) is considered a valuable basis for novel project management Koskela claim [9] construction should be considered as from a system of production perspective.

These novel approaches to project delivery and management are instantiated through mechanisms and tools such as Last Planner (LP) or Last Planner System (LPS) developed by Ballard [11] as a response to failure of conventional PM. The Lean Project Delivery System (LPDS) specifies what must be done and who is the responsible party for the task at the very beginning of the project [12]. The traditional delivery versus LPDS is mainly different in terms of project phases and participants in each phase, value,
and control concepts. Traditionally, project design and definition are performed by the architect in isolation or with the client, however the LPDS concerns overlapping iterations over five main project phases as shown in Hiba! A hivatkozási forrás nem található. [12]. The LPDS enables teams involved in every stage to be involved from project start to completion. The conventional design management is frozen in the design phase and any change causes rework and extra cost. However, the LPDS design decisions are systematic and enable more time for exploration of design alternatives which enhance value generation as per client requirement. From a control point of view, traditional project control refers to monitoring the actual versus planned performance and identifying possible variance. In contrast, the LPDS control is based on systematic process for making tasks to be formed along with explicit organization liability at production level to what need to be released to client in the next plan phase. Moreover, in traditional project delivery, the information about operation, maintenance and decommissioning is not often considered as part of the process which leads to customer dissatisfaction and neglecting value generation. In contrast, the LPDS consider end-user value generation as the information about operation and maintenance are considered from beginning of project. Therefore, For the LPDS successful implementation, early-involvement, aligned incentives beside early-involvement of stakeholders are required [2],[11],[12].

Figure 2 Lean Project Delivery System [12]

2.3. key Similarities and Differences between Lean Construction and BIM

Lean and BIM notions have largely been developed as two distinct initiatives to enhance the performance of AEC industry, each possessing different communities and interests [4]. Lean is a conceptual approach to project construction management and BIM is considered as Transformative information technology which cause fundamental change in the AEC industry [8]. The main similarities and differences between BIM and Lean are presented from various perspectives as backgrounds, application, design management, lifecycle, and supply chain information management.

- The background and generation of Lean and BIM concept are different. Since mid1990s Lean construction (LC) has appeared as a novel theory in the construction domain adapted from manufacturing [5], [7] It is an adaptation of core concepts and principles of the Toyota Production systems (TPS) [10]. In mid 1970s, Eastman [3] introduced the basic concept of BIM as a computable interpretation of a building object, transforming the traditional approach based
on descriptive geometry used to signify the objects to be constructed. However, the idea of BIM implementation could not be applied until 1990s, as computers technologies improved and enabled practical implementation of the BIM idea [3], [8], [13].

- The application and adoption of both (Lean and BIM) are similar as both concepts require organizational cultural change which is challenging. For instance, Koskela [2] explain: “Changing procedures, techniques and corporate systems is the easy part; changing minds is the real challenge.”

- Design management follows different approaches to the application of Lean and BIM. Project design management by using Lean tools, enhance operations, minimize waste, improve value generation and client satisfaction [14]. During this stage, design process is understood as a flow and value creation that can be improved by using Lean tools. Using lean tools facilitate coordination and collaboration among project team regardless of their physical geographic location and facilitate effective information sharing between project team. Therefore, overall design duration reduces, and client satisfaction is ensured. The BIM process during design stage includes several design disciplines that need to work effectively to achieve client requirements to prevent conflicts. However, as usually there is no standard for collaboration among design teams and responsibilities are not well defined, the whole process face challenges [13].

- Lifecycle information management and supply chain management is similarly challenging for both Lean and BIM as the nature of projects in the AEC industry is fragmented [15]. The management of supply chain across construction industry is a challenge as due to the temporary nature of construction as well as unwillingness of project team to cooperatively share information due to existing contracts contents and clauses. Therefore, this led to challenges in trust and cooperation [16].

2.4. Application of both (BIM & Lean) from information management perspective

Over the last decade, BIM and Lean concepts have begun to diffuse into advanced practice. As Sacks [8] claims, “BIM technology could also be used as an enabler or catalyst for lean transformation”. Today, the emerging methods of BIM and Lean are reshaping the worldwide business environment of the AEC industry [15],[17]. The insight about both initiative’s synergies and benefits is being increasingly explored by academia and leading practitioners as illustrated in figure 3 [4]. As Koskela [8] state: “lean construction arguably facilitates the implementation for BIM, especially when this is based on robust and reliable technology.”

Figure 3 Benefits of using Lean and BIM [4]

One way to bridge the gap and enable a Lean approach to project delivery supported through BIM, is to look at the question through the lens of information management (IM). Several standards and bodies of knowledge are beginning to be developed in this regard. For instance, the International Standard
Organization has published the ISO 19650 series to provide direction for information management, collaborative working, information delivery plan creation, software’s application, roles, and responsibilities of different stakeholders across the built environment. On one hand, creation of standards and protocols cause positive effect by enabling information exchange consistency across project team. On the other hand, it causes negative effect on the innovation process as it promotes robust and solid factors for innovative technologies, mainly because they are developed with modest or without theoretical foundation. Accordingly, Succar [18] claim: “Foundational questions remain as to what should or should not be standardized in the fast-evolving domain of construction technologies and, more consequentially, questions relating to the appropriateness of these standards for information integration between overlapping domains.”

In the BIM and Lean integrated approach, the balance between people, process and technology is fundamental. As Dave [4] state “A Lean and BIM project is people-and process-oriented, where BIM as a technological platform acts as an enabling tool”. An example of information exchange and information flow among supply chain to support key appointing party decisions is illustrated in figure 4 [19]. The information from project teams flows and exchanges across project phases which require validation and verification at every project stage. To outline, manage, and integrate lifecycle information exchange and transformation, physically and digitally, among project team, there is requirement for foundation of information management (IM) [18].

![Diagram](image)

**Figure 4 Example of Information delivery through information exchange to support key appointing party decisions [19]**

The question of lean and effective IM practices enabled through BIM is also garnering considerable attention in academia. As such, researchers have investigated ways to better define, manage, and integrate asset and project information across their lifecycles. For instance, the Lifecycle Information
and Exchange (LITE) framework [18] (figure 5) provides a structured approach to understanding how information flows and transforms across an asset’s lifecycle. The LITE framework acts as a visual rendition summary of many conceptual components and their relationships in one Information Cycle. It is composed of several conceptual contents that require independent and collective recognition. The ten components of this Information Cycle are described by Succar and Poirier [18]. They include the status of information, which defines the continuous information transformation through lifecycle defined as two statuses of Targeted Status and Actual Status. The States refer to the information transformation from initial intend to deliver new asset upon its delivery which are represented as three states: Purposes, Deliverables, and Resources and Methods. The Sets refer to collection of information covering all targeted and existing information as the information transforms and exchanges between Statuses and States. There are eight Milestones as manifest track of asset’s lifecycle information where each milestone is a clear transformation from being an intent of an asset, to a digital representation and to become Physical Asset itself. The Flows refer to the movement of information within and in between the Milestones which can move forward, reverse, inward and outward directions and the Gates refer to the mechanism of controlling these movements. The Routes refer to the information once they enter into the Loops which are three categories as Assisted Flow, Automated and Automatic Flows, and Autonomous Flow. The Loops consist of open loops where information flows once along a route, whereas close loops information flows more than once along a route during asset lifecycle. The Actions are collections of granular information activities, sub-Activities, Tasks and sub-Tasks shows the connections between information and milestones. The Shortcuts refer to the information flows that avoid milestone(s) with a valid reason of potential risk or a divergence from routes. The Tiers refer to organizing and sharing of information through a Common Information Environment to minimize duplication of contents and avoid reliance on disconnected documents.

The LITE framework puts emphasis on transformation of information flow from defining the purpose to deliver new asset to recognizing the actual Digital/Physical Assets to managing during entire lifecycle. The LITE framework, similarly to Lean Construction, provides information flow primacy to pull activities. However, Succar and Poirier [18] state that “the Lean Construction focus on the product and production system, it focuses on the information flow itself across Milestones and transforms through Statuses and States”. Further development and investigation toward similarities and differences between LITE framework, and other emerging process-oriented approaches are valuable to engage other communities [18].

Figure 5 The LITE framework [18]
3. Key limitations and gaps in current literature

Digital transformation in construction implies a departure from conventional practice, demands the implementation of advanced technological solutions across a project’s lifecycle. There are two gap and limitation respectively identified.

First, there is a gap in integration of BIM and Lean in practices. It is understood from the existing literature review that many interesting connections have been highlighted in theory from academia about the integrated BIM/Lean. However, there is lack of BIM/Lean application in practice [8]. As Dave [4] mention, currently organizations practice either BIM or Lean. Therefore, further efforts from both academia and practice are needed to bridge the gap in knowledge and to enhance productivity and efficiency of the construction industry.

Second, to fully benefit from potential advantages in the innovative technological resolutions, parallel innovation in policies, processes and practices are needed. As a result, many countries around the world formalized standards, protocols, specifications nationally and internationally for information management across the built environment [18]. The LITE framework concepts identified requires further testing, validation and development. The BIM and Lean integration through the LITE framework require clear definition of milestones, value mapping and value generation. Additionally, identification of adequate resources and suitable methods that bridge both approaches are the gaps to be addressed. Furthermore, the Lean coupling of assets, resources, deliverables, etc. requires continuous synchronization of actual Digital Asset with their Physical counterparts [18] is another field of study in line with the emergence of Digital Twin as a concept which is beyond scope of this paper.

4. Conclusion

The construction industry has suffered from poor productivity and performance for many years. The individual areas of BIM and Lean have emerged as two separate initiatives within the AEC, and both have been explored extensively in latest years. Nevertheless, there seems to be a deficiency of research to explore their synergies and integration of both concepts. The TFV theory of production as foundational theory for construction was discussed to identify the potential benefits of BIM and Lean. The two concepts of BIM and Lean were explored from different perspectives such as background, application, design management, lifecycle information management, tools, methods, and enablers, etc. to identify similarities and differences. The application of both concepts were investigated from an IM perspective by identifying their relationships, benefits, tools, and techniques for their integrated implementation. The paper highlights a gap in integration of BIM and Lean in practices as there are limited studies on BIM and Lean projects delivery both in theory and practice and further efforts are needed to bridge this gap. Future work will investigate the synergies in a structured manner from an IM perspective and pull from existing frameworks, namely ISO 19650 and the LITE framework. The concepts and their relation to BIM and Lean integrated approach require further investigation and development. A follow-up study will be conducted to address these gaps.

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