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INTEGRATION OF LEAN CONSTRUCTION AND BUILDING INFORMATION MODELING IN A LARGE CLIENT ORGANIZATION IN MASSACHUSETTS

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Abstract: Recently the construction industry has started to study and implement together Lean Construction (Lean) and Building Information Modeling (BIM) to better manage projects. Previous research findings suggest that several changes in the work practice and business processes are needed to fully take advantage of BIM and Lean. Even if the client's role is very important to drive the entire process, the literature lacks of comprehensive examples of client's implementation. The paper shows how a large client organization is integrating Lean and BIM in real projects and how it is possible to measure it thanks to a Maturity Matrix. The research is based on a case study involving both active participation and interviews. The main results indicate that a) internal change is needed in the client organization; b) clients need to drive the process in order to maximise benefits; c) BIM does not fit in the traditional procurement process; and d) existing contracts need to be modified to support BIM and Lean. Research findings are useful for large client organizations that would like to integrate BIM and Lean in their operational strategy as well as for researchers. Further studies could be done to compare the work of different client organizations.

Keywords: Lean Construction, Lean, Building Information Modeling, BIM, Large Client Organisation.

1 INTRODUCTION

Building Information Modeling (BIM) and Lean Construction are considered two of the most relevant drivers in the construction industry (Sacks et al. 2010). However, the lack of a unique definition of BIM and Lean often generates confusion and misunderstanding in the industry as well as in academia (Succar 2009; Modig and Ahlstrom 2015).

As a term, BIM has grown tremendously over the years and is now the current expression of digital innovation across the construction industry (Succar 2017). BIM is a set of technology, processes or policies, enabling multiple stakeholders to collaboratively design, construct and operate a facility in virtual space (Succar 2017; Succar 2009).

Lean can be seen as an operational strategy that priorities flow efficiency over resource efficiency (Modig and Ahlstrom 2015). The car dealer Toyota was the first to adopt it using the so called "Toyota Production System" (TPS) (Koskela 1992; Modig and Ahlstrom 2015).

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Lean Construction is the application of this approach to the construction industry (Koskela 1992; Koskela 2000). In this research the term 'Lean' stands for 'Lean Construction'.

Initially, Building Information Modeling and Lean Construction have been separately developed (Sacks et al. 2010; Dave et al. 2013; Dave 2013). Recently, they have been analysed together and several constructive interactions have been identified (Sacks et al. 2010; Eastman et al. 2011; Dave et al. 2013; Dave 2013). Alarcón et al. (2013) have provided a literature review on this topic, even if the difference between BIM and Virtual Design and Construction (VDC) is not totally clear and the two terms are used as synonyms.

When implementing BIM and Lean, several changes in the work practice and business processes are needed (Succar 2009; Eastman et al. 2011; Dave et al. 2013; Dave 2013). While the client's role is very important to drive the entire process (Eastman et al. 2011; Ciribini et al. 2015), the literature lacks of comprehensive examples of client's integration of BIM and Lean and ways to measure and compare different organizations.

2 Research Aim and Methodology

The research aims to identify the current maturity of BIM and Lean integration in a large client organization using the Maturity Matrix developed by Bilal Succar (2010). The study is a preliminary research for further and more depth research to compare the situation of different client organizations working on BIM and Lean.

The work is a case study on a large USA client organization, the Massachusetts Port Authority (Massport), an independent entity governed by a board of directors appointed by the State's governor. Massport owns and operates both horizontal and vertical assets such as Boston Logan International Airport, and Worcester Regional Airport.

The research project started in October 2015 and lasted for six months. During this period of time, it was possible to daily work with the Design Technologies Integration Group (DTIG) that is responsible for the BIM and Lean implementation within Massport. In order to complete the Maturity Matrix, it is essential to have sufficient insight into the organisation' systems and culture and to conduct the assessment as a group activity involving individuals representing different roles, disciplines and seniority levels (BIMe Initiative 2016). For this reason, four different projects at different stages (conceptual, design, construction and operation and maintenance) have been analysed to better understand Massport's operational strategy. The work is supported by the study of client's documents, direct observation during internal and external meetings with consultants and semi-structured interviews with client's projects managers, cost estimator, assistant director and the DTIG manager.

One of the authors, Dr. Luciana Burdi, is adjunct assistant professor at Worcester Polytechnic Institute and Deputy Director of the Capital Programs and Environmental Affairs Department at Massport. The authors would like to state that, even if there could be a potential conflict of interest, the study has been conducted independently and it is an accurate representation of the trial results.

3 The Integration of Building Information Modeling and Lean Construction at Massport

3.1 BIM and Lean Integration: start with the end in mind

Several large client organizations, such as government departments (GSA 2015; U.S. Department of Veterans Affairs 2010; MoJ 2016), State owned companies (COBIM 2012;

Statsbygg 2013) and States (State of Wisconsin 2012) are implementing BIM-based strategies supported by BIM guides, protocols and mandates (Kassem et al. 2015). Recently, the NIBS (2017) published the National BIM Guide for Owners and also the European Commission is working on a BIM Handbook for client organizations. However, Massport is the only client that has implemented a multi-year strategy based on BIM and Lean.

Lean and BIM are equally essential enablers in Massport's strategy for innovate project delivery and maintain assets. The BIM and Lean integration is summarised in Figure 1. Every project starts with the identification of the Conditions of Satisfaction (CoS), explicit client's requirements to be satisfied by suppliers. CoS are similar to Employer Information Requirements (EIR) defined in PAS 1192:2 (BSI 2013). The CoS definition forces suppliers in providing the exact required information avoiding lack or overflow of data.

Later, the BIM Execution Plan (BIMxP) is developed together with stakeholders in order to define BIM Uses (such as clash avoidance) and Lean tools (such as Pull Planning and Last Planner System®) that support CoS execution. During client's needs definition, any constraint against CoS accomplishment is identified in the BIMxP and removed or mitigated thanks to BIM Uses (such as Laser Scanning or Modeling of Existing Conditions) and Lean tools. The main Lean tools and principles are described in the Guideline (Massport 2015a). Each CoS can be split in several actions with different levels of priority and responsibilities. It is important to remark that each CoS can be satisfied by several BIM Uses and there is not a 1:1 relation.

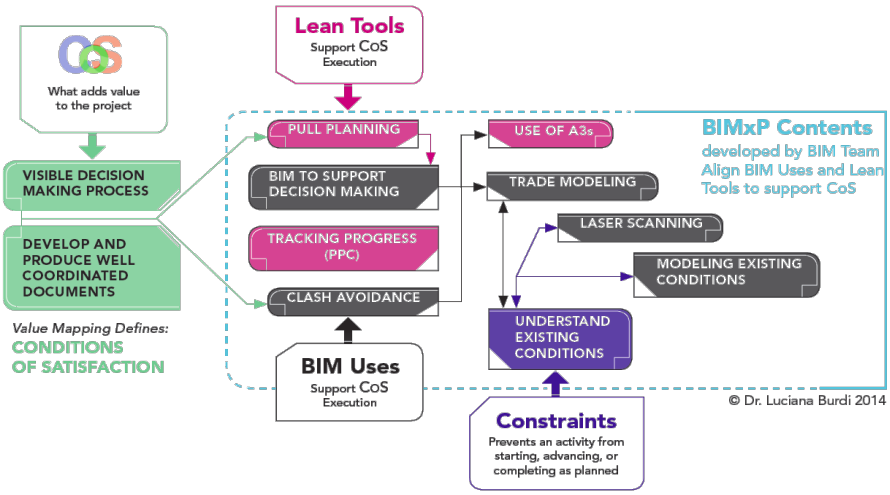

Figure 1: BIM and Lean Integration (Massport 2015a)

3.2 Introduction to BIM and Lean Maturity Matrix

In order to better evaluate Massport's BIM and Lean implementation, the BIM Maturity Matrix created by Succar (2010) has been used. Originally, the Matrix (Succar 2010) has not been developed to assess BIM and Lean together, but the research shows that is it a valid support because it takes into account three main BIM fields, Technology, Process and Policy and their sub categories (Succar 2009) where Lean can contribute.

Another Lean and BIM maturity model, based on NBIMS work (2007), has been created (Dave et al. 2013). Its limitations have been discussed by Succar (2010). Similar considerations can be done on the new version (Dave et al. 2013) because the 10 maturity levels are not well explained and the 11 areas of interest are not clear and they mix different aspects such as Lean tools (e.g. Target Value Design and co-location of teams),

BIM Uses (e.g. BIM for production and Accurate as-built model) and policy aspects (e.g. relational contracting). Finally, the matrix is project-based and it does not allow organizational assessment.

3.3 Technology: Software, Hardware and Network

For Massport the technology improvement is essential to support BIM and Lean implementation. For this reason, investment in equipment is tightly integrated with financial plans, business strategies and performance objectives. The DTIG team constantly evaluate new versions and solutions available in the market to support defined BIM uses. Data usage, storage and exchanges are monitored and controlled using a specific platform where only authorized people can access. Due to technology limitations, full interoperability data exchange cannot be performed and BIM and Lean software are usually used to manage singular projects.

3.4 Process

3.4.1 Resources, Activities & Workflows and Products & Services

Based on the Lean principle of continuous improvement, Massport's staff is periodically asked to fill Plus and Delta template on events and overall working experience. Moreover, documents to support BIM and Lean knowledge are collected in a digital platform.

BIM roles such as the DITG Manager and competency targets are imbedded within the organization and traditional teams are replaced by BIM and Lean oriented ones thanks to specific training.

The BIMxP defines the Level of Development (LOD) during different project milestones in accordance with specific BIM Uses. This approach is innovative because it avoids information waste, promoting detailed specifications thanks to a Lean approach. However, in the Guideline (Massport 2015a), LOD is associated to both the entire Building Information Model and Model Elements, in contrast with the reference document, the LOD Specification (BIMForum 2015), where LOD is associated only to Model Elements.

3.4.2 Leadership & Management

Massport set a multi-year strategy (2014-2020) for implementing BIM and Lean (Massport 2015c) because organizational, processes and technological changes are needed and they require time to be fully integrated using a gradual approach. Lean Benefit Realization Management (LBRM) (Smith 2013) has been used to develop the strategy thanks to stakeholders engagement.

The roadmap (Massport 2015c) is divided in three sequential phases: 1) Normalise (2 years and half); 2) Optimize (2 years); and 3) Institutionalize (1 years half).

During the first phase the DTIG is established in order to coordinate the BIM and Lean implementation and the entire staff is trained. It is important to establish an internal team and not rely only on external consultants because the client needs to drive the entire process.

Different standards are defined, such as the BIM Guideline (Massport 2015a), an Appendix on BIM Uses (Massport 2015b) and the BIM Execution Plan (BIMxP) template, to clarify Massport's needs. Several pilot projects are carried out to gradually implement the new strategy and support the definition of requirements.

In the second phase, the BIM-based process is fully integrated with the Geographical Information System (GIS) and Facility Management systems and procedure. The last phase is based on integrated real-time information exchanges and monitoring. During the research project, Massport was completing the first phase.

3.5 Policy

3.5.1 Preparatory

Training on BIM and Lean is integrated into organisational strategies and performance targets as stated in the first part of Massport's strategy. All staff has a basic knowledge on BIM and Lean principles and specific training programs are set based on different roles and respective competency objectives. For example, project managers are trained to open, view and mark up BIM Models as well as to take part into Pull Planning sessions.

3.5.2 Regulatory

Massport realized that the manuals were based upon traditional processes in conflict with Lean and BIM. For this reason, after a deep analysis on intrenal strandards and Facility Management (FM) data requirements, the *BIM Guidelines for Vertical and Horizontal Construction* (Massport 2015a) has been published. A glossary of terms and acronyms has been included to avoid misunderstanding, improve team communication and allow stakeholders to better understand client's needs. The guideline contains a 'BIM decision Matrix' to define requirements based on project types and Estimated Construction Cost (ECC). A BIM-based approach is required for all projects with ECC over 1M $; for project below 1M$, instead, a traditional approach is accepted. A separate Annex (Massport 2015b) on BIM Uses is available with a list of well-defined 51 BIM Uses that has been used as a reference for the Modular Requirements Clarification Language on BIM Uses developed by Succar et al. (2016).

3.5.3 Contractual

In order to successfully use BIM and Lean, procurement methods and contracts must be analysed. For this reason, Massport reviewed existing contracts and laws. Massport delivers projects under the Commonwealth of Massachusetts General Law using several procurement methods (Chapter 30, 149 and 149A). The allowed procurement methods are Design-Bid-Build (DBB), Design-Build (DB) and Construction Manager at Risk (CM@Risk) (Commonwealth of Massachusetts; Massport 2015a). Collaborative procurement methods, such as Integrated Project Delivery (IPD) (AIA 2007), are more suitable for BIM-Based and Lean processes (Sacks et al. 2009; Eastman et al. 2011). However, IPD cannot be used because some principles, such us the use of multi-party contracts and profit sharing, are in contrast with the General Law (Massport 2015a).

Massport believes that the procurement method influences the success of the process and BIM does not fit in the traditional procurement method (DBB). For this reason, Massport favors DB and CM@Risk, where there is an early contractor involvement. Based on a Lean approach, the client organization promotes the early involvement of key players because they can bring better value to the project. In this way, it is possible to avoid possible issues and improve the decision-making process as demonstrate by literature (Eastman et al. 2011; Bolpagni 2013). The client organization noticed that existing contracts do not manage risk for BIM-based projects. Thus, Massport worked with a legal expert to re-write contract documents. Two BIM Exhibits, for CM@Risk and DBB, have been created. The BIM Exhibits state that Building Information Models are the primary contract documents and drawings must be produced from them. Other sections of the exhibits define the responsibility for model development, ownership and management.

3.6 Results of Massport's BIM and Lean Maturity Matrix

Based on the previous discussion, Table 1 illustrates results of BIM and Lean integration at Massport using the last version of the Maturity Matrix (BIMe Initiative 2016).

Table 1: Results of Massport's Maturity Matrix on BIM and Lean integration

BIM Maturity Matrix - Assessment at Granularity Level 1		a	b	c	d	e
Technology	Software			x		
	Hardware				x	
	Network				x	
Process	Resources			x		
	Activities & Workflow				x	
	Products & Services				x	
	Leadership & Management					x
Policy	Preparatory				x	
	Regulatory			x		
	Contractual				x	
Stage	Modeling-Based Collaboration [2]				x	
Scale	Organization [9]				x	

4 DISCUSSION

The definition of clear client's needs (CoS) is a key part of the overall process and the BIMxP should be structured to solve and manage CoS thanks to BIM Uses and Lean. Also in the UK, client's requirements (EIR) play a relevant role (BSI 2013), but they have not be fully integrated in the workflow. The NBS BIM Toolkit (NBS 2017) has tried to fill this gap, but it is quite rigid and EIR are not associated with BIM Uses and Lean.

Even if Lean is an operation strategy that could be a strategic choice for all organization to improve flow and resource efficiency, how it is realized depends on the context (Modig and Ahlstrom 2015). An optimal solution for an organization will not necessarily be applicable in another organization (Modig and Ahlstrom 2015). The environment influences the way a client organization procures projects and set requirements. For example, the Commonwealth of Massachusetts does not allow collaborative delivery methods, such as IPD (AIA 2007), that can improve the overall process (Eastman et al. 2011; Dave et al. 2013). In addition, Massport is allowed to include explicit references to commercial software in bids. This approach could not be applicable by other clients, especially in Europe. The European Directive on public procurement (European Parliament 2014), indeed, states that technical specifications shall not refer to a specific make, source or a particular process that favour or eliminate certain undertakings or certain products.

The BIM and Lean integration is part of a long-term strategy and results presented in this paper represent only the first part of a longer journey. For these reasons, results reflect the current situation and other assessments should be repeated in the future.

Each client organization should first analyse their own business strategy and understand what value they would like to create and how to complete it (Modig and Ahlstrom 2015).

5 Conclusions and Future Work

By today, Massport is one of the few client organization working on a multi-year BIM and Lean integration strategy. In order to integrate BIM and Lean in real projects, Massport discovered that it is essential to start with the end in mind defining clear clients requirements (CoS/EIR). In addition, internal change is needed in the client organization and a multi-year strategy must be implemented. Owners need to drive the process in order to maximise benefits and an internal team is needed. In addition, BIM does not fit in the traditional procurement process and existing contracts must be modified.

The Maturity Matrix developed by BIMe Initiative (2016) has been found a valuable support to evaluate BIM and Lean implementation in a client organization.

Research findings can be used as a reference for large client organizations that would like to integrate BIM and Lean in their operational strategy as well as for researchers.

Further studies could be done during the second and third phases of the roadmap in order to follow the process evolution. Finally, it would be useful to further investigate the BIM and Lean Maturity Matrix using assessment at Granularity Level 2 (Succar 2010) and to compare the work of different client organizations.

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