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Building Information Modelling and Lean Construction

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6.1. Introduction

The recognition of the connection between Building Information Modelling (BIM) and Lean Construction is relatively recent. Although these fields share a common objective, namely to improve the efficiency of construction, they had been advanced by their own communities or researchers and practitioners, with practically no interaction. The synergy between these fields was first spotted on the ground, by a contractor with simultaneous initiatives in BIM and Lean **(Green Construction Purchasing, Q3Markgraff 2008)**:

« Tocci Building Companies uses BIM as the cornerstone of its lean activities »

« We're finding that BIM is the foundational tool for implementing an efficient delivery process » **says Tocci**.

The idea of this synergy was surprising and intriguing, and led to the first journal paper specifically addressing it in 2010 (Sacks et al. 2010b). In that article, 56 interactions between BIM and Lean were found. This seminal paper has now (April 2020) been cited more than 500 times, which provides evidence on the rapid proliferation of the topic. Especially, this synergy has been analysed in more specific areas, such as operations and maintenance (Guzman and Ulloa 2020), mechanical, electrical and plumbing engineering (Tillmann 2020), demolition activities (Marzouk et al. 2019) and facilities management (Terreno et al. 2019).

The aim of this chapter is to give an overview and analysis on the connection between Building Information Modelling and Lean. It is structured as follows: The next section endeavours to give a high-level overview on the component parts of the topic and their relations. The following sections discuss the contributions of BIM to Lean, respectively, in design, construction and facilities maintenance. The contributions of Lean to BIM are discussed in the subsequent section, and the chapter is completed by a conclusions section.

6.2. Overview on BIM and Lean

6.2.1. Building Information modelling (BIM)

The US National Building Information Model Standard Project Committee defines BIM as follows— [\(National Institute of Building Sciences 2021\)](#) ~~[\(National building information modeling standard 2007\)](#)~~:

« Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. » [\(page\)](#)

According to [Sacks et al. \(2018\)](#) [Eastman et al. \(2008, synopsis on the back cover\)](#), BIM is « a new approach to design, construction, and facilities management, in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format ». [\(page\)](#)

These definitions deserve to be expanded for some critical aspects. Building Information Models usually have an object oriented, parametric data structure for the geometry of designed entities. Other information can be attached to such objects. The models are solid, that is, they are three-dimensional models.

Because of their characteristics, Building Information Models provide a central database and a multitude of functionalities that are new in comparison to the previous situation where information was presented on drawings and documents, leading to duplication of information across diverse documents, and great potential for errors.

6.2.2. *Lean*

Lean Construction can be understood in terms of tools, principles and theoretical foundations.

Tools provide for the best known and practice-facing aspect of Lean, aiming to reduce waste in processes and generate better value to customers. A representative list of tools is provided by Umstot and Fauchier (2017):

- Collaboration
- 5S (a method for creating order on work place)
- Last Planner System
- Visual work place
- Root cause analysis
- A3 (a problem solving method)
- Value stream mapping
- Target Value Design
- Just-in Time.

In turn, principles provide rules which have to be interpreted in the context and situation at hand; the methods and tools listed above usually embody one or more principles. Sacks et al. (2010a) discuss a number of principles of Lean Construction, summarised in Table 6.1.

Theories and foundations provide the explanation to Lean Construction. In (Koskela 2020), it is argued that Lean is a theoretical and philosophical innovation on three frontiers: (1) theory of production, (2) ontology (branch of philosophy addressing what is there in the world), and (3) epistemology (branch of philosophy addressing how knowledge is acquired). These are explained in the following.

In terms of the theory of production, it is claimed (Koskela 2020) that Lean means a shift from the transformation theory of production to two other theories, namely the flow theory and the value generation theory. The transformation theory looks at production as a black box; the flow theory brings time and uncertainty, both being causes of waste, into the analysis of production, while the value generation theory adds the customer and value into the picture.

Focus area	Principles
Flow	<ul style="list-style-type: none"> Reduce variability Reduce cycle times Reduce batch sizes (strive for single piece flow) Increase flexibility Select an appropriate production control approach Standardize Institute continuous improvement Use visual management Design the production system for flow and value
Value generation process	<ul style="list-style-type: none"> Ensure comprehensive requirements capture Focus on concept selection Ensure requirement flowdown Verify and validate
Problem-solving	<ul style="list-style-type: none"> Go and see for yourself Decide by consensus, consider all options
Developing partners	<ul style="list-style-type: none"> Cultivate an extended network of partners

Table 6.1. Principles of Lean Construction according to Sacks et al. (2010a)

The philosophical foundations of lean embrace ontological and epistemological considerations (Koskela 2020). Regarding ontology, Lean is supported by process ontology (Koskela and Kagioglou 2005), which stresses the changing as well as the relational nature of phenomena. This replaces the mainstream approach of thing ontology, based on the idea of stability and decomposability of things. Regarding epistemology, lean is compatible with Aristotelianism (Koskela et al. 2019), addressing both the derivation of knowledge from the empirical world, and the deductive use of existing knowledge. The mainstream counterpart is Platonism, which emphasises the one-directional deductive use of existing knowledge.

6.2.3. Relation between BIM and Lean

The connections between Lean and BIM are multiple and of various characters (Sacks et al. 2010a). It is thus opportune to present a simplified overview on them. This is possible by looking at the theoretical and philosophical foundations of Lean, and the compatibility of the functionalities of BIM with them.

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Before proceeding further, it is important to stress that the interaction between Lean and BIM is claimed to be mutual: BIM supports Lean, and Lean supports BIM (Figure 6.1). Originally, the focus was almost exclusively on how BIM supports Lean, and the other direction was overlooked.

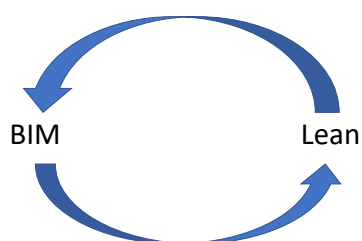


Figure 6.1. *The relations between BIM and Lean*

6.2.3.1. *BIM supporting Lean*

Now, the rapid proliferation of BIM can be associated to its extraordinary compatibility with the theoretical and philosophical foundations of Lean, outlined in Table 6.2. BIM is instrumental in removing problems causing uncertainty and wasteful use of time. It facilitates client evaluation of design solutions through better visualisation and understanding. Furthermore, BIM supports process ontology by facilitating collaboration to tackle the relational nature of design and production, and by allowing continuous improvement. Finally, BIM allows simulated experimentation, in the spirit of Aristotelian epistemology. In all these aspects, the previous counterpart of BIM, in terms of paper drawings and documentation, was remarkably weak.

6.2.3.2. *Lean supporting BIM*

It is contended that when BIM is implemented into a design and construction context where also Lean principles have been applied, the results will be better than

Area of theory/philosophy	Specific theory/philosophical approach	Contributions of BIM (and associated technologies)
Theory of production	Flow theory	Removing problems (for example through clash detection)
	Value generation theory	Facilitating client evaluation of designs (for example through visualisation)
Ontology	Process ontology	Supporting collaboration (for example through easier sharing of information and by providing common ground) Supporting continuous improvement (for example through rapid generation of alternative solutions)
Epistemology	Aristotelian epistemology	Supporting evaluation of solutions (especially through analysis and simulation)

Table 6.2. *Theoretical and philosophical foundations of Lean and contributions of Building Information Modelling to them.*

otherwise. The Lean Construction context arguably facilitates the implementation of BIM, especially in its initial stages, and generally supports the achievement of correct and useful models. This is especially the case with firms adopting Lean features like discipline and predictability, collaboration and experimentation, as well as continuous improvement. Moreover, Lean principles have turned out to be applicable in information systems work in general, and related practices are usable also in regard to BIM.

6.3. Contributions of BIM to Lean in design, construction and facilities maintenance

6.3.1. BIM for Lean in Design

The synergies between BIM and Lean are perhaps most apparent during the design phase. In early design, where the scope and feasibility of a project are determined, BIM enables rapid creation, communication and comparison of multiple design alternatives (Sacks et al. 2010a). Supported by BIM's advanced visualisation and simulation capabilities, this facilitates the practical execution of set-based design, a Lean design management approach that advocates keeping design options flexible for as long as possible during the development process instead of choosing a single point solution upfront (Lee et al. 2012) – and consequently, verification and validation, and focusing on concept selection for project value (Parrish 2009). Some necessary non-

value adding activities in the early design phase like creating bill of quantities (BOQ) for different design alternatives are automated by BIM tools, which reduces the risks associated with mistakes in estimating and overall procurement durations (Khosakitchalert et al. 2020). When model elements are linked with accurate cost data, automated cost estimates by different design alternatives can be rapidly generated (Smith 2016), which guides procurement decisions and facilitates the execution of the lean design management practice of Target Value Design (TVD), a collaborative design development process focusing on delivering project value for or below a targeted project cost (Ballard 2008).

Alongside the rapid generation of alternatives and BOQs, automated production of design drawings, documents and coordinated views on BIM models helps reduce design cycle-times (Eastman et al. 2011). Those BIM features prevent duplicated efforts, reduce risks associated with design documentation (e.g. mistakes in drawings) and automate some necessary non-value adding tasks like the need for preparing different sets of design drawings e.g. plans, facades, and controlling consistency across those drawing sets/views (Eastman et al. 2011). This enables designers to focus their efforts on generating design solutions for greater project value. The ability to automatically generate and navigate the model views at will supports information flows and information-pull (on demand information) for project stakeholders.

BIM also streamlines the design process with fewer mistakes through (Vermeulen and Ayoubi 2019): (i) parametric design (i.e. the user defines associations between design elements and geometries – «this window depends upon this wall and will move with it. »), (ii) design automation (i.e. the ability to automate tasks within parametric models with scripts created on, for instance, Autodesk's Dynamo - «create a door for every x meter of a wall. »), and (iii) computational modeling (i.e. the user explicitly describes a process to create a design outcome - «create a number of windows on the facade and evaluate how many exits per unit area. ») features.

Design technology is progressing towards the generative design model, where describing a set of design goals and constraints (e.g. minimum amount of light in a particular space, maximum amount to be spent for construction etc.) leads to automated generation and optimisation of multiple-design options (see for instance Autodesk's Project Refinery). Supported by other technologies like cloud computing and Artificial Intelligence (AI), parametric design and design automation capabilities of BIM are enabling this progression, which will further help realise Lean ideals, i.e. better concept selection, verification and requirements capture (Sydora and Stroulia 2020). Another fast progressing area in design automation leading to less necessary non-value adding efforts for designers and improved design quality with better standardisation is automatic rule-based code checking and compliance. This involves

assessing design compliance to codes and regulations in automated or semi-automated ways (Bloch and Sacks 2018, Sydora and Stroulia 2020).

The collaborative design processes enabled by BIM help minimise delays, mistakes, misunderstandings and improve information flow, design process control, reduce variability and compress the overall design cycle time (Dave et al. 2013). The current practice in industry is for different design disciplines (i.e. architectural, structural, MEP etc.) to create their own models, which have to be periodically combined and validated (federated/coordinated). Although useful, this gives rise to issues like model interoperability, need for specific data creation and exchange protocols, and considerations for intellectual property rights (Dave et al. 2013).

In line with collaborative design processes, project teams can jointly hold iterative modelling coordination meetings to carry out design reviews, to monitor design status (e.g. checked, approved, final), to control and visualise design revisions, and to address clashes, errors and omissions that have been identified in the design (Eastman et al. 2011, Tauriainen et al. 2016). This supports information flows, reduction of variability and increased standardisation in the design phase. Those iterative meetings enabled by BIM are also necessary for Target Value Design (TVD) (Tauriainen et al. 2016, Pishdad-Bozorgi et al. 2013, Do et al. 2014).

Geometric and semantic/rule-based clash detection and management of hard and soft clashes have been widely described as a «low hanging fruit» benefit from BIM, which is relatively easy to achieve in practice. Addressing the clashes early in the design phase increases design quality, compresses project delivery times, and reduces re-work in the construction phase (Tauriainen et al. 2016).

Early stakeholder involvement increases BIM benefits towards greater project value and better information flow. BIM information can be used downstream by contractors, commercial managers/quantity surveyors and suppliers in processes like estimating, detailing for fabrication/off-site construction, site planning, production planning (4D, i.e. 3D models linked with construction schedule) and resource planning (5D, i.e. 4D linked to costs and resources) (Dave et al. 2013). BIM streamlines workflows for stakeholders as well. For instance, the machine-readable nature of BIM models facilitates the automatic generation of detailed drawings, fabrication of complex designs on CNC machines and coordination of logistics for prefabricated elements (Hardin and McCool 2015).

Immersive technologies like Virtual Reality (VR)/Mixed Reality (MR) are now more frequently used with BIM in client and stakeholder engagement for the communication of design intent, requirement capture as well as coordination and

verification through advanced visualization (Zaker and Coloma 2018, Wang et al. 2018, Ergün et al. 2019).

BIM allows the design model to be simulated against performance criteria. Simulation and analysis of the models through different performance parameters such as architectural/spatial layout, seismic, acoustic, thermal, ventilation, energy/sustainability, life-cycle cost, constructability indicators etc. can be automatically executed by BIM tools (Dave et al. 2013). Alongside many positive synergies, increased complexity in the management of both Lean and BIM processes, increased inventory of alternative designs and design drawings can be listed as the potential negative synergies between BIM and Lean in the design phase (Sacks et al. 2010a).

6.3.2. BIM for Lean Construction

The use of BIM for Lean Construction efforts has been widening in the construction (production) phase of the project life-cycle. This manifests in two forms: (i) BIM helps realise some Lean principles and (ii) BIM supports and enhances some Lean Construction techniques. One of the prominent Lean techniques where the interaction with BIM is apparent is the Last Planner System (LPS) for construction planning and control. The LPS is a collaborative project planning process that involves trade foremen or design team leaders (the last planners) in the planning and control process in greater detail as the time for the work to be done gets closer from master plans to lookahead and weekly plans (Ballard 2000). It supports construction production planning and control by providing systematic routines to increase workflow reliability and process stability. In the UK, it is known as Collaborative Planning and, in the USA, it is sometimes called Pull Planning (Daniel et al. 2017).

In the LPS, BIM is used for 4D planning during the master scheduling (long-term) to select, sequence and size work, and for 3D visualisation of construction processes, location-based planning, constructability analysis and clash detection during the lookahead (medium-term) and weekly (short-term) work planning to make work ready by screening and pulling (Bhatla and Leite 2012, Garrido et al. 2015). Online communication of product and process information through BIM also supports continuous improvement efforts within the LPS, where site teams take note of the discrepancies between designs, plans and actual site conditions on mobile devices (Tillman and Sargent 2016). Commercial software facilitating this LPS integration with BIM workflows, such as VisiLean (Dave et al. 2011), are becoming available. There are also prototypes that enable enhanced functionalities through the combined use of BIM and the LPS such as Lean Enterprise Web-based Information System (LEWIS) (Spriraset and Dawood 2003), the “pull” based and visual construction

work planning and control system KanBIM (Sacks et al. 2013), Smart Construction Planner (Guerriero et al. 2017), and BIM-based Last Planner System (Heigermoser et al. 2019).

At the Lean principles level, the BIM integration with the LPS contributes to (Hamdi and Leite 2012): (i) model-based coordination across different construction disciplines, which increases planning reliability, reduces planning cycles times and supports shared understanding of work for better constraint identification; (ii) reduction of variability, waste, errors and conflicts in site operations; and (iii) verification and validation of design and construction processes for right the first time site operations.

Alongside 4D modeling and clash detection, the BIM functionality of model-based, automatic quantity take-offs reduces the amount of non-value adding activities (waste) and errors in work planning and progress calculations (Monteiro and Poças Martins 2013, Hardin and McCool 2015, Bryde et al. 2013). Furthermore, the programmable nature of BIM models gives way to many rule-based automation and simulation opportunities for construction such as, automatic site layout planning (Schwabe et al. 2019, Kumar and Cheng 2015), site safety (Zhang et al. 2013) and hazard identification (Zhang et al. 2015), real-time construction quality (Wang et al. 2015) and progress control (Han and Golparvar-Fard 2014, Golparvar-Fard et al. 2015), automatic production of documents for quality management (Chen and Luo 2014), monitoring and tracking of logistics operations (Irizarry et al. 2013), on-site monitoring of carbon emissions with the use of BIM systems (Wong and Zhou 2015, Chong et al. 2017), and BIM-based demolition and renovation waste estimation and planning (Cheng and Ma 2013), saving the time spent in those unproductive tasks while reducing the subjectivity and variability associated with them.

The visualisation capacity of BIM offers new avenues for maintaining the information flow and creating transparency in construction processes across different disciplines and organizational levels. Gerber et al. (2010) demonstrate examples from case studies around the world such as communicating the complex erection sequences of a solar chimney with on-site teams through detailed snapshot images from the chimney's BIM-based work package or detailed BIM outputs on precast elements, enabling on-site teams to more easily and precisely «pull» what they need from information provided by engineering teams.

In large scale infrastructure projects, BIM models and their outputs are used to support the daily huddle meetings with site teams, and to maintain the coordination between subcontractors working dispersedly in different areas (Tezel and Aziz 2017). Virtual gemba walks – management's observation of the site conditons and site

walkthroughs for work coordination (Mahalingam et al. 2015), creating a shared understanding (Johansson et al. 2015), and quality and safety analyses (Zou et al. 2017) with project teams are realized on BIM models. BIM also constitutes the technological foundation for the Obeya (Big Room) concept, where co-located project teams (integrated through relational contracts) manage and execute construction projects through direct, face-to-face interaction over BIM models, reducing delays in decision-making and problems in communication (Dave et al. 2015). On site communication platforms, together with mobile devices integrated with cloud-based BIM viewers, BIM-stations (Vestermo et al. 2016) or BIM-kiosks (Bråthen and Moum 2016) are employed for the teams in the field to pull design information from the building information model when they need it.

The growing demand for engineer-to-order (ETO) prefabricated systems in the construction industry aligns well with the Lean principles and ideals. From a broader perspective to off-site construction, BIM helps to establish better connections between off-site manufacturers and construction sites by allowing construction (and design) data to be machine processable and components to be manufactured without human intervention (Eastman and Sacks 2008). This results in greater precision in specifying material requirements and dimensions, which can reduce over-ordering and thus decrease construction site waste, particularly regarding complex structures (Abanda et al. 2017). Also, BIM can assist manufacturers and contractors by providing a 3D model of off-site element positions, connections and construction (Abanda et al. 2017).

The ability to integrate BIM data with advanced hardware such as 3D laser scanners to collect as-built data and establish a point cloud model for system coordination supports site operations with robotic total stations (Zhang et al. 2016). In this domain, BIM also helps in resolving complexities in logistics planning and control for site assembly of ETO prefabricated systems through 4D modeling (Bortolini et al. 2019). The wealth of information contained within or linked to BIM models enables the possibility for bridging the interfaces and continuous information flow between designers, suppliers, manufacturers and users for prefabricated systems (Ezcan et al. 2013).

6.3.3. BIM for Lean Facilities Management

A facility can be defined as «a collection of assets built, installed or established to serve the needs of an entity (people or an organisation)» (International Standards Organization 2017, p. 3 ~~page 3~~). Examples of assets can be infrastructure, real estate and utilities. Facility management (FM) is defined as «the effective management of place and space, integrating an organisation's support infrastructure to deliver services

to staff and customers at best value whilst enhancing overall organisational performance» (Royal Institute of Chartered Surveyors 2020, p. 7 ~~page~~). FM consists of several multidisciplinary activities and is essential to achieve success in any project and organisation (Noor and Pitt 2009)

Information management is recognised as the crux of effective FM and consists of delivering accurate, timely and relevant information (Terreno et al. 2019). In the conventional practice of FM, a significant amount of time is wasted and a great deal of extra work is carried out to search for the required and relevant information. Moreover, the generated information may not be used because the information was not created in time, relevant information may not be found among irrelevant information, or relevant information is ignored (Jylhä and Suvanto 2015). The use of BIM in FM can enable consistent and coordinated information exchange over a facility's lifecycle, from design to maintenance and operation.

In particular, BIM with its visualisation and analysis capabilities is conceived as an impetus to provide accurate information to FM systems in time and enhance other functions of FM (Becerik-Gerber et al. 2012). Such capabilities in BIM can aid FM by enabling localisation of facility components and indoor navigation (Volk et al. 2014). However, the adoption of BIM for FM has been slow compared to the adoption of BIM in design and construction (Talebi 2014a, Talebi 2014b). According to Volk et al. (2014), one of the major reasons behind such slow adoption is the difficulty to update and maintain information in BIM during the FM stage as stakeholders are not often willing to pay for this purpose. This challenge is originally traced to the deficient development of theory in FM (Edirisinghe et al. 2017).

The Transformation, Flow and Value (TFV) theory of production (Koskela 2000) has been used to explain the difficulties in implementing BIM in FM (Shou et al. 2014, Munir et al. 2019). From the TFV theory perspective, even though the focus of FM has shifted from cost minimisation in real estate operations to supporting end-customer requirements using BIM, the existing literature on BIM-enabled FM does not explain the customer value generation process or information flows between stakeholders (Munir et al. 2019). In other words, according to the existing literature, BIM-enabled FM is mainly focused on the "T" view (Jylhä and Junnila 2013). BIM is changing the operation of built assets (Love et al. 2014) by focusing on pointwise improvements (e.g. data visibility, data analytics, maintenance audit, service procurement) (Munir et al. 2019). Arguably, such a focus on "T" view is the cause of waste and value loss and does not provide a basis for managing the value creation challenges (Jylhä and Junnila 2013) or improving the flow of information (i.e. updating BIM during FM) (Lee and Akin 2009). A review of the literature reveals that some of the principles from Lean Construction are already adopted in FM but they

have not been widely implemented in this field yet to balance the Transformation, Flow and Value views. Streamlining processes is proven to be effective towards adopting Lean principles and facilitating the implementation of BIM in FM (Kasprzak and Dubler 2012).

Interoperability between BIM and FM (Love et al. 2015) and variability in information management (Bascoul et al. 2018) are significant challenges and result in unnecessary, excessive, irrelevant or defective information (Jylhä and Suvanto 2015). Building information models developed during design and construction does not contain a significant amount of required information for FM and also such information does not necessarily contribute to FM (Bonanomi 2016a) due to the lack of clear requirements for the adoption of BIM in FM (Edirisinghe et al. 2017). In other words, the utilisation of BIM from design to maintenance and operation is deficient (Kiviniemi and Codinhoto 2014).

Standardisation is proposed to resolve the barriers with interoperability and variability in information management. A number of standards, such as Industry Foundation Class (IFC) and Construction Operation Building Information Exchange (COBie), have been developed to support the concepts of interoperability and integration (Pärn et al. 2017). Moreover, Succar and Poirier (2020) suggest to use the concept of model-based deliverables for standardising and clarifying the required information for the adoption of BIM in FM.

A primary technique of the Lean Construction is «pull» (Ballard, 1999). Sacks et al. (2010b) discuss the potential contribution of BIM to enable «pull» technique to reduce variability in information. The pull technique (Womack et al., 1990) in the context of FM means that only such information should be produced upstream that the customer downstream needs to operate and maintain the facility (Succar 2009). The pull mechanism results in adequate, accurate and timely information (Ghosh et al. 2015). The existing practice of BIM-enabled FM still heavily relies on the push mechanism, which depends on forecasts to determine what information, when and how much should be generated (Becerik-Gerber et al. 2012). Ideally, the facility manager should enter the design stage early, influence the design and construction, and help produce a building information model that pulls the requirements of the customer (Azhar 2011), including those related to FM. In other words, early involvement of the facility manager leads to an understanding of what information should be modelled (Bonanomi 2016b) with the strong focus on the operation and maintenance (Kasprzak and Dubler 2012).

Continuous improvement (CI), which is at the heart of Lean (Womack et al., 1990), is essential to the success of any FM organisation (Beck et al. 2016). CI is an

approach by which: (a) small incremental improvement steps are taken to improve performance (Slack et al. 2010) and (b) waste in all processes of an organisation are identified, reduced and eliminated (Bessant et al. 2001). Standardisation and the pull technique are the foundation to continuous improvement (Gao et al. 2020). In particular, continuous improvement is essential in service provision due to the rising demand for quality FM services from customers (Smith 2010).

In conclusion, BIM is known as a solution to provide consistent and coordinated information exchange between stakeholders during the facility's lifecycle. However, the adoption of BIM for facilities management has been slow. Based on the TFV theory of production, it has been explained by the existing literature that BIM-enabled FM has been focused on the «T» view, which does not cover the customer value generation process or the flow of the information between stakeholders. It was further discussed that reduction of variability, standardisation and continuous improvement, which fall under the «F» category, as well as comprehensive requirements capture and requirements flowdown, which fall under the «V» category, seem essential to facilitate the implementation of BIM for Lean operation and facilities management.

6.4. Lean for BIM

Up to now, the focus has been on the support BIM can provide for the implementation of Lean. Here, the reverse relation is also considered: how Lean can support the implementation of BIM? This topic embraces two viewpoints: (1) how Lean can be applied in information system work (into which BIM partially falls) generally, and (2) how the Lean design and construction context supports the implementation and continuous improvement of BIM. The former viewpoint is related to the hardware and software viewpoints to BIM, whereas the latter deals with the design and construction processes into which BIM is embedded.

The use of Lean in IT work has attracted attention in the last 10 years, and practice-based guidelines have emerged (Plenert 2011, Bell and Orzen 2016, Williams and Duray 2017). These sources stress that Lean principles and tools apply to work on IT systems similarly to other contexts. At the most general level, the importance of value to the customer and waste elimination accentuate. Complete processes (where **IPDCA**T support is developed or maintained) should be addressed. The A3 problem solving method is recommended as a central approach in the design of information systems (for a thorough introduction of the A3 method, see (Sobek II and Smalley 20082011)). In turn, the Plan-Do-Check-Act (PDCA) cycle offers itself for evaluating designed solutions and for continuous improvement. Work on existing information systems tends to be reactive – solving emerging problems in the functioning of the systems. The Lean approach implies a proactive approach for realizing the target state.

The argument is that when BIM is implemented into a design and construction context where also Lean principles have been applied, the results will be better than otherwise (for initial evidence, see (Mahalingam, Yadav and Varaprasad 2015). Arguably, there is an analogy to Computer Integrated Manufacturing (CIM): « CIM acts as a magnifying glass. It makes the good system much better; it makes the poor system much worse » (Melnik and Narasimhan 1992, page p. 91). Such characteristics of the Lean Construction context as discipline, collaboration, experimentation, as well as continuous improvement are arguably paramount for facilitating both the initial and mature implementations of BIM. Discipline and collaboration are needed for the gradual build-up of correct and useful models; for this, the Last Planner System of production control has turned out to be an effective tool (Bhatla and Leite 2012, Mäki and Kerosuo 2020). Experimentation, realised through short cycles of PDCA, allows for exploring and trialling new possibilities of using the functionalities of a BIM. In turn, continuous improvement, likewise supported by the PDCA cycle, helps solving the various problems unavoidably emerging when new technology is implemented, and also facilitates the exchange of lessons learnt among projects.

6.5. Conclusions

As discussed in the previous sections, the large number of connections between BIM and Lean, which have been discovered in the last ten years, leads to one conclusion: construction projects, as well as companies involved in them, should simultaneously and synergistically implement both Lean and BIM. The situation is dynamic and evolutionary: the capabilities of BIM are constantly developing, and both understanding and practice of Lean are improving. This means that also the possibilities for synergistic interaction between Lean and BIM are deepening.

In view of this situation, the interaction between BIM and Lean continues to be a fertile topic for research. Up to now, the interest has mostly addressed how BIM can support Lean principles, and in explorative research, a multitude of related mechanisms have been found. It is now instrumental to also launch exploitative activities for codifying such existing knowledge into practical guidelines. Regarding how Lean principles can support BIM, more explorative research is still needed.

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