Leveraging Sustainable Construction with Lean and Integrated Project Delivery – A Socially Responsible and Smart Business Practice

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Abstract

This paper provides a review of sustainability in the built environment and examines its intersection with the emerging practice of Lean/Integrated Project Delivery (Lean/IPD) to forestall the growing threat to climactic conditions worldwide. A review of the literature on a number of projects addressed the potential impact of lean construction practices and sustainability practices in LEED-compliant projects on both initial costs and life cycle costs. It was noted that the adoption of LEED certification in projects is frequently inhibited by exaggerated estimates of the cost of compliance. Lean projects were observed to experience savings in the range of 5% to 20% below market prices. The so-called LEED premium was noted to be an average of 1.87% for LEED Silver, 4.0% for LEED Gold, and 8.57% for LEED Platinum (Matthiessen and Morris, 2004). In principle, a LEED Gold facility built through Lean/IPD could be built for a net cost no greater than a traditional non-sustainable project. Ongoing operating costs would be reduced as well. The construction industry is strongly encouraged to adopt this model. It represents a smart business practice and helps to protect the environment at the same time. Construction Management programs could be an important catalyst for this transition. It represents a smart business practice and helps to protect the environment at the same time.

Keywords

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Lean construction, Integrated Project Delivery, Sustainability, LEED standards.

1. Introduction

There is a growing threat to climatic conditions worldwide. Fossil fuels continue to be depleted at a relatively rapid rate – the world demand for oil is approximately 31 billion barrels/year, and forecasted to grow at 2% per year to 2025. Greenhouse gases are generated at a similar rate, and the ozone layer is also being degraded faster than climate change experts have hoped for in order maintain the planet on a sustainable path. The built environment accounts for 65.2% of total U.S. electricity consumption, over 36% of total U.S. primary energy use, and 30% of total U.S. greenhouse gas emissions. It also accounts for 136 million tons of construction and demolition waste (approx. 2.8 lbs/ person/day), 12% of potable water. Globally, the built environment accounts for 40% (3 billion tons annually) of raw materials use.

(US Green Building Council 2007). Forecasts project that temperatures will rise by 1.8 – 4.0 ^{o}C by the end of the twenty first century, relative to 1980-1990. The areas that are likely to warm more than the global average include most of North, South & Central Americas; all of Africa; Europe; and Northern & Central Asia.

1.1. Defining Sustainability

The Brundtland Commission's 1987 report (WECD, 1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development was defined as "The creation and responsible management of a healthy built environmental based on resources efficient and ecological".(Kibert, 1994). The overall goals for sustainability include: using resources efficiently and minimizing raw material resource consumption, including energy, water, land and materials, both during the construction process as well as throughout the life of a facility.

2. The Urgency for Action

The importance of sustainability in the built environment is emphasized by the fact that declining construction productivity calls for more resource inputs – labor, financial and material, to sustain required outputs. There has been a continuing decline in the productivity of the construction industry over the past fifty years (Teichold, 1999). This is in clear contrast to observable increases in productivity for non-farm related industries). A number of independent studies estimated that construction productivity increased by 33 percent between 1966 and 2003, approximating a rate of 0.78 percent per year. This productivity growth is less than one-half that of the observed nonagricultural productivity gains in the U.S. during the same period, which averaged 1.75 percent annually. An estimate by the National Institute of Science and Technology (NIST) points to a decline in US construction productivity over a 40 year period to 2007 that was -0.6% per year, versus a positive non-farm productivity growth of 1.8 percent annually.

2.1. Inadequate performance

The construction industry has had many project delivery options available, such as Design-Build, Design-Bid-build, and CM at Risk, yet many projects have had unsatisfactory outcomes in cost and schedule, and often do not meet clients' quality expectations (Alarcon and Mesa 2012, Lichtig 2006). These problems are attributed to lack of communication, coordination, and integration as well as other factors. There is extensive waste in the industry, in the range of 25 to 50 percent in coordinating labor and in managing, moving, and installing materials; a broad range of values for "wasteful activities" (1.6 – 93.1 percent, with an average of 49.6 percent (Horman and Kenley, 2005). The building SMART alliance at the National Institute for Building Sciences estimates that more than 50 percent of the cost of a building is waste; compared to other industrial sectors, the construction sector has experienced consistently rising costs over many years (Anheim, in Atkin et al., 2008). The poor life cycle performance of the built environment is also a major waste of resources.

3. Strategies For Managing Suatainability

Several sustainability initiatives have been implemented since the 1990's to promote "Green Architecture" and Sustainable Construction. These initiatives serve as a guide and reference for building owners, designers and builders to ensure that future buildings increasingly incorporate the "best practices" that will in time, lead to a sustainable environment for all. The most prominent ones are Leadership in Energy and Environmental Design (LEED) established by the U.S. Green Building Council (USGBC), the Building Research Establishment Environmental Assessment Method for buildings (BREEAM) and The DGNB Certification System in Germany. BREEAM is used to assess buildings and large scale developments in many countries around the world including the United Kingdom, Netherlands, Spain, Germany, Norway, and Sweden). The DGNB Certification System can be applied internationally. There are several other initiatives such as Energy Star, Green Globes, and Florida Green Building Coalition. Although these initiatives have significant differences between them, they all seek to promote high levels of environmental performance in buildings and communities.

Members of the USGBC from all segments of the building industry developed the LEED system (Leadership in Energy and Environmental Design) starting in 1995 to provide a national standard and continue to contribute to its ongoing evolution and growth. Its development included representatives from all sectors of the building industry with funding from the U.S. Department of Energy, and unique in having had its development open to both industry and public scrutiny.

The LEED® certification program awards buildings points for satisfying specified green building criteria. It provides a framework for assessing building performance and meeting goals for sustainability. It is based on proven scientific standards and promotes the use of state-of-the-art techniques for sustainable site development, energy efficiency, water conservation, materials selection, and indoor environmental quality. (Azhar et al. 2011) LEED promotes the dissemination of green building knowledge and expertise by recognizing achievements, and through a program of project certification and professional accreditation.

The categories in the LEED rating system are:

1) Sustainable sites, (SS)2) Water efficiency, 3) Energy and atmosphere (EA)

4) Materials and resources (MR): 5) Indoor air quality (EQ): 6) Innovation and design process (ID)

There are several subsets of LEED standards:

LEED-NC for New Construction, LEED-EB for Existing Buildings, LEED-CI for Commercial Interiors, LEED-CS for Core and Shell, LEED-H for Homes, LEED-S for Schools

LEED-ND for Neighborhood Development.

4. The Barriers to Sustainable Projects

The primary barrier to the introduction of sustainable construction is the widely held belief that sustainable construction is more expensive and involves a higher risk. The higher costs are attributable to new technologies, specialized materials, and additional design. In many projects, cost projections emphasize initial costs, with less attention to life-cycle costs. Some facility owners are not motivated to generate lower operating costs for building occupants or tenants. The LEED process involves paying fees for certification as well as hiring commissioning services to verify that specific processes have been followed. A number of owners have adopted sustainability initiatives, but have stopped short of seeking certification. In a 2013 survey of contractors, (Holloway, S. and Parrish, K.) the obstacles to sustainable building were "higher initial cost" (90 percent) and "difficulty/cost of certification" (57 percent) as primary obstacles to sustainable building, even though 81 percent thought it was "the right thing to do". In the same survey, 88 percent of respondents reported the additional cost of LEED certification as less than 2 percent of overall project costs.

A wider understanding of sustainability and life- cycle costing, as well as a lowering of initial cost will greatly affect the acceptance of sustainable building (Koskela and Tommelein, 2009). Nevertheless, recent studies suggest that designers have begun to incorporate green practices in standard designs. Some contractors have begun to institute paperless jobsites and to practice waste diversion.

An earlier study by Matthiessen and Morris, (2004) looked at the influence of climate and location on LEED ratings and project costs. The climates selected were Mid-coastal Santa Barbara and San Francisco, California Central valley – Merced, Gulf Coast – Houston, Northeast Coast – Boston, and Rocky Mountains - Denver. As indicated below, the average percentage premiums were 1.87 for LEED Silver, 4.0 for LEED Gold, and 8.57 for LEED Platinum.

In a follow up study in 2007 Matthiessen and Morris, (2007) the authors noted that construction costs had escalated, but many buildings were able to obtain LEED certification without additional funding, especially if clear goals were established from the project inception phase.

The primary barrier to sustainable construction is the client's widely held but exaggerated belief that sustainable construction will cost more and attract a higher risk. They believe that the initial cost will increase, while using new technologies, green materials, and extra design. The cost of registration is significant as well. This results, therefore, not only in higher capital cost but also in the lack of reliable accurate cost information. Most traditional projects only consider a short-term period, after that, all of the benefits may not be received by the builder/developer/owner. Consequently, the long term benefits from sustainable construction, including lower life-cycle costs, have been less than attractive to many developers or construction companies.

Certification level ⟹	Platinum	Gold	Silver
Average premium Costs – percentage of starting budget	8.57%	4.0%	1.87%

Figure 1. Cost Study Summary – Matthiesen and Morris, 2004.

5. The Intersection between Lean and Green

Lean Construction has caught the attention of the design and construction community in the USA, for its potential to improve construction performance. The McGraw Hill Company's Smart Market Report conducted an extensive survey of the U.S. construction industry in 2013, reporting that "business as usual can no longer be an acceptable approach in the construction industry. Lean Construction offers an alternative that allows companies to thrive in any economic conditions". The report cited many lean benefits reported by survey respondents. While the benefits were not quantified in the survey, the percentages of respondents reporting medium and high levels of achievement were: Higher Quality Construction 84 percent, Greater Customer Satisfaction 80 percent, Greater Productivity 77 percent, and Improved Safety, 77 percent.

Lean construction projects have been demonstrated to lower both costs and schedules simultaneously, in some cases by 10 percent or more (CII Report 234-11). In lean projects, constructors and designers can increase profitability even at a lower cost to the owner because of fewer mistakes, fewer delays and less waste of human and other resources. Green construction has been shown to lower ongoing operational costs as well – electrical and water consumption are often reduced by 50 percent and 30 percent, respectively. Combined, these methodologies represent a powerful prescription for sustainability. Lean may enhance environmental benefits (Horman et al 2004, Huovila and Koskela, 1998). On the contrary, the lean emphasis on providing value may be at odds with sustainability initiatives if project owners do not declare the reduction of environmental impacts as a value (Cusumano 1994).

Green buildings promote and support the concept of Lean construction. While Lean construction involves the minimization of waste, ensuring that the resources used in the building process enhance the value chain for a completed facility, green building design is based on design principles that promote environmentally beneficial long-term operation. Overall, a combination of these approaches significantly enhances sustainability. Not only is a "lean" building assembled using fewer resources – human, financial, energy, material, etc., but a "green" building has a lower environmental impact in its construction. It continues to have a lower environmental impact in its ongoing operation as well. Green practices may even reduce initial construction costs. The recycling of construction material reduces the amount of physical waste generated in a project, and the amount of pollution associated with the process is reduced as well. Sorting construction waste on a site is a recommended practice that qualifies for LEED credits. It can also reduce haulage costs for waste disposal as some of that material can be reused.

5.1. Lean Construction Principles and Practices

The term "lean construction" emerged from the application of lean methods/techniques to the design and construction processes, in order to derive the benefits that have been clearly established in manufacturing operations. It is a collaborative approach to project delivery, in which stakeholders – including the project team and the owner, seek to optimize the overall project, minimizing waste in all forms and maximizing value. It contrasts strikingly with traditional construction practices in which project team members seek local optimization to maximize their progress and their profits. This often happens to the unintended detriment of other team members and the project as a whole. (Forbes and Ahmed, 2010).

Effectively, lean construction is a generic term with several interpretations such as Lean Project Delivery (LPD), Integrated Project Delivery (IPD), and Lean/IPD. It relates to both design and construction and seeks to maximize value for project owners and minimize wastes; it draws on the Toyota Production

System that identified seven wastes and five lean principles (Womack et al., 1996). These principles are: value, as desired/defined by customers; mapping the value stream to expose and remove waste; maximizing flow of value-creating activities; stabilizing pulls in the system, pulling value from upstream activities; and striving for perfection in processes, reducing time, effort, cost and errors; although perfection might not be achieved. In lean projects, it is desirable for each facility (or project) and its delivery process to be designed together to better reveal and support customer requirements. Work is structured throughout the process to maximize value and reduce wastes such as overproducing, waiting, excessive transportation, over processing, excess inventory, wasted motion, and defective production. Building Information Modeling (BIM) is used to support the collaborative team interactions that are an essential component of the lean methodology.

Integrated Project Delivery (IPD) was developed to improve innovation by moving money across boundaries (Alarcon et. al., 2013). IPD is defined as a delivery system that seeks to align interests, objectives and practices, even in a single business, through a team-based approach. The primary team members include the architect, key technical consultants, a general contractor and key subcontractors. It creates an organization able to apply the principles and practices of the Lean Project Delivery System™. The American Institute of Architects (AIA) has recognized IPD as an effective project delivery method and defines it as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value, to the owner, reduce waste, and maximize efficiency through all phases, design, fabrication, and construction". The first IPD application involved a central chilled water plant built by Westbrook Air Conditioning and Plumbing of Orlando, Florida (Matthews and Howell, 2005). It evolved from a $6 million Design Build contract with the owner. The General Contractor/CM established a separate relational contract with the other members of the project team – the designers and the primary subcontractor. The relational agreement legally bound all members to the project and aligned their interests, with profit and cost sharing incentives to promote team-based behaviour. There were many team-based activities to foster trust, ranging from joint training to meals and other social activities to engender a spirit of trust and transparency. Financial information was shared openly as a condition of IPD. Through teamwork, innovation and optimization, work and costs moved between different companies to improve performance and reduce overall costs. The team saved 10% of the contract cost and met or exceeded their goals for the schedule and their overall satisfaction with the project.

6. Comparing the Benefits of Sustainable Projects and Lean Projects

Two studies, one by the New Buildings Institute (NBI) and one by CoStar Group, have verified that third party certified buildings outperform their conventional counterparts across a wide variety of metrics, including energy savings, occupancy rates, sale prices and rental rates. The NBI study results indicate that new LEED certified buildings perform 25-30 percent better than non-LEED certified buildings in terms of energy use. The study also indicates a correlation between increasing levels of LEED certification and increased energy savings. Gold and Platinum LEED certified buildings have average energy savings approaching 50 percent. The USGBC cites studies of green buildings in which workers had productivity gains of up to 16 percent, including better work quality and lower absenteeism.

The US General Services Administration (GSA) conducted a post occupancy survey of twelve sustainably designed buildings including seven that were LEED Certified. They reviewed environmental performance, financial metrics, and occupant satisfaction. Their key findings were that, compared to National Averages, these facilities experienced 26 percent less energy use, 13% lower maintenance cost, 27% higher occupant satisfaction, and 33 percent fewer CO_2 emissions.

6.1. Lean Projects

With regard to lean projects, there are several notable examples of successful project delivery.

A study of six projects in the healthcare and educational environments that used Target Value Design indicated cost savings relative to market costs ranging from 5.6 percent to 20.9 percent (Ballard, 2012).

The Sutter Health Care system in California embarked on a lean journey in the early 2000's following a state mandate to implement major capital improvements to their failing health facilities' infrastructure. Working with very tight budgets, they embraced lean project delivery methods as a leap of faith; and had surprisingly positive results. A study of 22 lean projects valued over $10 million dollars each and completed since 2005 revealed:

- No projects over budget or schedule
- No sacrifice of scope or quality
- Cost at completion 5.8 percent under budget, on average
- Cost at completion approx. 15 percent under market, on average

In addition, since that time Sutter initiated 135 active projects worth $4.4 billion. Through the lean process, these projects were mobilized with savings estimated at $125 million under budget. (Internal Sutter Report 2014). Examples of Sutter's successful projects are the Camino Medical Group Office Building in which costs were reduced by $9 million, and the schedule was shortened by 6 months. Labor productivity was increased by 15 – 30 percent and rework was reduced to less than 0.2 percent versus the 5 – 10 percent range of many traditional projects. The Cardinal Glennon Hospital project ($43 million) was completed 2 months early, with only 63 requests for information (RFIs) and no disputes. There were only 1.45 reportable safety incidents per 200,000 hours versus an industry average of 5.9.
Ballard, G. and Kim, Y. W., (CII Report 234-11) observed both tangible and intangible benefits with lean projects. These included savings of 10 percent or more and high levels of satisfaction for owners as well as project team members

6.2. Observations from Lean and Green Projects

The information available on projects that are both lean and green is limited for two important reasons – Lean/IPD is still in its emerging stages, having begun with very few adopters in the mid-1990's. While it is increasingly being adopted, it has been applied to only a small percentage of construction projects when compared to traditional delivery methods such as D-B-B and Design Build. The emphasis in those projects was on seeking the benefits of maximizing value and minimizing waste (primarily during the design and construction phases); that translated into on-time or faster delivery, lower cost, and higher stakeholder satisfaction. During that time, the facilities that were built to sustainability standards were focused on long term goals of supporting the health of the environment, and the owners may not have been aware of lean project delivery, or may have been reluctant to embark on a new method with the limited availability of experienced practitioners. With the passage of time there has been a gradual convergence of interests, with large institutions such as hospital systems and educational organizations leading the way.
Two such examples are described below.
The Sutter Health Eden Medical opened on December 1, 2012 and attained LEED Silver certification. This project was a 130 Bed, 230, 000 square foot acute care hospital in Castro Valley, California, and was built by an Integrated Project Delivery (IPD) team. The Devenny Group Ltd. were the architects and the contractor was DPR Construction – which has delivered many lean projects. This project claimed to have the first 11-party Integrated Form of Agreement (IFOA); the IPD team approach maximizes the interaction and communication between stakeholders, and has been credited with the positive outcomes of many lean projects. The team's goal was to design and deliver a facility of the highest quality, at least 30 percent faster than comparable projects in California, and for no more than the target cost". This target was set at $320 million, with a duration of 36.3 months. Building Information Modeling (BIM) was used for site logistics planning and to coordinate all elements of the project virtually. It facilitated maximum offsite fabrication and pre-assembly. Value Stream Mapping, a lean tool, was used to plan and streamline the design process. Model-based estimating, allowed rapid estimating and greater access to real-time cost

information. The IPD team completed the design in 15.5 months versus a 24-month standard, representing a 35 percent reduction in schedule.

Michigan State University's new dining hall exemplifies a successful Lean and LEED GOLD project, driven by a knowledgeable owner. MSU's Dr. Tariq Abdelhamid, a proponent of both lean and sustainability, assisted contract administration staff to guide the application of the lean process. The Vista at Shaw Hall was a renovation project completed in May 2013 at a cost of $12 million, and was the first Lean/IPD project at a US public university. Because of the challenging scope as a renovation with asbestos abatement, MSU selected Lean/IPD with an integrated form of Agreement (IFOA), with contingencies for hidden existing conditions, and construction risk. Building Information Modeling was used for clash detection, and the contractors were active participants in the design phase. Project outcomes were outstanding – the seating capacity was almost doubled from 455 to 720. The project was completed 3 weeks early, at a price 15 percent lower than comparable projects; the contract administration cost was 28 percent less. In addition, 84 percent of the construction waste was diverted from landfills; 11 percent was recycled – flooring, concrete, metals; and 21 percent of construction materials were obtained within 500 miles. Abdelhamid credits Lean Design and Construction with "achieving Green features at reasonable and competitive first costs to the owner".

7. Conclusions

Sustainability projects and lean projects have both clearly demonstrated their contributions to a better future state for the environment. Lean projects have routinely saved 5 to 20 percent of initial costs, and even more when compared with standard market costs. High stakeholder satisfaction has been observed as a hallmark of lean construction, and worker safety has been far greater than in traditional projects. There have not been reports of litigation in the hundreds of lean projects to date. Sustainable projects generally use 30 percent less water and up to 50 percent less electricity, resulting in lower operating costs indefinitely. Energy Star rated facilities emit 35 percent less carbon. During construction, many projects have used recycled wood and metals, diverting tons of waste from landfills. The many intangible benefits include better air quality, higher occupant satisfaction and greater work productivity. Recommendations from the Davis Langdon investigations include treating sustainability as a program issue, not as an added requirement. Budgeting should be closely aligned with team goals, and the team should have the expertise necessary to make critical early decisions and secure the best representation possible of the sustainability criteria. Similarly, lean project delivery benefits from early team collaboration and key program decisions in which lean thinking is included in a project – not seen as an additional feature.

The question of a premium for sustainable projects is the subject of a continuing debate but has been measured in the range of 1 to 5 percent for LEED Gold projects. Clearly, lean construction savings significantly exceed this amount. Forward thinking leaders can use the lean methodology to minimize resource depletion, maximize innovation and creativity, and reduce both initial costs and operating and maintenance costs. Sustainability and lean combined are indeed a smart and socially conscious business practice.

It is highly recommended that a collaboration be developed between advocates of sustainability such as the USGBC and the Lean Construction Institute in the USA to promote the merging of lean and green initiatives. Similar collaborations could be mobilized internationally between the International Group for Lean Construction (IGLC), and BREEAM, DGNB, and other regional certification systems in other countries.

Construction Management programs should begin to turn their attention to the joint practice of lean and green initiatives. Courses in sustainability practices have been well established for several years. As of this time, lean construction courses are relatively few in number. Courses that integrate lean with green are even more of a rarity. Construction Management programs now have the opportunity to play a leadership role in bringing these disciplines together.

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