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Driving lean and green project outcomes using BIM: A qualitative comparative analysis

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Abstract

Driven by a plethora of external and internal influences, the construction industry has independently embraced lean principles and green initiatives. Prima facie significant synergies have been reported between these two paradigms. It is foreseen that when tapped and adopted in unison, these paradigms may yield additional benefits for the construction projects. This synergy is investigated in this research. Further this study identifies and proposes Building Information Modelling (BIM) as an enabler for gaining lean and green project outcomes. The study uses crisp set qualitative comparative analysis (csQCA) method for exploring the causal combinations of different BIM capabilities and asserts that causal combinations of four BIM capabilities: MEP system modelling, energy and environment analysis, constructability analysis and structural analysis, when implemented on construction projects can lead to lean and green outcomes. With the help of sixteen cases it is shown that adoption of BIM leads to improved project outcomes especially ones targeting lean and green aspects.

Keywords: Building Information Modelling (BIM); Lean; Green; Crisp set qualitative comparative analysis (csQCA); BIM capabilities, project outcomes

1. Introduction and background

Today most of the construction work is carried out in the form of complex projects and hence, good project management practices are considered highly important (Maylor et al., 2008). Construction projects need to be expertly managed in terms of not only budgets and schedules, but also the quality and environmental impacts (Formoso et al., 2002; Howell and Ballard, 1998), as the construction industry is facing urgent pressure with regard to profitability, environmental management and sustainability (Planning Commission Government of India, 2013; Wang, 2014). Given the current conditions and the overall status of the sector, it is clear that business as usual is not tenable and hence, it is important that the industry embraces an agenda for change and continuous improvement. Inherent challenges such as excessive material and process waste, over reliance on resources, energy usage and carbon footprint are being addressed globally in order

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to meet the needs of the economy (WCED, 1987; UNEP, 2010). There is an urgent need to address the environmental challenges comprising of depletion and deterioration of natural resources to accelerate achievement of sustainable development goals (MoEF, 2011).

The built environment sector in particular is a major contributor of carbon emissions leading to climate change (Allu and Ebohon, 2015). For example, the construction sector in India accounts for nearly 24% of the total direct and indirect emissions of CO_2, and is the highest consumer of natural resources and energy in comparison to other sectors (Parikh et al., 2009). Energy efficiency and use of renewable energy; resource conservation; recycling; and minimization of waste are of utmost importance. The design, construction, operation and end-of-life processes embraced by the sector must continue to evolve for becoming highly efficient and sustainable. Not only is it important to deliver assets that are resource efficient and sustainable (through green principles) but also the delivery process must itself become highly efficient (through lean principles).

To deliver assets that are resource efficient and sustainable, the industry has embraced green principles. These principles, mostly used in the design stage of a project, allow project team members to create assets that are environmentally responsible and resource-efficient throughout the lifecycle of the asset. With low additional building cost, the adoption of passive design strategies and re-usable, recycled material into new construction helps to reduce the environmental impacts of building activities significantly (Chen et al., 2015; Coelho and de Brito, 2012). Certified green buildings decrease operating costs by 8 to 9 percent (Braham, 2007) with the productivity and health cost savings representing 70 percent of all savings in whole life cycle costs (Kats, 2003).

In the built environment sector a separate school of thought has emerged that focusses on eradicating the waste and inefficiencies that exist in the design and construction processes themselves. Encapsulated as the lean paradigm in construction, it strives to overcome the current challenges and inefficiencies in the project delivery process that are well understood and documented (Assaf and Al-Hejji, 2006; Ballard, 2000; KPMG, 2013; Odeh and Battaineh, 2002). The traditional project delivery system consisting of multiple tasks assigned to different agencies involved in a project, increases the likelihood of waste generation. This has also led to many problems such as cost overruns, schedule delays, poor quality, inadequate safety, disputes and litigation. With the lean construction movement, a new project delivery system called as Lean Project Delivery System (LPDS) was introduced as a method to reduce waste, to improve productivity and to maximize efficiency through all project phases including planning, design and construction (Ballard and Zabelle, 2000).

The industry has progressed on the two paradigms: lean principles and green initiatives independently without realizing the inter-linkages between the two agendas. This research investigated how green principles and lean principles are interlinked, determine benefits to projects when they are considered in a conjoint fashion and how they could be integrated into a single model. It is envisioned by the authors that combining lean and green methods is not only possible, but this also provides avenues to gain superior results on construction projects.

2. Problem statement

Lean is a production management-based approach to project delivery (Howell and Ballard, 1999) which emphasizes on changing the traditional project delivery and work to minimize waste and to achieve maximum value. Similarly, green practices focus on energy efficiency and conservation of natural resources, thus encouraging the profound changes in concepts of design and management processes to reduce the overall environmental impact of buildings (Chau et al., 2010). The existing literature claims lean and green as compatible initiatives with their shared aim of waste identification, waste reduction, resource optimization and process improvement (Al-aomar and Weriakat, 2012; Bergmiller and Mccright, 2009; EPA, 2007). At the same time it is also reported that combined benefits of lean and green implementation can help to overcome the existing challenges faced by the construction industry. While the lean implementation leads to enhanced sustainability by reporting green benefits of shortened lead times, improved quality and reduced material waste (Luo et al., 2005); and reduced carbon emission and improved value chain (Peng and Pheng, 2011), the application of green principles in construction industry on the other hand, help to improve the cooperation and coordination amongst all parties involved in a project (Shen et al., 2007); cost saving on projects (Saggin et al., 2015); and minimization of waste throughout the lifecycle of construction projects (Yeheyis et al., 2013). Overall, although a fairly robust body of literature exists on the synergies and combined benefits of lean and green, there is still a gap in practice, with construction industry embracing both the initiatives separately (Ahuja et al., 2014; Bae and Kim, 2008; Sawhney and Ahuja, 2015). Additionally, limited research has been done to look at mechanisms that allow both, lean and green improvements on projects simultaneously.

3. BIM as a mechanism to achieve lean and green benefits

A study by Spence and Mulligan (1995) stated that nations must proceed towards sustainable development by embracing new technologies which are less resource-intensive and less environmentally damaging. Advanced information and communication technologies, and in particular Building Information Modelling (BIM) is playing a crucial role facilitating the development of green buildings (Zuo and Zhao, 2014). With a variety of software systems, BIM is transforming the way AEC projects are designed, engineered, built and managed (Autodesk,

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