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Evaluating Integrated Design Process of High-Performance Green Buildings

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High-Performance Green (HPG) buildings are designed through an approach called Integrated Design Process (IDP). The approach emphasizes early collaboration of downstream stakeholders in upstream decision-making and consideration of interactions among various building systems (mechanical, electrical, etc.) by including the representatives of various disciplines in design team early on through the design process. Managing the IDP is of special importance if the teams are to be successful in achieving high-quality sustainable outcomes at regular prices. Therefore, owners and project teams need to comprehensively evaluate their performance on 'integrated design' in various points during project delivery in order to avoid the waste of resources and to improve efficiency. The main objective of this article is to use the Contextual, Input, Process and Product (CIPP) model of evaluation and apply a qualitative research to provide a framework for evaluation of IDP. The article reports the efforts and findings of researchers in this phase of a doctoral research project and presents the planned quantitative research design for its future phases.

Key Words: Integrated Design Process, Evaluation, High-Performance Green buildings, CIPP

Introduction

There is a wealth of literature on the importance of implementation of Integrated Design Process (IDP) for delivery of High-Performance Green buildings (HPG), its benefits and the important factors (7group and Reed 2009, Kibert 2008, Yudelson 2008). The process is an inclusive process where the representatives of various disciplines involved in design and construction of HPG buildings are called early on as part of the project team. Along with the owner, they discuss the ideas and opportunities for achieving project objectives and consider the impact of decisions across disciplines. Ideally, the final design alternative is a design that possesses optimum performance of building systems, given project constraints and priorities.

A successful IDP process requires an environment of collaboration, trust, systems-thinking, free exchange of information, etc. among the project stakeholders. There exists, however, no systematic comprehensive framework in the field for project teams of HPG buildings to evaluate their IDP process for its weaknesses and strengths so the teams can diagnose, treat and improve it.

Reporting a doctoral research project, this article intends to explain the theoretical framework and methodology of the research and present the findings of its previously-accomplished phases. The research objective is to advance understanding of Integrated Design Process (IDP) of HPG buildings and provide a comprehensive evaluation framework for the process using the Contextual, Input, Process and Product (CIPP) model which is considered among the most comprehensive approaches to evaluation of projects, services, products, etc. To achieve the research objectives, researchers apply a sequential mixed-method (qualitative-quantitative) methodology. The outcome of qualitative phase is a proposed evaluation framework which consists of a list of the criteria for evaluating the IDP along with the evaluation scale. The criteria are then assigned weight for their relative importance which can be aggregated into a numerical index, Integration Maturity Index (IMI), upon evaluation. The second phase of the research which is still underway is a quantitative research using questionnaire survey to test the hypothesis that "*more mature integrated design processes are able to deliver buildings which are more successful with respect to time, cost, and sustainability*".

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Literature Review

The literature review focused on three major issues: a) the issue of integration in construction industry and its applications in project delivery; b) green buildings and their integrated design process; and c) evaluation models, especially CIPP evaluation model.

Integration

Construction industry is suffering from the lack of efficiency and owner dissatisfaction and it is suggested that '*integration of processes and teams*' should be applied in the industry along with '*focus on the customer*', '*committed leadership*', '*commitment to people*' and '*quality-driven agenda*' to change toward more efficient, less wasteful outcomes (Egan 1998).

The term 'integration' is used in a variety of contexts including organization theory, management, manufacturing, construction, etc. The term is traditionally interpreted as coordination and collaboration of interdependent subsystems in order to achieve the characteristics of a unified whole in a system. The more differentiated a system, the higher the needed level of integration (Glouberman & Mintzberg 2001).

In construction industry, the term integration is often interchangeably used with collaboration (NASFA *et al.*, 2010) and refers to an environment where project stakeholders work closely together as a team towards project objectives through sharing of information, joint operations (such as decision-making, etc.) and alignment of their cultures (Baiden *et al.* 2006, Baiden & Price 2011, Dulaimi *et al.* 2002, Mitropoulos & Tatum 2000, Rahman *et al.* 2007). Nam and Tatum (1992) use integration as an antonym to disintegration which, according to them, is the outcome of "*incongruent goals and consequent divergent behaviors*" in construction projects. They also state that there is close relationship between integration and cooperative project environments. Similar to this application, Baiden and Price (2011) define integration as "*where different disciplines or organizations with different goals, needs and cultures merge into a single cohesive and mutually supporting unit with collaborative alignment of processes and cultures*".

An application of the term in construction industry takes place in the context of project delivery. Various project delivery systems allocate roles and responsibilities differently and implement different sequencing of project phases and activities. This results in different degrees of integrated project environments. In general, project delivery systems with more integrated project sequencing tend to benefit from more integrated project team environments. A recent approach to project delivery is Integrated Project Delivery (IPD), introduced to deliver value to owners by increasing collaboration and integration among parties. The IPD projects usually *integrate* four areas in construction practice (CMAA 2010): agreements (multi-party contract between key team members), leadership, information (BIM, etc.), and processes (adaption of lean theory).

Integration and Integrated Design Process of High-Performance Green (HPG) Buildings

Another related application of 'integration' is in the context of design process of High-Performance Green buildings which will be investigated in this research.

Buildings are among the major consumers of energy and natural resources and at the same time, have a significant role in producing wastes and emissions that jeopardize the health, life and survival of humans and species. Statistics show that buildings consume about 40 percent of extracted materials, 40 percent of primary energy and more than 70 percent of electricity in the US (EIA 2008). They also generate 30 percent of the waste produced in the United States (USGBC 2009). To improve the environmental performance of buildings, High-Performance Green (HPG) buildings have been introduced to the industry. These buildings are designed, constructed and rated against a set of strict performance requirements prescribed by rating systems such as LEED, BREEAM, etc. A HPG building is a building "*that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity*" (Energy Policy Act, 2005). For design of these buildings, various skills and disciplines are implemented in order to consider the interactions of various building systems with the objective of creating buildings that are more responsible towards the environment (Kwok and Grondzik 2007). Integration in this context can be defined as 'collaboration among project stakeholders with the goal of creating an environment of whole-system thinking in order to generate a friendly product for the environment and deliver the best value to owners'.

Evaluation Model - CIPP

Integrated design process of HPG buildings should be evaluated so that the sources of inefficiency in the process are diagnosed and treated and thus, the waste of resources is avoided and the process is improved. Moreover, evaluation of the process provides the project teams with the opportunity to benchmark their performance in a project with past and future projects.

There exist many evaluation approaches that are used to evaluate project, services, etc. in various contexts and for different purposes. Context, Input, Process, and Product (CIPP) evaluation model is considered the best of these approaches, with respect to feasibility, utility, accuracy and propriety, and can be used for improvement and accountability purposes (Zhang *et al*, 2011). In this evaluation model, proposed by Stufflebeam (2003), the performance of a program, service, project, etc., is evaluated through a "comprehensive framework" under four categories of context, input, process and product (Stufflebeam 2003, Stufflebeam & Shinkfield 2007).

In the CIPP model which has extensive use in education setting, context evaluation focuses on the needs, challenges and opportunities within a defined environment. Input evaluation makes an assessment of the resources available and proposed strategies. Process evaluation focuses on the activities and factors critical to successful completion of them. Product evaluation answers whether the intended outcomes were achieved (Stufflebeam & Shinkfield, 2007). A major advantage of CIPP model is that it provides the opportunity to assess a process, not at the end of it and based on its outcomes, but rather during the process and based on a combination of measures in addition to outcomes.

This research intends to apply the Stufflebeam's CIPP model in the context of HPG projects to construct a framework for evaluation of the maturity of integrated design process of HPG projects.

Research Methods

Following the review of literature in the field which was conducted with the aim of reviewing critical knowledge that surrounds the proposed research subject and establishing a theoretical framework for that, a sequential mix method research methodology (qualitative/quantitative) was designed to achieve the research objectives.

In qualitative phase, which will be further explored in next section of this article, a study on three case-studies and interviews with 15 expert professionals were conducted to identify the critical factors in IDP of HPG projects and achieve operational tangible criteria for those factors. Based on the findings of qualitative research, a CIPP model for evaluation of ID process of HPG projects was constructed by classifying the identified factors/criteria under four categories of context, input, process and product.

In the next phase, the model will be presented to 7 judges to evaluate it for its validity, reliability and accuracy and to score the items on the model based on their relative importance in IDP of HPG projects. Finally, a questionnaire survey will be prepared based on the refined model and distributed among project stakeholders, especially design team and owners, of HPG projects. The survey results will be used to validate the model and to find the quantitative association between the criteria in the model and the outcomes of HPG projects.

Criteria Identification and CIPP model development

The first phase of this mixed method research was a 'qualitative research' which aimed at advancing the understanding of integrated design process achieved through the literature review and identifying the '*context', 'input', 'output'* and *'product'* factors and criteria, based on the CIPP evaluation model, that are critical to be evaluated in integrated design process. At this qualitative phase of research, we did two separate studies. First, three case-study HPG projects were studied and 2-hour in-depth semi-structured interviews with their project parties (6 interviewees; owner, architect and general contractor) were conducted. The studied cases include a net-zero energy building certified by Living Building Challenge, a Gold-rated and a Silver-rated LEED building. In other study at this phase, in-depth semi-structured interviews were conducted with 15 professionals (representing architect, general contractor, mechanical engineer, and structural engineer) who possessed extensive experience of working as the integrated design team member of HPG projects. The questions of interest at this phase addressed type and extent of involvement of various disciplines, type of activities professionals carry out during the process, important collaborative issues that enable or challenge the success of the process, etc.

The collected qualitative data were coded in Dedoose, a qualitative research analysis tool, and analyzed. The outcome of qualitative research (case-study and interviews), and literature review, is 21 factors under four categories of context, input, process and product (figure 1) and operationalized into a total 75 criteria, that were recognized as critical in integrated design process and thus, could be used as criteria for evaluation of the whole process. The '*contextual'* factors were indeed the factors that are often set before the start of the process and that affect the structure and configuration of the design process. Examples of these factors include project complexity and uncertainty. Most of the times, the project team has little or no control over these factors. *'Input'* factors are the factors that feed the process and thus, impact both the process and its products. An example of these factors is team capability. '*Process'* factors were factors that emerged during the integrated design process itself as a result of interaction among the team members and their activities. Such factors include trust, communication, systems-thinking, joint operations, etc. Finally, the '*product'* factors are the outputs of the process and what is achieved through the interactions of team members during the process. In the context of this research, the '*product'* is the performance of a HPG project with respect to time, cost, and sustainability. Figure 2 shows a random process factor along with 4 criteria that operationalize it.

These factors/criteria can be measured by participants, especially owners and designers, of HPG projects through 7-point Likert scale which assesses the performance of the project team on each criterion based on a range of extremely low to extremely high.

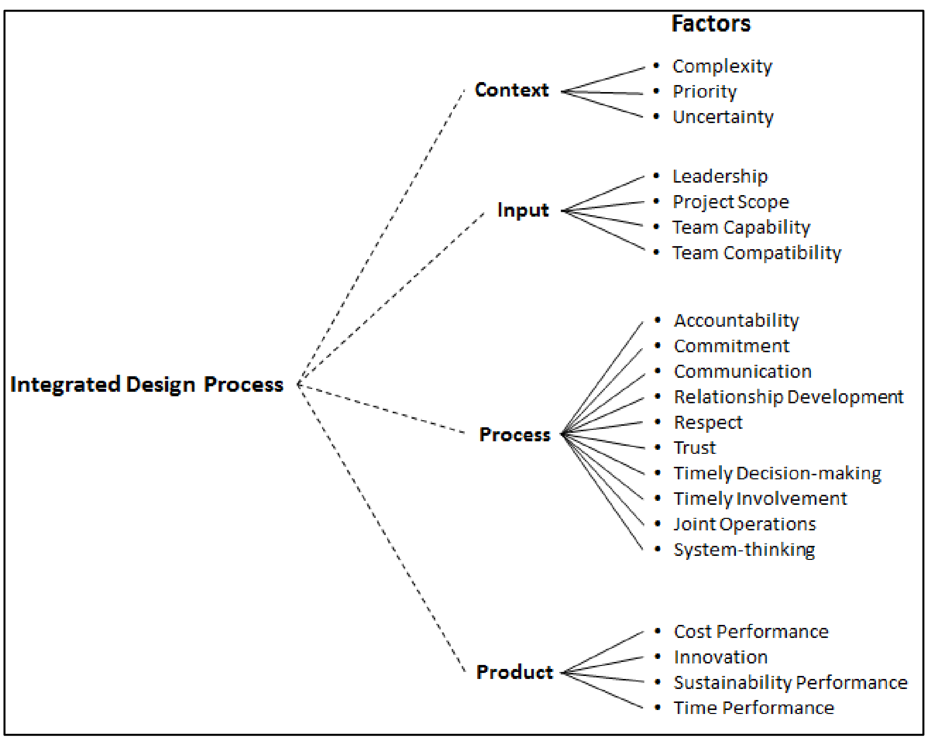

Figure 1. CIPP model for evaluation of Integrated Design Process (IDP).

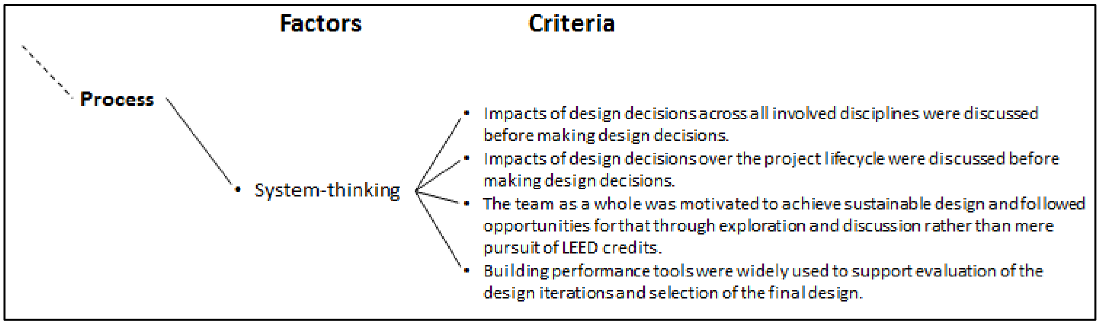

Figure 2. A random factor in the CIPP model along with its operationalizing criteria.

Weight Assignment and Scoring

The 21 factors and their operationalized 75 criteria that were identified through previous stages of the research, based on the CIPP model, are not equally important in integrated design process and their relative importance should be taken into account for any comprehensive evaluation. To account for this consideration, we will ask 7 judges with extensive expertise and experience in integrated design process, as recognized by their publications and research, at the next phase of research to assign weight to the factors and criteria based on their relative importance in integrated design process. The weights will reflect the extent to which the respective factor has the potential to enhance the effectiveness of integrated design.

The method that will be applied in this phase is Analytic Hierarchy Process (AHP) which is a widely-used method for multi-attribute decision-making. The criteria weights will be used later for constructing an index that represents the performance of integrated design processes.

Impact Assessment and Hypothesis Testing

Final phase of the research will be a quantitative research through which the researchers attempt to construct the Integration Maturity Index (IMI), as a reflection of the aggregate maturity of integrated design process, and tie it to the 'product' criteria (time, cost and sustainability) in order to test the hypothesis that "*more mature integrated design processes are able to deliver buildings which are more successful with respect to time, cost, and sustainability*".

To do this, a questionnaire survey consisting of checklist of the evaluation criteria will be designed and distributed among the project parties of LEED-rated buildings. The participants will be asked to rate the performance of their integrated design processes on the criteria through a 9-point Likert scale. Regression analysis then will be applied to investigate the association between the resultant IMI index and product criteria (i.e. project performance criteria). Using regression analysis will also enable researchers to realize the significance of the effect of context, input, and process criteria on product criteria.

Findings

The main outcome of the qualitative research phase of this doctoral project is a checklist of 21 factors and 75 criteria organized into a proposed CIPP evaluation model for IDP of HPG projects. The main characteristics of this model are summarized in the table below:

Table 1
Characteristics of the proposed CIPP evaluation model of IDP of HPG projects

Evaluation object	Integrated Design Process (IDP) of High-Performance Green (HPG) Buildings
Purpose	To diagnose the IDP To improve the IDP To provide an overall assessment of the IDP To guide decision-making To keep records and benchmark the performance of project teams
Suggested time of conduction	During the design process Following project completion
Foci	Process-related issues Team parameters
Criteria categories	Context Input Process Product
Criteria	21
Indicators	75
Audience	Owners of SHP projects Architects of SHP projects Core project teams of SHP projects
Suggested evaluation method	Interview Observation Survey

Some of the interesting findings of qualitative research that were used in development of evaluation framework are summarized below:

- Although many factors are critical in the success of integrated design, qualitative research revealed that collaboration, systems-thinking, communication and early involvement of team members are the major four factors. Indeed, about 17 percent of the themes explored in interviews with industry professionals corresponded to collaboration, followed by systems-thinking (16%), communication (11%) and early involvement (9%).
- Implementation of Integrated Design Process (IDP) by many of architectural firms is a procedure that is pursued not explicitly. In other words, these firms follow integrated design without explicitly naming it in their communications with owners and other project stakeholders.
- Integrated Design Process is more of a management exercise and the architect should have sufficient capability in bringing in the right consultant at the right time and leading the meetings in which the ideas for project and design alternatives are discussed.
- Coordination for involvement is an important element in integrated design. The architect should have the ability to realize and predict the design issues that need to be discussed at various points during schematic design. These design issues should be anticipated and discussed at the right time so that their impacts on other disciplines are considered timely and before any consequences.
- In an early activity, the project team should be focused on defining the goals and priorities of the project with the consensus of the whole team and set measurable performance criteria so that the success of the team can be measured throughout the process.
- Although consultants are not contractually under the umbrella of architects, it is still the architects who are, more or less, responsible for the consultants' work.
- Members of the team should be open to educate others throughout the process.

- Culture of the team is an important element for the success of the process. Architects should create an environment which team members in the meetings can ask questions that they think might be "dumb".
- Culture of the team should be based on trust and respect.
- The interviewees believed that they could trust other parties when they believed in their capabilities, when they could receive right information at right time without too much effort, and when their voice in design meetings, as a reflection of the concerns of their disciplines, were heard and valued.
- Respect occurred when people were sympathetic towards other parties' situations and went beyond their obligations in addressing those situations. In this way, all team members felt valued as part of the team.
- Unfortunately, most of times, eco-charrettees is only a place for discussing which LEED credits to pursue for a specific LEED rating. These meetings instead should be a platform for discussing innovative sustainable ideas.
- Attention should be paid that systems-thinking is applied to consider the performance of project over a complete life-cycle and across disciplines. Building performance tools should thus be applied widely before the selection of the final design alternative so that the project team can make the optimum design decision.
- A clear and easy-to-understand protocol for communication among the team members, especially with respect to sharing and updating of the documents, models, etc., should be established to avoid confusion and conflict.
- Building Information Modeling can be an important platform for achieving a shared understanding of project and for collaboration among various parties.

Conclusion

The findings of qualitative phase of this research along with the knowledge acquired through the literature review constructed the foundation of the CIPP evaluation model of Integrated Design Process of HPG buildings. The model evaluates the IDP process under four evaluation categories of context, input, process and product. C*ontext* evaluation has to do with complexity, priority and uncertainty of a HPG project. *Input* evaluation assesses project scope, leadership, and team capability and compatibility. *Process* evaluation focuses on collaboration, trust, involvement, systems-thinking, etc. Finally, *product* evaluation assesses cost, schedule and sustainability performance of a HPG project. The model is planned to be evaluated through a quantitative research.

The research findings reveal that success of the IDP process depends on a variety of issues which calls for higher levels of management and leadership by project team. This further justifies the importance of the present research in establishing a systematic framework for evaluation of the team efforts in IDP process.

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