BIM BASED CONCEPTUAL FRAMEWORK FOR LEAN AND GREEN INTEGRATION

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ABSTRACT

Lean and green philosophies have more or less remained separate and parallel initiatives within the construction sector. Intuitively there seems to be significant overlap between the two philosophies. As these have separately matured, there is now a need to synthesize the two parallel streams into one to garner more benefits for the industry. Efforts to demonstrate the overlap between lean and green concepts is available in literature. However, an integration framework has not been developed or reported. As such this paper, which is part of an on-going research, identifies operational and tactical connections of lean and green philosophies, with an aim to provide a conceptual integration framework. The authors envision that Building Information Modeling (BIM), a friend of both lean and green philosophies can provide the needed linkage between the two. With BIM as the common tool that acts as a catalyst, a conceptual framework for lean and green integration is developed. This framework is tested using three case studies and findings reported in the paper. Preliminary findings show that projects that use BIM can more easily integrate lean and green and add value.

KEYWORDS

Building Information Modeling (BIM), lean, green, sustainability

INTRODUCTION

The Indian construction contributing to roughly 10% of the GDP stands as an important pillar of the Indian economy (Govt. of India, 2013). In the past, research shows that lean philosophy and its methods in construction help overcome the uncertainty and complexity of the construction industry, thus making it more efficient. Waste is everywhere in construction and reduction of this waste will greatly affect process efficiency in construction (Soward, 2008). Though the lean theory and tools have found their way in construction industry, there is a lack of research on quantitative data. (Koskela, Owen, & Dave, 2010) states that waste in construction is due to rework along with non-value adding activities such as waiting, moving, inspecting, and missing information etc. According to (Josephson & Lasse

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Saukkoriipi, 2005) , a relatively large part of a workers time is spent on material handling, preparation, waiting, rework and motion that add no value. By reducing waste and increasing flow it is possible to achieve better quality, lower cost and shorter delivery time (Liker, 2004).

On a parallel note, green design and philosophy has separately matured and helped to maximize the reuse, recycling, and utilization of renewable resources(Arif, Bendi, Toma-Sabbagh, & Sutrisna, 2012; Arif, Egbu, Haleem, Kulonda, & Khalfan, 2009). Sustainable construction aims to adopt high performance green building delivery system which seeks to ensure that the project is designed, built and handed over for operation in a cost- effective manner. It is seen that several resources such as ground cover, forests, water, and energy are depleted to give way to buildings. Several voluntary building rating systems such as LEED, BREEAM, have been instrumental in raising awareness and popularizing green design. A similar kind of national green rating system used in India is Green Rating Integrated Habitat Assessment (GRIHA), which is formulated, keeping in view the Indian climatic conditions and is suitable for all kinds of building in different climatic zones of the country (MNRE, 2010).

At the same time there have been efforts to demonstrate the overlap between lean and green concepts which is available in literature (Hyatt & Ap, 2011; Peng & Pheng, 2011; Rosenbaum, Toledo, & Gonzalez, 2012). This paper tries to establish and capitalize the synergies between lean and green with the help of BIM. BIM is identified as the enabler to establish a conceptual integration framework between lean and green based on the GRIHA Evaluation procedures. The adoption of BIM is a major evolution in the ways in which information about a construction project is generated, shared and managed.

RESEARCH METHODOLOGY

The study is based on extensive literature review (Bae & Kim, 2007; Bergmiller, Mccright, & Florida, 2009; Valente, 2013), conceptualization of a BIM based framework, solicitation of input from industry experts on the developed framework, revision of the framework based on input received and testing the framework on three case study projects.. The research questions that underpin this study are:

- What are the synergies between lean and green?
- Can BIM provide a linkage between lean and green?

To answer these questions, this research consisted of the following tasks:

1. Problem Formulation: A literature review on the construction industry and the field of lean and green was conducted in order to acquire basic knowledge. This was done in order to structure, shape, and define the problem area (Gerber, Becerik-gerber, & Kunz, 2010; Lapinski, Horman, & Riley, 2006; Parrish, 2013) and research question.

2. Literature Review: Literature found on BIM as lean and BIM as green, lean and green interconnects was studied and amalgamated. The key concepts within the fields of lean, green, construction, BIM and other relevant topics were covered in literature review.

3. Development of Framework: The studies and findings from the literature review and observations were combined to develop a BIM based conceptual framework for lean and green integration. Using GRIHA framework, an attempt is made to see how BIM can combine lean and green measures i.e. can we measure both lean and green improvements on a project using this framework. Using the GRIHA evaluation procedure an evaluation framework on BIM was drafted to serve as a prototype.

4. Validation: The framework was discussed with the construction industry professionals by conducting semi structured interviews in order to get their perspective on it and find improvement areas. This framework was tested and validated through documentation in three case study projects.

BIM AS AN ENABLER FOR LEAN AND GREEN INTEGRATION

Lean construction aims to reduce waste, optimize resources and add value to the customer through continuous process improvement. Green construction aims to achieve reductions in energy consumption and waste generation through the efficient use of resources. (Gerber et al., 2010) provides insights into how BIM can facilitate lean measures through design to construction to occupancy, operations and maintenance. Sacks et al (2010) have explored the various positive interactions between BIM and Lean. The most significant synergy identified is reduction in variation with use of BIM that helps to reduce the waste due to rework. BIM allows visualization of form at design stage of the project allowing exploration of design alternatives and helps in identification of clashes which finally results in design and construction optimisation. BIM focusses on modelling and tracking schedules that helps to reduce cycle times. As such, several case studies reveal that BIM has facilitated both lean and green implementations.

Figure 1 as derived from the literature study, depicts how BIM acts as a catalyst to develop synergies between lean and green. Several BIM applications such as modeling, clash detection, quantity take-off, simulation and record model have been identified which effectively contribute to sustainability by reduction of waste, cost efficiency and increased efficacy of the construction process.

Figure 1: BIM acts as a catalyst to develop synergies between Lean and Green

The semi-structured interviews conducted during the study revealed that adoption of BIM in a project ensures leaner and greener outcomes. Figure 2 and Figure 3 elaborate upon the intricacy and advantages of using BIM in various phases of construction. Benefits of BIM at different phases of project are as follows:

- In the design stage, the 3D model generated by BIM can be used to visualize the design at any stage and the ability to make alterations and modifications rapidly, enhances sustainability. BIM helps in production of zero defect design as it allows collaboration of multiple design disciplines and reduces design errors. It essentially makes the design and the design process lean and green.

- 4D modelling tool helps in better understanding of project milestones. Generation of construction schedules results in effective planning of the project. With the help of quantity take-off, accurate quantities can be generated at any stage of the project with much ease. Implementation of technologies such as JIT results in optimized material and resource solutions thus reducing the cost and allow better collaboration at the site thereby promoting lean principle. The synergies between BIM and green are evident by the use BIM energy analysis tools that allow evaluation of energy use to improve building quality
- During the post construction operations and maintenance phase, information about installed materials and maintenance can be linked to the object in building model. This provides an appropriate source of information about the as-built spaces and systems which further contributes to improved facility management systems
- The vast advantages of BIM include reduced time and cost for sustainable design and construction, reduced cost for energy use, improved building performance and reduced construction cost and time

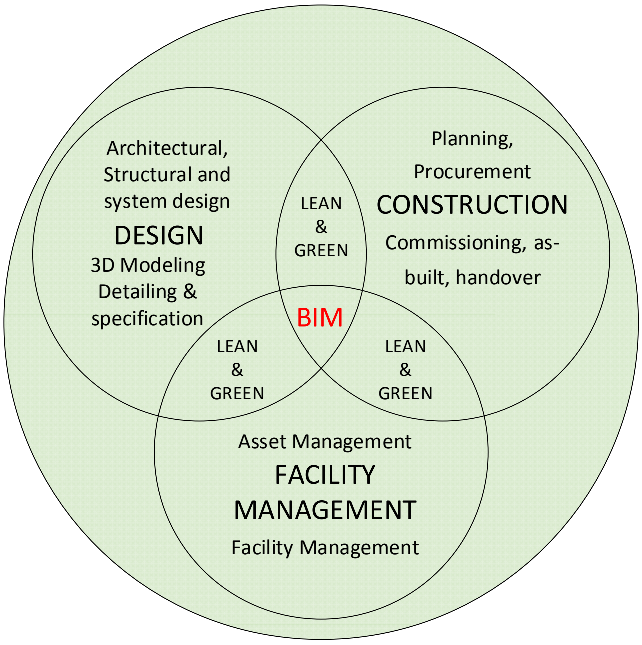

Figure 2: Role of BIM in Lean and Green

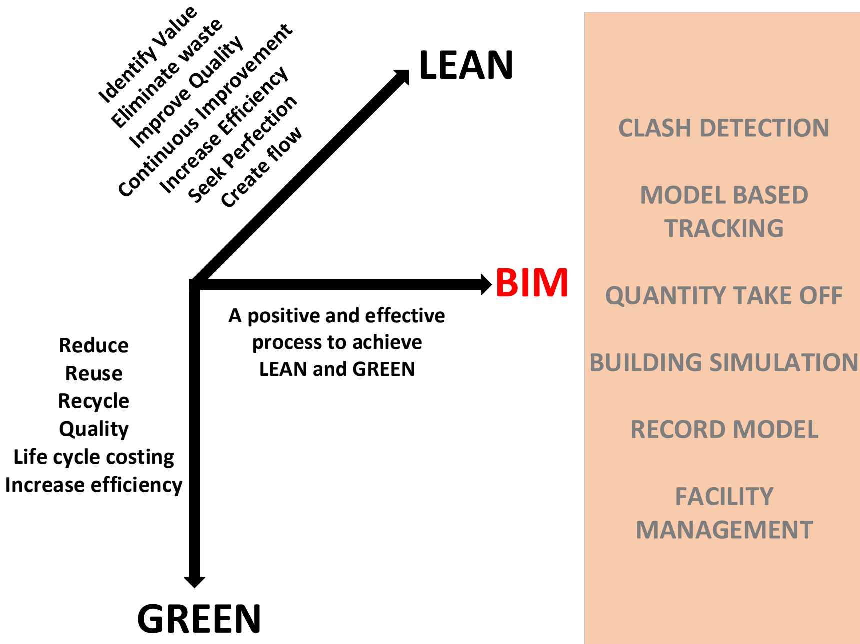

Figure 3: Interacting dimensions of Lean, Green and BIM

In this paper, 8 lean principles and 15 selected GRIHA criteria as shown in Figure 4 are identified to establish the link between lean and green. The selected GRIHA criteria include points to preserve landscape, inclusion of existing site features, safety facilities, building design and energy performance optimisation, utilisation of fly ash and low energy materials, adopting efficient technology and waste reduction. BIM contributes to effective implementation of various lean principles identified as customer value, create flow, seek perfection, and establish pull, standardisation and continuous improvement. Figure 4 shows BIM score card which illustrates that a number of GRIHA criteria can be supported by BIM to increase the design and construction efficiency. GRIHA is a guiding and performance- oriented system where points are earned for meeting the design and performance intent of the criteria compiled in GRIHA Manual (2013). A total of 34 criteria are listed in Figure 5 which are classified as mandatory and non- mandatory respectively.

Subsequently, an evaluation framework was developed to measure BIM and lean, green interconnects as shown in Figure 6. Different lean and green principles were analysed and accordingly distributed along various BIM phases - design, construction and facility management. This framework can be used as an effective BIM based measuring tool for quantifying lean and green measure adopted on a project.

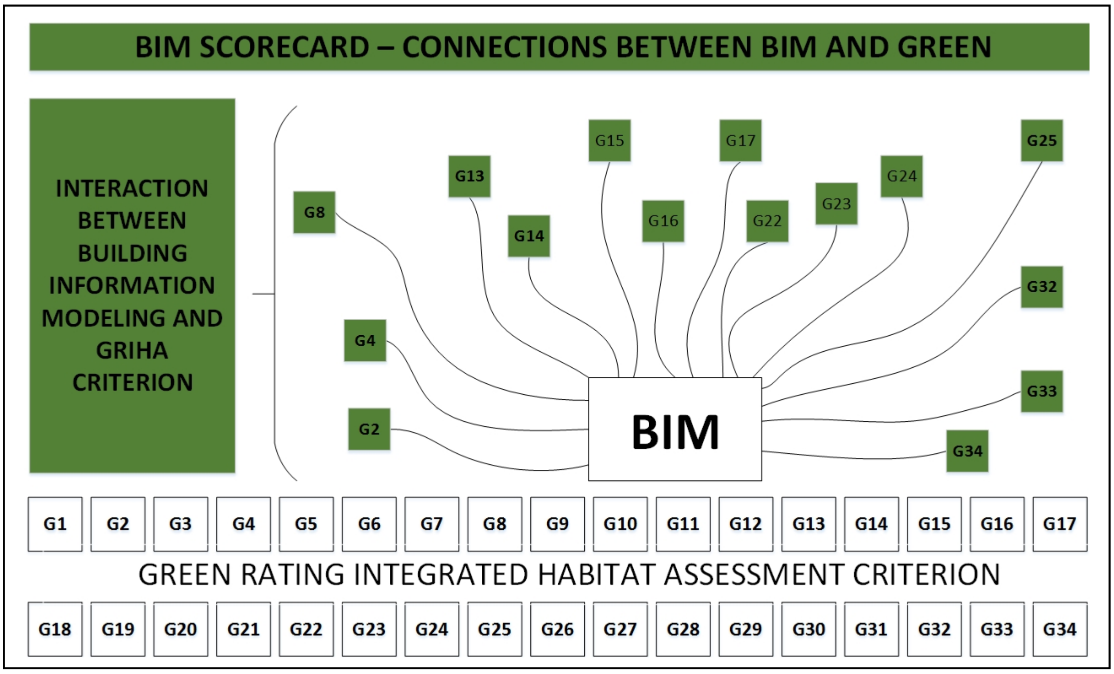

Figure 4: BIM score card - Connections between BIM and GREEN

	Evaluation system of GRIHA criteria		
S.no	Description	Points	
Criterion 1	Site Selection	1	Partly mandatory
Criterion 2	Preserve and protect landscape during construction/compensatory depository forestation.	5	Partly mandatory, if applicable
Criterion 3	Soil conservation (post construction)	2	
Criterion 4	Design to include existing site features	4	
Criterion 5	Reduce hard paving on site	2	Partly mandatory
Criterion 6	Enhance outdoor lighting system efficiency	3	
Criterion 7	Plan utilities efficiently and optimize on-site circulation efficiency	3	
Criterion 8	Provide, at least, minimum level of sanitation/safety facilities for construction workers	2	Mandatory
Criterion 9	Reduce air pollution during construction	2	Mandatory
Criterion 10	Reduce landscape water requirement	3	
Criterion 11	Reduce building water use	2	
Criterion 12	Efficient water use during construction	1	
Criterion 13	Optimize building design to reduce conventional energy demand	8	Mandatory
Criterion 14	Optimize energy performance of building within specified comfort limits	16	Partly mandatory
Criterion 15	Utilization of fly-ash in building structure	6	
Criterion 16	Reduce volume, weight, and time of construction by adopting efficient technology for example, pre-cast systems, ready-mix concrete, and so on)	4	
Criterion 17	Use low-energy material in interiors	4	
Criterion 18	Renewable energy utilization	5	Partly mandatory
Criterion 19	Renewable energy based hot- water system	3	
Criterion 20	Waste water treatment	2	
Criterion 21	Water recycle and reuse (including rainwater)	5	
Criterion 22	Reduction in waste during construction	1	
Criterion 23	Efficient waste segregation	1	
Criterion 24	Storage and disposal of wastes	1	
Criterion 25	Resource recovery from waste	2	
Criterion 26	Use of low VOC paints/adhesives/sealants	3	
Criterion 27	Minimize ozone depleting substances	1	Mandatory
Criterion 28	Ensure water quality	2	Mandatory
Criterion 29	Acceptable outdoor and indoor noise levels	2	
Criterion 30	Tobacco and smoke control	1	Mandatory
Criterion 31	Universal accessibility	1	
Criterion 32	Energy audit and validation		Mandatory
Criterion 33	Operations and maintenance protocol for electrical and mechanical equipment	2	Mandatory
Criterion 34	Innovation (beyond 100)	4	
		104	

Figure 5: Evaluation system of GRIHA criteria (Source: GRIHA Manual 2013)

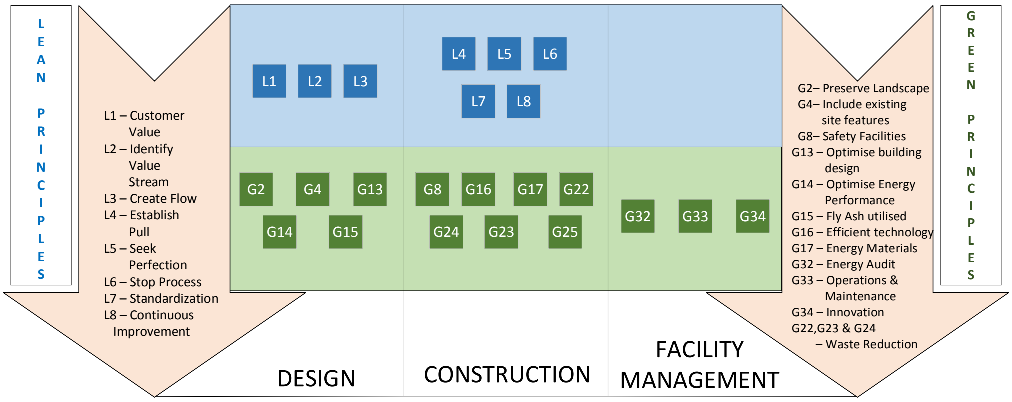

Figure 6: BIM framework

The conceptual framework once prepared, was sent to various organisations for reviews and comments. To validate the framework, architectural firms and BIM consultants were contacted and BIM managers of prestigious projects were interviewed to learn about best practices. The preliminary framework was tested on three case study projects. The benefits of BIM implementation to achieve lean and green principles is discussed in Table 1 below.

Table 1: Case Studies on BIM implementation

Lean and Green principles achieved with BIM implementation	**Projects**		
	Case Study Project 1	**Case Study Project 2**	**Case Study Project 3**
Clash Detection	Navisworks was used to detect the clashes and collisions. Approximately 500 clashes were detected and resolved in the basement. 350 clashes were detected and resolved at the ground floor level Reduced cost and time	Around 4000 clashes between MEP services, civil works were identified. Resolution of clashes and coordination between architecture, structure and MEP services was achieved through BIM	Around 900 clashes were detected. After resolution, coordinated and clash free drawings were issued in the form of shop drawings BIM helped in smooth functioning of the project
4D Modelling tool for construction schedules	-	-	-

Quantity Take – Offs	BIM facilitated the laborious part of quantity extraction Reduction of waste	-	Helped in achieving better billing process Delays and rework reduced
Energy Simulation	-	-	-
As-built Model	-	-	-

CONCLUSION

The paper discusses how BIM proves to be an effective enabler in establishing the linkage between lean and green. A BIM based preliminary framework that can measure lean and green improvements was developed and tested with the help of industry experts. Further studies are needed to finalize the proposed framework. Figure 7 comprehensively reflects how BIM enabled framework results in lean and green integration from design stage to the completion stage of a project. It shows the various applications of BIM that can be extensively used to achieve lean and green integration. The inter-linkages between lean and green that were driven by BIM were captured and are shown in Figure 7.

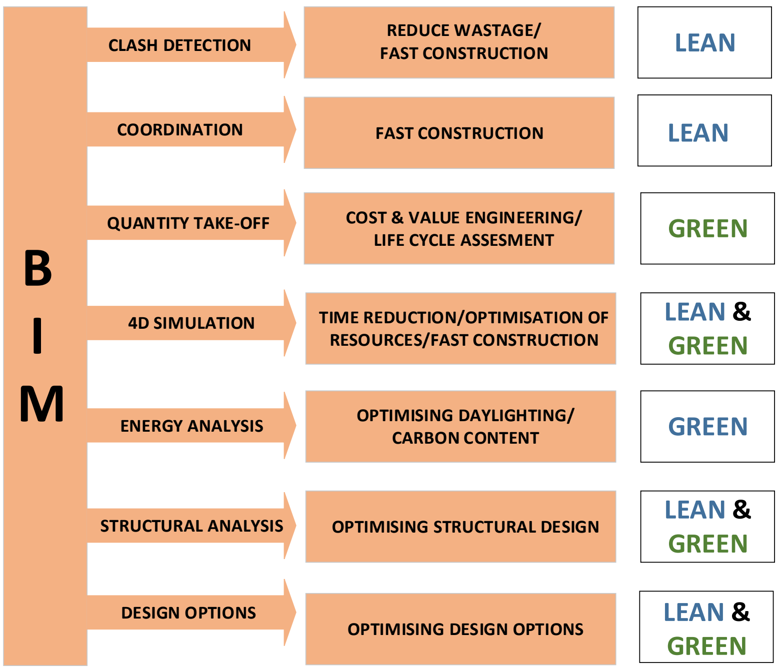

Figure 7: Various elements of BIM leading to Lean and Green

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