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THE CONFLUENCE OF LEAN AND GREEN CONSTRUCTION PRACTICES IN THE COMMERCIAL BUILDINGS MARKET

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ABSTRACT

Lean and Green construction methodologies are prevalent in today's construction industry. Green construction implementation in buildings progressed quickly over the last 10 years due to the popularity and development of building rating systems, such as LEED. Similarly, lean construction has become more popular as it often results in efficient construction and improved owner satisfaction.

The goal of this study was to assess whether or not practitioners reported the same thoughts on the interaction, or lack thereof, of lean and green construction as reported in academic literature. The authors identified common elements of each methodology through semi-structured interviews with five construction industry professionals with extensive experience with lean and green construction. Interviewees report lean and green construction are different "flavours" of the industry; however, interviewees also state if implemented together, these processes often result in a high-performance building. The authors note that the number of interviewees is small by design – this small sample size allowed the authors to test this research method for validating academic findings reported in literature. This work also brings the practitioner perspective to the conversation about the confluence of lean and green.

KEYWORDS

Lean construction, green construction, waste reduction, efficiency.

INTRODUCTION

Construction professionals typically implement tenets of lean and green construction separately, as they are viewed as two different methodologies; indeed the IGLC community supports this claim with the works of Carneiro et al. (2012), Campos et al. (2012), and later, Valente et al. (2013). The Lean Construction Institute defines lean construction as a "production management-based approach to project delivery" that extends from the objectives of maximizing value and minimizing waste (2016). Lean

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construction practices are slowly becoming standards in the industry; they are used to "optimize project results and maximize efficiency through all phases of design, fabrication, and construction" (jmcmahon 2014). Kibert defines green construction, also known as sustainable construction, as "the practice of erecting buildings and using processes that are environmentally responsible and resource efficient" (2012). The green building outlook continues to accelerate, growing almost $70 billion in just 6 years, from 2005 to 2011. The Dodge Report states, "by 2016, this number is expected to reach $204 billion to $248 billion" (Dodge Data & Analytics 2013). Given the popularity of both methods, this paper builds on existing work about how the methods compare, contrast, and complement through interviews with US practitioners experienced in both systems.

This paper begins with a definition of lean construction and green construction in terms of their practical application on commercial building projects, and discusses the perceptions of each within the construction industry. The authors interviewed five construction professionals in a semi-structured interview format to determine how practitioners implement lean and green and to find common practices among lean and green methodologies. This paper describes the research method and presents results from interviews. After comparing the results to literature review, three different theories emerged, representing a departure from existing literature, which characterizes the relationship without the consultation of practitioners.

LITERATURE REVIEW

This literature review focuses on the literature commonly read in the construction industry, rather than in academic literature. The authors selected these sources in order to relate definitions to those that the interviewees would be familiar with and likely to incorporate in their own personal definitions of lean and green construction.

LEAN CONSTRUCTION

Lean construction is an operational process that employs practices aimed at reducing effort, increasing production, and eliminating waste. Lean construction experts define waste not only in the physical form, but also as non-productive time and activity during construction projects. The Lean model was codified in the 1950's based on the Toyota Production system: it focuses on process efficiency through techniques including just-in-time, load leveling, and suggestion systems (Liker 2004; Morgan and Liker 2006).

While construction is not a manufacturing process, per se, as each construction product is unique (compared to producing thousands of a single product, e.g., cars), construction does involve repetitive processes that suggest manufacturing process improvements may be applicable. Researchers state that promised work is often not completed on time (Lichtig 2005; Howell and Lichtig 2008; Teicholz 2013), leaving room for improvement and reduced waste. Lean construction offers a method to reduce wastes and improve productivity in the construction industry. Thus, most lean construction applications focus on communication and reliability. For instance, scheduling practices put in place, such as the Last Planner System and pull planning, require project teams to "think in terms of flow rather than optimizing discrete activities" (Howell and Lichtig 2008). Project teams may implement prefabrication, just-in-time

deliveries, preventing excess material, and building information modeling to improve process flows. Teams may also use tools like building information modeling, or BIM, to facilitate clear communication. Teicholz stated that teams who use BIM reduce the project schedule for building construction; he also stated that prefabrication and efficiency have a direct relationship (2013). Another application of lean in the industry is in the continuous improvement sector, where project teams develop tools to reduce effort in different ways, e.g., once workers are trained in safe and efficient work practices, teams implement the "Plan Do Check Act" cycle (Shewhart 1939; Deming 1986; HCi 2008; Parrish 2013) to improve these practices. The construction industry is accustomed to solving problems as they arise to maintain schedule, but they may not be as familiar with documenting the success or failure of the solution. By implementing PDCA, companies can better assess which solutions work well when given issues arise; thus, companies can be more proactive and more quickly implement proven solutions on future projects, saving time and cost (Howell and Lichtig 2008). At its core, lean construction implementation counters low productivity and supports a more efficient industry.

GREEN CONSTRUCTION

Kibert documents seven principles to sustainable (green) construction: (1) reduce resource consumption, (2) reuse resources, (3) use recyclable resources, (4) protect nature, (5) eliminate toxics, (6) apply life-cycle costing, and (7) focus on quality (2012). Green projects often address the social, environmental, and economic bottom lines.

Project teams can assess green buildings to determine their impact on the environment using a variety of rating systems. The LEED (Leadership in Energy and Environmental Design) building rating system is the most popular system in the United States, and it has helped green construction gain traction; given its popularity in the US, where the authors conducted their study, this work focuses on LEED rather than another rating system. LEED provides a framework for building a "holistic green building," using energy and water efficient materials, diverting waste and recycling materials during construction, and in operations, using strategies to provide a healthier building; LEED awards credits for building on a sustainable site near public transportation amenities (USGBC 2015). The environment is increasingly considered in building design and construction, in the lean context, the environment could be considered a "customer."

RESEARCH METHODS

The goal of this study was to assess whether or not practitioners reported the same thoughts on the interaction, or lack thereof, of lean and green construction as reported in academic literature. To do so, the authors adopted a semi-structured interview approach (e.g., (Wengraf 2001). Based on the literature review described above, the authors developed an interview protocol. The authors determined a list of interviewees with the help of Arizona State University's (ASU) Office of the University Architect. That office provided a list of contractors that successfully implemented lean and green construction on campus projects. They solicited input from leading practitioners in the fields of lean and green construction, where "leading" refers to lean and green construction experience on the Arizona State University (ASU) campus. The semi-structured interview approach

allowed the authors to begin with a list of questions, but divert and allow new ideas to enter the conversation during the interview as appropriate (Wengraf 2001). As mentioned previously, the authors take an industry-based approach, rather than an academic one; the authors compare their results to those of other academic studies in the Discussion section.

The sample size for this study was 5 separate interviews with representatives from 4 general contractors. The small sample size allowed the authors to test the efficacy of the method and their interview protocol. Each organization represented has revenues over US$1Billion annually; respondents draw from this wealth of experience in their responses. Table 1 documents the interviewees. Each interview was recorded, transcribed and coded using nVivo software (qrsinternational.com) that facilitated comparison between interviewee's responses.

Table 1: Interviewee Profiles

Name	Role	Organization	Experience	# of lean ASU projects	# of green ASU projects
Lew Laws	Sr. Project Manager	DPR Construction	25	3	3
Phil Macey	Collaborative Project Delivery Expert	JE Dunn	23	1	1
Brooke Coffin	Lean Specialist II	JE Dunn	12	3	3
Tom Dobson	Vice President	Holder Construction	17	4	4
Steve Clem	VP, Pre-construction	Skanska	19	0	0

RESULTS

The authors compiled all of the interview transcripts in the nVivo Word Cloud generator to create Figure 1. Figure 1 comprises 110 words that were used more than 5 times across interviews. The words that were used most frequently signify the different Lean and Green construction practices implemented on projects. The following sections describe results from the interviews on lean and green construction, respectively.

LEAN CONSTRUCTION

The synthesis of the qualitative data from the interview questions discussing lean construction produced the following themes: 1) collaboration, accountability, and effective scheduling; 2) process and effort reduction, continuous improvement; and 3) set-based design and design-construction integration.

Collaboration, Accountability, and Scheduling

Laws emphasized that the most prevalent connection between Lean and Green construction is in the collaboration and accountability. Employing lean practices enables the project team to "keep score" and hold team members accountable for their responsibilities (2015). He stated an effective way to do so is enable the Last Planner System for scheduling; "…this system provides a framework for the subcontractors

onsite to get behind the 'I get, I give' philosophy of lean" (2015). Another positive to the Last Planner system is it utilizes a pull planning schedule that essentially builds the project backwards (Clem 2015). DPR keeps a whiteboard updated with the activities for the day so the entire project team can see what is going on, which puts positive pressure on the subcontractors to honour the commitments they made to each other and the broader project team (Laws 2015).

Figure 1: Word Cloud generated from interview transcripts. Researcher produced. 31 Mar. 2015.

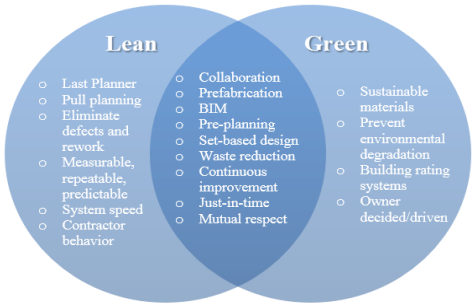

Figure 2. Venn Diagram for Lean and Green practices. Researcher produced. 31 Mar. 2015.

Process and Effort Reduction and Continuous Improvement

To reduce effort and provide the same results is an ultimate goal of implementing lean practices (Dobson 2015). Holder Construction has an initiative for de-cluttering to rid wasteful processes that use too much time or too many resources. Another effort reduction practice is implementing a strategy to provide what is needed and not to bring excess material to a jobsite (Dobson 2015). A general contractor knows what is coming to the jobsite through planning and this enables less waste on the jobsite and less wasted time due to transporting and handling unnecessary materials or equipment. The other effort reduction piece comes from continuously improving, such as Skanska offering improvement workshops for associates to assess the current stage of how a process is working, for example, subcontractor prequalification (Clem 2015). Project teams can also track variances in the schedule activities and use Five Whys analysis to promote continuous improvement in daily activities. The Five Whys is an effective questioning method to determine what the root cause of a problem is in lieu of making excuses. This is particularly helpful when a task is delayed due to an issue that is not directly related to that task (Coffin 2015). These continuous improvement changes can make an associate or company leaner and in result, more efficient and productive. The industry needs changes that will allow contractors to deliver a project faster (Clem 2015), and implementing lean can be an answer for many companies.

Set-Based Design and Design-Construction Integration

The process of set-based design is focused on considering several possible solutions and gradually narrowing the sets down to decide on a final solution without backtracking. The project team also keeps project file of considered solutions and decision reasoning

(Parrish 2009; Tuholski and Tommelein 2010). Dobson stated, "set-based design focuses on defining goals and pushing each goal to the extreme to see what the result is" (2015). In an effort to move forward with a project and promote productivity, set-based design may be employed. Macey emphasized an effective lean concept is to restructure the design process to work with the construction process in an effort to produce constructible drawings (Dobson 2015; Macey 2015). In order to build lean, the project team needs to be the right fit for the project type; "to get the best people working on the task at hand is the most efficient practice", though not always the most cost efficient (Clem 2015).

GREEN CONSTRUCTION

The synthesis of interview data from discussing green construction yielded the following: 1) using a building rating system and installing sustainable materials; 2) building morally for the environment and waste reduction; and 3) creating respect for peers.

Rating Systems and Sustainable Materials

Green construction is a "subset of sustainability" (Clem 2015) in which the owner, builder, and design team collaborate on design and construction in an effort to build sustainably. A typical practice of building green is to leverage a building rating system, such as LEED, Green Globes, or the Living Building Challenge, to shape the design (Clem 2015). The owner typically selects the rating system and requires the design and construction teams execute their processes in compliance with the rating system. Most rating systems award points for using sustainable materials in the building, such as FSC certified wood, low-flow fixtures, and flooring or paint with low VOCs. These materials are typically decided in the design phase and specified by the design team (Clem 2015; Laws 2015). In other cases, the contractor can select these materials. For instance, Skanska Construction is certified through the ISO 14001 standard that enables Skanska to identify particular environmental risks for operations and mitigate and minimize their environmental impact during construction (Clem 2015).

Moral Building, Waste Reduction

Using the ISO 14001 standard also relates to designing a green building and the quality that goes into the process. Macey states that in order for a building to be high-performing, it must have high quality first. Building a project conceptually should first begin with quality, then performance, and then sustainability (2015). Building a highly sustainable project is also building morally for the environment. Laws stated that green buildings are built "with the future in mind" (2015). During the construction process, all activities need to have a positive impact on the future rather than a negative one. This is where waste reduction practices onsite become a key to successful project delivery. Few contractors consider building a project without developing an efficient recycling and waste plan with efforts to divert as much waste as possible from the landfills (Dobson 2015).

Respect for Peers

A less obvious method of green construction is the respect and opportunity found in the green building method. Clem immediately answered the question about what green construction is by stating, "green construction is treating our employees with respect and

opportunity and providing an industry leading safe environment" as well as "providing opportunity to the project team that enable sustainable interactions" (2015). Further, all interviewees noted that more and more clients prefer, and often require, green construction experience; organizations with it gain respect from contractors and owners.

CONFLUENT TENANTS OF LEAN AND GREEN CONSTRUCTION

In an effort to find the confluence between lean and green construction practices, the authors reviewed interview transcripts to find words and themes discussed in response to **both** the lean and green construction questions. Prefabrication and pre-planning as well as continuous improvement, emerged as confluent practices (Figure 2).

Prefabrication and Pre-Planning

Prefabrication, and the preplanning it requires, is a confluence of lean and green construction. Prefabrication is green and lean due to reduced wastes, and particularly lean due to the decreased need for onsite labour. If products are manufactured offsite in a warehouse, the controllability and quality of the result is more likely as compared to fabricating it onsite, therefore reducing waste (Dobson 2015). Prefabrication also allows the general contractor to build a strategy during the pre-planning phase, in which manpower can be decreased since fabrication will be done offsite. The green aspect to reduced manpower is reduced transportation to and from the project site. Having fewer workers requires less gas and reduces fossil fuel effects on the environment (Coffin 2015).

Continuous Improvement

The concept of building greener and more sustainable materials is a practice of lean in and of itself. Lean is focused on continuously improving, while green building is also focused on finding the next greatest product that will reduce the environmental degradation impact from building construction. For example, there is now a toilet that uses 1.6 gpf (gallons per flush), who says we can't have a toilet that is 0.5 gpf? There are constantly improvements in technology and manufacturing that will enable green construction to thrive due to lean construction practices (Coffin 2015).

DISCUSSION

Through the interview analysis process, a few different schools of thought emerged on the synergies, or lack thereof, of lean and green construction implementation in projects. Academic literature to date illustrates clear overlap. The authors found that while this overlap exists and is recognized in industry, practitioners interviewed still felt lean and green were quite different, in terms of fundamental ideology and their driver on a project.

LEAN VS GREEN: DIFFERENT IDEOLOGIES

Two of the interviewees stated that the two methodologies are different and not simply relatable; rather, they are two different "flavours" of construction. Practices of each can be derived and applied to the other, but it is not a confluent or synergistic relationship. Although there may not a direct connection between the methods, Laws stated that it

seems general contractors and subcontractors become more sophisticated, in terms of technology use, when using practices from lean and green (together or separately) (2015).

LEAN VS GREEN: LEAN IS COMPANY DRIVEN, GREEN IS OWNER DRIVEN

The overall impression of lean construction among interviewees is that it is a behavioral and cultural mindset for a company. In order to be lean, participants need to adopt certain attitudes. Adopting lean principles encourages continuously improving methods and de-cluttering initiatives. This is the main difference between Lean and Green construction. Green construction is a choice to implement, typically decided by the owner or client. It is not so much behavioral, as it is documentation and product based.

Coffin stated that some owners do require contractors to implement lean practices in the project via the contract; requirements range from utilizing prefabrication to BIM to Last Planner scheduling to having associates analyze the root cause of problems by asking the Five Whys (2015). Asking a project team to become lean differs from asking them to build green. Building green can range from working with the design team to determine benefits analyses of certain types of equipment, tracking points on a building rating system score card, or coordinating green materials and techniques with the subcontractors. Essentially, respondents felt that due to the party in charge of implementation of these methods, these methods fundamentally differ and can be synergistic, though they doubt the methods will ever reach confluence.

LEAN VS GREEN: SYNERGISTIC IN NATURE

Interview responses suggest another school of thought: lean and green as synergistic without one being dominant. That is, these methods work together hand-in-hand. Dobson stated that pre-planning is a theme between the two, in that if lean and green strategies can be implemented in the beginning phases, then the contractor can build a package for the owner that includes a strategy for utilizing the lean practices, such as prefabrication and just-in-time delivery, to deliver a green project. Another emergent theme is in the design phase, where the building is designed to be constructible and efficient. In this phase, contractors in a CMAR or design build delivery system are able to work closely with the design team to produce constructible drawings, essentially skipping the design development phase of the project (2015). Macey stated that when there is a purposeful integration from a project's inception, lean and green come together (2015).

Overall, implementing the two methodologies together sets up the potential for a successful project, although there may be a few caveats of comparing the efficiency of green construction practices to lean principles. Dobson stated that design members tend to run with experimental products and techniques, and try to be the "bleeding edge" of the industry, which is not necessarily the most efficient method. Implementing experimental design and equipment can cause field installation issues, confusion for the contractor, and eventually re-work. Another green construction technique, pointed out by Clem, is requiring the specifications to reflect the desired properties of the product in its "green" composition, whether it is durability, maintenance or other factors. It is not a lean practice to include standard specifications in lieu of choosing a palette of sustainable material that can be used and meets the environmental standards. This could require the

project team to submit substitution requests, which can waste time that could have been saved upfront had the design team developed new specifications (Clem 2015).

CONCLUSION

The implementation of lean and green construction can produce varying results, however, research shows that these methodologies work together and separately to create high-performing buildings with a reduced schedule, collaborative project teams, and continuously improving performance. Through implementing lean practices, such as prefabrication, Last Planner scheduling, and pre-planning, green buildings can be built more efficiently. Vice versa, utilizing green construction practices, such as implementing a building rating system, waste reduction techniques, and using sustainable materials, can be effectively managed by using lean practices. The theories that emerged in this work reflect an industry viewpoint of lean and green construction, and show that there is no black and white answer to whether or not lean and green is the *right* way to build, but the practices the authors analysed reflect the overall efficiency of implementing both. The authors hope that in asking the question about confluence, and finding a research method that addresses such a question, the IGLC community and others will continue to collect more data to better understand how these two methods support an improved industry.

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