GREEN BUILDING RATING AND DELIVERY SYSTEMS IN BUILDING CONSTRUCTION: TOWARD AEC+P+F INTEGRATION

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ABSTRACT

Within the past decade, new building construction in the United States is being affected by the availability of the Leadership in Energy and Environmental Design (LEED). This rating system profoundly alters design and operational issues that include energy and water use, indoor health, recycling for occupants, access to mass transit, materials impacts, landscaping, construction waste management, and maintenance. However, very little is known about the cumulative effects of the rating system across different phases of the project life cycle, such as planning, architecture, engineering, construction and operational facility management (AEC+P+F). As project stakeholders embrace AEC+P+F integration in the quest for improving project performance indicators (e.g., cost, time, quality, etc.), the impact of LEED on this integration, or vice versa, is still unknown. Moreover, the implications of the delivery system in LEED attainment are not clearly associated with the level of AEC+P+F integration.

This paper presents the early stages of research focused on determining the associations between LEED criteria, project life cycle, stakeholders and typical delivery systems used in building construction. Results are validated using opinions from experts across the different disciplines in a future study. A matrix of weighted indices is also presented and explained so that increased collaboration may be incorporated into the construction process. The effects of this collaboration on the overall project life cycle, and the association with lean construction (LC) are discussed.

KEY WORDS

LEED rating, project life cycle, delivery system.

INTRODUCTION

Lean thinking can be applied at different stages in the project development process, i.e., design management, workflow control or supply chain monitoring (Leiringer 2001). Previous research proposed three ways of conceiving design: as a process of converting inputs to outputs (conversion process), as a flow of information and materials (flow process) and as the generation of value for customers (Slack 1998, Koskela and Houvila 1997). Any problem related to the timing of information transfer, to designers overloaded with unnecessary design information or to not having the right information at the right time, creates the risk of failure of design tasks, deficient analysis and wrong decisions with potential for waste in the process due to rework (Huovila et al. 1997). Early

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involvement of the contractor in design, or overlapping design and construction practices are ways of improving the construction process flow, thereby minimizing the potential for waste. These practices are mainly prescribed by the project delivery system to be adopted by the owner. However, little is known about the best processes to deliver green buildings, which demand intense interdisciplinary collaboration during design and careful material and system selection early in the project delivery process. Using conventional delivery methods results in process waste on green projects that reduces levels of sustainability and unnecessarily increases project costs (Klotz et al. 2007).

It is the contention of this paper that in the quest for green ratings, project participants are collaborating in every stage of the project development process, thereby setting a new framework for green project delivery. This framework approaches lean thinking, in particular the TFV theory of production (Koskela 2000), by generating value to the owner, improving flow, and transforming the inputs required for the selection of materials and systems, to outputs in the green rating scale.

The decision making criteria for new construction LEED score (USGBC 2005) provides information on the project stakeholders who are required to be involved with certain credits and prerequisites in the overall LEED rating table. Other assessment methods, such as UK 'Building Research Establishment Environmental Assessment Method' – BREEAM (Baldwin et al. 1998); the Canadian 'Building Environmental Performance Assessment Criteria' – BEPAC – program (Cole et al. 1993); the US 'Leadership in Energy and Environmental Design' – LEED – program (USGBC 1999); the 'Green Building Challenge' – GBC assessment framework (Cole and Larsson 1999); and the Hong Kong 'Building Environmental Assessment Method'–HK-BEAM (CETC 1996), contain similarities and dissimilarities regarding the consideration of environmental issues such as minimising construction waste, salvaged materials, energy use, preservation of soil and existing trees, wastewater discharge, noise during construction, hazardous materials, etc. (Cole 2000). Previous research has addressed the importance of considering long-term environmental aspirations and awareness of the environmental aspects of the product during the design phase. The impact on the product will be greater if this consideration is made earlier in the design process, using a "Design for Environment" (DFE) management program approach (Karlsson 2001).

To consider the full nature of the project life cycle, decisions will have an impact not only during preconstruction but across other stages, such as construction, commissioning and close out, operation and maintenance and decommissioning. For this reason, LEED attainment may be a catalyst for the integration of the project life cycle, including architectural planning and design, engineering analysis and design, construction, and facility management (AEC+P+F). This statement brings along several research questions: is there a relationship between LEED attainment and AEC+P+F integration? Assuming that LEED can contribute to AEC+P+F integration, can the latter be measured? Are the current delivery systems adequate for building projects pursuing LEED certification? Is there a need for a novel delivery system?

Based on a detailed analysis of the project life cycle under a common delivery system used for LEED-certified buildings, and on the rating system criteria itself, a matrix is proposed. The matrix contains the interactions that take place at every stage of the project that have implications on the LEED rating criteria. To identify possible relationships between the environmental assessment tool, the delivery system and the integration of AEC+P+F, the processes by which stakeholders interact must be identified.

METHOD

In order to explain the mutual influence of LEED categories on project life cycle activities, an analysis could have been developed by describing each category, its influence on project life cycle and project participants involved; whereas through an illustration this could be explained more precisely. Thus a matrix chart was developed elucidating the presence of project participants in each phase of the project life cycle and projecting their influence on the LEED credit decision making. This chart will be validated through experts who are involved with a LEED project. The project life cycle activities in the matrix were based on the design-build delivery option, as it is the preferred option in LEED projects. Six major LEED v2.2 categories include 65 sub categories, which were aligned on the vertical axis and 89 important project life cycle activities were then aligned on the horizontal axis. Each intersecting cell for a LEED subcategory and the project life cycle activity was considered to represent mutual influence between the two components. As a result, for each LEED category there are 89 possible influences. Cells were then filled with appropriate project team members involved in that specific activity. The specified project members would not only have impact on the activity but have influence on the corresponding LEED credit category.

MATRIX DESCRIPTION

A matrix chart was prepared by aligning important project life cycle phases on the horizontal array, while the vertical array has LEED-NC v2.2 categories. A zoom in of the matrix is shown in Figure 1. The project life cycle is based on the design-build delivery method with phases from concept and feasibility studies to decommissioning of the project. Each cell in this matrix represents the influence of LEED credit to the project phase or vice-versa.

"FOCAS" is used as notation to represent project participants, where F – Facility Manager, O – Owner, C-Contractor, A- Architect, S – Specialty Consultants. Since the construction process involves varied work process with each one having a specific consultant, all of them are grouped into "Specialty Consultants". So named as the FOCAS matrix, each cell is filled with the F/O/C/A/S letters based on the project participant's involvement to attain a particular LEED credit and the project instance where they make crucial decisions.

For example, the Prerequisite 1 in "Sustainable Sites" LEED category is "Construction Activity Pollution Prevention", the contractor is mainly required to prevent excessive soil erosion during "Construction Process". But effective implementation would be possible only when the contractor is also included in the "site selection process". So letter "C" would be inserted in cells where contractor would make decisions to successfully attain this LEED credit, resulting in "C" shown in both the site selection and Prerequisite 1 categories. The frequency of team member's participation during the project is also important to attain a LEED credit, the matrix chart clearly brings out this fact.

There are certain project life cycle activities like "Prepare Rough Order Estimate" under concept and feasibility studies that are purely administrative in nature. No mutual influence could be established between these instances and LEED categories. In such instances columns are left blank in the FOCAS matrix.

	Owner - O, Architect- A, Contractor-C, Consultant- S, Facility Manager-F											PLA
	FOCAS	Concept & Feasibility Studies										
	LEED - AEC Integration	Identify Key Stakeholders	Identify Potential Funding Source	Request for professional Services (if required)	Contract Professional Consultant (if required)	Define Need and determine Return on Investment	Identify Potential Sites	Identify Potential Project Risks	Conduct Feasibility/Engineering Study (Technical & Economic)	Review of Regulatory Considerations	Conduct existing condition survey	Identify Design Team
	Sustainable Sites											
Prereq 1	**Construction Activity Pollution Prevention**						OSAC	OSAC	SAC	SAC	SAC	
Credit 1	**Site Selection**						OSAC	OSAC	SAC			
Credit 2	**Development Density & Community Connectivity**						SA	OSAC	OSAC			
Credit 3	**Brownfield Redevelopment**						SA	OSAC	OSAC	OSA		
Credit 4.1	**Alternative Transportation**, Public Transportation Access						SA	OSAC	SA			
Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms						SA	OSAC	SA			
Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel-Efficient Vehicles						SA	OSAC	SA			
Credit 4.4	**Alternative Transportation**, Parking Capacity						SA	OSAC	SAC			
Credit 5.1	**Site Development,** Protection of Restore Habitat						SA	OSAC	SA	SA		
Credit 5.2	**Site Development,** Maximize Open Space						OSA	OSAC	SA	SA		
Credit 6.1	**Stormwater Design,** Quantity Control						SA	OSAC	SA	SA		
Credit 6.2	**Stormwater Design,** Quality Control						SA	OSAC	SA	SA		
Credit 7.1	**Heat Island Effect,** Non-Roof						SA	OSAC	SA			
Credit 7.2	**Heat Island Effect,** Roof						SA	OSAC	SA			
Credit 8	**Light Pollution Reduction**							OSAC	SA			
	Water Efficiency											
Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%						SA	SAC	SAC	SAC		
Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation						SA	SAC	SAC	SAC		
Credit 2	**Innovative Wastewater Technologies**							FSAC	FSAC	FSAC		
Credit 3.1	**Water Use Reduction**, 20% Reduction						SA	FSAC	FSAC	FSAC		
Credit 3.2	**Water Use Reduction**, 30% Reduction						SA	FSAC	FSAC	FSAC		
	Energy & Atmosphere											

Figure 1: FOCAS Matrix Zoom in

The following data represents the results of the pilot FOCAS matrix prepared for the Design-build Low bid delivery method: total matrix cells: 5,785; total filled cells (T): 638 (11% filled); Owner's Involvement: 84 (13.17 %); Consultant's Involvement: 510 (79.94 %); Facility Manager's Involvement: 282 (44.20 %); Architect's Involvement: 415 (65.05%). The involvement of each project team member in the decision making during the execution of a LEED project is as follows: owner: 5%, LEED consultant: 32%, architect: 26%, contractor: 19%, and facility manager: 18%.

The implementation methodology, depicted in Figure 2, creates a state of continuous improvement of the processes executed by AEC+P+F project participants. The design charrette process is a focused and collaborative design effort and brainstorming session. The purpose of this is to promote the exchange of ideas and information, thereby allowing integrated solutions to develop. Similar to the PDCA cycle and target and kaizen costing methodology (Robert and Granja 2006), the LEED-FOCAS cycle follows a routine of continuous improvement, starting at the planning and development phase through engineering design, construction, operation and decommissioning.

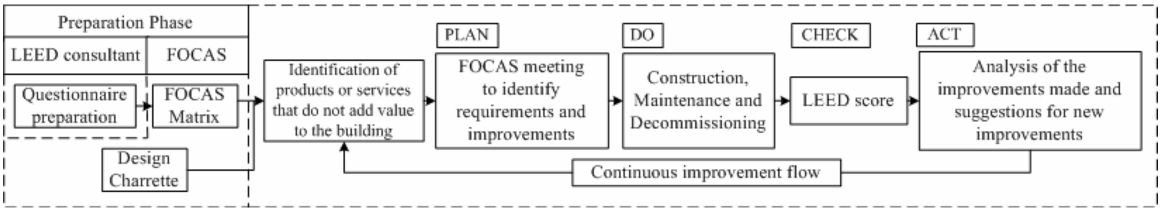

Figure 2: LEED-FOCAS Implementation Methodology (adapted from Robert and Granja 2006)

RELATIONSHIP WITH LEAN CONSTRUCTION

This research addresses lean construction (LC) by proposing a matrix with associations between LEED criteria, project life cycle and stakeholder participation. Lean production principles, such as to make everyone responsible for product quality, and to make the process transparent so the state of the system can be seen by anyone from anywhere (Howell and Ballard 1998, Ballard and Koskela 1998) are reflected in the matrix by means of engaging stakeholders in the attainment of LEED certification from the early stages of building design, to commissioning and operation. In the classical definition of LC, which is to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value (Koskela and Howell 2002), these early interactions in the stages of building design, construction and facility management take place to meet the green rating requirements, which represent the maximum possible amount of value for the client in the quest for the LEED target level. Furthermore, designing a production system to achieve the stated ends is only possible through the collaboration of all project participants at early stages of the project. This goes beyond the contractual arrangement of design-build or constructability reviews where constructors, and sometime facility managers, merely react to designs instead of informing and influencing the design. This paper intends to set a base for further research in the quest for an increase in project stakeholder collaboration due to the implementation of LEED in new construction. An innovative delivery system for LEED projects will be proposed, which in addition to serving as a better arrangement for targeting credit points and prerequisites for certification, it will represent a better channel for collaboration throughout the project development.

In addition to the lean principles directly impacted by the adoption of LEED in buildings (i.e., collaboration, deliver the product while maximizing value, eliminate anything not needed for delivering value, etc), the integration of AEC+P+F opens the possibility for other lean benefits. For instance, the design and construction project schedule may be compressed due to more opportune decision making. Costs may be also reduced due to expediting material ordering, and also as a result of the schedule compression. In general, the AEC+P+F integration due to LEED will address one of the most important lean principles, which is the underutilisation of people.

DELIVERY METHOD FOR LEED PROJECT

Design and construction of green buildings have created a different outlook towards project delivery methods. Conventional project delivery options are incapable of providing increased collaboration among project team members, which is a necessity for a true green building project. Various other factors that would help in successful LEED certification of buildings would be:

- Selection of project team members with LEED accredited professional designation.
- Better coordination among the team members earlier in the project.
- Designing energy efficient buildings through rigorous simulations.
- Systems selections based on their environmental impact through value engineering.
- Sustainable construction process requires reducing construction waste through waste management and controlling environmental impact.
- Better indoor environmental quality achieved by reducing the exposure of construction materials to atmosphere during construction.
- Contingency to allow the ability to absorb any change or unforeseen condition in the process of construction.

DESIGN-BUILD

The Design-Build (DB) delivery method provides a single point of contact to the owner, whereby one firm assumes the responsibility for both design and construction of the project. Entities offering this service can be a single firm or a joint venture between design and construction firms that come together contractually to perform a single project. This delivery method is popular for “Fast tracking” the project, where the overall project schedule is reduced. The contractor can start with the foundation work while the design process is still in the design development phase. Better communication among the design and construction team allows for construction input during the design phase. Inputs like constructability analysis, value engineering and subcontractor pricing issues are provided by the contractor. This arrangement allows easier and earlier incorporation of changes due to scope change or any unforeseen condition since the designer and constructor fall within the same contractual entity. The design-builder mainly relies on the owner’s program in the design phase. The owner’s program is generally called the “Bridging Documents”, which is prepared by the bridging architect/consultant or owner’s in house expertise to communicate requirements to the design builder clearly and accurately.

The owner generally stays away from the day-to-day activity and relies heavily on the problem solving approach of designer and contractor. This delivery method lacks traditional method’s “checks and balances” provided by designer during construction, as both designer and constructor represent the same company. The owner’s marginal involvement and lack of checks and balances might be a possible disadvantage for this delivery method. Even though design-build is utilised as the preferred option for a LEED project, it might not be a complete success as other project participants are not involved in the design or construction process.

CM AT RISK

This delivery method is newly evolved from “Traditional” and “Design-Build” delivery options. Here the owner has a contract with the designer and a separate contract with the constructor, who is also referred to as CM at Risk. Both the designer and constructor are brought in early by the owner in the project. The constructor provides preconstruction services, holds trade contracts, takes responsibility for the performance of the work and guarantees the project cost and schedule. A significant difference between CM at Risk and CM agent is that the latter provides project management services while the former takes project risk of schedule/cost and holds trade contracts.

A major advantage of this arrangement is that good communication between owner, designer and constructor is established early in the design process and continues until project completion. This delivery method also supports "fast tracking" similar to design-build. Designers have a say in the selection of CM at Risk and review their work during the construction phase, eliminating the potential risk associated with DB's one-contract format. Figure 3 describes both DB and CM at Risk delivery options, showing project participant's involvement.

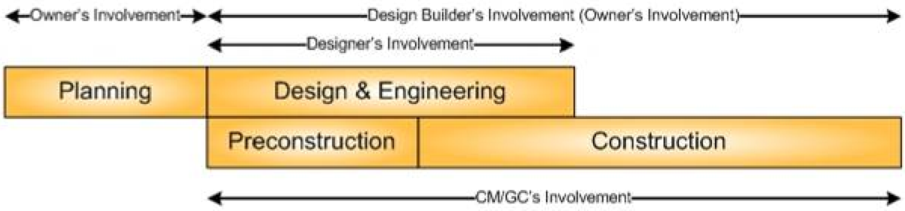

Figure 3: DB and CM at Risk Project Delivery Method

GREEN PROJECT DELIVERY METHOD

Green project delivery method (GPDM), depicted in Figure 4, is a variant of the DB or CM at Risk delivery methods based on the project phases, but with additional responsibilities for the project team involving greater communication among members. Here, all project stakeholders are involved right from the planning phase so that everyone understands the project's goals and objectives. Facility Manager (F), Owner (O), Contractor (C), Architect (A) and Specialty Consultants (S) or "FOCAS" team members are formed early on in the project's development phase to benefit the LEED project. Specialty Consultants(S) is the lobby of all possible consulting agencies involved in the project, even including those who perform during the operations and maintenance phase. Team members are required to understand the concepts of green building and become familiar with the LEED credit requirements. The presence of a LEED Accredited Professional among the team would be an added advantage for the team, in addition of earning an additional credit point. Project Team members should be able to contribute to the group meeting process also called "Charrette", where each participating member looks into the opportunity of scoring LEED credit points and approves its attainability. A target LEED score of "Platinum" or "Gold" is set by the group based on the project characteristics.

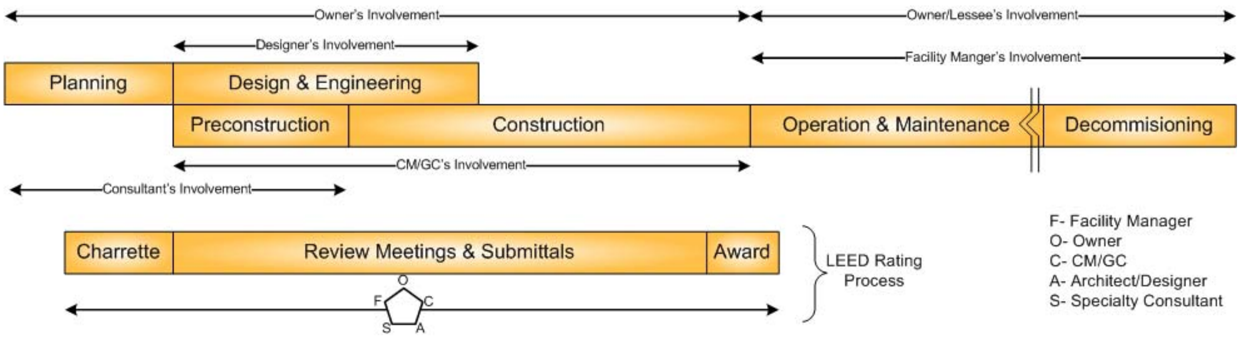

Figure 4: Green Project Delivery Method

The charrette is followed by regular review meetings to monitor the progress to attain the target LEED score. Project team members are also required to go through specific documentation process or “Submittals” to facilitate the LEED certification process. This goes along with the regular design and construction process similar to other delivery methods. Upon completion of the project, submission of all documentation to the U.S. Green Building Council and the technical review of the facility’s operations, an approval and a metal LEED plaque indicating the certification level is awarded to the project team.

A comparison between LPDS and GPDM, is presented in Table 1. This comparison is inspired from a previous study that compared lean to other forms of project management (Owen et al, 2006).

Table 1: Comparison between LPDS and GPDM (after Owen et al. 2006)

	LPDS	GPDM
Evolved from	Toyota Production Methods/ Koskela TFV Theory/ Theory of Constraints/ Complexity Theory/ Systems Thinking	Design-Build Delivery Method CM at Risk Traditional AEC construction project management
Key Tenets	Waste Reduction, Flow and Value	Early design involvement, Environmental performance, Sustainability
Features	Work structuring, production control, project definition, lean design, supply and assembly	Charrettes, project goals, target score, FOCAS matrix
Essential	Reliability	Environmental sustainability

Decisions Delayed Until Last Responsible Moment	Partial (Last Planner) but evolving	Yes
Environmental Sustainability is a Priority	No	Yes

The intersection of production systems, defined in the domain of the Lean Project Delivery System, or LPDS (Ballard 2000) bears a resemblance to the concept of the GPDM. In the LPDS, the project is structured and managed as a value generating process, downstream stakeholders are involved in front end planning and design through cross functional teams, and project control has the job of execution as opposed to reliance on after-the-fact variance detection. In the GPDM, when the client convenes the first charrette with other project stakeholders to discuss and define the level of LEED certification required for the new building, the LEED attainment process is designed. This process is designed with the participation of all parties involved with the design, delivery and assembly of materials on site, who are expected to make suggestions to improve product quality, safety, productivity or quality of work. This is one of the principle guidelines for LC. There is no data to substantiate the impact on productivity due to LEED attainment, but it is certainly a potential area for future research. In order to get the LEED credit points, the contractor and the client need to document the design, construction and facility management processes as they impact the green performance of the building. Material suppliers, inspectors and subcontractors provide feedback on the operations, material delivery and quality control.

CONCLUSIONS AND FUTURE RESEARCH

This paper presented a review on the LEED green building rating and related delivery systems for new construction in the United States, and their implications to AEC+P+F integration. A proposed FOCAS matrix provided new ways to view all phases of building design, construction and maintenance, and to allow for means of collaboration and better customer satisfaction with the project due to LEED attainment. Regarding the proposed delivery system for green projects, the intersection of production systems, defined in the domain of the LPDS bears a resemblance to the concept of the GPDM. In the LPDS, the project is structured and managed as a value generating process, downstream stakeholders are involved in front end planning and design through cross functional teams, and project control has the job of execution as opposed to reliance on after-the-fact variance detection. In the GPDM, when the client convenes the first charrette with other project stakeholders to discuss and define the level of LEED certification required for the new building, the LEED attainment process is designed. This process is designed with the participation of all parties involved with the design, delivery and assembly of materials on site, who are expected to make suggestions to improve product quality, safety, productivity or quality of work. This is one of the principle guidelines for LC. There is no data to substantiate the impact on productivity due to LEED attainment, but it is certainly a potential area for future research. In order to get the LEED credit points, the contractor and the client need to document the design, construction and facility management processes as they impact the green performance of the building. Material suppliers, inspectors and subcontractors provide feedback on the operations, material delivery and quality control. Further research, as it pertains to application of lean principles is needed to determine the contribution from this practice to improving the sequencing of tasks, to simplifying coordination, to revealing new opportunities for improvement, and to making project outcomes more predictable.

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