Development of a Maturity Framework for Lean Construction

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ABSTRACT
The issue of time and cost consuming activities such as rework, conflicts, and overlapping has received considerable critical attention by construction industry. Using benefits of lean thinking has a significant impact on the construction processes in order to achieve perfection at the whole building life cycle. The Lean construction methodology is an increasingly important area for the construction industry due to its effect on cost and value. However, the Lean construction methodology is not implemented by the construction industry professionals due to the complexity of methodology, change requirements in company organization, lack of guides for the process, etc. This study provides a comprehensive framework that focuses on defining processes which enables lean methodology implementation by demonstrating the whole building lifecycle. It will provide a broad explanation for the characteristics of each level and logical relationships between concepts. The levels of the maturity framework such as; Level 0 Traditional Construction, Level 1 Lean Construction, Level 2 Lean Construction, and Value Engineering, Level 3 Lean Construction, value engineering, and building information modeling, and Level 4 Lean Construction, value engineering, building information modeling, and data analytics were identified with a comprehensive literature review and comprehended. The findings of the study will be helpful to increase comprehensibility and implementation of lean concept.

KEYWORDS
Big Data, BIM, Lean Construction, Value Engineering

INTRODUCTION
The construction industry suffers from chronic problems such as cost overruns, delays, rework, coordination, productivity, quality, lack of innovation. (Mahalingam, Yadav & Varaprasad, 2015; Khaba, & Bhar, 2016). Due to globalization and fierce competition, leading construction companies are seeking new methods to offer more value to their customers (Ekanayake, & Sandanayake, 2017). Also, decrease in productivity in construction industry pushes practitioners to find new methods offering value (Aziz, & Hafez, 2013).

The lean practice was first implemented by Toyota Production Systems (Koskela, 1992). After the success rate of lean practices identified in terms of productivity, quality, etc., in the manufacturing
industry, the first implementation of Lean Construction (LC) practices in the construction industry was performed by Koskela (1992). The author adopted lean principles that were implemented in manufacturing industry into the construction industry by eliminating some incompatible principles since construction industry differentiates from other industries due to production structure, complexity, on-site production, unique production, and features of the end product (Salem et al., 2006). LC, as a promising concept to refine operational and organizational deficiencies or wastes in construction projects, is one of these methods.

The reason for needs for LC idea is to change construction industry practices in order to obtain more contemporary industry practices, more value, and technology dissemination into industry-wide (Sarhan et al., 2018; Alves, Milberg, & Walsh, 2012). In the literature, lots of studies stated that LC implemented project management enables a reduction in project completion time, increase in project performance, and increase in productivity (Sarhan et al., 2018). To increase implementation level of LC in the industry, different concepts, analytics and tools are used with LC by the researcher and practitioners.

In the literature, BIM usage in the LC concept has been intensively investigated. In this context, the first study which mentions a synergy between BIM and LC was performed by Sacks, Koskela, Dave, and Owen (2010). The authors stated that this synergy helps the projects to get more detailed waste elimination process. In another words, these two concepts complement each other by increasing their maturity levels (Sacks et al., 2010). Oskouie, Gerber, Alves, and Becerik-Gerber (2012) acknowledged that BIM and LC integration are promising in terms of value increase and quality enhancements. Also, Mahalingham et al. (2015) stated that LC concept facilitates adoption of technological advancements into construction industry, such as Building Information Modeling (BIM). From the value point of view, BIM system helps to protect design and construction information for operation phase. According to Kelly et al. (2013), construction industry spends millions of dollars and more than thousands of man-hours for getting this information, and it causes wastage in terms of cost and labor.

Another strategy that is derived from the competition between the companies is integration of value engineering and LC concept (Ekanayake & Sandanayake, 2017). As known, LC concept focused on minimizing wastes and increasing value for the customers. When performing this, the primary focus is not cost reduction. LC aims to eliminate cost waster between the processes. However, foci point of value engineering is a reduction in cost. For this reason, value engineering is a complementary method for lean construction. For example, Kelly, Serginson, Lockley, Dawood, and Kassem (2013) states that “The operational phase of a building is the main contributor to the building lifecycle cost. Estimates show that the lifecycle cost is five to seven times higher than the initial investment costs.” According to this argument, estimating the lifecycle cost is important to optimize cost in terms of value engineering. BIM data capturing during the lifecycle makes broader vision for estimating cost of the operation and maintenance activities and leads to improve efficiencies of facility management functions (Kelly et al., 2013).

Also, historical records about wastes are important to eliminate unnecessary activities. To retrieve useful and accurate information from data sets, practitioners need faster data analysis tools. This can be possible with data warehouses or Big Data Analytics. In the literature, the first study about Big Data Analytics to eliminate wastes in the construction projects was performed by Bilal, Oyedele, Qadir, Munir, Ajayi, Akinade, and Pasha (2016).

However, there are minuses for LC, as well as its cons. Even though lean construction concepts have attracted attention for over 20 years, the effort for LC needs more clarification and approval from all participants to disseminate LC practices to industry-wide. Also, although LC practices in construction industry present an opportunity for construction companies, the adoption rate of LC is very low (Alves et al., 2012). There are several reasons that cause a low adoption rate for LC. For example, changing requirements in organizational behavior, organizational culture, approach to human resources, awareness and knowledge about LC implementations, LC tools, training requirements, procurement types, conventional management practices, lack of technical skills, communication
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