Design Process Integration for Sustainable, High Performance Buildings

Authored by

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ABSTRACT
Buildings that address energy efficiency, durability, life-cycle performance, occupant well-being and productivity are known as sustainable, high performance buildings. There is broad recognition that these buildings demand increased levels of optimization among structural, envelope, mechanical, electrical and architectural systems. Therefore, a whole system thinking approach, interpersonal skills, and improved project delivery processes become more critical in these projects compared with traditional ones.

To rigorously quantify the benefits of delivery attributes for sustainable, high performance buildings, recent research piloted preliminary metrics that included owner commitment, project delivery methods, contractual arrangements, procurement methods, design integration, construction applications, and project team characteristics. Verification of these metrics through case studies in a follow up study showed timing of contractor’s involvement, owner commitment, and integration in the design process as critical aspects of project delivery aside from the delivery method adopted. Although the delivery methods (e.g., design-build, design-bid-build) contributed to facilitating various levels of integration, other attributes such as multidisciplinary collaboration, level of interaction and chemistry among project participants, sharing common goals, and team competencies showed to be more important for level of design integration and successful outcomes across all performance metrics (i.e., cost growth, delivery time, and sustainability goals).

A case study conducted through post-construction interviews with key project team members points out to important variables in the design process for achieving project success through integration. A shortcoming observed in this research was the difficulty of design integration evaluation through post-construction interviews and survey applications. Ethnography can serve as a better alternative methodology for design process observation starting from early stages of planning until construction. Careful investigation of the metrics used and findings in this case study lays the foundation for a well-designed future ethnography research for evaluating the level of design integration in sustainable, high performance building projects.

KEYWORDS: Sustainability, high performance buildings, project delivery, integration.

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INTRODUCTION
The concept of sustainability was raised because of growing awareness of the global links between mounting environmental problems, socio-economic issues to do with poverty and inequality, and concerns about a healthy future for humanity (Hopwood et al. 2005). Brundtland Report (1987) provides the widely acceptable definition of sustainable development as “development that satisfies the needs of the present generation without compromising the chance for future generations to satisfy theirs” (WCED 1987). Sustainability covers three interdependent and mutually reinforcing pillars, which are environmental responsibility, economic return (wealth creation), and social development (UN 2005; Ding 2008) Since its inception in the 1970s, sustainable development has become a new paradigm of development around the world (Lele 1991).

As one of the main sectors of the national industry, construction is expected to contribute more to sustainable development. Construction markets accounts for 13.4% of the $13.2 trillion U.S. GDP (USGBC 2010). This includes all commercial, residential, industrial and infrastructural construction. New commercial and residential building construction constitutes 6.1% of GDP (USGBC 2010). Building construction consumes 38.9% of U.S. primary energy use and 72% of U.S. electricity consumption (EIA 2009), and 40% of raw materials globally (Roodman and Lessen 1995) and 13.6% of all potable water (USGBC 2010). Moreover, residential and commercial-building sectors generated approximately 7.9% of carbon dioxide emissions worldwide in 2004 (IPCC 2007).

While traditional design and construction focuses on cost, performance and quality objectives, sustainable design and construction expands its realm to attributes such as low energy consumption, reduced air emissions, and minimal waste generation (Vanegas et al. 1995). Many green-building assessment systems such as Energy Star (Energy Star 2010) Leadership in Energy and Environmental Design (LEED) (USGBC 2010), Green Globes (Green Globes 2010), and Spirit (SPiRit 2010) have been developed. These systems aid project teams in sustainable building design and construction. Their use has accelerated. For example, the number of architecture engineering and construction (AEC) industry professionals who have participated in the construction of a building that achieved LEED certification went from one in ten to one in five between 2003 and 2006, and this number continues to grow (BDC 2006). $10-20 billion value of green building construction starts by 2010 is expected (MCH 2007).
Although the market for sustainable buildings is still growing, the scope of the required performance from such buildings has increased. Sustainable buildings are now expected to have a maximum energy efficiency of envelope, mechanical and lighting systems, coupled with improved indoor environmental quality to enhance occupants’ well being. These buildings are categorized as sustainable, high performance buildings. These buildings offer many benefits in terms of energy efficiency, improved indoor environmental quality, increased health and occupant productivity and reducing resource usage on building construction and occupation (Fisk 2000; Heerwagen 2000; Morton 2002; Lapinski et al. 2006; DOE 2009).

Even though sustainable high performance buildings offer many benefits, sustainable building development faces challenges (Lapinski et al. 2006). Those challenges are related to additional requirements which need to be fulfilled by owners and project teams before achieving the benefits of high performance sustainable buildings. They also require integrated design process, interdisciplinary collaboration, complex design analysis, careful material and system optimization (Riley et al. 2004; Lapinski et al. 2006).

A general belief in the AEC industry is that high performance sustainable buildings require increased initial costs of building construction. The higher cost is due to project delivery cost instead of the direct cost of the building construction (Kats et al. 2003). The current project processes used to deliver sustainable building are often laden with wasteful re-work, delays, changes and over production (Horman et al. 2004). Therefore, improvement of the delivery process used to deliver green building projects can be a solution to the high initial cost problem.

The purpose of this paper is to explore different attributes of project delivery and their impact on level of design integration through a case study. Post-construction interviews were conducted with key project participant members to point out important variables in the design process that affect project success through integration. Finally, shortcomings of this research are recognized. Alternative methods are discussed for further understanding design integration for sustainable, high performance buildings.

BACKGROUND
Chan et al. (2004) describes five main categories of critical success factors of a construction project. Those factors are human-related factors, project-related factors, project procedures, project management actions and external environment. All of those factors can be addressed in the delivery of the project. Therefore, construction project procurement and delivery
system employed by the owner should be improved and enhanced to achieve successful project performance.

Project delivery processes include programming, procurement, design, construction, and turnover (Lapinski et al. 2006). Project delivery systems define how project teams form, their working relationship, and levels of involvement over project time lines, and incentives to encourage contribution of to the project (Korkmaz, 2007). Common project delivery systems in the U.S. include design-bid-build, design-build, and construction management at risk. Each system has a different process and involves different relations between project participants.

Project delivery impacts on building outcomes are often misunderstood, and limited to the choice of methods; e.g., design-bid-build, construction management at risk (Konchar and Sanvido 1998; Thomas et al. 2002; Ling et al. 2004). When examined more carefully, exemplary outcomes in sustainable, high performance buildings are related to many other attributes than simply picking a delivery method (Korkmaz et al. 2010b). Project delivery method and its attributes should be selected according to the projects’ characteristic. Misunderstanding a project’s characteristics is likely to lead to defective delivery processes and higher costs (Smith 2003).

Unlike traditional buildings, sustainable ones have more delivery constraints (Riley et al. 2004; Horman et al. 2006; Kibert 2008). Characterized by technical systems with high levels of interdependency and interaction, these buildings demand increased levels of design collaboration and coordination between structural, envelope, mechanical, electrical, and architectural systems during design (Magent et al. 2009). This interdisciplinary interaction suggests that attributes such as early involvement of participants (Riley and Horman 2005), team experience (GSA 2004), levels and methods of communication, and compatibility within project teams result in better outcome (Lapinski et al. 2006; Korkmaz et al. 2007; 7 Group: Boecker and Reed 2009; Enache-Pommer and Horman 2009). Recent research has also shown that early introduction of, and owners’ commitment to, “green” enables achievement of green goals at lower costs (Beheiry et al. 2006; Lapinski et al. 2006).

There is extensive research presenting relations between project delivery process characteristics and performances outcome (Konchar and Sanvido 1998; Molenaar and Songer 1998; Thomas et al. 2002). The research provides a set of indicators to define project delivery characteristic and describe performance metrics to measure project outcomes. Korkmaz et al. (2010a) piloted preliminary metrics that included owner commitment, project delivery
methods, contractual arrangements, procurement methods, design integration, construction application, and project team characteristics.

Korkmaz et al. (2010b) verified these metrics through case studies in a follow-up study showing that among the seven metrics, timing of contractor’s involvement, owner commitment, and integration in the design process are the critical aspects of project delivery aside from the delivery method adopted (Korkmaz et al. 2010b). Verification also show that although the delivery methods (e.g., design-build, design-bid-build) contributed to facilitating various levels of integration, other attributes such as multidisciplinary collaboration, level of interaction and chemistry among project participants, sharing common goals, and team competencies showed to be more important for level of design integration and successful outcomes across all performance metrics (i.e., cost growth, delivery time, and sustainability goals).

METHODOLOGY

This paper presents a detailed case study conducted through post-construction interviews with key project team members. This case study points out important delivery variables for achieving project success for sustainable, high performance buildings.

The research team interviewed project participants of a commercial office project located in Southern California. The building is 66,000 sq.ft and belongs to a private owner. Owner, designer and contractor (in this case a design build (DB) team) of the project were interviewed separately.

The sustainability performance of the projects was evaluated under Leadership in Energy and Environmental Design (LEED) rating system under New Construction category. LEED is a point based system developed by US Green Building Council (USGBC) focusing on the: sustainable site development, water savings, energy efficiency, materials selection, indoor environmental quality, and innovation in design. With the LEED green building certification process buildings can achieve a certification, silver certification, gold certification or platinum certification (USGBC 2010).

The interviews addressed several structural and open ended questions regarding the building design process and its relation to the performances outcomes in term of cost, time, quality (owner satisfaction) and high performance achievement of the buildings. Following Korkmaz et al. (2010b) some attributes of the project’s delivery was investigated carefully to define their contribution to project’s design integration. The interviews also addressed other
related questions such as background of the idea to pursue green (green initiation), project delivery and procurement method, contractual arrangements, and project performance.

RESULTS
Green Initiation
The idea to pursue a green building was initiated by the owner. According to the owner this choice was directed by the vision of his company to pursue an environmentally friendly building. The DB team, however, said even though the vision for building green was initiated by the owner, it was a result of the owner wanting to set an example of sustainability for its clientele as the owner is a water utilities company in Southern California. The installation of Photovoltaic (PV) cells was driven by motivation to take advantage of the State of California PV installation initiative.

Contractual Arrangements
According to the owner, the projects objective from inception was to achieve a LEED Gold Certification, and this was a contractually binding clause with the contractor. There was also clauses regarding incentive for achieving LEED Platinum certification and liquidated damages clause for delays. The DB team to the contrary claimed that the objective of the project was to achieve LEED platinum, which was contractually mandated. There was also a penalty clause for not achieving the platinum certification. The DB team also claimed that there were liquidated damages for exceeding the schedule and bonus clauses for bringing the project ahead of schedule; but there were no clauses regarding damages or bonuses in term of cost, quality and safety.

Project Delivery and Procurement Methods
The project was delivered though a design-build (DB) method. However, the design and build team was involved after about 20% of the design had been completed by a previous designer. In terms of the procurement method, the owner used a qualification based process to select the first architect who he contracted under a cost plus fee. When the owner terminated the relationship with the first designer, he invited three design and build firms to bid on the project. The eventual winning bid was selected using a best value selection. The winning design and build company was a joint venture between a construction and a design firm. The DB contractor was contracted under a Guaranteed Maximum Price terms.
**Design Process Integration**

As mentioned before, the DB team was involved after about 20% of the design had been completed by a previous designer without the involvement of any green strategies. Hence, they had to incorporate the green design strategies as a continuation of the previous design. The owner required that the building should follow the envelope designed by the previous designer. The DB team claimed that the fact that they have to build up on the previous design gave a level of inflexibility to their design team as they probably would have pursued different options if they had been contracted to design the project from inception. They had problems later on with the building’s orientation, panel joints, and windows layout which according to them were not designed with an aim of achieving sustainable goals in mind.

Due to the project delivery method chosen for the project, the design and construction team were acting as a single entity from inception. As part of the design-build team, the mechanical, electrical and plumbing (MEP) consultants were on board as a part of the design team from the time the DB team got awarded the project.

The role of the design coordinator was undertaken by the construction outfit in the DB team. There were at least two design charettes lasting three to six hour involving the owner, designer and a consultant of sustainable design as a part of DB team. There is no LEED Accredited Professional (LEED AP) from the owner or DB team side. During these charettes, metrics where developed regarding points to be achieved, when they will be achieved, the documentations needed for achieving them; and responsibilities for achieving them were assigned accordingly to all member of the team including the owner. Besides the design charettes, there was regular communication between all parties including weekly meetings and regular communication through email, fax and phone conversations.

There was no specific project coordination technology such as Building Information Modeling (BIM) in the design and construction process. All submittals and correspondences were logged using Microsoft Excel sheets, and the contractor used Primavera as the scheduling software on the project. These methods of communication were judged as effective by all parties.

Both owner and DB team claimed that the project method selected facilitated the design integration. This method allowed the DB team to incorporate efficiencies not only in the construction process but also in the design. Even though the DB team consists of a joint venture between a contractor and a designer company, both of them acted as a single entity during design and construction process.
The owner and DB team valued that regular communication between all project participants. Even though none of coordination software such as BIM was used, they can maintain the regular communication. All submittals and correspondence was logged and followed using spreadsheet. This fact proved that a sophisticated tool of communication is not a must in achieving high level of interaction among project team members. Both parties rated their level of communication as excellent.

Furthermore, the owner and DB team claimed that they had a perfectly synchronized relationship. A good chemistry between parties made it possible of the project teams to act as a single entity with a shared common goal. The penalty and bonuses clause also facilitate this harmonic interaction, and at the end of the project all parties are satisfied with the result.

**Project Outcomes**

Even though all parties are satisfied with the final performance of the project, some shortcomings still could be observed: 10% cost growth, and delay in the project as the result of late involvement of DB team. As mentioned before the DB team had to continue the project based on 20% design that had been done by another designer.

In relation to project schedule, the owner claimed that the project was delayed, which resulted in $5,000 liquidated damages charged against the contractor. However, according to the contractor they were no delays on the project. As intended in the contract, the project achieved a LEED Platinum certification after completion.

**SHORTCOMINGS AND FUTURE RESEARCH**

A shortcoming observed in this research was the difficulty of design integration evaluation through post-construction interviews and survey applications. Some information provided by different parties seemed to contradict. There are two main possible reasons for this to happen. One is that the project participants cannot recall what really happened during the project because the interview was conducted after construction. The other possible reason is that each project participant has their own opinion and understanding about the project. To overcome this shortcoming, future researchers should use ethnography as an alternative methodology for design process observation starting from the early stages of planning until construction.

As one of the common methods in social sciences, a research can use ethnography to observe project participants interaction over time and in detail (Atkinson and Hammersley 1994). The observation can be documented into a daily log to describe the actual phenomenon within the project organization including integration in design process. This
method will enable the simultaneous recording of events as they occur, which should lead to objective evaluation of the integration level in their delivery processes. Based on the result gathered from ethnographic observation, further research using social network analysis (SNA) can be used to model and analyze project team integration. Developed by Moreno in 1934 to analyze group interactions, SNA has been recently adopted to model construction projects and organizations (Chinowsky and Taylor 2007; Chinowsky et al. 2008; Di Marco et al. 2010). Information gathered from ethnographic observation can be translated into a social networks model of construction organization using SNA.

The social network emphasizes that to achieve high performance result in construction, projects should be managed as social collaborations (Chinowsky et al. 2008). Build under social collaborative perspective, the model will show how all participants in project organization develop into a team that has shared common objectives, values and trust. SNA will model all of the integration variables on the entire delivery process of the project. Such variables include experience, reliance, trust, values, and communication (Chinowsky et al. 2008). Using a SNA analysis and visualization package such as UCINET (Hanneman and Riddle, 2005; UCINET, 2010), the information and data of the integration variables gathered from ethnographic observation can be transferred into mathematical models and visual maps. The combination of ethnography and SNA will facilitate research for defining the level of integration in the delivery of sustainable, high performance buildings and all its variables.

CONCLUSIONS
The case study presented in this paper shows the selected project delivery method contribute to design process integration. However, project delivery method selection is not the only factor that can bring high level of integration. There are some other factors that are even more important than the delivery method. All project participants in this case study reported that they were able to achieve the intended project goals due to several distinct factors, including: intense communication among project parties, shared project team goals, and good chemistry among project members. The DB team also pointed out the importance of involving other consultants with multidisciplinary area of competencies starting from the early stages of the project. It is also very important to involve sustainability and project participants with expertise in sustainability starting from the earliest stages of the project. Scope changes during the later stages of design and/or construction can cause delays and cost growth.

Observing some difficulties in design integration evaluation through post-construction interviews and survey application, the researchers suggest ethnographic observation for
understanding integration in future project delivery research. This method combined with SNA will allow objective evaluation of design integration and also development of social network model of construction organization to simulate team integration and its impact on sustainable, high performance achievement of building projects.

REFERENCES


