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By

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ABSTRACT

INFLUENCE OF PROJECT DELIVERY METHODS ON ACHIEVING SUSTAINABLE HIGH PERFORMANCE BUILDINGS

By

Lipika Swarup

Buildings addressing energy efficiency, durability, life-cycle performance, occupant well being and productivity are known as sustainable, high performance buildings. Incorporating all high performance attributes to these buildings increases their complexity; therefore, interdisciplinary integration is required in their project delivery processes. However, the literature was found to be lacking in terms of the guidelines to lead these processes. Literature also indicates that project delivery methods adopted (e.g., design-bid -build, design-build, and construction management at risk) can influence the level of integration achieved by a project. To respond to the need in the industry, this study aimed *to understand the extent of the effect of project delivery methods and practices on the level of integration achieved by the project team and further its effects on project outcomes with a focus on sustainability goals.*

To achieve the study goals, the research adopted a case study approach and qualitative methods of analysis. The findings suggest that strong owner commitment towards sustainability, early involvement of contractor, and early inclusion of green strategies are attributes crucial to the delivery process that can have potential effects on project outcomes especially on sustainability goals. The results were verified through external validation with previous research findings.

To Baba and Nana,

"Who taught me to see the world for not what it is but for what it can be"

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CHAPTER 1

Introduction

1.1 Overview

The demand for sustainable buildings in the United States (U.S.) has been rising since the Arab oil restriction during the 1970's (Frej, 2005). However, since past years, due to the accelerated depletion of the natural resources, continuous damage to the natural environment, and U.S.'s significant contributions to the global waste generation, construction industry in the U.S. is undergoing transitions such as traditional to sustainable construction ([a]USGBC, 2008). Where traditional approach emphasizes only on cost, schedule, and quality performance of a building, sustainable construction expands its realm to attributes such as low energy consumption, reduced air emissions, and minimal waste generation (Vanegas et al. 1995). Although, the market for sustainable buildings is still growing, in the recent years the scope of the required performance from such buildings has increased and now it includes user satisfaction and occupant well being also. Such buildings along with sustainable issues also address issues such as indoor environment quality and user satisfaction, health, and productivity are known as sustainable high performance buildings (Harding, 2005).

As the level of complexity is mounting in the project program increased interdisciplinary interaction is becoming imperative for more optimized solutions. This interdisciplinary interaction is known as integrative design process and suggests that attributes such as early involvement of participants, level and methods of communication, and compatibility within project teams would result in better outcomes (7 Group and Reed, 2009). However, literature indicates that the above mentioned attributes might be affected by the project delivery methods (PDM) adopted by the project. There are primarily three PDM's that are utilized in the U.S. currently. These are: Design-Bid-Build (DBB), Construction Management at Risk (CMR), and Design-Build (DB). These essentially define the contractual relationship and communication lines between participants and therefore determine attributes such as time of entry / exit of participants, project team procurement methods, and contract conditions (penalties / incentives / risk / liabilities) between participants ([a]Korkmaz, 2007).

1.2 Need Statement

Literature indicates that attributes such as timing of participant entry, communication methods, and collaboration sessions have an effect on the level of integration achieved by the projects teams (WBDG, 2008). Also, it is reported that these could potentially affect project performance (WBDG, 2008). Although the sustainable industry and literature points towards integration and close relationships between players, a dearth of literature was found when the guidelines to achieve the same were researched upon.

To fill the gap in the literature this study attempts to understand (1) the level of project team integration achieved under each project delivery method in sustainable buildings and (2) if better project team integration leads to better project outcomes (e.g. higher sustainability achievement, lower cost, better construction schedule). Recent research piloted evaluation metrics for high performance green building project delivery, verified a data collection tool and analysis methods to improve the understanding on high performance green buildings (Korkmaz, 2007). This research will build on Korkmaz's exploratory study (2007) by employing its data collection tools and analysis methods and verifying its findings through utilizing a well thought case study selection process and analysis. The main research question this study is attempting to answer is: *'What is the extent of the effect of project delivery methods and practices on the level of integration achieved by the project team and further does it have an effect on project outcomes with a focus on sustainability goals?'*

1.3 Research Goals and Objectives

The main goal of this research study is to, "*determine the extent to which project delivery methods and practices affect levels of project team integration and whether this has an effect on project outcomes especially on achieving sustainable goals.*" The specific objectives of this study are to:

1. Determine the relationship between the level of integration achieved in the delivery process and sustainability goals;
2. Determine the relationship between various PDMs and the levels of integration achieved in the design process;
3. Identify the main project delivery attributes that have relations to project outcomes in a green building and examine the identified patterns according to various PDMs.

1.4 Research Methodology

Although traditionally, construction research is dominated by quantitative methods, recent researches (such as Korkmaz, 2007; Lapinski, 2006; Pulaski, 2005; Magent, 2005) recommend qualitative method as a valid approach for data analysis. Also due to the limited sustainable population and the variability that exists within it, conducting a statistically significant study was unfeasible. Therefore, it was determined that this research would follow a qualitative methodology. A description of the methodology steps is given next.

1.4.1 Conduct Literature Reviews

1. *Sustainable buildings:* This section describes a brief history of the concept of sustainability in buildings. It also addresses the current status and scope of the subject.
   a. *Sustainable high performance building:* All high performance buildings are sustainable buildings but it is not the same the other way around. This distinction was made with the help of the literature.
   b. *Green building assessment systems:* The level of sustainability in buildings can be evaluated by many different assessment systems. Each assessment system has its own way and criteria for calculating the level of sustainability achieved by a building. Therefore a thorough literature review of the available systems and their criteria's was important for this research. This review was instrumental in developing the performance metrics and choosing the case studies.

2. *Design management:* Design is one of the most important stages in the pre-occupancy phase of the project and has significant influence on the post-occupancy phase. Therefore it was important to understand in what ways the design stage can affect project performance and post-occupancy building performance.
    a. *Integrated Design Process:* Currently, the design process followed by the building industry involves participants from varied disciplines working in isolation. However, the literature supports the requirement of a more integrated process that advocates increased and early multi-disciplinary involvement.
    b. *Integrated Design Process in Green buildings:* Literature reports design phase as one of the most important stages in the preoccupancy phase suggesting that this stage can be responsible for the success or failure of the project. Therefore, for increased efficiency maximum integration and restructuring of the sequence is suggested in this phase.
3. *Project delivery methods:* Project delivery systems used by the industry at present such as the DBB, DB, and CMR are explained.
4. *Level of integration in the design and the project delivery systems:* This section explains the level of integration that exists in each PDM present. Superiority of no project delivery could be proven as each method had its own opportunities and constraints. These are described in this section with examples in the form of case studies.

5. *Project participants (roles and responsibilities):* This section discusses the roles and responsibilities of the project participants in the different stages of the project. Although there are many players involved in the projects participants whose roles are defined here are: owner, contractor, design team, commissioning agent, special value adding Consultants

6. *Performance Metrics:* The performance metrics to be utilized in the current study is one of the three main outputs of the research conducted by Korkmaz (2007). Guided by previous studies (Korkmaz, 2007; Konchar and Sanvido, 1998; Gransberg and Buitrago, 2002) this study has grouped the building evaluation metrics and attributes in to three categories. The three categories are 1) Project Delivery Attributes; 2) Building Performance Upon Completion, and; 3) Building Performance Post Occupancy. This study primarily focuses on the first two stages by investigating the effects of project delivery attributes (independent variables) on project performance at construction completion (dependent variables). Addressing the last stage occurs through owner perception, and therefore, the last stage becomes a component of the second stage as "Owner's Perception of the Resource Consumption and Level of User Satisfaction in the Post-Occupancy Phase." The description and scope of the two categories are given below.

   a. *Project Delivery Attributes:* This category evaluates the process followed for the execution of the building by documenting the subjective experiences and the method of evolution of innovative ideas for the optimization of project outcomes. It includes owner commitment; project delivery method, project team procurement, contract conditions, integration in the design process, and project team characteristics.

b. *Building Performance Upon Completion:* Metrics such as schedule, cost, quality, safety, levels of high performance, and owner's perception of the resource consumption and level of user satisfaction in the post-occupancy phase achieved (comparing the intended vs. achieved performance levels) clearly and quantifiably demonstrate the success or failure of the project (Korkmaz, 2007; Fowler et al., 2005; Gransberg and Buitrago, 2002; Konchar and Sanvido, 1998). Therefore this study has adopted these to evaluate the performance of the outcomes of the projects.

1.4.2 Develop, Test and Verify the Data Collection Tool

The data collection tool employed in this study is the second main output of the research conducted by Korkmaz (2007). It was utilized by the author to collect data from 40 high performance green projects. The current research has adopted and altered the tool according to research specific criteria (explained in Chapter 3).

This research was funded by the Charles Pankow Research Foundation and is part of a joint research conducted by scholars from Michigan State University, University of Colorado, University of Oklahoma, and Pennsylvania State University. The research team worked with an industry panel, consisting of leader's in the field of sustainable buildings, to get feedback at certain milestones, receive verification on research tools and outcomes, and receive support in case study selection and data collection. Therefore, after tool development, it was verified by the research team and the industry panel. It was then submitted and approved by the Institutional Review Board (IRB) at Michigan State University for compliance with human participant research rules. Next, the tool was tested on one pilot case study further to which final changes were made to the tool. Finally, the tool was used to collect data from 30 participants of the 12 case studies selected for this research.

1.4.3 Case Study Selection Criteria

This research focused on sustainable projects that have achieved one of the four levels of certification under United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®) assessment system. Although the research prioritized 8 projects that defined the boundary conditions; as the resources allowed the number was expanded to 12 case studies. The sample for this study was limited to green projects in the U.S., those included in the USGBC's database as LEED® 'New Construction' and 'Core and Shell' categories. The other criteria were: PDM selected, USGBC's LEED® rating, USGBC's LEED® certification level, location, function, personal rapport, and size.

1.4.4 Data Collection Process and Follow Up

The data was conducted in the form of structured interviews (General Accounting Office methodology to be followed). It was intended that a personal rapport was developed with the respondents to approach them with follow up questions. It was attempted that three respondents (i.e., owner, designer, and contractor) were contacted from each case study however, due to circumstances such as unavailability of the respondent or one entity performing the role of two, on an average two respondents were interviewed from each case study. Interviews were conducted via email and phone.

1.4.5 Data Coding

For the ease of analysis, the collected data was coded and managed at three levels (1) coding open ended responses, (2) coding survey responses and, (3) proposition development. These are discussed next:

1. *Coding open ended responses:* Two kinds of coding were used for the open ended responses (a) priori: codes developed before examining the data; (b) inductive: codes developed based on the frequency of the occurrence of the themes. This was conducted to find suitable quotes supporting or negating the survey results.
2. *Coding survey responses:* The data points were mostly coded as -1, 0 or, +1 based on their position in the data set as below average, average or above average correspondingly. This assisted to ascertain the level of success achieved by a project when compared to other projects within the data set.
3. *Proposition Development:* Due to the qualitative nature of the data from limited case studies, expected patterns defined as propositions were tested for validity. If the data strongly supported the proposition they were converted to results else were discarded. The primary four propositions used in this study are:
   a) Higher levels of integration in the design process will lead to higher levels of sustainability;
   b) CMR and DB will provide higher levels of integration in the design process compared to DBB;

c) Project delivery attributes affect final outcomes;

d) PDM's affect project outcomes through the level of integration in the project delivery process;

1.4.6 Data Analysis

This research adopted a case study methodology (Taylor et al., 2009) and followed a protocol, for qualitative methods of analysis, as suggested by Yin (2003) and Korkmaz (2007). Three approaches were adopted to examine the data; these were ***pattern matching, cross case synthesis and explanation building***.

1.4.7 Discussions and Report Results

Limited sample population resulted in non-generalizability of the findings. Therefore, to prove the validity of the current results they were discussed with results of six recent researches conducted in the same field. These studies are:

1. *Beheiry et al. (2006) Examining the Business Impact of Owner Commitment to Sustainability:* The purpose of this study was to establish a research mechanism to investigate the impact of corporate commitment to sustainability on capital project planning and capital project performance.
2. *Lapinski et al (2006) Lean Processes for Sustainable Project Delivery:* The purpose of this paper was to evaluate the life cycle of Toyota's capital facility delivery process to empirically identify the critical activities and capabilities that led to Toyota's South Campus project success. This utilized a post hoc process-

based analysis to identify where value and waste were generated in Toyota's delivery system.

3. *Korkmaz (2007), Piloting Evaluation Metrics for High Performance Green Building Project Delivery:* The research attempted to provide a foundation for future research by defining meaningful evaluation metrics, methods, and tools to collect and analyze high performance green building project delivery data.
4. *Enache-Pommer (2008), Lean and Green Healthcare Facilities: Improving the Delivery Process in Children's Hospitals:* This main aim of this study was to understand the building delivery process in green children's hospitals, starting from programming, through design, construction, operations and maintenance. An emphasis was placed on the affects of the delivery process and the stakeholders present in each project on the final product.
5. Molenaar et al. (2009), *Sustainable, High Performance Projects and Project Delivery Methods: A State-of-Practice Report:* This paper is the first part of a broader study that seeks to determine project delivery methods influence on owner's ability to achieve their sustainability goals in delivering building projects. This paper describes the state-of-practice in project delivery methods for achieving sustainable, high performance building projects.
6. *Bilec and Ries (2009), Preliminary Study of Green Design and Project Delivery Methods in the Public Sector:* The aim of this study was to examine possible relationships between design-bid-build (DBB), construction management (CM), and DB PDMs and green design with the goal of beginning to identify potential positive correspondence between them.

1.5 Research Scope

This study focused on determining the extent of the effects of PDM's and practices on the level of integration achieved by the project team and further on achieving successful outcomes with a focus on sustainable goals. The research boundary is stated below.

1.5.1 Scope of the Study

The study aimed to understand the underlying relationship between PDM's, level of integration achieved, and the final outcomes. Therefore, to achieve the intended target research scope and study boundaries were defined. It was determined that only the projects that adopted one of the three primary PDM's (i.e., DBB, DB and CMR) would be considered for the study. Also, due to the resources available and the location significance only U.S. based projects were considered. As the study focused on sustainable buildings it was determined that projects from the different certification levels under the USGBC's LEED® will be adopted. However, to reduce variability in the usage of the building, materials, and process, office buildings categorized under the new construction and core shell sections of USGBC's LEED® were selected.

Due to resources available for this study, building performance evaluation was primarily conducted from the owner's perspective. Although, 8 case studies were prioritized as the time and finances allowed the scope was expanded to 12 case studies. It was attempted that the data be collected from the three primary participants of a project (i.e., owner, designer, and contractor) however, due to circumstances (explained in chapter 4) on an average two participants were interviewed from each project. Finally, it was observed that due to the limited number of case studies, practices followed by exemplary projects could not be generalized. Hence, the final results were validated by discussing them with those of past research. Unlike exemplary practices, it was detected that flawed practices could be generalized as *not to be followed*.

1.6 Results and Deliverables

The following are the deliverables of this study:

1. Identification of the best practices in the case study protocol capitalizing and establishing team integration;
2. Identification of certain flawed practices, which if followed can potentially lead to unsuccessful outcomes;
3. External validation of results by discussing them with those of past researches;
4. Based on the results, developed a guideline of exemplary practices that should be followed and flawed practices as not to be pursued as they could lead to unsuccessful outcomes;
5. A comprehensive performance evaluation metrics (project inception to occupancy stages);
6. A tested tool / procedure to collect data from sustainable high performance buildings;
7. Based on past researches and literature this study defined and illustrated in detail the case study methodology and qualitative methods of analysis;
8. Database of exemplary projects and contacts with the team member's;

9. A foundation for future research in sustainable project delivery by providing a protocol and tool to collect data, and most importantly variables to understand project delivery process and performance outcomes such as timing of participant involvement, level of owner commitment and contractual associations between project stakeholders.

1.7 Reader's Guide

Chapter 2 describes the literature review conducted for this study. The methodology followed to realize the stated research goals and objectives are composed in Chapter 3. Next, in Chapter 4, methods and process for data collection, categorization, and coding is presented followed by Chapter 5 where the findings of the study are listed. Finally Chapter 6 includes summary of the results, limitations of the research, discussion of the results with past studies, list of exemplary and flawed practices that could potentially lead to successful or unsuccessful projects and recommendations for future research.

CHAPTER 2

Literature Review

2.1 Introduction

Any endeavor or a project has many facets. To address them the project requires a team of people who have expertise in various fields. The 'successful' execution of the project is the result of efforts of many people. The individuals who constitute these multi disciplinary teams need not just work together but must consciously and systematically reduce professional clashes amongst themselves. They must specifically focus their thoughts and ideas towards a common goal. The aim in this case is the successful execution of the project where success is defined as achieving the project intent set out by the project team in the beginning (e.g. certain green building rating, cost boundaries, incorporation of sustainable strategies in buildings).

A review of the literature is crucial to this research as it reinforces the ideas presented above. With the dwindling natural resources and high-energy bills, sustainable buildings are becoming increasingly popular amongst participants having financial stakes in projects. This chapter outlines studies enumerating the advantages offered by sustainable buildings economically and environmentally. The chapter also describes and details the different green building assessment systems available. This section is referred to again in the end, for the development of metrics, for this research.

Another important feature of this chapter is highlighting the importance of design management and integrated design. Here, the projects need for increased communication between various design disciplines, contractor's input for constructability information of materials and technologies and a formally managed design phase are elaborated upon. Next, in the chapter project delivery methods are discussed. Here, the delivery methods and their variations, used by the industry at present, are elaborated upon. It reports the opportunities and constraints presented by each method. Finally the chapter lists and outlines the roles and responsibility of the pivotal players in the project team. This section is critical during the adoption of the data collection tool.

2.2 Sustainable Development

United States Bureau of Labor (2006) states that, almost 86% of the employed population spent an average of 7.6 hours per day at their work places (USBL, 2006). Another statistic by the U.S. Environmental Protection Agency Green Building Workgroup shows that each year, approximately 170,000 commercial buildings are constructed and nearly 44,000 commercial buildings demolished (USEPA, 2004). Smart Market Report states that corporate buildings in the United States (U.S.) contribute to 40% of all energy consumption, 71% of electricity consumption, 38% of CO_2 emissions and 36% of all green house gas emissions and according to High Performance Building Guidelines (1999) almost $10-60 billion is wasted in combined health premiums, absenteeism, and annual productivity losses due to sick building syndrome and building-related illnesses (Smart Market Report, 2007; High Performance Building Guidelines, 1999). Finally, Cole et al. (1999) states that raw materials annually extracted from the earth are transformed into the concrete, steel, glass, rubber, and various other construction materials. In the process the natural environment is destroyed and various pollutants are released in soil, water, and air. This pollution manifests itself in poor indoor air quality leading to loss in productivity of individuals resulting in wastage and financial losses (Cole et al., 1999). From the presented statistics it can be satisfactorily concluded that buildings especially commercial one's directly or indirectly affect our lives and environment significantly. Although the need for commercial buildings cannot be denied it is essential that the construction industry strongly attempts to alter design, construction, and operation process to reduce their negative affects by minimizing energy use, water use, green house gas emissions, and waste.

The demand for environmentally responsible buildings is not new. The oil crisis (due to Arab oil restriction) faced by the U.S. in the 1970's has already put pressure on the construction industry to reduce its dependence on natural resources (Frej, 2005). Realizing that natural fuels cannot indefinitely power un-optimized and underutilized buildings the industry is constantly revising its construction practices. These revisions and changes of practices and processes is part of a paradigm shift experienced by the construction industry such as *traditional* to *sustainable development*. It is illustrated in Figure 2.1.

Agenda 21 (CIB, 1999) defines sustainability as *"the condition or the state that would allow the continued existence of homo sapiens."* (CIB, 1999). A more common and accepted definition is by the United Nations World Commission on Environment and

Development (Brundtland Commission) Report and it states that, *"those paths of social economic and political progress that meet the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987). This development incorporates the three focal points (time, cost and quality) of the traditional development in to its comparatively larger realm.

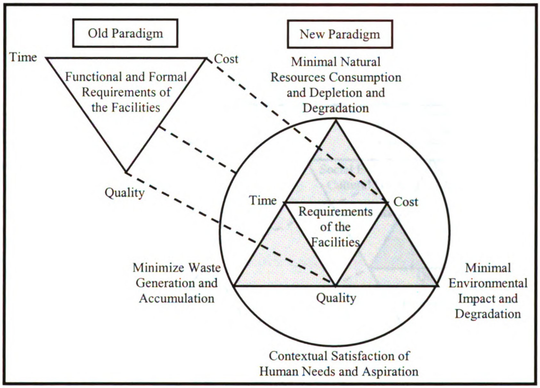


Figure 2.1 The Paradigm Shift (Traditional to Sustainable Development) Experienced by the Construction Industry (Modified from Vanegas et al., 1995)

The added foci's includes minimal usage of natural resources, minimized waste generation, and accumulation and contextual satisfaction of human needs and aspirations. It aims at limiting adverse impacts on the natural environment natural (i.e., surroundings, materials, resources, and processes present in nature) throughout the life of the building (i.e., from cradle to grave) and requires the designers to understand the environmental impact of their design decisions such as energy and resource consumption by the building (Karolides, 2002). This understanding is important, as building designs are one of the main determinants of the level of impact on the natural environment.

2.2.1 Sustainable High Performance Buildings

Currently the construction industry is experiencing another shift. Agenda 21 (2003) expands the new paradigm in the global context to include social, cultural, and environmental implications (Figure 2.2) (Agenda 21, 2003).

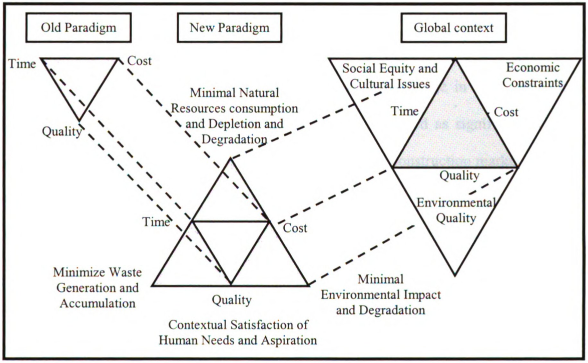


Figure 2.2 Shift from the New Paradigm to the Global Context as experienced by the Construction Industry (As modified from Agenda 21, 2003)

Buildings addressing these implications in a global context are known as High Performance Sustainable Buildings. Title IX, Subtitle A, Section 914 of the 2005 Energy Policy Act defines a high performance buildings as a, *"building that integrates and optimizes all major high-performance building attributes, including energy efficiency,* *durability, lifecycle performance, and occupant productivity."* (The Energy Policy Act, 2005). The U.S. Office of Energy Efficiency and Renewable Energy (DOE, 2008) defines a high-performance building as: *"A building with energy, economic, and environmental performance that is substantially better than standard practice. It's energy efficient, so it saves money and natural resources. It's a healthy place to live and work for its occupants and has relatively low impact on the environment."* (DOE, 2008). These definitions expands the scope of project programs by taking in to account stress on economic benefits from energy conservation, indoor environment quality (IEQ) and occupant satisfaction along with increased environmental performance.

Since the idea of 'green' tends to improve the building's image in the market, it is imperative that business and financial advantages be perceived as significant benefits. According to the Smart Market Report (2007), commercial construction market professes advantages such as decreased operating cost by 8-9% (due to decreased water use and energy savings such as lighting, heating ventilation air conditioning), increase in building value by almost 7.5%, and almost a 6.6 % improvement on investment returns. The report also suggests that the occupancy ratio increases by 3.5%; therefore increasing the rent ratio by 3% (Smart Market Report, 2007).

United States Green Building Council's (USGBC) The Leadership in Energy and Environment Design (LEED®) platinum rated, Genzyme Center, in Massachusetts, presents is a very good example of financial advantages. In the first year of its operation, the building used 42% less energy and 34% less water than a traditionally built building of comparable size (Lockwood, 2006). 15% increase in employee productivity was the result of the usage of alternative materials. These materials that did not emit toxins like formaldehyde, commonly found in standard building materials, therefore improving indoor air quality. Also, the green design criteria such as abundant day lighting, individual climate control, and outdoor views enhanced employee morale and hence were instrumental in increasing productivity (Lockwood, 2006).

2.2.2 Sustainable Building Assessment Systems

Although sustainable buildings aim towards lower impact on the environment, each building due to its unique nature reaches different levels of sustainability. In recent years, many methods have been developed to evaluate and recognize the various levels of sustainability. Over the years they have resulted in continuous evolution of buildings and have established a comprehensive means to assess a broad range of environmental considerations (Inge, 2006). Cole et al. (2005) reports that these evaluation models represent an 'industry standard' of the constituents of a green building inclusive of improved building performance, cost and practicality. These prioritize environmental issues consequently providing focus to designs; also, they summarize building performance that is communicated to stakeholders to further education and development (Cole et al., 2005). These methods encourage innovation and materials and product suppliers to develop new environmentally beneficial products, services and practice (Todd et al., 2001). Finally, assessment systems also affect the construction market as they bolster the growing consumer concern for sustainable products. The *'environmentally friendly and responsible'* label they provide to buildings advertises the improved environmental qualities and increases the real market value of buildings (Roper, 2006).

Today, worldwide, many green building assessment models and methods exist, but the most widely accepted are Building Research Establishment Environmental Assessment Method (BREEAM), Green Globes, Energy Star, and United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®). The characteristics of these agencies are summarized in Table 2.1.

Building Research Establishment Environmental Assessment Method (BREEAM): Developed by the Building Research Establishment Limited (BRE Ltd) in England, it was established in 1990 as an environmental assessment method. It evaluates the environmental performance of both new and existing buildings in the UK and applies to the following building types: offices, homes, retail, industries, schools, and health buildings. This model provides weights to different environmental aspects/ criteria. The building is evaluated and awarded credits on the basis of its performance on the various criteria. The final score achieved is rated on a scale of pass, good, very good, or excellent (BREEAM, 2008).

Green Globes: Green Globes™ is a Canada based green building guidance and assessment program. It was established in 1996 by the Canadian Standards Association (CSA) as BREEAM Canada for Existing Buildings. In 2002, the system became an online assessment and rating tool under the name Green Globes for Existing Buildings. It comprehensively assesses the environmental impact on a 1,000 point scale in multiple categories such as Energy, Indoor Environment, Site Impact, Water, Resources, Emissions, and Project / Environmental Management. It facilitates and encourages multi-disciplinary collaboration from the earliest stages of a project and introduces the elements of sustainability from goal setting to construction documents and building operations. This model not only evaluates a building after the construction, but further helps to enhance the building during the life of the project (i.e., from inception to construction). Both new building projects and existing buildings environmental management and operations can be enhanced through the use of the Green Globes online software tools. Qualified third party assessors interface with project teams and building owners to review progress, make enhancement suggestions, and validate environmental achievements (Green Globes, 2008).

Energy Star®: Introduced in 1992, Energy Star is a joint program between the U.S. Environmental Protection Agency and the U.S. Department of Energy. It is a voluntary labeling program that identifies and promotes energy-efficient products. The label of Energy Star® can be seen on major appliances such as office equipment, lighting, and home electronics. Recently the label was extended to cover new homes and commercial and industrial buildings. To measure, track, and improve energy performance, Energy Star provides web-based tools, calculators, resources, and training. The energy performance of commercial and industrial buildings is scored on a scale of 1-100. Facilities achieving a score of 75 or higher are eligible for the Energy Star label. The energy performance rating is derived from fuel consumption data of existing commercial buildings, which includes the total energy use associated with the buildings. The Energy Use Intensity (EUI) reflects the distribution of energy performance in commercial buildings derived from the 2003 Commercial Buildings Energy Consumption Survey (CBECS) (Energy Star, 2008). The required data inputs in the tools are understood as the primary drivers of energy use. The tool includes the ZIP codes to determine the climate conditions that the building would experience in a normal year (based on a 30-year climate average), and the energy fuel mix is used calculate the total annual EUI. The tool also displays percent electricity and natural gas defaults used to calculate design.

Although Energy Star does not require integrated design to be a mandatory practice, it supports and promotes the method. It suggests integrated design criteria such as a multi-disciplinary project team and design charrette. The project team should include stakeholders such as the building owner, architects, energy consultants, engineers, and proposed tenants. The charrette must be organized to determine project intent that would eventually become a common goal for all the members. It would address energy objectives pertinent to the design, identify synergies between design concepts and energy use, and investigate energy performance design strategies that would eventually help in the development of a plan for a top performing energy-efficient building. The team must also determine ways to integrate these strategies in the design (Energy Star, 2008).

United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®): The LEED® system, developed by the USGBC in 1998, is the U.S. national standard for developing sustainable buildings. It is a third party certification program and the nationally accepted benchmark for the design, construction, and operation of green buildings. This certification symbol demonstrates that a building is environmentally responsible, profitable and a healthy place to live and work (USGBC, 2008). Over the years it has evolved and presently applies to new commercial construction and major renovation projects (LEED® NC), existing buildings operations (LEED® EB), commercial interiors projects (LEED® CI), core and shell projects (LEED® CS), homes (LEED®-H) and neighborhood development (LEED® ND). All certified projects receive a LEED® plaque at various levels according to their achievements in green strategies. The certification levels are ***certified, silver, gold, and platinum***. Platinum is the highest level in certifications and recognizes buildings achieving exceptional success in applying green strategies. This system prioritizes different criteria by giving them points which, when, added together, make a building eligible for different plaques (USGBC, 2008).

Table 2.1 Characteristics of Leading Assessment Systems across the World (USGBC, 2008; BREEAM, 2008; Energy Star, 2008; Green Globes, 2008)

	USGBC's LEED®	BREEAM	Green Globes™	Energy star®
Established in	USA, 1998	UK, 1990	Canada, 1996	USA, 1992
Building types	New Construction, Existing Building, Core and Shell, Commercial Interiors, Homes, Neighborhood development	Offices, Homes, Retail, Industries, Schools and Health buildings	Offices, Homes, Retail, Industries, Schools and Health buildings	Major appliances, Office Equipment, Lighting, Home Electronics, New Homes, and Commercial and Industrial buildings.
Rating Scale	Point System	Point System	Point System	Point System
Certification levels	Platinum, Gold, Silver, Certified	Pass, Good, Very Good, Excellent	One Globe, Two globe, Three Globe, Four Globes	Energy Star Label
Evaluation Categories	Energy and Atmosphere, Indoor Environment, Sustainable Site, Water Efficiency, Materials and Resources, Indoor Environment Quality, and Innovation and Design Process	Management Health and well being, Energy, Transport, Water, Material and Pollution	Energy, Indoor environment, Site, Water, Resources, Emissions and Project/ Environmental management	Effective Insulation, High Performance Windows, Tight Construction and Ducts, Efficient Heating and Cooling Equipment

2.2.3 Critique of Assessment Systems

Although the various assessment methods, discussed, are successful in providing stimuli and focus to projects, buildings do not always perform as intended. In 2008, a study by U.S. Green Building Council (USGBC) and New Building's Institute (NBI), analyzed the measured energy performance for 121 LEED® New Construction (NC) buildings providing critical link between predicted and actual outcome for LEED® projects (Turner and Frankel, 2008). According to the report, measured EUIs for over half the projects deviated by more than 25% from design projections, with 30% significantly better and 25% significantly worse (Turner and Frankel, 2008). This variability between predicted and actual performance can have significant affects on the accuracy of the life cycle cost evaluations for any given building. Therefore continuous evaluation is required throughout the life of the building (i.e., from cradle to grave) (Akatsuka, 1994; Harputlugil and Hensen, 2006; Bordass et al. 2001).

Typically evaluation criteria consist of energy and water efficiency, cost, schedule, environmental impact (e.g., emissions and carbon footprint) as well as productivity and health of the occupants (Fowler et al. 2005; Carr and Beyor, 2005; Gransberg et al. 2007; Ibbs et al. 2007; Fisk & Rosenfeld, 1997). However, the literature significantly suggests that decisions taken during the design process have considerable impacts on the final outcome as the affects of the decision taken earlier in the design phase manifest in the post occupancy phase (discussed in further detail in Section 2.3 of this chapter) (OGC, 2005; Heintz, 2002; Chan and Tam, 2000). Therefore, the final performance of the building is relative to the performance of the project during the pre-occupancy phase. Results only from a post-occupancy evaluation can be considered as ambiguous and skewed. It is important to conduct a pre-occupancy evaluation to gain a complete picture of the project consequently helping in understanding the success/failure of the performance of the building during the post occupancy phase. Recent research piloted evaluation metrics for high performance green building project delivery, verified a data collection tool and analysis methods to improve the understanding on high performance green buildings (Korkmaz, 2007). However, before going further in the metrics it is important to understand project delivery methods and other pre-occupancy concepts such as design management and integrated design, and then their impact on the final output i.e., the performance of the building.

2.3 Design Management

Design Management can be defined as a management process that integrates the different disciplines, to reduce conflicts and increase compatibility, during the design phase of a project to result in better project outcomes (DMJ, 1998). In the design phase of a project multidisciplinary participants / stakeholders with varied objectives are brought together to derive a composite design solution that is consistent with the design requirements (Reed and Gordon, 2000). However, as the majority of project complexities lie in this phase, in most cases, this combined effort results in clashes between the different disciplines leading to the maximum amount of wastage and inefficiency such as incompatibility between design and its constructability leading to change orders during the construction phase (Formoso et al, 1998). Alarcón and Mardones (1998) discuss that designers invest almost 40-50% time of the total project in working on the changes. They also suggest that almost 20-25% of the total construction period is wasted due to design deficiencies arising from these clashes (Alarcón, L. F. and Mardones, D. A., 1998- refers Undurraga, 1996). Architecture, engineering and construction, owes 78% of quality problems to design (Koskela, 1992). From the point of view of cost, design caused defects are fairly large contributors to the expense of the building hence considerably lowering eventual profits (Rounce, 1998).

Hammond et al (2000) proposes that design phase owes its inefficiencies to the currently followed conventional design process, which can be defined as sequential and non-interactive (Hammond et al., 2000). Chua and Tyagi (2003), suggest that in the conventional design process generally the architect leads the phase by preparing the project program that is then used by other disciplines to prepare their designs. In this process the information exchange between the various disciplines such as architecture, mechanical, electrical and HVAC needs to happen at two levels i.e., broad and detailed. However, the interaction takes place only at the broad level. Once the detailed design begins each discipline works in isolation, interacting only in case of potential conflicts (Chua and Tyagi, 2003). In most cases the contractor is ignored entirely and therefore no constructability information is added to the design of any discipline. This lack in communication results in deficiency in the information available to all the disciplines to complete the design tasks, inconsistencies within construction documents, and lack of coordination between disciplines; therefore, leading to inconsistent decision-making.

From the literature presented it can be inferred that the conventional design process lacks integration causing inefficiencies in the whole process that results in less than optimal products. Therefore, it is imperative, that the project participants interact from the beginning and continue their communication process throughout the life of the project. This would facilitate integration of the design phase consequently minimizing clashes and eventually leading to improved outcomes such as lower project costs, faster payback period, realistic schedules, and a significant leap in the actual building performance.

2.3.1 Integrated Design Process

Integrated design process can be defined as a process constituting teamwork between multiple disciplines to achieve optimized solutions in coherence with the design requirements for better project outcomes (BCBC, 2001). Integrated design process is more comprehensively defined as a method for creating high performance buildings through a collaborative process that focuses on the design, construction, operation and occupancy of a building (Larsson, 2002). The definition also suggests that this process facilitates client and other stakeholders to develop and define functional, environmental, and economic goals and objectives. Integrated design process proceeds from whole building system strategies; working through increasing levels of specificity, to realize more optimally integrated solutions (Larsson, 2002; WBDG, 2008). Table 2.2 compares integrated design process with the traditional design process.

Table 2.2 Integrated Design Process vs. Traditional Design Process (adopted from BCBC, 2001; Larsson, 2002; WBDG, 2008)

Categories	Integrated Design Process	Traditional Design Process
Level of Collaboration	Facilitates early collaboration of all the players	Has predefined phases for the involvement of the team members
	Collaboration is maintained throughout the project life although the design phase receives the maximum communication.	Collaboration is minimal (only when required) players mostly work in isolation
	Whole-systems thinking	Systems often considered in isolation
Project Phases	Project phases happen in parallel to each other	Project phases are more or less linear
Decisions	Decisions are influenced by members from different disciplines	Decisions are taken by member's primary to the discipline in question (suggestions are taken only in cases of clashes).
	Life-cycle costing	Emphasis on up-front costs

It is used extensively in sustainable construction, as a green building requires optimum building system solutions / balance, achieved only by close working relation between multidisciplinary teams (Zimmerman, 2005; PTI, 1996; Frej, 2005). For example – the effective use of climate responsive design (proper building orientation, massing and shading and effective use solar energy and passive cooling and heating attributes) and the use of high performance envelope technologies has considerable impacts on mechanical and electrical systems, failure to optimize the solution can have significant negative effects on the first cost and operational energy costs of the systems.

Allison Hall Fitness Center (2005), a Green Globes™ case study, poses an example of integrated design. It is located in Sackville, Canada has earned 3 globes out of four. According to the case study the design was a collaborative effort between architect, engineers, consultants, and occupants. Day lighting was optimized through building orientation and window-to-wall size ratios (95% of windows are located with brise soleil, 5% wall) and electrical lighting was integrated with day lighting, taking into account daily and seasonal variations. Consequently, it has affected the envelope of the building requiring close working relationship between the architect and the lighting and electrical consultants. To maintain and enhance the interior thermal comfort that could have been upset by the 95% windows in the envelope, a low U value (2.52) glazing was used (Green Globes, 2005).

2.3.2 Integrated Design Process in Sustainable Buildings

Integrated design process although still in nascent stages is gaining momentum in the construction industry. Due to its multidisciplinary approach and optimized results this process is highly recommended by the assessment models and other industry standards (USGBC, 2009; Green Globes, 2009; DoE, 2009). Evaluation methods and other literature suggest project stakeholders to organize design charrettes and integrated design workshops. Such programs provide a common focus to the project and facilitate positive communication and chemistry amongst the participants (Frej, 2005).

Sustainable buildings in particular are encouraged to adopt integrated design process as it is futile to add or overlay environmental systems on an existing building. For a building to be genuinely green; it needs to benefit from the integrated or whole systems, design approach from the inception (7 Group, 2004; Enache-Pommer and Horman, 2009). The success of integrated design in green buildings depends upon the time frame that it is practiced in. According to Building Green Inc. (2001) integrated design process practiced early in the project (to integrate green strategies) yields better outcomes than when it is practiced later (Figure 2.3). This is so because the goals and objectives determined at the beginning enable a clear understanding of project scope requirements and project needs, the adoption of green early in the project saves project rework due to accurate project bids and costs and save time for incorporating these sustainable objectives later in the future (Enache-Pommer and Horman, 2009). Sustainable strategies are added later in the projects life either behave as add-ons that don't perform as intended to or they change the approach towards design (sometimes the design itself) resulting in extensive rework and increase in cost.

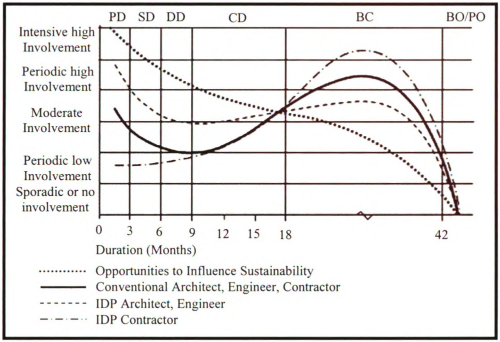


Figure 2.3 Change in Energy Saving Opportunities According to the Phases of Design Process (Modified from Perkins and Stantec Consulting, 2007)

An example of the use of integrated design approach is the commercial office building Heifer International Center (2002) (LEED® -NC-Platinum). This case study demonstrates the use of integrated design throughout the life of the project. Through the integrated design process the project team participated in discussions ranging from methods of finance to site selection. A charrette was held for the project participants to establish a list of attainable environmental goals eventually leading to the final design of the building. The team was very particular about the structural concept of the building and aimed to minimize ornamentation and express the functional detailing of steel. To achieve goal the mechanical, electrical, and plumbing (MEP) systems had to be integrated. The construction team involved in the design process incorporated constructability information to understand the feasibility of the design and suggested alternative material that was in compliance with the indoor air quality needs and local availability. Along with the broad objectives of the project, the design team also communicated the process of documenting LEED® criteria to the construction team bringing the two teams in concurrence with each other (USGBC, 2008).

Another striking example is the Aldo Leopold Legacy center (2007) (LEED®-NC-Platinum). Functionally it houses an interpretive center, commercial office and meeting spaces an archive and a workshop organized around a central courtyard. According to the case study from the start of the schematic design phase through construction, project team meetings included the environmental consultant, energy simulation consultants, commissioning agent and control system. The goal of the project was to demonstrate the relationship between human activity, built environment and the natural world. To achieve this goal, the project strictly adhered to a holistic design process. One of the main challenges of the project was to only use locally available resources. This required extensive inputs from the various disciplines for information such as properties of the material and their affects on building systems and actual building performance (USGBC, 2008).

Literature demonstrates the importance of integrated design and early involvement of participants. However, the timing and the level of involvement of participants is significantly affected by the contractual arrangements/ project delivery methods (PDM) chosen by the projects. According to Bilec and Ries (2009) the delivery system affects the level of integration in a project as it is the delivery system that establishes the communication, coordination, and contractual interfaces between the owner, contractor, and designer. The next section details the different project delivery methods presently adopted by the industry.

2.4 Project Delivery Methods

Project delivery and contracting strategies define the formation of project teams, their working relationships and levels of involvement over project timelines ([a]Korkmaz, 2007). The decision that confronts each project is determining the framework that is most suitable to optimize the results and maximize project and building performance (Konchar and Sanvido, 1998). Generally, depending on the project details and objectives of the owner, one of the prescribed approaches is selected. Therefore, it is imperative that the alternatives be well defined from all the aspects so that finally a framework can be chosen in the projects best interest. The Primer on Project Delivery, jointly provided by The American Institute of Architects and The Associated General Contractors of America (2004), defines the three most common Project delivery methods / frameworks used by the industry at present. The U.S. construction industry either uses these methods or variations and combinations of them. The three methods are Design-Bid-Build (DBB), Construction Management at Risk (CMR), and Design Build (DB) (AIA-AGC, 2004). Next is a discussion of the methods and the characteristics have also been listed in Table 2.3.

The Design-Bid-Build method: This method is often described as the traditional method of project delivery, consisting of three main roles of owner, architect, and builder. This delivery method is best defined as sequential s the project is executed in clearly defined phases that are design, bidding, and construction, conducted in a linear sequence (Miller et al., 2000). In this approach, the owner contracts with an architect and contractor separately. First the owner contracts with an architect for a design package, including contract documents. Second, competitive bids are secured from contractors with the procured design documents (produced by the architect) used by the owner. The owner submits the package for bidding and unless otherwise mentioned in the tender document, selects the lowest responsible bidder to undertake the construction of the project. The method requires the owner to monitor contractor's activities to assure adherence to contract requirements (Ibbs et al. 2003). The contractual relationship and the direction of information flow for this PDM is illustrated in Figure 2.4.

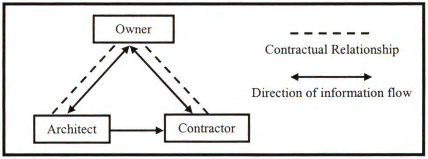


Figure 2.4 Contractual Relationships and Direction of Information Flow between Owner, Contactor, and Designer in Design-Bid-Build

AIA-AGC (2004) suggests that the initial low project costs, typically due to the price competition between bidding contractors is the reason that most federal projects are built using the design-bid-build delivery method. Many times large private projects such as churches and schools are also required to use sealed bids and formal procedures, similar to procedures for public projects. However, Klotz (2005) reports that because this method does not incorporate constructability information into the design phase, many times it leads to conflicts between design and construction (due to differing perspectives of contractor, owner and architect over the work scope and items), leading in change orders, repairs and lawsuits, negating the initial cost advantage of the design-bid-build system (Klotz, 2005).

The Construction Management at Risk Method: This approach is a relatively new approach of project management. According to Dorsey (1997) it was developed as the existing delivery systems failed to address the issues arising in the projects. Some of the main reasons are rapid inflation of construction costs; increasing complexity in buildings; prolonged construction schedules for complex buildings; difficulty in compressing the traditional design-bid-build time requirements; rise in litigations (Dorsey, 1997).

The construction manager (CM) delivery system consists of a single individual or a team of professionals. Here, the construction manager can be hired only to coordinate the project on the owners behalf or can offer the owner, contractual arrangement to facilitate a single source of responsibility for design development coordination and construction (Koppinen and Lahdenpera, 2000). Depending upon the area of expertise on the CM, he/she can offer services such as constructability reviews, value engineering studies, construction estimates, and contract packaging. During construction, the CM coordinates contractors' activities and controls the project (Al Khalil, 2002). Although this offers the owner an experienced construction professional, this professional works just as a consultant, and hence does not have responsibility for any failure faced by the project. The 'at risk' is added to construction management when the CM takes on the risk of building a project. Owner contracts with the architect separately. The CM holds contracts with schedule and price warranties significantly delegating owner's control and risk over the project. The contract is held typically in two stages i.e., First, CMR manages and undertakes services during conceptual & preliminary design phases with the design professional. Second when the design is complete, owner and CMR then agree on a price and schedule for the completion of the construction work (Al Khalil, 2002). The formal and informal relationship between participants in this PDM is illustrated in Figure 2.5.

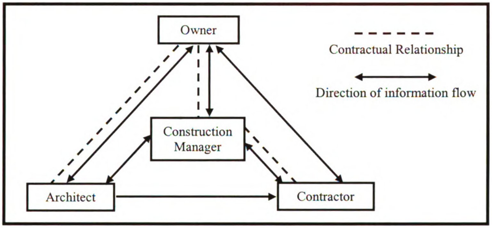


Figure 2.5 Contractual Relationships and Direction of Information Flow between Owner, Contactor, Designer, and Construction Manager in Construction Management at Risk

The Design Build Method: In DB, design and construction take place simultaneously, unlike DBB where the process was sequential. Here the owner contracts with a single entity for both design and construction, therefore, eliminating the bidding phase. As now the design and construction is being done by the same body, this method not only reduces the overall project time, it also permits the incorporation of constructability information, by taking contractors input, during the design phase (CII, 2002).

In this approach the contractual relationship is very simple and straightforward. The owner maintains a single contract with the architect-contractor or design-build entity (Figure 2.6). This process consolidates the contracts that the owner has with several parties, as now there is only one entity that is responsible for providing both design and construction services to the owner. Due to the change in the contractual arrangements, the project can be led either by an architect or a general contractor or both. This method requires much defined allocation of the roles and responsibilities in the design-build team and is particularly successful in cases where the scope is clearly laid out; the design is standard and repetitive with a tight schedule (Chan et al, 2001).

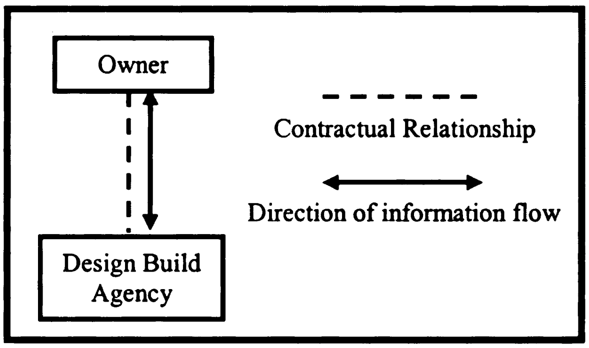


Figure 2.6 Contractual Relationships and Direction of Information Flow between Owner, and the Design Build Agency in Design Build

This method is relatively contemporary and addresses many of the problems with the design-bid-build or traditional method. Here, as the design team and contractor are both part of the same entity, the chances of then with each other rather than as adversaries' increases drastically. The resulting advantages are typically lower project costs (owed mainly to less design changes and less change orders), improvement in performance both project and building and decreased project duration (due to the simultaneous execution of the design and construction phases).

Table 2.3 Characteristics of the Three Main Project Delivery Methods (Al Khalil, 2002; CII, 2002; AIA-AGC, 2004)

Characteristics	Design Bid Build	Design Build	Construction Management at Risk
Team members	• 3 prime players - Owner, Designer, Builder	• 2 prime players - Owner, Design-build entity	• 3 prime players - Owner, Designer, Construction Manager
Contractual Arrangement	• Two separate contracts - owner-designer, owner-builder	• One contract - owner to design-build entity	• Two separate contracts - owner to designer, owner to CMR
Contractor Selection	• Final contractor selection based on lowest responsible bid or total contract price	• Final provider selection based on aspects other than total cost	• Final provider selection based on aspects other than total cost
Project Phases	• 3 linear phases - design, bid, build	• Overlapping phases - design and build (fast track)	• Overlapping phases - design and build (fast track)
Roles and Responsibilities	• Well-established and broadly documented roles	• Project-by-project basis for establishing & documenting roles	• Specific contractual arrangement determines the roles of players
Basis for choosing the team	• Lowest responsible bid that provides a reliable market price for the project	• Either cost or solution as the basis for selection of the design-build entity	• Preconstruction services offered by the constructor (such as constructability review, bid development and management)
Planning and Scheduling	• An opportunity for construction planning based on completed documents	• Overall project planning and scheduling by the design-build entity prior to mobilization (made possible by the single point of responsibility)	• A fast track schedule achieved by dividing the project into several contract packages and phasing the packages, the CM can achieve.
Cost	• Low first cost	• High first cost	• High first cost
Construction Decisions	• Contract documents completed before construction begin, requiring construction-related decisions in advance.	• Some construction-related decisions after the start of the project	• Some construction-related decisions after the start of the project

2.4.1 Level of Integration in the Design and the Project Delivery Systems

Through literature, integration is understood as participation of multi disciplinary stakeholder in a project. It has also been established that earlier the integration happens better are the project outcomes. However, the section on project delivery establishes that the entry and exit of participants in a project is regulated by the contractual arrangements. This directly suggests that level of integration gets strongly affected by the project delivery system chosen. Even though the balance tips towards DB the superiority of any project delivery method has not been proven in the literature. Each project delivery method has its own opportunities and constraints and they can be understood with the help of examples in the form of case studies.

The Hawaii Gateway Energy Center (2004) (LEED® - NC- Platinum), a USGBC case study is one such example. The delivery method chosen for this project was DBB. According to the case study the choice of the project delivery method restricted contractor involvement until after the design. Therefore, contractors input for important information like constructability of the design, value engineering and waste management could not be received and added to the project (USGBC, 2008). Another example is the CBF Merrill Environmental Center (2000) (LEED® - NC- Platinum). The case study states that the contractor was not very experienced with the green systems and construction and the project would have benefited if he shared the clients goals and objectives. Such a situation could be avoided if project delivery methods such as D-B or CMR had been chosen (USGBC, 2008).

Due to the early involvement of the contractor and flexibility in the contractual arrangements it is easily assumed that project delivery methods (PDM) such as DB and CMR allow a lot of integration and would automatically result in better project outcomes. However, these PDM's have their own constraints that include restricting client's involvement only till the design phase. They tend to reduce the clients control over decision making because in DB a single agency is responsible for design and construction therefore many decisions are taken internally and independent of the client (CDE, 2002). Where as in the DBB method the owner contracts with two different entities and hence maintains control over the project by the responsibility of coordination. According to Lahdenpera (2001), owners choosing DB as they need to be very clear of their objectives and need to state them lucidly to the DB team unlike the traditional system where the client loosely states his/her intentions and then the program is developed after a series of meeting. Here unlike DBB the client does not have the luxury to change the scope, as the projects are generally fast-tracked.

2.5 Project Participants (Roles and Responsibilities)

The importance of multidisciplinary participants cannot be disputed. However, to further understand the importance of early collaboration it is important to conduct a literature review recognizing the main project participants and their roles and responsibilities. According to Frej (2005), the main project team includes architects, landscape designers, civil, mechanical electrical plumbing and structural engineers, contractors and facility managers, commissioning agent, design managers and construction managers, human resources and marketing staff (Frej, 2005). Depending upon the team's experience and level of knowledge specialists such as sustainability consultants, energy consultants, indoor air quality consultant, can also be made part of the team.

1. *Client / Owner / Tenant:* The owners or the clients are the most important and powerful players in the construction industry. Such status is given to the owners as they create construction jobs, by creating construction projects and being the primary consumers of construction services and project finances, they are often at pivotal positions in the project (Carr, 2000; Huang, 2003). Traditionally, they controlled design, construction, contract documents, and selection of the project team. However, this control has seen a shift due to the different project delivery systems adopted by the industry. Although owner still controls the design intent and to a large extent the design itself, the owner's can now choose the level of risk and control to have on the project (Col Debella, 2004). The contractual arrangements can be modified to facilitate shifting of risks and management control on other participants such as construction manager, contractor, and/or design-build entity. Typically owner's responsibilities include determining the project's objective, focus, budget, schedule, and operating requirements and the communication of the same to the team members. The choice of contractual arrangements would determine the lines of communication between the team members (Huang, 2003). The owners should carefully choose the contractual arrangements as they can have significant affects on the end product.

2. *Design Team:* This consists of all the disciplines that are involved in the 'designing' of a building. The main team members consist of the architect, mechanical, electrical, and plumbing (MEP) engineers, HVAC consultants and

structural engineers. Regardless of the scale/type of project and project delivery method, contractual arrangements have to be such that all these disciplines must be present during the design phase. Even if one of the above stated disciplines were missing it would create a gap that would lead to an incomplete building design. Although communication and integration of design are highly recommended, it depends on the team dynamics, project requirements, and the focus on goals and strategies that the team works together or in isolation.

3. *Contractor:* Traditionally the role of the contractor is to physically put up the building. However, contractual arrangements can be organized in a way to involve the contractor from the design stage lasting up-till commissioning. In the case of the contractor being retained by the owner from the design phase his services would include comprehensive cost estimating, system value analysis, products and regional material identification, master scheduling and constructability reviews (Frej, 2005). In case of a green building the contractor must be made part of the design charrette providing sustainability reviews developing cost data, local market analysis, information on availability of materials, lead times for delivery, evaluation of tradeoffs (value engineering), analysis of constructability and overall scheduling for the projects (Myers, 2005). The contractor can provide the owner with the first cost and also be instrumental in doing a risk assessment of the project.

During the construction phase, contractor must procure the right subcontractors and trade contractors by ensuring that they match with the intent of the project.

The standards of the green products, materials, equipments, and systems must be ensured by, making sure that they follow the guidelines of the assessment systems (Forbes, 2001). Most assessment systems require detailed documentation of the process followed. This documentation starts from the design phase. During the construction phase the contractor must maintain proper documentation so that at project end, complete information is available for review and analysis.

In the post construction phase contractor's main input is required for commissioning. The contractor must assist the commissioning agent and designers with reviewing and testing systems and training the owner's O&M staff. Once all the systems are performing as designed a performance manual is to be prepared comparing as built results with the original intent.

4. *Commissioning Agent:* Commissioning is an organized process which ensures that a building's performance is in accordance with the design intent and the contract documents (Haasl and Sharp, 1999). This process typically takes place during the turnover phase of the project however; a commissioning agent can be included in the project team from the design phase itself to make certain that the design is in coherence with the owner's operational needs (U.S., 2005). Enache-Pommer and Horman (2009), suggest that the commissioning process should be specified early and the quality assurance should be focused on the specification phase itself as it can significantly influence the cost quality and timeframe of the project.

   During commissioning all the equipments are examined and tested to make sure that they were installed correctly and worked in accordance with the specifications. The process is heavily documented and results in a training program for ongoing performance and many times also for a longer-term validation of continuous efficient performance (WBDG, 2008). Typically, a third party with whom the owner contracts with directly executes commissioning. This allows an unbiased evaluation of the design and installation.

5. *Special Value-adding Consultants:* This consists of all the consultants that are not essential to the project however, are made part of the team to add value to the project such as sustainability, energy, and indoor air quality consultants. They are employed for their expert knowledge in the particular discipline. This is not mandatory in all projects and is based project-by-project, for unique requirement. These are generally hired during the design phase; however, they can be hired at any point in the project depending upon their area of expertise.

2.5.1 Summary

In the above section roles and responsibilities of various participants in a project are discussed. The main participants that this research recognizes are owner, design team (designer, mechanical, electrical, and plumbing consultants), contractor, commissioning agent, and special value adding consultants. These are the pivotal players in a project. However, the intensity of their role can change depending upon the liability and risk allocation in the project. It can also be affected by the onus of management. The intensity manifests in the timing of involvement of the participant in the project. In any case the individual and collaborative performance of these players has significant affects on the performance of the final outcomes in a project. The next section describes the various metrics / methods for the evaluation of the project team and the outcomes of the project.

2.6 Performance Metrics

The literature review presented above strongly justifies the need of integrated design process in sustainable building to achieve optimized results. However, so far the literature only focuses on *'what'* is required to achieve sustainability in a project, integrated design process being one of the attributes. A gap was seen in the literature when *'How'* to achieve a high level of integration in the design process (consequently resulting in higher levels of achieved sustainability) was researched upon. This section intends to describe performance evaluation metrics for the life span of the project to compare the performance of the project in the project delivery phase with the occupancy phase. This will help in identifying key factors in the design process that lead to the achievement of high levels of sustainability via level of integration in the design process.

Guided by previous research (Korkmaz, 2007; Gransberg and Buitrago, 2002; Konchar and Sanvido, 1998) this research has classified a building's project timeline into three categories: (1) project delivery attributes; (2) project performance upon the completion of construction and building performance in the preoccupancy stage; and, (3) post-occupancy user satisfaction or building performance in the post-occupancy stage. This study primarily focused on the first two stages by investigating the effects of project delivery attributes (independent variables) on project performance at construction completion (dependent variables). Addressing the last stage occurs through owner perception, and therefore, the last stage becomes a component of the second stage as "Owner's Perception of the Resource Consumption and Level of User Satisfaction in the Post-Occupancy Phase." The description and scope of the two categories are given below (Figure 2.7).

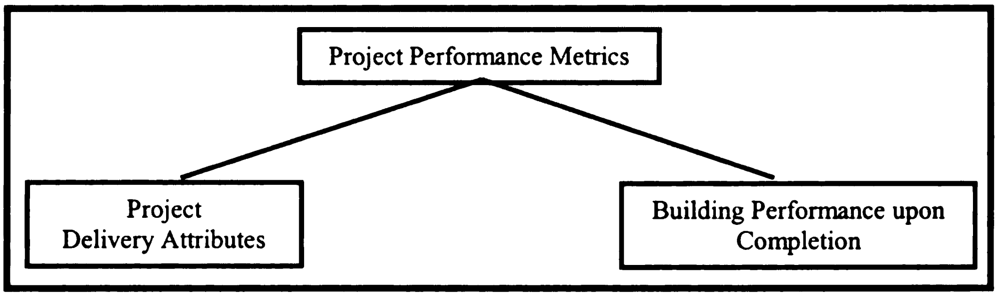


Figure 2.7 Categories of the Project Phases

2.6.1 Project Delivery Attributes

These attributes assess the delivery phase of a building project. Until present, the literature lacked an evaluation metric for the delivery phase. Recent research, "Piloting Evaluation Metrics for High Performance Green Building Project Delivery" (Korkmaz, 2007), comprehensively documented and listed project delivery attributes to assess the project. This research has adopted six out of the seven attributes listed in Korkmaz (2007). These are as follows: owner's commitment, project delivery system selection, project team procurement, contract conditions, level of integration in the design process, and project team characteristics. These attributes are explained in further detail below and are also summarized in Table 2.4. The seventh project delivery attribute, construction application, was omitted because of its minimal affects on project performance. It was observed in Korkmaz (2007) that although this attribute has significant affects on the long term *'building performance'*, and includes metrics such as commissioning agent's role in the project and the quality control procedures conducted, it does not have consequential affects on project performance (i.e., level of success achieved in cost, schedule, safety, levels of sustainable high performance achieved and owners perspective of quality and user satisfaction in the post occupancy phase). However, certain metrics such as education to the contractors were considered important for this research and therefore are addressed under other attributes.

1. *Owner Commitment:* Korkmaz (2007) defines owner commitment as the level of an owner's dedication towards high-performance green features and predetermined goals in a building project. This is inclusive of criteria such as the party to introduce "green" features to the project, the reason to pursue "green" objectives, the timing of introducing the "green" concept in the process, and the importance of the "green" goals for the project.

   The owners or the clients are the most important and powerful players in the construction industry. According to Carr (2000), such status is given to the owners as they create construction jobs, by creating construction projects (Gulgel and Russell, 1994; Carr, 2000). Being the primary consumers of construction services and project finances, they are often at pivotal positions in the project (Huang, 2003). Traditionally, they have controlled design, construction, contract documents, and selection of the project team. However, this control has seen a shift due to the different project delivery systems adopted by the industry. Although for obvious reasons the owner still controls the design intent and to a large extent the design itself, the owner's can now choose the level of risk and control to have on the project (Col Debella, 2004). The contractual arrangements can be modified to facilitate shifting of risks and management control on other participants such as construction manager, contractor, and/or design-build entity. Typically owner's responsibilities include determining the project's objective, focus, budget, schedule, and operating requirements and also the communication of the same to the team members. The choice of contractual arrangements would determine the lines of communication between the team members (Huang, 2003; Bubshait and Al-Musaid, 1992). The owners should carefully choose the contractual arrangements as they can have significant affects on the end product. According to Enache-Pommer and Horman (2009), increased owner commitment leads to better project planning consequently leading to improved cost and schedule performance.

2. *Project Delivery Method Selection:* Project delivery systems define major project participants' official involvement in the project, the level of integration, and contractual relationships between project parties (Oyetunji and Anderson, 2001; Al Khalil, 2002; Ibbs et al., 2003, AIA-AGC, 2004). Three types of project delivery systems are widely used in the USA: design-bid-build, design-build, and construction management at risk. Enache-Pommer and Horman (2009) suggest if the sustainable project objectives are integrated with other delivery aspects during programming, design and construction would eventually reduce delays, costs, and rework on the project.

3. *Project Team Procurement:* The method and process followed to procure the project teams can have significant affect on the final outcome (Korkmaz, 2007). The procurement method can strongly affect the relationship between different project participants and the chemistry that they share with each other. Literature suggests various procurement systems such as past experience of a project team, technical aspects of a proposal, sole source selection, best value source selection, competition, negotiation, low bid, fixed budget/ best design and qualification based selection. Each of the mentioned method stresses on different qualities therefore it is up to the procurer to select particular method according to the requirement (Gransberg and Senadheera, 1999; Molenaar and Gransberg, 2001; Molenaar et al., 1999; El Wardani, 2004). For example if the procurer does not have the required know-how they might decide to use qualification based procurement method however, a more qualified procurer may choose low bid.

4. *Contractual Conditions:* This variable includes evaluation of contractual terms of the project, the importance of "green" in the contract, contractual relations between important team members, incentive/penalty clauses within the contract, established criteria for communication such as timing, milestones, and level completed work and established criteria for the shift of liability of safety, productivity, risk and quality (Korkmaz, 2007; Ibbs et al., 2003; Gransberg and Molenaar, 2004).

5. *Level of Integration in the Delivery Process:* Integration in the design process suggests early collaboration of the project participants for optimized results (USGBC, 2009). It does not necessarily mean that all the participants should enter at the same time. Rather it means that all the participants should be involved in the project at the 'correct' time (Bubshait and Al-Musaid, 1992; Drexler and Larson, 2000). Integration also includes methods and timing of communication amongst the participants, and chemistry amongst participants. The former would have strong affects on integration as working comfort/discomfort would arise from participants past experience of working with each other and on the type of facility in question (OGC, 2003; Pocock et al., 1997).

   Finally this metric includes energy modeling. Enache-Pommer and Horman (2009), suggest that this would help to optimize the building design and allow the design team to prioritize investments in the strategies that will have the greatest effect on the building's energy use. Achieving energy modeling would not only require technical effort but also input from the various team member's thereby reflecting on the multidisciplinary integration during the design phase.

   The evaluation of this metric includes timing and method of communication, facilitation of design charrette, employ project peer review at regular intervals through the project, the level of owner involvement in the project, chemistry amongst participants, ease of communication amongst participants and techniques for energy modeling.

6. *Project Team Characteristics:* Project teams are made up of individuals having very unique and diverse characteristics. These characteristics can either be compatible or completely incompatible with each other. The purpose of this metrics is to evaluate the level of compatibility by measuring communication and chemistry amongst project team members (Korkmaz, 2007; Chan et al. 2002; CII, 2002). This metrics also includes team member's experience in similar projects and owner's capabilities to understand the project team competencies.

Table 2.4 Project Delivery Attributes (Adopted from Korkmaz, 2007)

Project Delivery Attributes	Focus
PM # 1 Owner Commitment	• Party to introduce "green" features to the project; • Reason to pursue "green" objectives; • Timing of introducing the "green" concept in the process; • Importance of the "green" goals for the project; • Mandating green metric (contractually or verbally);
PM # 2 – Project Delivery System Selection	Inclusion of either one the three primary PDM's • Design-Bid-Build; • Design-Build; • Construction Management at risk.
PM # 3 Project Team Procurement	• Negotiated vs Competitive selection process; • Restrained pools of potential participant; • Benchmark of restraint; Sole source selection, best value source selection, competition, negotiation, low bid, fixed budget/ best design, qualification based selection.
PM # 4 Contract Conditions	• Green features part of whose contract; • Contractual relations between important team members; • Incentive/ penalty clauses within the contract; • Likert scale evaluation of onerous contract clauses.
PM # 5 Integration in the Delivery Process	• Timing of contracting; • Methods and timing of Communication; • Presence of a LEED® A.P. and contractual position; • Design Charettes; • Teams prior experience as a unit; • Level of communication within team members; • Level of compatibility within team members; • Education to contractors.
PM # 6 Project Team Characteristics	• Team member's experience in similar projects; • Owner's representative's capabilities; • Owner's ability to define scope; • Owner's ability to make decisions; • Evaluation of the level of compatibility by measuring communication and chemistry among project team members.

2.6.2 Project Performance

This is the performance evaluation at the turnover stage i.e, in between the pre-occupancy and the occupancy phase. These performance metrics are used to understand the effects of project delivery attributes on the project outcomes. The literature review helped to identify six metrics in this category. These are as follows: Schedule, Cost, Quality, Construction Safety, Levels of High-Performance Sustainability, and Owner's Perception of the Resource Consumption and Level of User Satisfaction in the Post-Occupancy Phase. The measurement approaches and techniques for each described metric are listed in Table 2.5.

1. *Schedule:* This is an important metric and is one of the factors that define the success/failure of project performance. Every project has time is allocated to its different phases; in the first two phases that is the design and construction the owner's invest money in the building. It is the third phase that the owner's expect the building to pay back that investment by becoming functional. It is safe to assume that the owners would want the building to be functional at the earliest or no later than a predetermined time for the payback to begin. Therefore time becomes equal to cost which makes time an important metrics for evaluation (Korkmaz, 2007). The potential measures to evaluate high performance green project performance that are based on the definitions provided by Konchar and Sanvido (1998) and Gransberg and Buitrago (2002), are schedule growth, construction speed, design speed, and delivery speed.

Although time growth is useful in showing a snapshot of the project it is ambiguous in nature and lacks clarity. It is expressed as positive or negative where positive is considered 'bad' for the project and negative 'good'. However, time growth does not explain the reasons behind the variation, neither does it numerically show the reason behind the change, nor does it assign responsibility for the change (Gransberg and Buitrago, 2002). Therefore, construction and design time growth should be separated to understand where exactly did the delays lie. Also, difference lies in the project delivery chosen as unlike DBB, DB allows overlap between design and construction phase. Hence the time growth needs to be relatively understood.

2. *Cost:* Cost defines the magnitude of the investment made by a facility owner or a developer to design and construct a building and excludes property costs, owner costs of installed process or manufacturing equipment, furnishings, fittings and equipment, or items not included in the cost of the building (Korkmaz, 2007). The potential measure to evaluate high performance green project performance that is based on the definitions provided by Konchar and Sanvido (1998) and Gransberg and Buitrago, (2002) is cost growth.

   Similar to Schedule growth this too presents ambiguous results and for more lucid results construction and design cost growth should be separated. However, depending upon different project delivery methods the segregation of construction and design cost might not be possible. Therefore the data collection tool will contain separate tables for the three PDM's.

3. *Quality:* Quality being relative significantly differs for different team members. Being on the receiving end of the project, quality should be seen from the owner's perspective. The quality metric for the preoccupancy stage includes turnover quality (Konchar and Sanvido, 1998) and value of the cost and schedule growth for the project owner.

Turnover quality: This evaluates owners' perception of project quality that depends on the ease or difficulty of the turnover of a facility. This metric combines the difficulty of facility start up ($Q_{startup}$), number and magnitude of call backs during the turnover process ($Q_{call\ backs}$), and the difficulty of the submittal review process if the facility went through a documentation submission process for receiving certification from any of the environmental building assessment systems ($Q_{submittal\ review}$). Each category in this metric is evaluated by the respondents in a Likert scale, ranging from 1 to 5, where 1 represents high, 3 represents medium, and 5 represents low difficulty in these processes. A total of 15 points are possible in the evaluation of this metric. The formula to calculate facility turnover quality is as follows:

$$Turnover\ Quality = Q_{startup} + Q_{call\ backs} + Q_{submittal\ review}$$

Owner's satisfaction with the cost and schedule growth of the building: Cost and schedule growth if positive, can have a negative impact on the owner's perception of quality. However, if the growth is due to owner related scope changes, they could be satisfied with the results (Naoum 1994; Korkmaz, 2007). Therefore, value of the cost and schedule growth to the owner needs to be calculated to determine if it was the owner's decision or a flaw in the design and construction phases. The Likert scale used in measuring turnover quality is also used in this metrics. The range will be from 1 to 5, where 1 represents high, 3 represents medium, and 5 represents low difficulty in these processes. A total of 10 points are possible in the evaluation of this metric.

4. *Construction Safety*: The management determines level of safety during design as policies and during construction on site. Project delivery methods shift the liability of this on different players. This shifting of liability has major affects on the safety. For example, according to Toole (2002), under the traditional design-bid-construct project arrangement, subcontractors have a high ability to influence root causes, general contractors have a moderate ability to influence root causes, A/Es have a mixed ability to influence root causes, and owners have a low ability to influence root causes. Therefore, safety is an important metric to consider in the evaluation of high performance green project performance outcomes.

   Safety can be measured by Occupational Safety and Health Administration (OSHA) recordable incident ratings on the projects. The following metrics are used to measure constructions' safety levels in this research: (1) OSHA Recordable Incident Rate (RIR); (2) DART Rate (Days Away/Restricted or Job Transfer Rate); (3) Lost Time Case Rate (LTC); (4) Lost Work Day Rate (LWD). These were found to be the only post construction collectable metrics however, based on previous research they have not proved to be very helpful. Therefore open ended questions were added to the data collection tool such as onus of the responsibility of safety on the participants and how important were the safety issues for the project.

5. *Levels of High-performance Sustainability:* Sustainable building assessment systems address the critical aspects from the definition to enable high-performance buildings. Among these assessment systems, LEED® (USGBC, 2008) has received the most recognition in the U.S. green building community. Therefore, this research utilizes High Performance criteria from LEED® to assess energy and indoor environmental quality (IEQ) to measure high-performance levels of green projects. According to Korkmaz (2007), energy and IEQ sections reflected that some of the criteria in these sections might conflict with each other. However, the results of a regression analysis conducted demonstrated a positive relationship but only with a 13.4% of the variance (Korkmaz, 2007). Therefore, these sections are to be considered as different metrics.

The metrics used to measure levels of high performance green in project that are based on the definitions provided by Korkmaz (2007) are: energy performance, level of green, level of high performance, and indoor environment quality performance. Finally, one more metric was added to the existing ones this is achieved certification vs. intended. This directly determined the success of the project i.e., the project being below, above or on target.

6. *Owner's Perception of the Resource Consumption and Level of User Satisfaction in the Post-Occupancy Phase*

    a. *Energy:* Energy consumption and reduction is the most important building utility affecting building performance. It is typically responsible for the highest building cost and has an environmental impact based on the energy sources used (Fowler et al., 2005). It would include Heating, Cooling, Lighting Ventilation, and Equipment. For the purpose of this research no actual data was collected instead the owner/facility manager were asked to rate the level of their satisfaction with the energy performance of the building on a likert scale from 1 (poor) to 5 (excellent).

    b. *Water:* Potable water consumption is the second most important building utility representing costs and resource use (Fowler et al., 2005). The evaluation of this metrics will be similar to that of energy.

    c. *Quality:* In the post occupancy phase quality is defined by the level of user satisfaction of the facility. This metric includes system quality (Konchar and Sanvido 1998) and overall quality (Korkmaz, 2007) and facility usage quality.

        - *Facility usage quality:* This again is a relative metric and combines project usage satisfaction from the owner's perspective. This metric uses a Likert scale from 1(poor/did not meet expectations) to 5 (excellent/exceeded expectations) respectively and is calculated with the formula given below. A total of 20 points is possible for each project in this metric, where high points indicate higher levels of project success.

$$Facility\ Usage\ Quality = S_{water\ consumption} + S_{energy\ consumption} + S_{occupant\ turnover\ rate} + S_{absenteeism}$$

- *Overall Quality:* This is a relative metric and combines project success from a project team's and owner's perspective, with the condition of meeting the intended project and high performance green goals. This metric uses a Likert scale from 1(poor/did not meet expectations) to 5 (excellent/exceeded expectations) respectively. A total of 20 points is possible for each project in this metric, where high points indicate higher levels of project success.

$$Overall\ Quality = S_{project\ team} + S_{owner} + S_{goals} + S_{high\ performance\ green\ goals}$$

- *Indoor Environment Quality:* Level and quality of indoor pollutant concentrations, thermal comfort conditions, lighting quality, Acoustics, and Day-lighting and views are environmental characteristics that are collectively referred to as indoor environmental quality (IEQ) (NIBS, 2005). These together as well as individually have the potential to influence the health and productivity of building occupants (Fisk and Rosenfeld, 1997).
- *Thermal comfort:* This includes ventilation temperature and humidity levels. Although thermal comfort standards were developed by keeping occupants clothing and activity levels in consideration such as ASHRAE / ANSI Standard 55-1992, it is difficult to satisfy all the occupants because thermal preferences vary among people. Therefore

this is a relative metric and would evaluate thermal comfort from the user's perspective. Other than the temperature and air velocity, humidity also will adversely influence thermal comfort (Building Green Inc., 2001). This metric uses a Likert scale from 1(poor/bad) to 5 (excellent) respectively.

- *Lighting comfort:* The quality of the indoor environment depends significantly on several aspects of lighting (Veitch and Newsham, 1996) including the illuminance (the amount of light that reaches a surface.), and glare. Lighting characteristics impact performance by influencing the quality of vision and having psychological influences on mood and on perceptions of the space (Veitch, 1997; Deru and Torcellini, 2005). Similar to thermal comfort standards were developed to determine occupant comfort such as ANSI/IESNA—RP-1-1993, however, experience varies amongst the users. This metric uses a Likert's scale ranging from 1(poor lighting comfort) to 5 (excellent lighting comfort) respectively.
- *Acoustical comfort:* Internal noise is a significant factor in terms of occupant satisfaction and wellbeing. World health organization recognizes that acoustics can be very influential on health and wellbeing and can also be a health hazard. It is measured in decibels (dB) where 0 dB corresponds to the lowest possible audible sound and 140 dB to the level at which pain will occur. Noise level should usually lie in the range between 30dB -35dB. Acoustical comfort for

the users is calculated by a Likert's scale ranging from 1 (very uncomfortable) to 5 (comfortable) respectively.

- *Health and Productivity:* Finally IEQ is reported to have effects on health and productivity of the building occupants (Heerwagen, 2000; Fowler et al., 2005). Increase or decrease in health and productivity can be detected through occupant turnover rate and absenteeism. This metric used a Likert scale from 1 (poor/bad) to 5 (excellent) respectively measuring the buildings perceived IEQ through turnover rate and absenteeism at the time of evaluation.

Table 2.5 Measurement Approaches and Techniques for Building Performance Evaluation Metrics at the Completion Stage (Konchan and Sanvido, 1998; Gransberg and Buitrago, 2002; Korkmaz, 2007)

Metrics	Measurement Approach	Measurement Technique
Schedule	• Schedule Growth • Construction Speed • Design Speed • Delivery Speed	[(Total Actual Delivery Time-Total as Planned Time) / Total as Planned Time]* 100 (Area / Actual Construction Time in Days)/30 (Area / Actual Design Time in Days)/30 (Area / Total Actual Delivery Time in Days)/30
Cost	Cost growth	[(Final Project Cost-Contract Project Cost) / Contract Project Cost]* 100
Quality	• Turnover • Owner Satisfaction	Qstartup + Qcall backs + Qsubmittal review Likert scale responses of owner perception
Safety	• OSHA Recordable Incident Rate • Days Away/Restricted or Job Transfer Rate • Lost Time Case Rate • Lost Work Day Rate	Archived Documents
Levels of High-Performance Sustainability	• Energy Performance • Level of Green • Level of High Performance • Indoor Environment Quality Performance • Achieved vs. Intended Certification	(Achieved Energy Points in LEED® / Total Possible Points in Energy Section)*100 (Achieved Total Points in LEED® / Total Possible Points in LEED®)*100 (Achieved Energy Points+ Achieved IEQ Points in LEED® / Total Possible Points in Energy and IEQ in LEED®)*100 (Achieved IEQ points in LEED® / Total Possible Points in IEQ Section)*100 Below, above, or on target
Owner's perception of the resource consumption and level of user satisfaction in the post-occupancy phase	• Energy • Water • Quality • IEQ	Likert scale responses of owner perception

2.7 Summary

This chapter has addressed the need and importance of sustainable construction in the present times. It also reports the details and characteristics of the green building assessment systems that evaluate sustainable construction. As the assessment systems are critiqued on being only product based and lacking process based guidelines such as utilization of multidisciplinary collaboration, integrated design, and contractual arrangements. Therefore, next in the chapter, integration in the design process is discussed that advocates early collaboration of the participants. However, it was understood that the timing of the involvement of the participants depends upon the contractual arrangements that are categorized under PDM's. Therefore the chapter next describes the various PDM's that are prevalent in the U.S. construction industry. Finally the chapter presents a review of the performance evaluation metrics available in the literature that will help in the identification of key characteristics of the integration that lead to better performance. In particular for the project delivery phase the metrics was adopted from Korkmaz (2007). The current research intends to build on this study by also employing its data collection tools and methods and verifying its findings through utilizing a well thought case study selection process and analysis. To achieve the goals of this research the following chapter describes the methodology steps to be undertaken.

CHAPTER 3

Methodology

3.1 Introduction

A review of the literature conducted in the last chapter established that higher levels of integration achieved in a project result in better performance outcomes. It also suggests that the achieved level of integration gets affected by project delivery methods (PDM) because it formally defines the relationship between the project participants. Based on literature, previous researches, and green case studies a relation exists between PDM's, integration and the final achieved/ to be achieved sustainable goals. However, no cause-effect relation was identified or researched upon rigorously by previous studies. To fill this gap in the literature the current research is attempting to answer the question: *'What is the extent of the effect of PDM's and practices on the level of integration achieved by the project team and further does it have a significant effect on project performance especially on achieving sustainable goals?'*

In the pursuit of answering the stated question, this research aims to qualitatively analyze the influence of PDM's over the relationship existing between players. The current project is a follow up study to a recent research at Penn State University, 'Piloting Evaluation Metrics for High Performance Green Building Project Delivery', (Korkmaz, 2007). This study intends to adopt and build on the lessons learned from the previous research. In this quest the data collection tool and evaluation metrics will be adopted from Korkmaz (2007), however, both will be evolved to fit the specific needs of this research. This chapter contains a description of the research process and specific methodological steps that will be followed in the investigation of the research question.

3.2 Research Goals and Objectives

The main goal of this research study is to, *"determine the extent to which project delivery methods and practices affect levels of project team integration and whether this has an effect on project performance especially on achieving sustainable goals."* The specific objectives of this study are to:

1. Determine the relationship between the level of integration achieved in the delivery process and sustainability goals;
2. Determine the relationship between various PDMs and the levels of integration achieved in the design process;
3. Identify the main project delivery attributes that have relations to project outcomes in a green building and examine the identified patterns according to various PDMs.

3.3 Research Approach

Case study approach to research as defined by Yin (2003), is "an empirical inquiry that: (1) investigates a contemporary phenomenon within its real life context, especially when (2) the boundaries between the phenomenon and context are not clearly evident." Yin further suggests that in this approach there are several variables of interest than data points therefore it requires collecting and triangulating results from multiple sources of evidence. For collection and triangulation this approach encompasses a variety of data collection and analysis methods such as ethnography, evaluation, experiments, grounded theory and quasi- experiments (Yin, 2003), therefore including both qualitative as well as quantitative methods of analysis.

Similar to other approaches this method is also subject to negative critique. One of the main critiques received by this approach is the generalizability of the results due to limited sample size (Flyvbjerg, 2006; Yin, 2003; Taylor et al. 2009). However, Platt (1992), suggests that cases should be selected based on their ability to support analytic generalization as opposed to statistical generalization (Platt, 1992). Another negative critique as reported by Taylor et al (2009), states that many manuscripts based on case study research are executed with insufficient precision, quantification, objectivity or rigor where investigators have not followed standard procedures, or have allowed a biased view to influence the direction of the findings. However, bias on the part of the researcher can occur and be controlled with any research method (Taylor et al. 2009).

Although the negative critiques are very valid and support quantitative and statistical methods of analysis, it must be understood that in the construction industry many phenomenon are often too large to be tested in a traditional quantitative and statistical fashion. Also, the number of variables within the research can be beyond finite hence becoming out of the managing capacity of the researcher (Taylor et al. 2009).

According to Taylor et al. (2009) in the field of construction research case studies allow researchers to study phenomenon set in reality thereby allowing the researcher to witness decisions made about real issues that impact factors such as a time, cost, quality, and safety. This approach also allows researchers to observe and document causal factors and quantify the impact of new technologies or techniques on a project by a exploring the details of particular application and capturing the participants own observations about difference between the case in question and other projects. Furthermore case study allows researchers to work at a variety of levels of granularity (Taylor et al. 2009).

Along with case study approach other methods also pose the following limitations such as access to (Taylor et al. 2009):

1. a willing respondent;
2. the project details; and
3. information that is often considered propriety or confidential.

However, Taylor et al. (2009) suggests that "as a researcher establishes a relationship with a case study project, these barriers are often overcome because the researcher is committed to an in depth study and considered as part of the project team".

3.3.1 Choice of Research Strategy

Over the years, research methodology and theory of inquiry have undergone complex discussions and arguments, however, no consensus was found. The main dilemma that the researchers face is to choose the most 'scientific' method between qualitative and quantitative processes of analysis. Where qualitative research explores attitudes, behavior and experiences through methods such as interviews and focus groups, quantitative research generates numerical data through large-scale surveys and questionnaires (Dabbs, 1982). Due to its nature of relating to numbers and measures (therefore *implied* precision) quantitative methodology is *impulsively* considered to be more scientific than qualitative (Berg, 2006). Other reasons for a comparatively lower popularity of qualitative methodology are that the research takes longer period of time, requires greater clarity of goals during design stages, and can't be analyzed be running computer programs (Berg, 2006).

The above presented argument is clearly biased towards the quantitative methodology however; this approach cannot be considered as absolute. This method is limited to the development and utilization of mathematical models, theories and/or hypotheses pertaining to natural phenomena (Silverman, 2001). Unlike qualitative methods it does not have the potential to examine, analyze and interpret observations for the purpose of discovering underlying meanings and patterns of relationships, including classifications of types of phenomena and entities (Patton, 2002). The contrast between the two methodologies and the debate to choose one over the other is extremely common and documented in the social sciences. In construction studies researchers still tend to follow quantitative methods however; recently qualitative methodology is accepted as a valid approach for research.

Adopting a qualitative approach is essential to this study because it aims at understanding the process followed during the execution of the project by comprehensively assessing and documenting the subjective understanding of the events, to optimize strategies for sustainable high performance buildings, experienced by the project participants. This will be achieved by evaluating cross-discipline interactions, team dynamics, and consensus-based decision-making that are understandably unquantifiable.

3.3.2 Qualitative Approach in Construction Research

As mentioned earlier construction research is traditionally dominated by studies analyzed quantitatively. However, considering the diverse, dynamic and people centric character of this field recently qualitative methodology is accepted as a valid approach to research. Descriptions of some relevant qualitative examples are presented next. Also, to show the change in the methodology trend in construction research Table 3.3 summarizes additional qualitative and quantitative studies.

1. *Piloting Evaluation Metrics For High Performance Green Building Project Delivery (Korkmaz, 2007):* The main goals of this research study were to: (1) Define meaningful evaluation metrics for high performance green building project delivery, (2) Develop tools/methods to collect high performance green building project delivery data, and (3) Illustrate data analysis methods for high performance green building project delivery research.

   The research used mixed methods *(qualitative and quantitative)* for data analysis. Under qualitative approach two methods were employed: (1) Pattern matching, and (2) Cross case synthesis. Both techniques were performed over multiple case studies. The case studies were selected based upon research specific case study selection criteria. The analysis primarily included performance comparisons of two sets of projects according to the predetermined performance criteria. The process attributes of the two categories were recorded and compared to observe any difference in patterns. Results were reported to support or reject and add to the quantitative analysis results.

Pattern matching was performed using similar case study pairs. It was conducted by assigning scores to the performance metrics of the case studies using a qualitative scale (-1: Poor, 0: Average, 1: Good). It was then determined whether any differences occurred in the sum scores of performance outcomes based on changes in the project delivery attributes. Finally, it was determined that the projects showing similar scores were focusing on almost same attributes thus presenting a pattern.

The results of this approach provided support for four out of seven process indicators (PI) defined in the research. These process indicators, in the order of their importance were: (1) contract conditions, (2) owner commitment, (3) integrated design, and (4) project delivery methods. Although the PI's were not rejected due to the lack of contradictory results their influence over performance outcomes was determined to be inadequate as they failed to yield positive evidence.

In the cross case synthesis approach, projects were categorized as good and poor performing and a comparison was conducted by marking the project delivery attributes that differ in the two project categories. Table 3.2 illustrates an example of this method. According to the research the results aligned with the expected outcomes i.e., certain attributes were present/ emphasized upon in the projects rated vs. the poor ones.

2. *Lapinski et al. (2006). Lean Processes for Sustainable Project Delivery:* The purpose of this paper was to evaluate, using a scientific approach, the life cycle of Toyota's capital facility delivery process to empirically identify the critical activities and capabilities that led to the success of Toyota's South Campus project. This involved comprehensive process-based analysis to identify accurately the critical juncture for the generation of value and waste in Toyota's delivery system.

To document the process for evaluation, a modeling approach was developed to map the entire capital delivery process, i.e., programming through design, procurement, construction, handover, and operation. These maps provided a pictorial representation (with levels of detail increasing) of the steps Toyota uses to deliver their capital facilities. An example of the process model is given in Figure 3.1

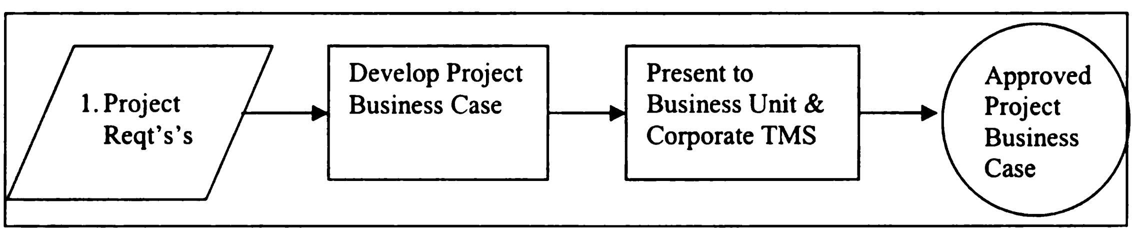


Figure 3.1 Toyota Capital Delivery Process Map: Levels Top 2 and Bottom 3 (Modified from Lapinski, 2006)

The main qualitative method used in this study was content analysis in the form of value assessment. Essentially, the developed process maps underwent value assessment. Here, each activity was scrutinized to evaluate if it met the needs of either the end user, or the environment. If a certain activity could attribute no value in these terms it was categorized as waste. However, in some instances, an activity was found to be wasteful, but essential to achieve a value added outcome. In these cases, the activity was categorized as non-value adding.

For purpose of this study, the aim of conducting a value assessment was to identify all occurrences of value and waste generation (inclusive of non value adding) in conjunction with Toyota achieving sustainable goals. Having assessed the locations of value and waste generation in the delivery process, activities were then examined for their contribution to the sustainable goals for the project. This provided an understandable breakdown of the value-adding activities that contributed to the sustainable objectives during project delivery. Finally, the analysis focused on identifying opportunities for delivery process improvement which assisted in revealing the process improvements in building project delivery.

3. *Pulaski (2005), The Alignment of Sustainability and Constructability: A Continuous Value Enhancement Process (CVEP):* The goal of this research was to develop a process based model enabling project teams to continuously generate new ideas and identify optimal building solutions concerning sustainability for high performance building projects. This research used mixed methods *(qualitative and quantitative)* for data analysis. Under qualitative approach two methods were employed 1) Content analysis and, 2) Comparative analysis. Content analysis refers to "any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings" (Patton 2002) and Comparative analysis is a

common analytical technique used in qualitative and quantitative studies to compare empirically based patterns, models or events with a predicted one (Patton 2002).

Under content analysis the data was coded according to clearly defined context specific categories with each data point coded under only one category. Comparative analysis was conducted by two methods; qualitative and quantitative. The qualitative portion of the analysis applied to assess the systematic nature of the model by comparing the details of the evaluation process (CVEP) to a leading industry organization (TPS – The Toyota Production System) (Table 3.1) This research technique enabled key aspects of the model to be examined for alignment with existing research and state-of-industry practices. The results indicated that the CVEP model had an impact on the performance of building projects. This model enabled the project teams of the selected case studies to optimize and improve first and life cycle costs by promoting new ideas. However, comprehensiveness and external applicability tests were not completely validated although the data suggest that the model possessed these capabilities.

Table 3.1 PVEs from Pilot Study on Project 1 (Modified from Pulaski, 2005)

Value enhancement log (Wedge 2)	Cost	Quality	Schedule	Process Efficiency	Safety/ Health	Maintainability	Resources Use	LEED Credit	Timing	CSI Division
Offsite Fabrication of the smart walls	0	1	1	-1	1	1	1	1	SD	9
Carpet tile in lieu of Broadloom	1	1	1	1	1	1	1	1	75%	9
Mechanically crimpted (Propress) fittings versus solder joints in the plumbing piping	1	1	1	1	1	1	0	0	RFP-35%	15
The Universal Space Plan (mock up) helps to create user acceptance and promotes knowledge of the new system and functionally of the space	1	1	1	1	1	1	1	0	RFP	1
Use of PDS ribbon fibre significantly reduces the amount of EMT required	1	0	1	0	0	1	1	0	50%	17
Kits of parts furniture as a standardized repeatable component of the building system	1	1	1	1	0	1	0	0	75%	12
Optional glass infill panels maximize day lighting within delineated suites	0	1	0	0	1	1	0	1	SD	12
Factory applied carpet on access flooring improves air quality on site (glue vapors) and reduces the risk of safety hazards.	0	1	1	0	1	1	0	0	50%	9
Energy Management Control System (EMCS) to control lighting and HVAC.	0	1	0	0	1	1	1	1	RFP	15
Recycled content Gypsum Wallboard	0	0	0	0	0	0	1	1	Procurement	9
Low-e Windows throughout the building	0	0	0	0	0	0	1	1	SD	8
Refurbish existing hand rails	1	0	-1	0	0	0	1	1	CD	6
Thermostat Occupancy Pushbuttons recommended vs. Suite Entry Pushbuttons for after hours override lighting control.	1	0	1	-1	0	1	1	0	15%	16
Totals	7	8	7	2	7	10	9	7		

4. *Magent (2005) A Process and Competency-Based Approach To High Performance Building Design:* The aim in this research was to provide a methodology to evaluate continuously and improve the value, relationship, and timing of decisions in the design process of high performance buildings through a reduction in the waste generated during the design process. The author opted for a qualitative research approach to achieve the stated aim. Essentially two methods were adopted to analyze the data (1) Content analysis and (2) Cross case synthesis.

Data collection was in the form of interviews. Content analysis was conducted on these interviews to identify project events that were related to the predetermined six research propositions. Once the events were categorized they were analyzed individually to see if they supported the proposition positively or negatively. Next, each event that was determined to support a given proposition was compared to other events within the individual case study for replication. Replicated event occurrences that supported a proposition were identified and an internal case study proposition validation was developed for each project. The analysis of individual cases was followed by a cross-case analysis. Here the occurrence of similar events in each project was studied to triangulate the results to determine the degree of proposition support within and between cases. An example of the method described above is given in Table 3.2.

Table 3.2 Final Results of Proposition Event Replication (Modified from Magent, 2005)

	Replications Required for Validation	Total Number of Replications	Event Occurences By Project		
			Cambria	SALA	AIHI
Proposition #1 Function Based Process Design	3	7	10	4	4
Proposition #2 Design Decisions Charachteristics	4	4	3	1	1
Proposition #3 Decisions Timing and Sequencing	5	9	15	17	13
Proposition #4 Pull Driven Commitments	5	6	11	8	11
Proposition #5 Competemcy Centerd Team	6	8	22	15	16
Proposition #6 Decisions Based Evalutaion Model	4	0	0	0	2

The final results confirmed validation of five out of six propositions. According to the author failure in the validation of the sixth proposition was not due to the disproval of the proposition rather it was inadequacy of the evidence gathered from the case study. However, due to the lack in validation of the sixth proposition it was omitted from the research findings.

Table 3.3 Review of the methods utilized in project delivery literature

Reference & Description	Methods: Quantitative	Methods: Qualitative	Limitations
Pocock (1996): Compared the performance of traditional projects to those using alternative delivery approaches	- Regression Analysis N= 209		
Konchar and Sanvido (1998): Empirically compared the cost, schedule and, quality performance of the U.S. building projects that used CMR, DB and DBB project delivery systems	- Univariate and - Multivariate regression models N=301		Objective data for quality performance was collected by direct interactions b/w researcher and owner that could be biased based on owner perception
Molenaar and Songer (1998): The study provides a formalized selection model for public sector design build project.	- Regression Models N=122		The model cannot produce accurate predictions a 100% of the time.
Pulaski, (2005): Develop a process-based model for detailed project decisions concerning sustainability on high performance building projects	- Categorize and Plot (+) and(–) rated data, Sign Test and, Null Hypothesis Testing	- Content Analysis - Comparative Analysis - Document Review	- Short period of time to effectively gauge any continuous improvement - Unclear whether results would increase or decrease with extended timeframe - Limited sample size
Magent (2005): Evaluate and continuously improve the value, relationship, and timing of decisions in the design process of high performance buildings.	N=3	- *PM - **CCS - Explanation Building	- Researcher Bias - Limited sample size
Beheiry et al (2006) Establish a research mechanism to investigate the impact of corporate commitment to sustainability on capital project planning performance.	Regression Analysis N=17		- Limited sample size - Low level of significance in the findings
Lapinski et al. (2006): Evaluated the life cycle of Toyota's capital facility delivery process to empirically identify the critical activities and capabilities that led to the success of Toyota's South Campus project.		Process Mapping	
Korkmaz (2007): Define meaningful evaluation metrics for high performance green building project delivery.	- Univariate and - Multivariate regression models N=40	- *PM - **CCS	- Limited sample size Handpicking case study threatens the external validity
Enache-Pommer and Horman (2009): To provide understanding of the key process those are most critical for delivery of good health care facilities.	N=4	- Process mapping - *PM - **CCS	

*PM=Pattern Matching **CCS= Cross Case Synthesis

3.3.3 Summary

Qualitative methods of analysis are not commonly utilized in construction research. However, recent studies have successfully attempted to use this methodology for collection and interpretation of data. The studies listed above successfully developed and validated models and metrics or validated pre-developed models and metrics. These were majorly done by developing propositions from the literature or previous research that were validated by data collected from case studies. Their final results are published in peer reviewed journals and conference proceedings.

The summary of the analysis methods and their utilization in the studies is presented above. They strongly support the use of qualitative methods of analysis for understanding certain phenomenon in this field. All the studies presented above either used only qualitative methods or adopted mixed (qualitative and quantitative) methods of analysis to triangulate the results for increased validation. The main qualitative analysis methods selected in these recent researches are content analysis, pattern matching, and cross case synthesis or a variation of them. Content analysis essentially categorizes the data under different themes and topics. The themes can be predetermined or developed during the course of analysis. Depending upon the aim of the research pattern matching is used to recognize emergence of any pattern in the data set or to compare empirically based patterns with predicted patterns. Finally cross case synthesis is adopted to mark distinct differences between data sets. This is generally conducted between data sets at the extreme ends of the sample spectrum.

3.3.4 Research Strategy Adopted for the Current Study

This research seeks to understand the influence of PDM's on high performance sustainable buildings outcomes by analyzing its affect on the level of integration achieved. To achieve the intended objectives this study will follow a qualitative approach for data collection and analysis. The procedures followed and their outcomes in each step of this research are illustrated in Figure 3.2.

- *Unit of analysis:* To satisfy the research goals the author will employ a variety of projects for analysis. The relationship between the players and affects of those interactions on the performance outcome of the building can be understood only by studying the participants of the various building projects. Therefore, "*projects*" will be considered as the unit of analysis in this study, rather than organizations or individuals.

This study is based on the finding of a recent research 'Piloting Evaluation Metrics for High Performance Green Building Project Delivery' (Korkmaz, 2007). It will use the outcomes and lessons learned from the previous study as a building block for further investigation. Also it would adopt and according to the research specific objectives alter the outputs developed by the previous researcher. The main outputs of the research conducted by Korkmaz (2007) were:

1. Defined meaningful evaluation metrics for high performance green building project delivery;
2. Developed tools/methods to collect high performance green building project delivery data;

3. Illustration of data analysis methods for high performance green building project delivery research.

This research piloted an evaluation metric for the project delivery phase to fill the gap in literature. The developed tool was based on previous research conducted at Penn State University and was again tested by the author on 40 high performance green projects. Finally, the study used mixed methods for data analysis that was used as a foundation for the choice of analysis approach of the current research.

The literature review has assisted in the development of the methodology for this research. The research process and steps followed are listed in Table 3.4. This includes sequentially the steps and the chapters that the mentioned steps belong to. The research steps include review of relevant literature, research approach, data collection tool development, data collection, qualitative data analysis procedure, discussions, results, and conclusions.

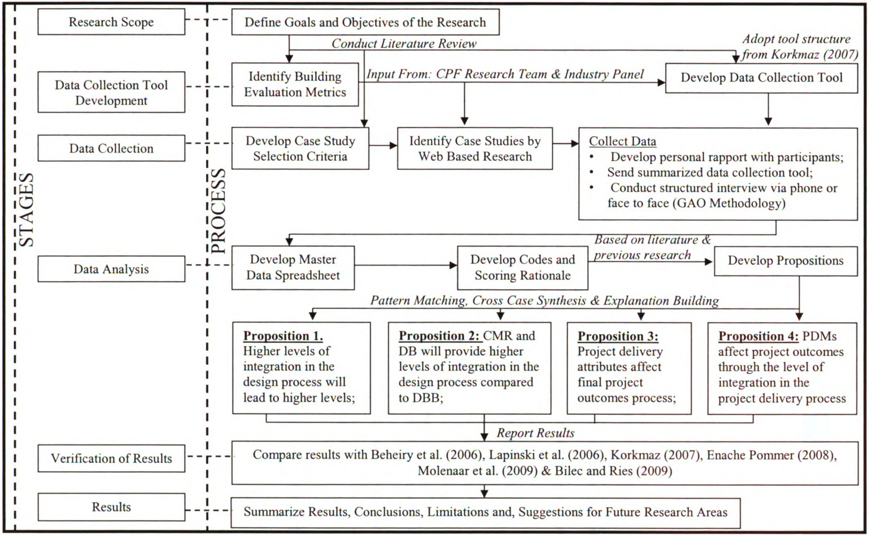


Figure 3.2 Process Map of the Steps Followed to Achieve the Objectives of the Research

Table 3.4 Methodology Steps

Research Process	Steps
1. Review of Relevant Literature (Chapter 2)	• Conduct Literature Review • Document : o Relevant project delivery and level of integration - opportunities and constraints; o Performance metrics; o Data collection and analysis methods; o Sources for data collection
2. Research Approach (Chapter 3)	• Research approach: o Choice of research strategy o Qualitative research in construction studies o Research strategy adopted for the current study • Data Quality
3. Development of the Data Collection Tool (Chapter 2)	• Adopt and alter evaluation metrics from previous research Korkmaz (2007); • Preliminary Survey/Structured Interview Design adopted and altered from Korkmaz (2007) • Survey Verification o Charles Pankow Foundation Research team o Industry Professionals o Pilot survey
4. Data Collection Process (Chapter 3)	• Case study selection criteria • Data Collection Steps o Institutional Review Board Approval - Contact respondent via email or phone o Data Collection and Follow-up - General Accounting Office methodology for structured interviews
5. Data Analysis Procedure (Chapter 3)	• Code data under developed propositions; o Priori o Inductive • Develop proposition based on literature and collected data; • Data Analysis - Pattern Matching - Cross Case Synthesis - Explanation Building
6. Data Collection Procedure (Chapter 4)	• Study Response Rate • Data Verification • Study Population Characteristics
7. Results (Chapter 5)	• Findings • Lessons Learned
8. Discussions, Limitations and Conclusions (Chapter 6)	• Comparisons with the findings of the previous research • Summarize findings of the study • Identify the limitations of the research

3.3.5 Data Quality

To ensure quality design in case study research, four widely used tests will implemented: construct validity, internal validity, external validity, and reliability (Yin, 2003).

1. Construct validity: This is necessary to create correct operational measures. To implement this tactic Yin (2003) suggests use of multiple sources of evidence, establishment of a chain of evidence and finally having a draft of case studies reviewed by key informants. In the current research, this was accomplished by, interviewing multiple participants from each case study facilitating cross-referencing and triangulation of the results. Also, the draft case study report was reviewed by the Charles Pankow Foundation (CPF) research team and the industry panel associated with the team members, who commented on the comprehensiveness of the data collected. This took place in the data collection and final report composition phases of this research.
2. Internal validity: This is important in explanatory studies to establish casual relations. Yin (2003) proposes five tactics to approach this test. This study has adopted three out of the five approaches; these are pattern matching, cross case synthesis and explanation building. Pattern matching was accomplished by identifying emerging patterns in the data collected from projects. Cross case synthesis focused on identifying distinct differing attributes in the case studies. Finally, explanation building was adopted to understand the specific practices that lead to success or failure in outlier projects. These took place in the data analysis phase of this study.

3. External validity. This test establishes that the study findings can be generalized. According to Yin (2003) a replication model should be implemented via various case studies. Therefore, for the purpose of this research data was collected from multiple similar case studies with similar characteristics. However, it was observed that due to the limited number of case studies statistically significant results could not be generated. Therefore, to bolster the results and achieve external validity explanation building was adopted by cross referencing and discussing the results with those from previous research. Although this physically took place during the data collection and analysis phase it is categorized under research design. This is because this test was a significant deciding factor for deciding the number of case studies that were selected to prove the stated goal for this research.
4. Reliability: This represents the operations of a study and is important for the repetition of similar studies. Yin (2003) suggests development of standard protocol for data collection. Therefore, this research altered and utilize the data collection tool i.e., structured interview, to collect data from the case studies. This was the standard data collection tool for all the projects. This test was implemented in the data collection phase of this research.

The section above has described in detail the various tests to be performed to ensure data quality. It also describes tactics suggested by Yin (2003), tactic that will be implemented in this research, and phase of the research that the tactic will be implemented in. the various tests and tactics have again been listed in Table 3.5.

Table 3.5 Data Quality Tests and Tactics (Adopted from Yin, 2003)

Test	Tactic suggested by Yin, (2003)	Tactic to be implemented in this research	Phase of research in which tactic will occur
Construct Validity	Use of Multiple sources of evidence	Data triangulation through interviews of multiple project participants;	Data Collection
	Establish chain of evidence	Develop research design process for each step of the case study data collection;	Data Collection
	Have draft case study report reviewed by key informants	Request comments on report from the CPF research team and industry panel;	Composition
Internal Validity	Pattern Matching	Identify multiple similar characteristics of the project execution process in similar projects;	Data Analysis
	Cross case Synthesis	Identify multiple differing characteristics of the project execution process among projects of variant attributes;	Data Analysis
	Explanation Building	Identify specific characteristics and practices in outlier projects;	Data Analysis
External Validity	Use replication logic	Collect data from multiple similar sets of projects;	Research Design
		Discuss final results with past research;	Research Design
Reliability	Use case study Protocol	Develop standard protocol for conducting interviews;	Data Collection
	Develop case study database		Data Collection

3.4 Date Collection Procedure

This section summarizes the data collection procedure including the performance evaluation metrics adopted for this study, methods to test and verify the data collection tool including the lessons learned from the pilot case study, case study selection criteria and finally the data collection and follow up process.

3.4.1 Performance Evaluation Metrics

The performance metrics to be utilized in the current study is one of the three main outputs of the research conducted by Korkmaz (2007). The author aimed to examine the relations between the project delivery attributes and project performance outcomes in high-performance green (high performance green) buildings. As literature lacked an evaluation metrics for the project delivery phase the research first conducted a comprehensive literature review to define and list meaningful attributes to be evaluated which are adopted by the current research.

Based on previous research (Korkmaz, 2007; Konchar and Sanvido, 1998) and existing literature this study has categorized the building evaluation metrics and attributes in to three phases of the project life span. The three categories are 1) Project Delivery Attributes; 2) Building Performance Upon Completion and; 3) Building Performance Post Occupancy. This study primarily focuses on the first two stages by investigating the effects of project delivery attributes (independent variables) on project performance at construction completion (dependent variables). Addressing the last stage occurs through owner perception, and therefore, the last stage becomes a component of the second stage as "Owner's Perception of the Resource Consumption and Level of User Satisfaction in the Post-Occupancy Phase." The description and scope of the two categories are given below. The individual list of the adopted metrics can be seen in the literature review (Chapter 2) section of this research.

1. *Project delivery attributes*: The evaluation metrics for this phase is adopted from the recent research conducted by Korkmaz (2007). This category evaluates the process followed for the execution of the building. The span of this category is from the conception of the project until it is turned over to the client/ owner/ tenant. It aims to document the subjective experiences and the method of evolution of innovative ideas for the optimization of project outcomes. The main themes that this category is addressing are owner commitment; project delivery method, project team procurement, contract conditions, integration in the design process, and project team characteristics. However, this research has prioritized project delivery method, project team procurement, contract condition, and integration in the design process. During data collection these will be addressed first, later if the resources allow, data pertaining to the remaining two will be collected.
2. *Building Performance upon completion*: This category consists of metrics such as schedule, cost, quality, safety, levels of high performance, and level of user satisfaction in the post-occupancy phase achieved (comparing the intended vs achieved performance levels) achieved (Korkmaz, 2007; Konchar and Sanvido, 1998; Gransberg and Buitrago, 2002; Fowler et al., 2005). These metrics are adopted because they clearly and quantifiably demonstrate the success/failure of the project. Success/failure can be defined by the owner's satisfaction with the growth (negative/positive) in cost and schedule and level of performance achievement in safety and high performance.

3.4.2 Test and Verify the Data Collection Tool

The tool to be utilized in this study is the second main output of the research conducted by Korkmaz (2007). It was already based on previous research of Konchar and Sanvido, 1998 and El Wardani et al., 2006 conducted at Penn State University. It was then verified two times by industry professionals. The first round of the survey verification was executed at the Partnership for Achieving Construction Excellence (PACE) Roundtable at Penn State in 2005. The second round of the verification was completed in Washington D.C. where industry professionals with experience of green buildings expressed their opinions on the lucidity and the competency of the survey questions, to measure the desired attributes. Finally Korkmaz (2007) utilized the tool to collect data from 40 sustainable high performance projects. The current research has adopted and altered the tool according to research specific criteria.

This research is funded by the Charles Pankow Research Foundation. This study is part of a joint research conducted by scholars from Michigan State University, Colorado State University, University of Oklahoma, and Pennsylvania State University. The research team works with an industry panel, consisting of leader's in the field of sustainable buildings, to get feedback at certain milestones, receive verification on research tools and outcomes, and receive support in case study selection and data collection.

Therefore, after developing the data collection tool (Appendix A), it was verified by the research team at the Charles Pankow Research Foundation (CPF). Also the tool was assessed by the industry panel associated with the research. After the approval of the research team and industry panel the tool was be submitted for the review and approval by the Institutional Review Board (IRB) at Michigan State University for compliance with human participant research rules (Appendix B and C). Finally, the tool was tested on one pilot case study. Since the core purpose of this research was to understand the affect of PDM's on the level of integration achieved and its consequent effects on the final outcome, these aspects were the focus. The next section discusses the results from the pilot case study.

3.4.3 Pilot Case Study

An office building in the state of Michigan was selected as the pilot case. Personal contact with the respondent and the physical proximity to the research team were the major determining factor in the selection. The project adopted the construction management at risk (CMR) delivery method. Also, it achieved United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®) platinum rating in two areas; core and shell and commercial interiors. A structured interview was held with the concerned project manager of the facility. This pilot study evaluated the validity of the building performance metrics and the data collection tool and methods. Lessons learned from the pilot study were as follows:

1. *The results showed that the identified evaluation metrics was entirely useful and collectible:* As the project followed the guidelines of several agencies, most data was well documented and since rest of the information requested from the respondent was intended to be more of an opinion than a fact the respondent felt comfortable in responding.

2. *The data collection method was successful in gathering information:* A personal relationship with the respondent was significant in data collection. Since the respondent already knew the research team the data was shared willingly. Structured interview was a successful form of data collection as a lot of the respondent's reaction could be documented unlike other quantitative measures such as a survey. Moreover, contacting various participants of the project for different sections of the project helped to minimize the time for the survey completion for each participant, improved the participants; willingness to participate, and decreased the number of non-response questions within the survey due to lack of knowledge in the area.
3. *The data collection tool requires follow up questions depending on the project:* Many unpredictable events can occur in a projects life. These events can have significant affects on project performance such as a weather change can cause schedule delay and consequent cost escalation or removal of a team player due to extreme situations can cause not only a schedule delay but loss of morale for the team members. Therefore depending on the preliminary interview, follow up questions will be added such as "Did anything extreme and out of the project team's control happen during the delivery process that affected project performance outcomes such as schedule and cost or team chemistry?"

3.4.4 Case Study Selection Criteria

This research focused on sustainable projects that have achieved one of the four levels of certification under USGBC's LEED® assessment system. Kats et al. (2003) reported the costs and financial benefits of green buildings. However, the author also reported the distinct difference in benefits between the four certification levels. According to Kats et al. (2003) though certified and silver buildings provide costs benefits in terms of energy and water consumption, gold and platinum buildings benefits are larger because they are represented by productivity and health of the occupants which is far larger than the costs of buildings and energy. Similar, results are presented in a report 'Building Better Buildings', prepared by the Sustainable Building Task Force and the State and Consumer Services Agency (2003). The report suggests higher benefits from gold and platinum rated buildings than certified and silver (BBB, 2003). Hence, it can be satisfactorily concluded that certified and silver projects can be achieved by standard practices; however, gold and platinum projects require more optimization. This achievement for higher optimization is reflected from high level of integration achieved during the design process.

The research prioritized on selecting 8 projects that defined the boundary conditions, however, as the resources allowed (time and money), the number of case studies was expanded to 12. For minimum bias, the ideal case study distribution was as following. The case studies were to be from 3 different locations with 1 Platinum rated buildings belonging to each location. There were supposed to be 3 certified buildings belonging to each PDM. To triangulate the results 1 project was to be selected from the silver certification under design bid build (DBB) and 1 project was to be gold certified under design build (DB). This distribution was to maintain minimum variability and bias. However, due to circumstances such as disinterested participants and non availability of the concerned respondents the case study distribution changed. The final case study distribution (prioritized and final) can be seen in Table 3.6., with the prioritized break down in parenthesis.

Table 3.6 Distribution of Case Studies

	Platinum	Gold	Silver	Certified
Design Build	1 (1)	2(1)	1	0(1)
Design Bid Build	1 (1)	0	1(1)	1(1)
Construction Management at Risk	2 (1)	0	1	2(1)

The variability in the projects was emphasized to strengthen the reliability of the results. The sample for this study is limited to green projects in the U.S., those included in the USGBC's database as LEED® *'New Construction'* and *'Core and Shell'* categories. Also, due to the limited population projects were selected until version 2.2. Version 3.0 is not addressed in this study as it was released after data collection phase. The other criteria for choosing the case studies for this research are listed next.

1. *Project delivery methods:* The case study must include one of the three PDM's: DBB, DB, or CMR. Efforts were made to achieve an equal number of PDMs within the study sample to eliminate bias towards any of the methods;
2. *USGBC's* LEED® *Rating:* USGBC's LEED® is the one the most popular assessment systems in the country and has in 2006 had 775 million sq ft of commercial space registered that is approximately 2% of the corresponding commercial built space (Smart Market Report, 2007). Therefore, it was considered as an apt data base for project selection. Also, this research is focusing on projects that were recently constructed. Hence, projects rated as new

construction were selected. Also, project under the core and shell category were considered as the evaluation metric for both are very similar. However, careful attention was required when choosing the projects because many projects in the USGBC's database listed as new construction or core and shell, had major renovated portions. This significantly changed the details of the project; hence, comparison with a new construction project was not valid;

3. *USGBC's* LEED® *Certification Level:* Projects were selected over all the categories of certification, such as platinum, gold, silver, and certified. Further, all the projects were compared, to observe any emerging patterns (successful or flawed). The projects were compared across certification levels to see the distinct differences;
4. *Location:* Certain regions, cities, and states in the U.S. are known to support the sustainability movement with enabling legislation. Location can also affect project outcomes with the available pool of contractors/designers in the area. Therefore, location variety in the sample was preferred to eliminate bias in the results towards any city, region, or state;
5. *Function:* For the purpose of eliminating functional and major construction systems / materials differences in projects selected, the focus was on the projects that were essentially office spaces. Minimal combination with other functions was focused upon;
6. *Personal rapport:* Certain projects posed as good case studies, however, due to lack of contacts or respondent disinterest information was not unavailable. Also, as this study was qualitative in nature, respondents were contacted several times

for data. Therefore, this research preferred case studies where there are preexisting interested contacts.

3.4.5 Data Collection Process and Follow Up

The data collection on identified buildings took place once the data collection tool had been developed and verified on the basis of the pilot case study. Target projects were limited to sustainable office buildings and other criteria listed in section 3.4.4 of this chapter. Based on the lessons learned from the pilot study, previous research, and existing databases, this research followed the General Accounting Office methodology (1991) for structured interviews. Respondents were contacted via email, phone, or both. The outline for the email and phone conversation can be seen in Appendix D and E. Three primary respondents (owner, designer, and contractor) were contacted from each case study. Questions in the data collection were segregated depending upon the respondent. On an average each interview took approximately 40-50 minutes and was conducted on the phone.

General Accounting Office (GAO) Methodology (1991)

The design of a GAO (1991) evaluation encompasses seven elements:

1. The kind of information to be acquired;
2. Sources of information (for example, types of respondents);
3. Methods to be used for sampling sources (for example, random sampling);
4. Methods of collecting information (structured interviews and self-administered questionnaires);

5. The timing and frequency of collecting information;
6. The basis for comparing outcomes with and without a program (for cause-and-effect questions);
7. The analysis plan.

According to GAO (1991), the first element i.e., the nature of the information to be acquired can be categorized into three evaluation strategies:

1. Descriptive: Provides descriptive information about specific conditions of a program or activity;
2. Normative: Compares an observed outcome to an expected level of performance;
3. Impact (cause-and-effect): Assists in determining that whether observed conditions, events, or outcomes can be attributed to the operation of the program or activity.

Considering the presented definitions the author has determined to adopt the descriptive strategy.

GAO (1991) has termed the technique for collecting data as data-collection instruments (DCIs). A DCI is a tool that contains a series of questions that are presented systematically and are highly ordered to enable the evaluator to obtain uniform data. The information obtained can then be categorized under themes and propositions and eventually can be subjected to analysis using quantitative, qualitative, or both methodologies. The form of a DCI varies according to the method of collecting information i.e., a structured interview, a self-administered questionnaire, or a pro forma schedule to obtain information from records. An interview that uses a DCI to gather data, either by telephone or face to face, is a structured interview. In this technique the same DCI is used to interview several participants thus the information received is precise and does not go much beyond the scope of the tool.

In contrast, an unstructured interview contains many open-ended questions, which are not asked in a structured, precise manner. Different evaluators interpret questions and often offer different explanations when respondents ask for clarification. As this research needed precise data, the structured interview strategy was adopted. Also the interviews were conducted over the telephone. As the DCI for this research contains a series of open ended questions, mailed questionnaires could not be used to maintain the response rate. It was also important for this research to adopt the face to face or telephone interviewing strategy to develop a personal rapport so that respondents can be approached again for follow up questions.

3.5 Data Analysis Procedure

Based on previous research and literature (Korkmaz, 2007, Lapinski, 2006; Pulaski 2005; Magent, 2005) it was determined that qualitative methods must be adopted to efficiently document and analyze innovative ideas and thought process that will evolve in the sustainable building market over time to improve their project delivery processes.

3.5.1 Data Coding

Once collected the next step was to manage the data. To arrange the data for analysis several methods could be adopted such as expanded accounts, memos, codes, and data displays. For the purpose of this research the data was managed by coding. In qualitative research, 'Coding' is understood as marking segments of data with symbols, descriptive words, or category names (Auerbach and Silverstein, 2003).

The data was coded at two levels for the ease of analysis:

1. *Coding Open Ended Responses:* This study used two kinds of coding for the open ended responses (1) priori: codes developed before examining the data; (2) inductive: codes developed based on the frequency of the occurrence of the themes. The priori codes were the description of the six independent variables used in this study. For example under owner commitment themes such as reason to pursue green, mandating green contractually or verbally, and participant to include green notions were used as codes. Further as the data was analyzed new themes occurred that were not listed before such as contractor commitment to the project, team commitment to the project, positive market image of the project. Therefore inductive coding had to be conducted by developing new codes that were later accommodated within the independent variables. This open ended responses were coded categorize quotes that would bolster and provide validity to the results achieved from pattern matching, cross case synthesis and explanation building.
2. *Coding Survey Responses:* To achieve the intended objectives certain survey data had to be coded to ascertain their level of success when compared to other projects within the data set. Primarily it included the data about the building performance upon completion i.e., schedule, cost, level of high performance achieved, quality, and post occupancy evaluation. The last two metrics were

based on owner's perception. The list also included two independent variables i.e., owner's commitment and level of integration in the delivery process. The other independent variables were not coded such as contract conditions, project team procurement, and project delivery method selected because the data within them was more inclined towards being practices rather than codable success factors. The coding logic and description are presented in Chapter 4.

3.5.2 Proposition Development

Considering the qualitative nature of this study, in place of hypothesis, that needs to be proved or disproved, propositions were developed. This research defines propositions as *'expected patterns'*. Essentially based on literature and the preliminary review of the data, existence of relationships between the different variables was observed. However, concrete analysis had to be conducted to bolster these propositions and converting them to results. Therefore, this research followed a spiral format of analysis i.e., a proposition was developed/observed, next analysis was conducted focusing on the concerned variables, further if the analysis supported the proposition then it was converted to a result else it was discarded and another proposition was tested. The spiral process is illustrated in Figure 3.3.

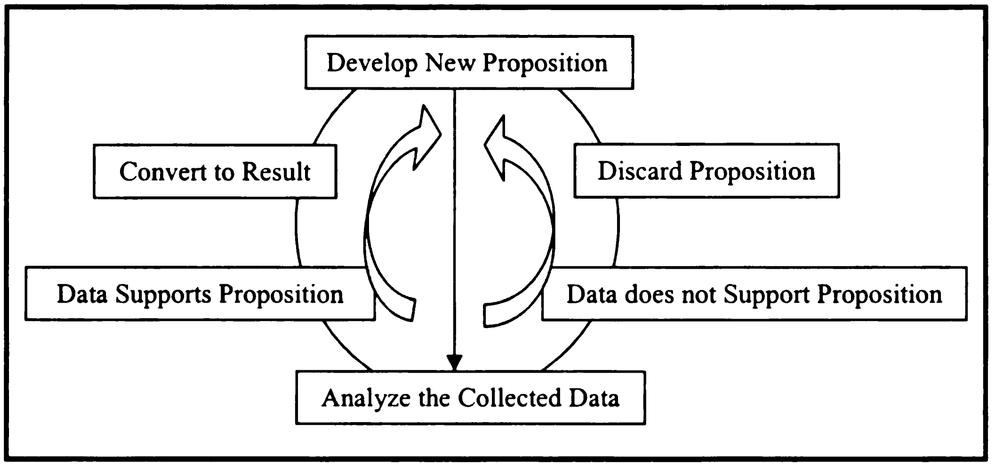


Figure 3.3 Proposition Analysis Process

Based on the objectives and the collected data this study developed four propositions that were tested for their relevancy and strength. The four propositions are given next:

1. Higher levels of integration in the design process will lead to higher levels of sustainability;
2. CMR and DB will provide higher levels of integration in the design process compared to DBB;
3. Project delivery attributes affect final project outcomes, and
4. PDMs affect project outcomes through the level of integration in the project delivery process.

3.5.3 Data Analysis Methods

Three methods were adopted analyze the data: (1) Pattern matching; (2) Cross case synthesis; and (3) Explanation building.

1. *Pattern Matching:* This refers to emergence of similar attributes in different projects. It demonstrates the existence of a pattern in projects of similar types and

can help explaining a recurring phenomenon. This analysis method was applied to the three objectives sequentially. The process followed for the application is as follows:

- Proposition 1 : Higher levels of integration in the design process will lead to higher levels of sustainability;

  First the projects were listed according to the level of integration achieved by them in the delivery process i.e., high medium low. Next, listed were the scores achieved by them in the three sustainability metrics. Once the table was created, different combinations of metrics were compared with the projects to see any emerging patterns such as higher integration resulting in better achieved vs intended performance or better sustainability scores.

- Proposition 2: CMR and DB will provide higher levels of integration in the design process compared to DBB;

  For this proposition first the projects were listed according to the level of integration achieved by them in the delivery process i.e., high medium low and then by the PDM adopted by them. Next, the dependent variable scores achieved by them were listed. Similar, to the previous objective the data was compared across rows and columns in different combinations to see emerging patterns.

- Proposition 3: Project delivery attributes affect final project outcomes;

  This was the largest and the most complicated objective as it required comparing all independent variables with the dependent variable to see patterns. To analyze, responses and coding, for independent and dependent variables was listed. Next, different combination of independent and dependent variables was compared to observe patterns. For example, in one combination level of owner commitment was compared with all the dependent variables to see if different levels of owner commitment results in different success outcomes. In another example two independent variables (i.e., owner commitment and integration in the design process were compared with the dependent variables to observe their combined affect on the outcomes.

- Proposition 4: PDMs affect project outcomes through the level of integration in the project delivery process.

  The testing this proposition was similar to the last proposition with only one primary difference. Here, all the independent and dependent variables were listed together in one table to check for patterns. This was conducted as this proposition encompassed the entire main goal of this study.

2. *Cross Case Synthesis:* In this approach pairs of projects on the extreme ends of the success spectrum were compared with each other to distinctly illustrate the differences between them. To conduct this analysis pairs of projects were selected with certain control variables (such as certification, size, PDM) kept constant between the two. This method assisted (1) in bolstering the pattern matching results; (2) explained the outliers within the pattern matching tables. An example of this method is given in Table 3.7.

Table 3.7 Example of Difference in the Available Propositions between Projects

	Owner Commitment			Contractual Terms		
Project	Green incorporated. by	Reason to Pursue Green	Timing of Green	Designer	Contractor	D-B
Exemplary.	Owner	Vision Statement	Con.D.	--------	---------	COST
Flawed	Designer	Grants	Des.D.	LUMP	LUMP	--------

* Con.D. = Conceptual Design, Des.D. = Design Development

3. *Explanation Building:* Within the pattern matching results a number of outlier projects were seen. Outliers were projects that displayed different results than expected. To explain these, each outlier project was analyzed individually to understand the specific characteristics.

3.6 Summary

This chapter contains a description of the methods and process that were followed in this research study. The research utilized a qualitative approach for data analysis and adopted pattern matching, cross case synthesis, and explanation building as the primary analysis methods. Based on the GAO methodology, structure interview, was selected as the primary data collection tool. To increase the response rate it was determined that phone interviews would be conducted. The main sections described in this chapter are data collection tool design, data collection process, data quality, and data analysis process.

CHAPTER 4

Data Collection, Categorization, and Coding

4.1 Introduction

Qualitative research attempts to identify and report the various facets of a phenomenon and the multiple perspectives towards the same. Therefore, it is important that the before presenting the results, sample data characteristics and steps taken to refine the data for analysis are defined. This chapter presents the study population characteristics, sample description, data collection procedure, data quality and verification methods and procedures with which to record, categorize, and code.

4.2 Sample Characteristics

Although the market for sustainable high performance buildings has existed for almost 3 decades it is still developing and has an extremely limited population. However, even in this limited population there exists a wide variety of characteristics. Therefore, a case study selection criterion (as explained in chapter 3) was employed to reduce the variability in the sample. As the original population in itself was very small the selection criteria further reduced the pool of potential case studies. This consequently reduced the control of the selection criteria and resulted in slightly different study population characteristics than as previously predicted.

In the descending order of priority the current study population characteristics are described next.

1. *Function:* It is suggested by Korkmaz (2007) that owners are mostly motivated to employ sustainable features on office buildings, due to reduced building life-cycle costs and improved occupant productivity provided by these buildings. Also, for the purpose of eliminating functional and major construction systems / materials differences in projects selected, the target population for this research was limited to sustainable office buildings. Also it was important for this research to understand the influence of integration over sustainable strategies therefore only new construction projects were chosen as these projects include maximum green strategies and need to achieve high level of integration to be successful.
2. *U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental design (LEED®) Rating:* Projects listed under new construction and core and shell in the USGBC's LEED® system were considered. This is because these ratings include the major buildings systems that this research attempts to understand. Also both ratings i.e., new construction and core and shell under USGBC's LEED® version 2.2 follow almost the same credit list making it an equal comparison.
3. *Project Delivery Methods:* It was essential for this research that the case studies broadly include one of the three PDM's: DBB, DB, or CMR. Efforts were made to achieve an equal number of PDMs within the study sample however due to the shortage of consenting respondents an equal distribution was not possible. Table 4.1 lists the current case study distribution. The intended distribution is given in parenthesis.

Table 4.1 Case Study Distribution

	Platinum	Gold	Silver	Certified
Design Build	2 (2)	2 (1)	1 (1)	0 (1)
Design Bid Build	1 (2)	0 (1)	1 (1)	1 (1)
Construction Management at Risk	1 (2)	0 (1)	1 (1)	2 (1)

Although Construction Manager at Agency is also a valid and a widely used PDM this study did not include this method in the sample due to the lack of study specific case studies. The majority of the projects found by the web research, adopted one of the primary three PDM's

4. *USGBC's Certification Level:* Projects were chosen over all the categories of certification, such as platinum, gold, silver and, certified. As can seen in Table 4.1, an equal distribution was attempted however, due to project delivery method selection being a higher priority and a lack of willing respondent an unequal distribution occurred.
5. *Personal rapport:* This research preferred case studies where there were preexisting contacts. However owing to the current economic situation many contacts we not available in the companies therefore a web based search for case studies was conducted.
6. *Location:* It was been attempted that project from locations with similar characteristics be chosen however due to the lack of consenting case studies projects were selected from all over the country. Figure 4.1 shows the location distribution of the study population.
7. *Size:* It was attempted that projects be of similar size however due to lack of projects this criterion was not prioritized. The resultant project sizes range from

7000 sqft to 190,000sqft. The study population characteristics including the size distribution is shown in Table 4.2.

Table 4.2 Study Population Characteristics

Project Codes	State	Type	PDM	Certification	Size (Sqft)	Responses	Respondents
A1	New York	Confidential	DBB	Certified	25,000	3	Ow, D & C
A2	Texas	Private	CMR	Certified	7000	2	Ow/D & C
A3	Colorado	Private	CMR	Certified	89,200	3	Ow, D &, C
B1	Colorado	Private	DBB	Silver	60,000	3	Ow, D &, C
B2	Colorado	Private	CMR	Silver	7,700	3	Ow, D &, C
B3	Alabama	Private	DB	Silver	12,900	2	Ow/C & D
C1	Ohio	Private	DB	Gold	14,077	2	Ow/ C & D
C2	Pennsylvania	Developer	DB	Gold	35,000	3	Ow, D &, C
D1	Colorado	Private	DB	Platinum	186,000	1	Ow/D/C
D2	Arkansas	Private	CMR	Platinum	94,000	3	Ow, D &, C
D3	California	Private	DB	Platinum	66,000	2	Ow & D
D4	Missouri	Public	DBB	Platinum	120,000	3	Ow, D & C

* Ow= Owner, D= Designer, C= Contractor

4.3 Data Collection Steps

This section describes the specific steps taken to conduct data collection for this research. It includes the process followed to gain the institutional review board approval, the process of administering interviews, and data collection procedures followed in this study.

4.3.1 Institutional Review Board Approval

After the data collection tool design was finalized, the interview questions and the data collection procedures were reviewed and approved by the Michigan State University's Institutional Review Board (IRB) (Appendix B), for its compliance with the rules of human participant research. A consent form was created that was used to inform the respondents about the research goal, objectives, interview conduct process, the time required time for the interview, its storage, and the use of collected data. The interview questions were in a survey format and the consent form was a MS Word document and can be seen in Appendix A and C. The consent form and the questionnaire were sent to the respondent prior to the interview. The consent forms were collected from the respondents via email or fax before the interview was conducted.

4.3.2 Interview Application

For this research 12 projects were selected and from each project three main participants i.e., the owner, designer and, contractor were asked to respond to the interview questions. All the three participants are crucial to the project as they are deeply involved in the process and therefore can provide keen insights. The interviews were telephonic and were individually held from the three participants. The projects were mainly identified through a web-based research and then personal rapport was developed with the point of contact to receive information about the potential participants.

A list of potential projects was generated from the USGBC's project directory. Some of the projects were available in the form of case studies on the website but many were not. Therefore anther web based research had to be conducted to filter the projects based on the detailed case study selection criteria. The projects that were not available online were contacted via telephone. Once an acceptable project list was established, the points of contacts were once again contacted and invited to participate in the study. Also the points of contact were asked for information of the relevant team members. The primary consent was required from the owner. Follow ups were conducted via telephone and email. A broad guideline of the email and the telephonic conversation can be seen in Appendix D and E.

Once the project teams (i.e., owner, designer, and contractor) agreed to participate in the study, consent forms, and a copy of the relevant questionnaire was sent to the individual member. Also they were requested for a convenient time to participate in the interview. On the relevant day and time of the interview the participants were once again informed about their rights and responsibilities as a respondent for this project. The main advantage of conducting telephonic interviews in this research was that owing to the respondents busy schedule they were not obligated to a certain time or location as in a face to face interview. The respondents had the freedom to stop the interview at any time and continue it another day or shift the appointment based on their convenience. Also as the entire process was conducted over the internet and phone the respondents could react to follow up questions at their pace and were not obligated to answer immediately. This convenience of responding affected the interest of the willing participants positively towards this study. Respondents were willing to answer follow up questions, volunteered to impart more information than asked for and go in a deeper discussion of the already present questions.

4.3.3 Problems Encountered in the Data Collection Process

Although the data collection method was very successful certain drawbacks were observed that affected the response rate negatively and increased the time to collect data:

1. There was a dearth of information about many projects over the web and therefore it was required by the author to call each project to find even the basic information;
2. For most projects point of contacts were not given. Therefore it took several calls before the first point of contact could be established;
3. For the projects that did give points of contact they mostly belonged to the marketing department who lacked the relevant information;
4. For a telephonic contact it was easy for the respondent to ignore the call and required the author to leave a message which elongated the time to collect data;
5. Owing to the current economy many professionals who worked on the specific projects did not continue with the firm in concern and therefore made it difficult and mostly not possible to reach them;
6. The length of the questionnaire was too long to hold the respondents interest. This was especially true because the interview was conducted over the telephone and the respondent had the luxury to shift it to another day;
7. The telephonic interview brought an informality in the process that reflected negatively in the respondents approach towards the interview there were instances of recall of commitments towards the study;
8. Due to the time lag in the project the respondents experienced difficulty and lack of motivation in finding the data needed to complete the entire interview;
9. In many cases there was just a lack of motivation to participate.

4.4 Data Recording and Categorization

This study adopted the performance metrics and data collection tool defined by Korkmaz (2007) to collect, categorize and, analyze the data. However, as no data was received on the safety metric, it is eliminated from the final performance metrics used in this study. The details and description of the performance metrics is presented in Table 4.3.

Also, due to the qualitative nature of the current study the data collection tool was altered on the basis of the GAO methodology (1991) of structured interviews. The resultant tool was a combination of structured interviews and survey questions (Appendix A).

Next, data collection was conducted over the phone and email. Finally, the received information was in the format of recordings and filled out survey forms. To facilitate analysis this data was categorized at several levels; these are:

4.4.1 Input survey data in excel sheets;

4.4.2 Transcribe open ended responses using Transana 2.12 (Refer Appendix F);

4.4.3 Categorizing open ended responses using ATLAS.ti (Refer Appendix G);

4.4.4 Eliminating discrepancies within responses for the same project.

Table 4.3 Performance Metrics Used in the Study

<table>
<tr><th>Independent Variables</th><th>Description</th><th>Control Variables</th></tr>
<tr><td>Owner Commitment</td><td>• Party to introduce "green" features to the project
• Reason to pursue "green" objectives
• Timing of introducing the "green" concept
• Importance of the "green" goals for the project
• Mandating green metric (contractually or verbally)</td><td>• Building Size
• Location
• Project Complexity
• Regulatory or Legal Constraints</td></tr>
<tr><td>Project Delivery Method</td><td>• Design-Bid-Build
• Design-Build
• Construction Management at risk</td><td rowspan="6">Dependent Variables
• Schedule performance
- Schedule Growth
• Cost performance
- Cost Growth
• Quality performance
- Facility start up
- Call backs
- Quality of
o envelope/roof/ structure/foundation
o interior/space/layout
o environmental systems
o process equipment/ layout
o overall
• Post occupancy (Owner Perception)
- Av. Water Consumption
- Av. Energy Consumption
- Occupant Turnover Rate
- Occupant Absenteeism
- General Satisfaction
- Acoustic Quality
- Ventilation
- Controllability
- Lighting
- Thermal Comfort
• Levels of Sustainable High Performance
- Level of Green
- Level of High Performance
- Intended v/s Achieved Certification</td></tr>
<tr><td>Project Team Procurement</td><td>• Negotiated v/s Competitive selection process
• Restrained pools of potential participant
• Benchmark of restraint
• Sole source selection, best value source selection, competitively negotiated, low bid, qualification based selection</td></tr>
<tr><td>Contract Conditions</td><td>• Green contract provisions
• Contractual relations between important team members
• Incentive/ penalty clauses within the contract
• Likert scale evaluation of onerous contract clauses</td></tr>
<tr><td>Integration In The Delivery Process</td><td>• Timing of contracting
• Methods and timing of Communication
• Presence of a LEED® A.P. and contractual position
• Design charettes
• Teams prior experience as a unit
• Level of communication within team members
• Level of compatibility within team members
• Education to contractors</td></tr>
<tr><td>Project Team Characteristics</td><td>• Team member's experience in similar projects
• Owner's representative's capabilities
• Owner's ability to define scope
• Owner's ability to make decisions
• Evaluation of the level of compatibility by measuring communication and chemistry amongst project team members</td></tr>
</table>

4.4.1 Input survey data in excel sheets

Data was collected from three participants from each project i.e., owner, designer, and contractor. The same data collection tool (comprising of 13 sections- respondent information, project profile, owner commitment, project delivery method, project team procurement, contract conditions, integration in the design process, project team characteristics, levels of high performance, project schedule performance, project cost performance, safety and lessons learned) was used for all the three participants. However, the owners were requested to fill out two more sections namely project quality and post occupancy evaluation. An excel file was created with each sections name as a tab; all the tabs were hyperlinked to one master tab. These tabs were used to store the survey responses received. Each tab, including the master tab had a 'projects' column and a 'respondent' column. In this manner all the information received form a single project could be accessed together. An example of the categories is given in Figure 4.3.

Project	Responses	OWNER COMMITMENT				
		Initial Idea	Primary Reason	Green Metric	Mandating Green	Timing of Green
A1	Owner	Designer	Grants	USGBC	Verbally	Con. D
	Designer	Designer	Grants	USGBC	Verbally	Des. D
	Contractor	Designer	Grants	USGBC	Verbally	Des. D
A2	Owner	Owner	Vision	USGBC	Contractually	Con. D
	Designer	Owner	Vision	USGBC	Contractually	Con. D
	Contractor	Owner	Vision	USGBC	Contractually	Sche. D

Figure 4.3 Example Sheet to Input Survey Responses

4.4.2 Transcribe open ended responses using Transana 2.12

Next, the open ended responses were transcribed verbatim with the help of commercial software called Transana 2.12. This software has been developed by the University of Wisconsin. Although there are new versions available, the author used an old free version. For a snapshot of this software refer Appendix F.

4.4.3 Categorizing open ended responses using ATLAS.ti

Once transcribed, the open ended data was then imported as primary documents in ATLAS. ti, a software commercially procured, for categorization purposes. The data was categorized based on the performance metrics described previously in Table 4.4. For a snapshot of this software refer Appendix G.

4.4.4 Data verification and eliminating discrepancies within responses for the same project

After creating the excel sheet and transcribing and categorizing the open ended responses, the next step was to eliminate the discrepancies within the data received for the same project. The primary verification was conducted by cross referencing the responses of the different participants from the same project. Also some information was cross-reference from web based research. As data was primarily collected by telephonic interviews personal rapport had been established with the participants. Therefore it was relatively easy to clarify and fill out any discrepancies and uncertain data over a course of a few phone calls and emails. For example there was a disagreement amongst the participants over the project delivery method was adopted for the project. Contractual relations and open-ended responses had to be referred to eliminate this discrepancy and have one single answer for the project. At the end of this step individual participant responses were eliminated and only one response was maintained for the project.

4.5 Data Coding

To manage and analyze the survey responses they were coded and input in excel sheets. The coding logic is presented next.

4.5.1 Owner's Commitment:

Coding for this metric was based on the patterns that were seen within the data. Out of all the parameters used to evaluate owner commitment primarily two were seen as having considerable affects on the success metrics. These were 1) reason to pursue green and 2) timing of incorporating green. It was seen that projects that performed well on the sustainability and success metrics had vision statement from the owner as their reason to pursue green. Also the timing of incorporating green was in the conceptual phase. Projects performing lower on success and sustainability metrics incorporated green in the schematic or design development phases. Also their reason to pursue green was achievement of a certain certification consequently translating into a positive public image or marketability, or financial remunerations in terms of grants and tax rebates.

On examining the literature and open ended responses similar trends were seen (Building Green, Inc., 2001). Both suggested that early incorporation of green results in better project outcomes, and as it gets late in the project it becomes difficult to fully utilize the potential of the incorporated strategies. Also it was reported that as the owner is the primary decision maker their *'buy-in'* in to the notion of green early in the project was very important for project success. Finally open ended responses stated that as sustainable high performance buildings include complex processes under designing and execution, for better project outcomes, the reason to pursue green should be more than only certification or financial remunerations. The owner should have an inherent faith in the notion of green that would reflect in their vision statement for the project. Therefore, based on the literature, patterns in the survey and open ended responses coding for owner commitment was established. This can be seen in Table 4.4 (Also refer Appendix I).

4.5.2 Level of integration achieved by projects:

The integration metric was evaluated based on the parameters presented in the previous table. Responses to most parameters were common amongst the project participants. For example timing of communication was reported to be weekly; every project except one had a designated green design coordinator or LEED® A.P., conducted collaboration sessions and educated their subcontractors for the LEED® submittal process. However discrepancies were seen mainly within three parameters: Timing of contractor involvement; communication methods; and quantitative performance metrics used to measure the sustainable performance of the building.

Literature suggests that early involvement of contractor results in better project outcomes. The open ended responses collected during the course of this study also aligned with the literature. In the majority of the projects respondents endorsed the idea of involving the contractor early. Therefore, the interviews showed that if the contractor joins the project at the construction documents or bidding phase it is too late to incorporate any major constructability reviews in the design. Also, the respondents suggested that better results can be achieved if the contractor was on board with the project team from pre-design or conceptual design phase. Hence, the study categorizes projects involving contractors as late as construction documents or bidding should be categorized as poorly integrated. Involvement of the contractor in the pre-design and conceptual phase point towards a highly integrated project and projects that involved the contractor in the phases in between can be considered as medium integrated. The coding logic is shown in Table 4.4 (Also refer Appendix K).

The other two parameters have not been used to indicate the level of integration achieved by a project as they did not show a significant pattern amongst the different methods adopted. However patterns have emerged within both parameters that suggest that they have an effect on the final outcome. These are discussed in detail further in the report.

4.5.3 Levels of Sustainable High Performance Achieved:

This metric is evaluated on three parameters; Level of Green, Level of High Performance, and Intended v/s Achieved Certification. Under intended v/s achieved, projects that achieved above the intended target, were on target, or were below target are coded as +1, 0, and -1 respectively. Level of high performance is evaluated by combing the achieved IEQ and energy scores in the USGBC's checklist. To make the scores comparable they were converted into percentages. Once listed the median in the data was detected and coded as zero, points above and below the median were coded as +1 and -1. The same process was followed for the level of green except this parameter was calculated by listing the total points achieved by the project. The resultant coding is shown in Table 4.4 (Also refer Appendix H).

4.5.4 Post- Occupancy and Quality:

To evaluate these metric owners were asked to respond to likert scale questions. The resultant scores under each metric were added and listed. Similar to last metric a median was detected and coded as 0 values above and below the median were given +1 and -1 respectively. The final coding is shown in Table 4.4 (Also refer Appendix K).

4.5.5 Cost and Schedule Performance:

Apart from the fact that cost and schedule metrics include critical information, it was still difficult to find data on these metrics because there are many variables that affect their performance. To find data on all the variables affecting these metrics such as material selection, technology, and day to day operations was not possible with the resources (time and finances) available for this study. Therefore, the coding of cost and schedule was based on the perceptions of the owner. If the owner suggested that project had a significant cost or schedule growth, the project was coded as -1. If they suggested that it was on target then the project was coded as 0. The final coding for both cost and schedule is in Table 4.4.

Table 4.4 Data Coding Logic for All Variables

METRIC	CODING PARAMETER	CODING
INDEPENDENT VARIABLES		
Owner's Commitment	Vision statement and Conceptual Design phase	**High Commitment**
	Certification and-or Grants and Schematic/Conceptual Design Phase	Medium Commitment
	Certification &Grants and Design Development	Low Commitment
Project Delivery Method	Design-Bid-Build	Design-Bid-Build
	Design-Build	Design-Build
	Construction Management at risk	Construction Management at risk
Project Team Procurement (Appendix J)	Benchmark of restraint; Sole source selection, best value source selection, competitively negotiated, low bid, qualification based selection.	Benchmark of restraint; Sole source selection, best value source selection, competition, negotiation, low bid, fixed budget/ best design, qualification based selection.
Contract Conditions	Contractual relations between important team members;	Contractual relations between important team members;
Integration in the Delivery Process	Timing of contractor entry: Pre-design, Conceptual	**High Integration**
	Schematic or Design Development	Medium Integration
	Construction Documents and Bidding	Low Integration
DEPENDENT VARIABLES		
Intended v/s Achieved Certification	Below target	-1
	On target	0
	Above target	+1
Level of High Performance	Less than 55	-1
	55-65	0
	More than 65	+1
Level of Green	Less than 50	-1
	50-70	0
	More than 70	+1
Post Occupancy	Below 39	-1
	39	0
	Above 39	+1
Quality	Below 26	-1
	26	0
	Above 26	+1
Cost Growth	High growth	-1
	On target	0
	Under budget	+1
Schedule Growth	High growth	-1
	On target	0
	Under schedule	+1

4.6 Data Quality

This research employed several tactics to satisfy the research quality criteria. These tactics addressed sampling error, response and non-response bias are explained in detail below.

4.6.1 Sampling Error

Under this section the following factors were focused on to eliminate bias;

1. *Location:* This study attempted to look at projects across the U.S. for a broader understanding of the issue. The literature suggests that certain locations in the U.S. affect sustainable construction by legislation such as having stringent state laws and financial remunerations in taxes. Also locations characteristics such as weather, terrain details, and availability of material and recycling plants can have affects on sustainable projects. Therefore geographical diversity was important to eliminate bias towards a certain region or location.
2. *Project Delivery Methods:* The study aimed to understand the level of affect of project delivery methods on integration and project outcomes, therefore having a mix of PDM's was important to this study to eliminate bias towards a single delivery method.
3. *Responding participants:* To facilitate cross referencing and understand the perspective of different stakeholders 3 project participants were requested to respond including owner, designer, and contractor.

4.6.2 Response Bias

As this study was conducted post completion of projects, responses of participants especially in the project team characteristics metric, was prone to bias. The bias was based on many variables such as the participant experience on the project, their relationship to the owner and to other participants, the owner satisfaction with the project, and time lag that skews memory of the project details. Therefore, to eliminate the response bias, all project participants for each project (the owner, designer, and contractor) were included in the data collection process for the team characteristics evaluation questions. The responses were eliminated when the participants evaluated themselves. The other responses were coded and their average generated the final response for these questions.

4.6.3 Non-Response Bias

To understand the different perspective and to confirm the project details, it was important for this research to eliminate non responses bias. Therefore, to cross reference or fill missing information, from every project maximum three and minimum two participants were requested to respond. Also, the respondents were contacted again and/or 'followed-up' if certain questions were not answered during the interview or in the survey. Finally, web research was conducted to cross reference or fill out missing, from external sources such as web research.

4.7 Summary

This chapter described the data collection, categorization, and coding procedures. The chapter characterizes and discusses the various data collection and categorization steps that were undertaken to satisfy data uniformity and quality for this research. The main sections under this chapter are; study population characteristics, participant recruitment procedure, data collection tool application, problems encountered in the data collection process, data recording and categorization, data quality and, data verification. The study is continued with the data analysis methods and results in the next chapter.

CHAPTER 5

Findings

5.1 Introduction

Qualitative methods were adopted to analyze the data for this research. The final results of the analysis are presented in this chapter. The chapter includes pattern matching results, cross case synthesis results, descriptions of outlier projects, and additional lesson learned.

5.2 Pattern Matching Results

Pattern matching was conducted on all the three objectives of this study sequentially. The consequent results are presented in the same sequence i.e., under the respective objectives.

5.2.1 ***Proposition 1.*** *Higher levels of integration in the design process will lead to higher levels of sustainability;*

The patterns within this objective were assessed based on Table 5.1. It is sorted by the level of integration achieved in the projects. The projects achieving high integration are listed on the top and coded as dark grey. Projects achieving medium and low integration are coded as 'light grey' and 'white', and listed subsequently. The table shows two exemplary projects marked by a * sign and two outliers marked by ** sign. The former two projects are considered as outliers because even with low and medium integration they performed exemplary on sustainability goals. The specific results seen within the table above are listed next:

1) Projects achieving high level of integration also scored high on the sustainability metrics;

2) Higher level of integration was seen within projects that achieved gold and platinum certifications under the USGBC's LEED® assessment system;

3) The probability of exceeding the intended certification target was higher projects with higher levels of integration.

Table 5.1 Level of Integration Achieved and Sustainability Goals

Project Codes	Intended. vs. Achieved.	Level of Green	High performance (IEQ + ENERGY)
D1*	+1	+1	+1
C2*	+1	+1	+1
C1	+1	0	+1
D3	0	+1	+1
D2**	+1	+1	+1
A3	0	-1	-1
B2	0	-1	-1
B1	0	-1	-1
A2	-1	-1	-1
D4**	+1	+1	+1
A1	0	-1	-1

* Exemplary Projects
** Outliers

High Integration
Medium Integration
Low Integration

Overall, the table shows that projects with high level of integration have high chances to be successful on the sustainable metric, versus projects achieving medium or low integration that may or may not be successful. This indicates that integration is a very important attribute that can potentially influence the level of sustainability achieved by a project. This is because sustainable strategies increase complexity within projects and therefore, require increased inter disciplinary interaction to develop optimized solutions. The open ended answers consistently suggested that under integration early involvement of participants was a significant metric. It facilitated timely inclusion of suggestions from all participants thereby resulting in adoption of more efficient alternatives. Apart from timing, there were also, other recurring themes, in the collected data such as communication and collaboration within participants. First a pattern was seen that all high and two medium integrated projects used more than one method of communication i.e., apart from email, fax and phone; project management software's (scheduling and estimation), and/ or online databases and/or building information modeling (BIM) were also used. These methods increased efficiency and reduced conflicts in the transfer of information. Second, a conscious effort was made to make sure, that all the participants were focused towards the same goals. One owner reported:

> *"…….we spend a lot of time in the programming of the building, being very clear about what our goals and objectives are. Writing those down in a clear and concise terms that we can communicate to everyone. And that is probably the most important step because it gives us something to go back to check ourselves, if we tend to wander. It also allows us to identify when we are done with a certain step have we accomplished it consistently."*

This focused the thought process of all the participants and assisted them to work towards a common goal. Conversely, another project that did not have an aligned team did not perform as well. The owner reported that they could not exceed the intended certification target because the general contractor (GC) was not committed to the project.

5.2.2 *Proposition 2:* *CMR and DB will provide higher levels of integration in the design process compared to DBB;*

The patterns within this objective were assessed based on Table 5.2. The three delivery methods adopted here are design bid build (DBB), design build (DB), and construction management at risk (CMR). The projects in this table are ranked according to the level of integration achieved by them. The table shows three exemplary projects marked by a * sign and two outliers marked by ** sign. The former two projects are considered as outliers because project B2 with a medium level of integration performed the worse in this sample however project D4 with low integration performed competitively with medium and high integrated projects. The trends seen within the data are listed next:

CMR and DB project delivery methods facilitated higher levels of integration;

1) Mostly DBB provided low level of integration within the project;
2) Medium level of integration could be provided by any of the three delivery methods through informal involvement of the contractor;
3) Although cost growth was seen under every project delivery method no trend was detected. However, projects that were executed with traditional DBB displayed a trend in cost growth.

Table 5.2 PDM's and the Levels of Integration Achieved

PDM	Project Codes	HPG	Intended vs. Achieved.	Cost	Schedule	Post-occupancy	Quality	Total
DB	**D1***	+1	+1	0	0	+1	+1	**4**
DB	**C1***	+1	+1	0	0	+1	0	**3**
DB	**C2***	+1	+1	0	0	0	+1	**3**
DB	**D3**	+1	0	-1	0	0	0	**0**
CMR	D2	+1	+1	-1	-1	0	+1	**1**
CMR	A2	-1	-1	0	0	+1	0	**-1**
CMR	A3	-1	0	0	0	+1	-1	**-1**
CMR	B2**	-1	0	-1	0	-1	-1	**-4**
DBB	B1	-1	0	0	0	0	0	**-1**
DBB	D4**	+1	+1	-1	0	-1	0	**0**
DBB	A1	-1	0	-1	0	0	0	**-2**

* Exemplary Projects ** Outliers DB= Design Build DBB= Design-Bid-Build CMR= Construction Management at Risk HPG= High Performance Green	**High Integration** Medium Integration Low Integration

Within the sample set DBB delivery method facilitated medium or low level of integration and CMR and DB provided competitive levels of high and medium integration. However it is the, author's understanding that DBB also, has the potential to facilitate high level of integration if the contractor is informally involved early in the project life.

From the received open ended data it was not possible to find consensus on the superiority of anyone delivery method as both positive and negative competitive arguments were available. Additionally, over the years with the growth in the construction market availability of contractors and design builders in location has started to become less problematic and not influential in selection of PDMs. The choice of PDM was not found to be dependent on availability of service and to be on the owner's discretion. Except for one criteria, it could not be concluded from the collected data that any discretionary views towards PDM's such as owners requirements for direct interface with the architect or need for tax savings, had negative or positive affects on the project. The one criterion that can result in flawed performance was the owner's requirement for the '*lowest price*', thus choosing DBB. The designer for project A1 suggested that:

> *"…….well especially with a LEED® building it would have been far preferable to have the builder on the team prior to it going out to bid there was I think a lot of the bidders were it was their first LEED® project so really didn't know what they were getting themselves into I'm not sure if the general contractor really understood so DBB did not benefit in any way other than getting a* ***fixed price and presumably a low price.*** *"*

This project performed low not only on the sustainability metric but also on the success metric. The responses from the participants suggested that it was mainly because the contractor was brought on, at the bidding phase. The contractor suggested that they should have been brought on board earlier to facilitate constructability reviews. The contractor reported that:

> *"…… if any team can facilitate the design constructability from a builder or someone from a building background earlier in the phase other than the bidding and once it's awarded will streamline and affectively smoothen out the project delivery and construction of the job."*

Contractor of one another DBB project suggested:

"..... It would have been better to have been involved earlier. In terms of a better way to do it, I think the design build for the contractor is online ahead of time or you can have input in being involved in LEED® decisions. ***And look at the cost impact of the items, is tremendous benefit over the DBB process.*** *"*

5.2.3 ***Proposition 3:*** *Project delivery attributes affect final outcomes*

The analysis of this objective was conducted by testing different combinations of independent and dependent variables to see the emerging patterns. This was first conducted by comparing all the variables together. The emerging patterns then were classified under four categories i.e., integration in the delivery process, contractual terms, contractual conditions, and owner commitment and are listed next according to their strengths. Strength can be defined as the difference between the normalized total scores of the categories. It defines the importance of the variables tested in potentially influencing the success metrics.

a) Integration in the delivery process

The results under this section are based on Table 5.3. This table is sorted at two levels; (i) according to the level of integration of the projects, and (ii) within each level of integration, in the descending order of the total scores achieved by the projects.

1) Projects with high level of integration displayed better performance under the success metric;
2) The contractor should be on board by design development phase (contractually or informally) for successful outcomes

3) Cost growth was mainly seen in project with low or medium integration;

Table 5.3 Integration in the Delivery Process

PDM	Integration in the Delivery Process (Project codes)	HPG	Intended vs. Achieved	Cost	Sch.	Post-occ.	Quality	Total
DB	**D1***	1	1	0	0	1	1	**4**
DB	**C1**	1	1	0	0	1	0	**3**
DB	**C2**	1	1	0	0	0	1	**3**
DB	**D3**	1	0	-1	0	0	0	**0**
CMR	D2	1	1	-1	-1	0	1	**1**
CMR	A2	-1	-1	0	0	1	0	**-1**
CMR	A3	-1	0	0	0	1	-1	**-1**
CMR	B2 **	-1	0	-1	0	-1	-1	**-4**
DBB	B1	-1	0	0	0	0	0	**-1**
DBB	D4**	1	1	-1	0	-1	0	**0**
DBB	A1	-1	0	-1	0	0	0	**-2**

* Exemplary Projects ** Outliers Sch.=Schedule Post-occ. =Post-Occupancy DB= Design Build DBB= Design-Bid-Build CMR= Construction Management at Risk HPG= High Performance Green	**High Integration**	Total Score	**10**	Normal -ized Score	**2.5**
	Medium Integration		**-6**		**1.2**
	Low Integration		**-2**		**-1**

The explanation to this metric is similar to objective 1. Once again within exemplary project strong emphasis was placed on team collaboration and participant's focus on common goals. The open ended responses emphasized that the success of projects depended on the, ***"degree to which the team is aligned around the purpose."*** Owner of project B2 reported:

> *"..... I really wasn't happy because the subcontractors in my opinion were not really committed to it as much as the owners were and so* ***they didn't work with us*** *to try and develop solutions that would enable us* ***to keep a reasonable cost*** *on the building and so perform adequately."*

The owner also reported that:

> *"…… my initial goal would have been gold but the project costs drove us to silver and we barely made silver and I had to appeal one of the points to get to silver.* ***It was a failure of the GC that I think significantly affected us."***

This shows that commitment from the GC is a significant factor in influencing project success. Compared to other participants, it was seen that, contractors were most insistent to join the project early and involve themselves in the design process advocating that it would result in better performance on the success metric. Supporting the results a contractor stated:

> *"……. in our opinion the sooner you bring on the GC the better the project goes you now you get the team work aspect of it, but at the point that we were brought in the project we offered a lot to the team* ***we provided a lot of estimating services*** *so you know I think it had a lot of positive affect over all it would have a more positive affect if they would have brought us in at the very beginning."*

b) Contractual terms

Table 5.4 shows patterns that are classified under this section. Here the owner commitment is tested with the contractual terms followed and finally with the total score achieved by projects under dependent variables. The contractual terms seen here are Cost plus fee (Cost), lump sum (Lump) and guaranteed maximum price (GMP). The table also shows normalized scores of projects under the three levels of owner commitment. Finally, the projects are ranked according to the total scores achieved by them.

Table 5.4 Contractual Terms

PDM	Owner's Commitment (Project Codes)	Contractual Terms			Total
		Designer	Contractor	D-B	
DB	**D1**	COST	COST	-----	4
DB	**C2**	-----	-----	COST	3
DB	**C1**	-----	-----	COST	3
CMR	D2	COST	COST	-----	1
DB	D3	-----	-----	LUMP	0
DBB	**D4**	COST	LUMP	-----	-1
DBB	B1	LUMP	LUMP	-----	-1
CMR	A3	LUMP	GMP	-----	-1
CMR	A2	-----	LUMP	-----	-1
DBB	A1	LUMP	LUMP	-----	-2
CMR	B2	LUMP	GMP	-----	-4

DB= Design Build DBB= Design-Bid-Build CMR= Construction Management at Risk	**High Commitment**	Total Score	9	Normalized Score	2.25
	Medium Commitment		-6		-1
	Low Commitment		-2		-2

1. Projects displaying better outcomes and higher certification mostly adopted the cost plus fee contractual terms;
2. Lump sum as a contractual term was more common in projects with low certification and lower owner commitment;
3. Cost plus fee is more common in project with high owner commitment.

Although, the survey data shows trends that in instances where the contractual terms were cost plus fee, projects, outperformed on the success metrics; positive and negative arguments for each type of contractual term were seen within the open ended responses. An owner suggested:

"..... GMP and lump sum are simply not as good. ***They are old school old thinking and they do not allow the embracing of innovation and new technologies.****"*

The owner suggested that both GMP and lump sum tend to make the stakeholders focus more on protecting their interest than the projects however cost plus fee removes this contention and assists the participants to look in a common direction. In contrast one contractor stated,

"....... Actually a ***lump sum made it clear and definitive on whose responsibilities the financial and cost fell in****. When you get into a GMP then you get owners who feel that u present them with a change and the change should be incorporated in the GMP and that you should have picked it up in the GMP, cost plus is the same way, where on the lump sum you issue it and its either shown or not shown and is straight forward."*

Another designer stated

*"......."****We prefer lump sum because it allows us to manage our risks*** *if we know what are paid upfront we can budget accordingly on occasions. GMP we don't like because it works for the owner but it cannot work for us if the scope starts to deviate scope creep for instance."*

However, the designer later reported that lump sum became a '***big***' problem because the owner refused to pay the additional fees that were incurred by including LEED® requirements. Finally cost plus fee was highly criticized by one of the designers who stated,

*"……. **cost plus fee** for the most part implies a percentage of the construction cost that by far **is the absolute worse way to do it** because in my view there are perverse disincentives to achieving performance for all parties because if the idea is to try and reduce the size of systems they cost less and if in fact my fees based on cost I'm therefore not incentivized for efficiencies."*

The designer further suggested that GMP / lump sum provided a fixed value reflecting on a clearly defined scope. Also if an integrative design process was followed then any upcoming contingencies could be adjusted and the project would not cost more.

Finally, the data collection tool included questions on competitive v/s negotiated contractual terms; however, no patterns were detected in terms of their effect on project outcomes such as cost and schedule growth.

c) Contractual Conditions

This section compared contractual relations within participants with scores achieved under sustainability and total dependent variables score. The results are on the basis of Table 5.5. Here, projects are ranked in the descending order of the total scores achieved by the project.

1. Project in which green design coordinator/ LEED® A.P. did not contract directly to the owner resulted in lower sustainability and success outcomes;
2. Projects displayed better outcomes when the all the primary participants (including mechanical and electrical subcontractors, LEED® A.P., commissioning agent, and energy and lighting consultants were contracted directly to the owner;

3. It was seen that when LEED® A.P. contracted directly to the owner the chances of exceeding the intended certification target increased.

Table 5.5 Contractual Conditions

PDM	Project codes	Contract Held By						Sustainability		Total
		Mech. Sub.	Elec. Sub.	LEED® A.P.	E Cnsl.	L Cnsl.	C Ag.	HPG	Int vs. Ach	
DB	**D1***	Ow	Ow	Ow	Ow	Ow	Ow	1	1	4
DB	**C1****	Ow	Ow	D	D	D	Ow	1	1	3
DB	**C2**	Ow	Ow	Ow	Ow	Ow	Ow	1	1	3
CMR	D2	C	C	Ow	D	D	Ow	1	1	1
DB	**D3**	DB	DB	DB	DB	DB	Ow	1	0	0
CMR	A2	C	C	D	-----	-----	-----	-1	-1	-1
CMR	A3	C	C	D	-----	-----	D	-1	0	-1
DBB	B1	C	C	D	D	D	D	-1	0	-1
DBB	D4	C	C	D	D	D	Ow	1	0	-1
DBB	A1	C	C	D	D	D	Ow	-1	0	-2
CMR	B2 **	C	C	Ow	Ow	Ow	Ow	-1	0	-4

* Exemplary Projects ** Outliers Ow= Owner C= Contractor D= Designer DB= Design Build DBB= Design-Bid-Build CMR= Construction Management at Risk Mech. Sub: Mechanical Subcontractor	Elec. Sub.: Electrical Subcontractor E Cnsl.: Energy Consultant L Cnsl.: Lighting Consultant CAg.: Commissioning Agent Int vs. Ach : Intended Vs. Achieved HPG= High Performance Green	**High Integration** Medium Integration Low Integration

d) Owner commitment

Strong patterns could not be detected within the data for this category. However, there were certain relevant findings that needed to be addressed. Table 5.6 is the basis for the results under this category. Projects here are ranked in the descending order of their total score.

1. High owner commitment increased the probability to exceed the intended sustainability target; Outlier projects: D2, D4
2. Green metric was mandated mostly verbally in low certification projects and mostly contractually in higher certification projects. (Contractual terms mainly included, including USGBC's green metric in the project and not necessarily the level of certification to be achieved); Outlier projects: A3, C1
3. Projects achieving high on the success metric and higher certifications had owner vision statement as the reason to pursue sustainability. Open ended answers suggested that due to the complexity in the sustainable process it is important that the owner have an interest in the notion of green itself instead of *'chasing points'* under the USGBC's LEED® system.
4. Including green in the design development or later phases of the project can result in a cost growth and achieving lower certification.

Table 5.6 Owner Commitment

PDM	Project	Primary Reason	Mandating Green	Timing of Green	Sustainability High Performance Green	Int vs. Ach	Cost	Total
DB	**D1**	VS	Contractually	Con.D.	1	1	0	4
DB	**C1**	VS	Verbally	Con.D.	1	1	0	3
DB	**C2**	VS	Contractually	Con.D.	1	1	0	3
CMR	D2	VS	Contractually	Sch.D.	1	1	-1	1
DB	D3	VS	Contractually	Sch.D.	1	0	-1	0
DBB	**D4**	VS	Contractually	Con.D.	1	0	-1	-1
CMR	A2	Learning Grounds and LEED®	Verbally	Sch. D.	-1	-1	0	-1
CMR	A3	LEED®	Contractually	Con.D.	-1	0	0	-1
DBB	B1	LEED®	Verbally	Con.D.	-1	0	0	-1
DBB	A1	Grants	Verbally	Design D.	-1	0	-1	-2
CMR	B2	VS	Verbally	Design D.	-1	0	-1	-4

*VS: Vision Statement Con.D. : Conceptual Design Sch. D.= Schematic Design Design D. = Design Development Int vs. Ach : Intended Vs. Achieved	DB= Design Build DBB= Design-Bid-Build CMR= Construction Management at Risk	**High Integration** Medium Integration Low Integration

Open ended responses repeatedly reported that owner commitment was an important attribute in affecting the success metric. First it was suggested that the inclusion of green should be earlier in the project life. One designer stated:

> *"…… clearly if the owner had embraced the notion prior to design and if the owner had made their decision to commit to LEED® earlier I think it would have been a better building."*

Although it was not stated clearly, on comparing open ended responses and projects performance on the success metric, it was observed that the reason to pursue green was a strong indicator of owner commitment and in certain cases affected the level of sustainability achieved. The data showed that projects that had a stronger commitment towards green itself, rather than the incentives that came with a sustainable building, performed better. One owner reported:

> *"……. we did not want to use the green scorecard as a design directive, because then you start chasing points, and cost effectiveness of your design direction becomes quite a challenge, because you start spending money in pursuit of points."*

Another owner reported:

> *"……. we used LEED® as a marketing tool and secondly we did it* ***because it is the right thing to do****."*

5.2.4 ***Proposition 4:*** *PDM's affect project outcomes through the level of integration in the project delivery process;*

Finally, the overall project goal was revisited in this proposition and it was concluded that project delivery methods do influence project outcomes through the level of integration in the project delivery process. The primary findings from this proposition are given below:

- Projects adopting DB method mostly ranged high in the success outcomes. They had high level of integration in the delivery process and owner commitment, also, adopted cost plus fee as the payment method;
- Projects adopting CMR demonstrated medium success in project performance. These projects had medium level of integration in the

delivery process and owner commitment, also, adopted either Lump sum or GMP as the payment method;

- DBB displayed medium and low level of integration and all three levels of owner commitment. Also success ranged from medium to low in projects that adopted the lump sum payment method;
- Under DB, projects that achieved high integration and high success, had most participants directly contracted to the owner.

5.3 Cross Case Synthesis Results

To conduct cross case synthesis, three pairs of projects (exemplary and flawed) were selected and compared to find the differentiating characteristics. The projects were chosen based on three primary control variables i.e., PDM (DBB, DB, and CMR), certification achieved (platinum, gold, silver and, certified), and size (small, medium large). All the control variables have not been used in all the three sets. The control variables used to choose the three sets of projects are described next;

Set 1: Both projects under this set are platinum certified and large in size i.e., their size is between 120,000 to 180,000 sqft. However the exemplary project has been delivered by the CMR method and the flawed project by the DBB method.

Set 2: In this set the control variables were size and PDM. Both projects were medium sized (i.e., 60,000 -100,000sqft) and had been delivered by the CMR method. Under certification the exemplary and flawed projects achieved platinum and certification respectively.

Set 3: Small sized (25,000-35,000 sqft) projects were chosen for this set.

Also it is as this study includes a very small sample size therefore generalizability of the results is a limitation. However, characteristics of flawed projects can be generalized so as not to be repeated. Therefore, characteristics of flawed project as opposed to good projects are listed next. Table 5.7 shows an example of this analysis method.

Table 5.7 Cross Case Synthesis Analysis

Project	Owner Commitment			Integration in the delivery process			
	Green incorp. by	Reason to Pursue Green	Timing of Green	Green design cord.	Design Charette	Collaboration. Session.	Timing of contractor involvement
Exemplary.	Owner	Vision Statement	Con.D.	Yes	Yes	Yes	Pre-Design (Contractually.)
Flawed	Designer	Grants	Des.D.	No	No	No	Bidding

Con. D = Conceptual Design, Des.D.= Design Development

The following characteristics were seen in flawed projects as opposed to exemplary projects:

5.3.1 *Owner Commitment*

a. Reason to pursue green: The process of sustainable, high performance building is complex in nature owing to the increased interaction of multi-disciplinary teams. Due to this increased complexity, owners must demonstrate high commitment towards the project and inclusion of green strategies as they are the primary decision makers. Especially for sustainability metrics, almost ten respondents reported that, as it is not a mandatory requirement, the owner must show strong interest and belief towards the notion of green for the building to be successful. It was seen within flawed projects that the reason for including green strategies was mostly LEED® certification leading to financial remunerations and marketability. Also these *'flawed'* projects generally stood at the lower end of the certification metric indicating that the owners did not pursue higher levels of certification due to lack of incentives.

b. *Timing of including green strategies:* Pattern matching results showed that projects performed better if green strategies were included in the conceptual or schematic phase. It was seen in cross case synthesis that projects categorized as flawed included the notion of green in the design development phase leading to projects performing low on the success metric.

c. *Mandating green verbally*: Most, lower certification and lower success projects did not mention green intentions in the contracts with the participants. This indicated unclear mindsets that affected participant commitment towards green as their roles and responsibilities, scope of the project and financial remunerations were not clear.

5.3.2 *Project Delivery Method*

a. All the delivery methods have the potential to facilitate *at least* medium level of integration by informal involvement of the contractor. However, projects delivered purely by the DBB method (i.e., contractor involvement at the biding phase) resulted in low integration and also lower performance on the success metric as the contractor could not provide input in the design phase.

5.3.3 *Contractual Conditions*

a. *Contractual Terms:* In flawed projects it was more common to use the lump sum as a contractual term for both designer and contractor. This indicated that cost was a priority for the owner thereby putting the other success factors such as level of high performance achieved and quality lower on the same list. Also due to the nature of the contractual term it reduced the commitment of the team towards over reaching the intended target if it resulted in a cost growth. Cost plus fee was more common in projects that performed better on the sustainability metric. The open ended responses suggested that this contractual term allowed innovation within the thought process of the design team as they were not constantly under the pressure of rising cost;

b. *Contractual relationship of LEED® A.P.:* It was seen when the LEED® A.P. was not contracted directly to the owner it resulted on less successful project. This was indicative of the importance of the green strategies for the project. Direct relationship between the owner and the LEED® A.P. allowed the latter to orchestrate the inclusion of green more efficiently because the contractual relationship demonstrated the importance of green goals for the owner.

5.3.4 *Integration in the Delivery Process*

a. Timing of contractor involvement: For successful outcomes, literature strongly suggests early involvement of the contractor in the project (7 Group and Reed, 2009). It was seen by cross case synthesis that flawed projects that involved the contractor, contractually or informally, schematic phase onwards. Also, the open ended responses from these flawed projects reported that the contractor should be involved from the pre-design or conceptual phase to facilitate clarity of common goals and higher commitment from the contractor towards the project.

b. Green Design Coordinator: The flawed projects either did not have a green design coordinator or they were a part of the designer's team. This lowered the priority of green inclusion as there was no direct coordination between the owner and the green design coordinator.

c. *Design charrette's:* These were either not conducted or if conducted only included the owner and the design team. Thereby excluding contractor and the mechanical electrical and plumbing subcontractors who are significant members of the team as they physically execute building construction and could provide important suggestions.

d. *Prior experience of the team members:* Previous experience of the project team with each other, their communication, and compatibility amongst the participants was not rated high on the likert scale, in flawed projects. This indicated that previous working relationships are important because then the team is more focused on the goals rather than on developing relationships with the other participants;

5.4 Description of the Outliers Through Explanation Building

While conducting pattern matching, it was seen, that there were certain projects, that performed differently (better or worse) than expected. These were categorized as outliers. As a part of results, it is important to discuss these projects, to gain a more meaningful and deeper understanding of the other variables, which have the potential to affect the success metrics.

a. Project D4

This project was delivered by the traditional DBB method where the contractor was involved in the bidding phase. The contractor reported that due to their late involvement in the project they were not privy to all the information. Although the project saw cost growth; both the owner and the designer stated that the contractor was very committed to the project goal, which was instrumental in achieving better outcomes. The designer particularly stated,

> *"……..we had the contractor came early, interested in learning about sustainability and worried about how to make a building with* LEED® *practices. They really took it on with the high level of dedication, commitment. We were very satisfied with the way that project with this executed from all the away from the bidding, contracting, all the way from construction. The contractor did a great job dealing with sub contractors' work, potential changes, scope, changes and cost, really keeping the team forward and cooperative way."*

b. Project B2

This project was delivered by the CMR method and the contractor was involved in the schematic phase. However unlike project D4 this was not a committed contractor. According to the owner, even though the contractor was presented with the opportunity of involving themselves early in the project they did not do so. It was stated that the contractor failed in providing sufficient cost estimation and value engineering services to develop optimized solutions. Although the owner acknowledges the market changes at the time for the exceeding cost of the project; they placed significant responsibility on the contractor for the under- performance of the project.

c. Project A2

The primary reason to pursue green was stated to be two folds 1) marketability and 2) the owner wanted to use this project as an ongoing lab to educate their own staff for future projects with outside clients. The owner reported that they were not experienced in this kind of construction and wanted to *'practice'* on their own building and therefore were pursuing silver certification. Primarily, this project under performed only in one metric, i.e., level of sustainability achieved. The project intended for a silver certification however achieved only certified. Reason for this underperformance was reported to be loss of certain points that the team had originally accounted for. The owner stated that they were satisfied with the project in general, as it achieved the intended needs, and blamed the under-performance on the inexperience of the entire team. It was also suggested that with the gained experience they were now in a better position to serve their clients achieve sustainable projects.

5.5 Additional Lessons Learned

Apart from the findings achieved from the survey responses. There were certain repeated themes seen in the open ended responses. These are listed below as additional lessons learned.

1. Contractor is a significant member of the team and high level of commitment towards the project is required from them;
2. The existing definitions of PDM's are not consistent or fully understood in the industry; for example many industry members consider early involvement of contractor to be a DB delivery method even if the owner holds separate contracts with the designer and contractor;
3. Lower certification projects were mostly the first sustainable project attempted by the team, therefore in some cases, they were treated as practice grounds for future projects;
4. Cost was of high priority in low certified projects. Many projects chose not to pursue higher certifications due to rising cost;
5. Based on the open ended responses it seems that there still a notion in the industry that suggests that LEED® projects cost more than traditionally built projects.
6. It was seen that more than the project delivery methods, project delivery attributes affect the final outcomes. the main attributes identified by this study are :
    a. *Timing of participant entry:* Project delivery methods suggest contractual relationships between participants and also to some extent direct the timing of entry of the participants. However that can be overcome by informally involving participants from the beginning.

b. *Team characteristics:* A thorough selection process should be conducted not only to make sure about the qualifications and capabilities of the participants but also to align their commitment to the project and green strategies, to avoid compatibility issues.

5.6 Summary

This chapter listed the results achieved by conducting qualitative analysis of the data. The primary findings supported the expected outcomes. The results point towards the need for high level of integration and owner commitment in projects. It was also reported that project team characteristics and commitment were also significant attributes that could potentially influence final outcomes. It was recognized that the current sample size was too small to provide generalizable results. However, the observed patterns provide important lessons learned in terms of practices that should not be followed for successful projects.

CHAPTER 6

Summary, Discussions, and Conclusions

6.1 Summary of the Results

This study attempted to understand the extent of the effect of projects delivery methods (PDM) and practices on the level of integration achieved in the project delivery and further their effects on project performance (e.g. cost, schedule, and quality) with a specific focus on sustainability goals. In pursuit of this aim, project delivery attributes such as owner commitment, level of integration achieved in the delivery process and project team procurement, were compared with project performance outcomes to identify potential relationships.

This study is the second step of a research that aims to determine the state of practice in green building project delivery and procurement. This study contributed to the larger research by developing a rigorous case study approach. It is a collaborative effort between Michigan State University, University of Colorado, University of Oklahoma, and Pennsylvania State University and is funded by the Charles Pankow Research Foundation.

The project delivery attributes and the performance outcomes were primarily identified through a literature review and input from the four university research team and industry panel. This research followed a case study approach and based on the defined case study selection criteria, selected 12 completed office building projects that received certifications from United States Green Building Council's (USGBC) Leadership in

Energy and Environmental Design (LEED®). 30 respondents were engaged in the data collection of the case study protocol (i.e., owners, designers, and contractors) with an average of two types of respondents per project. A combination of survey application and structured interviews were performed. Qualitative methods (i.e., pattern matching, cross case synthesis, and explanation building) were adopted to analyze the collected data. Analyses showed emerging patterns within the data that were converted to results by further bolstering with quotes from the open-ended responses.

The findings of this research suggest that owner commitment, contract conditions, and integration in the delivery process are critical project delivery attributes influencing project outcomes such as cost, time, quality, and especially sustainability goals. The findings also report, that strong owner commitment towards sustainability, early involvement of contractor in the project delivery process, and early inclusion of green strategies to the project are crucial to the delivery process for successful outcomes. Other factors affecting outcomes include increased contractor commitment towards sustainability and the project, previous experience of the team members with each other, arrangements of design charettes, and project team procurement.

A detailed list of these findings and their explanation is given next:

Owner Commitment:

1. Although the open ended responses suggested competitive arguments for mandating green both verbally and contractually, survey responses showed

patterns that owners of exemplary projects mostly mandated the achievement of sustainability goals in their contracts with design and build teams;

2. Sustainability is an extensive concept including complex processes that are very different from the traditional design and construction practices. The results lucidly demonstrate that strong owner commitment is required to satisfy even minimal aspects of it. However, it was observed that particularly, to achieve or exceed, high sustainability targets (i.e., USGBC's LEED® gold and platinum certifications) exceptionally high owner commitment is required. This is because a belief exists in the industry suggesting that sustainable buildings cost more than traditionally built buildings. Also, ***all*** the benefits of highly sustainable buildings do not always result in obvious materialistic returns to the owner such as low energy consumption and / or market credibility and / or increased occupant productivity. Therefore, owners really need to believe in the notion of green as the ***'right thing to do'*** and understand that green buildings can have important and positive consequences on the occupants and environment, that is worth investing their resources (i.e., finance, time, and commitment) on.
3. Green strategies need to be included until the schematic design phase to make them a fundamental part of the project and not add on. However, earlier inclusion of the notion of green is only possible if an owner demonstrates high level of commitment as the primary stakeholder and decision maker in a project.

Project Delivery Method (PDM):

4. Based on the literature and the collected data, this study defined the level of integration achieved by projects, primarily based on the timing of contractor

entry. The data showed that both construction management at risk (CMR) and design-build (DB) can provide high or medium level of integration as they inherently facilitate early involvement of contractors. On the other hand design-bid-build (DBB) provides low level of integration as the contractor is involved at the bidding phase. However, DBB too has the potential to provide higher levels of integration if the contractor is informally involved from the early phases of the project.

5. Between PDM's and cost growth, the only trend detected suggests that projects adopting the DBB method display positive cost growth. This mainly occurred because of contractor suggested changes that had to be incorporated at/ after the bidding phase.

Contractual Conditions:

6. Majority of the exemplary projects adopted the cost plus fee contractual term for the project participants such as the designer, contractor, or design-builder;
7. In exemplary projects LEED® Accredited Professionals (A.P.) were directly contracted to the owner: If the LEED® A.P.'s are directly contracted to the owners, who are the primary decision makers, it would raise the importance to include green strategies for the project team, as then, it would be considered as an owner priority. Also, the green implementation is orchestrated from a central source as opposed to contractors following the lead of the designer.

Integration in Project Delivery Process:

8. Early involvement of the contractor was seen as a key factor in the success of a project as well as defining the level of integration in project delivery process;
9. High level of integration in the project delivery process (i.e., involvement of the contractor in the project informally or contractually, until the schematic phase) mostly occurred in exemplary projects i.e., projects that outperformed and achieved/exceeded intended targets in terms of sustainability and success metrics such as cost, schedule, quality and owners perception of post-occupancy performance;
10. Projects that had low or medium level of integration in their delivery processes resulted in more cost growth than exemplary projects. Late involvement of participants in the design phase that mostly results in rework can be considered the reason for the cost growth;
11. Under *design charette and collaboration sessions*, consistent positive survey responses were observed i.e., a majority of projects conducted these successfully. However, the open ended responses stressed on the importance and the affect of these sessions on project success. The responses aligned with literature (USGBC, 2009; Green Globes, 2009; DoE, 2009; Frej, 2005) and reported that these are important factors towards the success of a project as they assist project teams to focus on common goals;.
12. In the metric, "*previous experience with team members*", variation in survey responses was not observed. It was consistently rated as high that reflected in the adoption of the sole source procurement method in the majority of the projects.

However, open ended responses explained the importance and need of previous experience with team members. It was reported that this metric was important for the compatibility of the team and also a determining factor for procurement of the participant's themselves (e.g., owner's are likely to go through sole source selection of the participants if they have already worked with the owner on previous project).

***PDM's** affect **project outcomes** through the **level of integration** in the project delivery process;*

13. Projects adopting DB method mostly ranged high in the success outcomes. They had high level of integration in the delivery process and owner commitment, also, adopted cost plus fee as the payment method;
14. Projects adopting CMR demonstrated medium success in project performance. These projects had medium level of integration in the delivery process and owner commitment, also, adopted either Lump sum or GMP as the payment method;
15. DBB displayed medium and low level of integration and all three levels of owner commitment. Also success ranged from medium to low in projects that adopted the lump sum payment method;
16. Under DB, projects that achieved high integration and high success, had most participants directly contracted to the owner.

Additional Lessons Learned:

1. The results showed that for successful project outcomes, apart from owners, increased commitment is required from other team members such as general contractors and design teams. The open ended responses suggest that each stakeholder must take leadership in delivering the green aspects of buildings instead of following the direction given by an outside entity (e.g. contractors following designers leadership for achieving certain levels of certification without being contractually obligated or fully responsible.)
2. It was also observed that project delivery attributes such as timing of participant involvement, design charrettes and collaboration sessions, contractual conditions and terms, and owner commitment, were more important for the project success than the adopted project delivery method itself.
3. Finally, it was observed that there should be direct contractual arrangements between the owner and other primary participants such as mechanical, electrical, and plumbing (M.E.P) subcontractors. A strong pattern was not observed in the data set as such applications existed only in three of the sample projects. However, it is considered as a valuable finding as it was strongly supported by the literature.

6.2 Verification of the Results

Due to the low sample size of this study, generalizability of its results might be questionable. However, recent research studies conducted in the same field have arrived at similar results to those of the current study. Therefore, this study conducted an extensive literature review to perform external validation procedure to verify its results facilitate their generalizability. The six researches selected for the comparison of results are presented below.

- *Beheiry et al. (2006) Examining the Business Impact of Owner Commitment to Sustainability:* The purpose of this study was to establish a research mechanism to investigate the impact of corporate commitment to sustainability on capital project planning and capital project performance.
- *Lapinski et al (2006) Lean Processes for Sustainable Project Delivery:* The purpose of this study was to evaluate the life cycle of Toyota's capital facility delivery process to empirically identify the critical activities and capabilities that led to Toyota's South Campus project success. This utilized a process-based analysis looking back in time to identify where value and waste were generated in Toyota's delivery system.
- *Korkmaz (2007), Piloting Evaluation Metrics for High Performance Green Building Project Delivery:* The research attempted to provide a foundation for future research by defining meaningful evaluation metrics, methods, and tools to collect and analyze high performance green building project delivery data.
- *Enache-Pommer (2008), Lean and Green Healthcare Facilities: Improving the Delivery Process in Children's Hospitals:* This main aim of this study was to understand the building delivery process in green children's hospitals, starting from programming, through design, construction, operations and maintenance. An emphasis was placed on the affects of the delivery process and the stakeholders present in each project on the final product.

- *Molenaar et al. (2009), Sustainable, High Performance Projects and Project Delivery Methods: A State-of-Practice Report:* This paper is the first part of a broader study that seeks to determine project delivery methods influence on owner's ability to achieve their sustainability goals in delivering building projects. This paper describes the state-of-practice in project delivery methods for achieving sustainable, high performance building projects through a content analysis and a nationwide survey of LEED® A.P.
- *Bilec and Ries (2009), Preliminary Study of Green Design and Project Delivery Methods in the Public Sector:* The aim of this study was to examine possible relationships between design-bid-build (DBB), construction management (CM), and DB PDMs and green design with the goal of beginning to identify potential positive correspondence between them.

There were strong or medium level similarities between the findings of the current study and previous research findings. No contradicting results were detected. However, there were some results in previous research that were not observed in the current study potentially due to the small sample size and the sample being skewed towards private type of building projects. For a detailed discussion only five out of the six studies were selected. Beheiry et al. (2006) is omitted from the detailed discussion as primarily addressed only one independent variable i.e., owner commitment. However, for the benefit of the reader its results have been discussed next.

Examining the Business Impact of Owner Commitment to Sustainability (Beheiry et. al., 2006): This paper tested five hypothesizes in order to establish a basis upon which the impact of owner corporate commitment to sustainability on capital project planning and performance can be studied. The author suggests that high owner commitment translates to better planning for sustainable project practices at the project definition level as the owner reflects positively on the other project participants and show commitment to sustainability the project results in better performance outcomes.

These results align completely with these findings. It was observed in the collected data that projects with high owner commitment performed better especially under cost and schedule growth and level of sustainability metrics.

Finally, the detailed discussion of the results of the other five studies is presented next. Table 6.1 illustrates the levels of alignment within the results.

Table 6.1 Checking for the Generalizability of the Study Results through External Validation

Current Study Metrics	Findings	Lapinski et al. (2006)	Korkmaz (2007)	Enache-Pommer (2008)	Molenaar et al. (2009)	Bilec and Ries (2009)
Owner Commitment	• Early inclusion of green (pre-design);	●	●	●	●	
	• The reason to pursue green should be owner driven factor;		●	●		◍
	• Owner to be the project driving force;		●	●		●
	• Mandating green contractually;		●	●		●
Project Delivery Methods	• CMR and DB out perform DBB;		●		●	◍
	• DB Outperformed CMR				○	
Contract Conditions	• Cost plus fee outperformed other contractual terms;		○		○	
	• LEED® A.P. to be directly contracted to the owner;		●		○	
	• All the primary participants to be directly contracted to the owner		●			
Project Team Procurement	• No pattern was seen;		○		○	
Integration in the Delivery Process	• Contractor is a key factor in the success of a project;		●		●	
	• All primary participants should be on board early in the design process;	●	●	●	●	●
	• Low integration can result in rework leading to cost growth;	●	●	●	●	
	• A project must have a LEED® A.P.;	●	●	●		
	• Design charrette's must be conducted at the start of the project;	●	●	●		
	• Prior experience of the team members with green strategies and LEED®	◍		◍		●
Project Team Characteristic	• Better evaluation metric is required for this metric;			●		
	• High commitment required from the project team;				●	

● Strong similarity ◍ Medium similarity ○ Slight deviation   Blank Space represents that no comparable results were found

1. *Owner commitment:* Under this metric except for Bilec and Ries (2009), the other four studies report that for better project outcomes, green strategies should be included early in the design process. In particular Enache-Pommer (2008), Korkmaz (2007), and the current research report that it should be included as early as the pre-design phase.

Requirement of strong owner commitment in terms of being a driving force in the project was a clear pattern seen in the majority of the open ended responses and as a characteristic in exemplary projects in the current study. Similar findings were observed in Korkmaz (2007) and Enache- Pommer (2008) and Bilec andRies (2009). Enache-Pommer (2008) reported that, *"dedication, belief, commitment, and executive mindset play a very important role in the delivery of the four case studies investigated."* Also, similar to the current study all the three studies suggest that inclusion of green should be an owner driven pursuit.

Next, Molenaar et al. (2009), Korkmaz (2007), Bilec and Ries (2009) and the current study all suggest that mandating green requirements contractually can result in better outcomes. According to Korkmaz (2007), *"project green specifications should be included in the request for proposals,"* and the author's cross case synthesis results showed that, *"achievement of the project "green" goals was inserted in the design-build team's contract."* Lapinski et al. (2006) reports, *"all RFP respondents should discuss relevant experience with sustainable facility delivery and **how they will help achieve environmental goals.**"* This shows that previous experience is important for team procurement. However, it is also indicated that the owner has to be conscious about introducing the notion of green as early as compiling Request for Proposal (RFP). This is supported by Bilec and Ries (2009) it is suggested that, *"The owner's experience is central early in the project, in particular the owner's development of the RFP in the initial design phase."*

2. *Project delivery method selection:* The current study, Korkmaz (2007), and Molenaar et al. (2009) suggested that CMR and DB methods out-performed the DBB method. Bilec and Ries (2009) have only medium similarity to this result as they suggest that DB outperforms the other two delivery methods. However, it was observed that DBB projects can lead to exemplary performance under the sustainability metric, achieved through early informal involvement of the contractor in the delivery process, when these projects were examined in detail the might show low performance in other categories. Specifically, a DBB project that achieved LEED® Platinum certification had higher cost growth than expected. Therefore this study concludes that it is possible to achieve high LEED® certification under any PDM, however, the chances are low to minimal for attaining high performance in all outcomes such as cost, schedule, and quality.

3. *Contract conditions:* Korkmaz (2007), Molenaar et al. (2009), and the current study consistently suggest that contract conditions is an important project delivery attribute that can potentially affect the success of a project. Korkmaz (2007) piloted evaluation metrics and therefore broadly suggested that negotiated

contractual terms performed better than lump sum. However, on a detailed level strong alignment in results is not seen amongst the other two studies. Molenaar et al. (2009) reported guaranteed maximum price (GMP) payment method is most likely to result in successful outcomes. However, the results of the current study showed that in exemplary projects cost plus fee was the common method of payment.

Difference in the sample characteristics of these studies might be influential on these results. The sample of the current study included mostly private projects where the project team was procured mostly through the sole source selection where as in Molenaar et al. (2009) most projects were public and competitively bid for. Therefore, with the current results this aspect cannot yet be generalized over the green building population.

Next, the results showed that for better project outcomes, LEED® A.P.'s should be must directly contracted to the owner. Also, all the primary participants including M.E.P subcontractors should be contracted to the owner. These results are strongly supported by Korkmaz (2007). It is suggested that direct contract between LEED® A.P. and the owner would assist the former to effectively coordinate the inclusion of green strategies in the project. The cross case synthesis results of Korkmaz (2007) support direct contract between owners and other primary participants for higher communication and transparency in the delivery process.

4. *Project team procurement:* Korkmaz (2007), Molenaar et al. (2009), and the current study suggest that procurement of project teams have the potential to affect project outcomes. Both Korkmaz (2007) and Molenaar et al. (2009) specifically report that low bid procurement method should be avoided as it can potentially lead to unexpected cost growths. However, discrepancies were observed within the results of the two studies: Molenaar et al. (2009) reports that most exemplary projects adopted qualifications based selection where as Korkmaz (2007)'s sample inclined towards sole sourced and best value selection. The current study cannot contradict or support these findings because of the low sample size. No patterns were detected in the current study as most of the projects procured participants by sole source selection method. Therefore, in absence of conclusive results this attribute cannot be generalized to the whole population.

5. *Integration in the design process:* Under this metric results of all five studies strongly align with each other. Lapinski et al. (2006) reports that all primary participants should be involved in the project early in the design phase. Molenaar et al. (2009), Korkmaz (2007), Bilec and Ries (2009), and the current study support this finding and additionally suggest that **early involvement of the contractor is a key factor for project success**. Based on all the studies it was inferred that the contractor involvement should be as early as the pre-design or conceptual phase to effectively include all the value engineering and constructability reviews.

Lapinski et al. (2006) and Bilec and Ries (2009) also suggest that prior experience of team members with LEED® could result in positive outcomes the lack of the same can create delays. This finding was strongly supported by Enache-Pommer (2008). Although the current study, agrees with this finding based on the open ended data, no concrete patterns were seen either in the survey responses or in comparison with project outcomes. According to the findings of the current study this result is not generalizable especially because even the other two studies have not supported this directly.

Other results under this metric include:

- Green design coordinators are key members to guide the project team for the inclusion of strategies and documentation processes and therefore are critical to project success;
- High cost growths are seen in projects with low integration, mostly due to rework;
- Design charrettes and collaboration sessions are important aspects that assist the project team to focus towards common goals.

These findings are strongly supported by Korkmaz (2007), Enache- Pommer (2008) and the current study.

6. *Project team characteristics:* Korkmaz (2007) and Lapinski et al. (2006) suggest that project team characteristics (e.g., past experience with sustainable buildings, project delivery methods and with other team members) can potentially affect the final outcomes of a project. However, Korkmaz (2007) also suggests that the

Likert scale evaluation adopted to collect data was not the best method as it included a lot of bias from the respondents. The current research supports this statement as no strong pattern was seen within the Likert scale responses. Also, the responses were highly influenced by the experience of the team members on the project.

Next, Enache-Pommer (2008), reported that for successful outcomes apart from the owners commitment, increased commitment was also required from the team members towards the project. The current study supported this result. It was seen that strong commitment especially from the contractor could lead to significantly successful outcomes.

The external validity procedure presented above showed that most study findings on owner commitment, project delivery method selection, and integration in the delivery process can be generalized. The other findings show deviation with the previous research findings however, they cannot be entirely rejected as the deviation occurred mainly due to differing sample characteristics.

6.3 Comparison of study results with Molenaar et al. (2009)

Both Molenaar et al. (2009) and the current study attempted to answer the same research question through different research designs, level of detail, and sample sizes. Therefore, to bolster the external validity, a detailed comparison of results between the two research studies is conducted in this section.

The research approach followed by Molenaar et al. (2009) consisted of three primary levels, 1) an industry survey; 2) content analysis; and 3) structured interviews. The sample population was determined by the industry survey, where randomly selected 230 LEED® A.P. from the USGBC's online database were asked on their lessons learned about the project delivery methods and certification performance. The content analysis was adopted for a detailed analysis of solicitation documents from 92 public and private projects. Structured interviews were conducted with four design-builders and four owners to gain a deeper understanding of the results.

The current research study applied a case study protocol with 12 case studies for an extensive data collection procedure that included various parties of a project to get different perspectives of the full project delivery process (i.e., in total 30 respondents were engaged in this process) and an in-depth analysis of the data through a careful selection of the cases and a proposition testing procedure. The sample case studies for the current research were a good mix of all the three PDM's and the four LEED® certification levels.

Most projects in Molenaar et al. (2009) were public where as the current study included mostly private projects. This slightly skewed the results for both the studies especially in the project team procurement and contract condition attributes. For example, most exemplary projects in the Molenaar et al. (2009) database displayed GMP contractual term to result in positive outcomes as a majority of the projects were public and therefore were competitively bid for. On the contrary, such control did not exist in private projects that were in majority in the current study. Hence, most exemplary projects were negotiated with cost plus fee as their contractual term. Also, the differing sample sizes of the studies have resulted in deviant findings.

A discussion of the results based on Molenaar et al. (2009)'s findings are presented below.

1. *Deciding to go green/ The green guarantee*

   Molenaar et al. (2009) defines green guarantee "*as the contractual responsibility to deliver a building that will receive the owner's designated level of LEED® certification.*" It is further suggested that "*green guarantee defines the point where the owner's level of sustainability is compatible with the budget within which the project must be delivered.*" Based on the statements above Molenaar et al. (2009) concluded that the earliest guarantee is provided by DB where as the latest is by DBB. The green guarantee in CMR is based on the timing when the GMP is locked.

   The current study supports the concept of green guarantee, however, only slightly aligns with it. This is because based on the open ended responses in the current study, considering green guarantee as a point in the delivery process is a narrow outlook. Construction projects are inherently prone to positive or negative scope changes due to the flow of finances or any other unexpected circumstances such as weather calamities or city intervention. These can have a direct affect on the owner's sustainability requirements. Hence, even after contractual obligations are set they can be changed according to the owner's requirements regardless of the delivery method selected. Therefore, green guarantee should be considered as a fluctuating point that cannot be stabilized until substantial completion as it is dependent on owner's requirements and scope changes in the project.

For example, in the current study data set, a project delivered by the CMR method set a green guarantee for silver certification at the schematic design phase. However, during certification, they lost certain points slipped to certified level. The owner neither pursued higher certification further nor penalized the other participants, thereby changing the point of green guarantee. However, in DBB project, the owner was highly committed to sustainability and pursued platinum certification from the inception of design. The project eventually experienced a positive cost growth in its pursuit to platinum certification. As can be seen, in this case, the green guarantee was not based on contractor involvement rather it was an owner driven factor.

2. *Delivering Green: State of the Practice*

According to Molenaar et al. (2009) any level of LEED® certification can be delivered by any PDM. However, data also suggests that PDM's where the contract pricing provisions allow negotiation of scope and allow contractor to make relevant suggestions result in positive outcomes. The current study completely aligns with these findings.

However, the study also reports that; 1) 75% of its database was delivered by integrated project delivery that included DB and CMR projects and; 2) CMR was the most successful PDM within the sample. Both the results seem a little flawed as results from the current study show that DBB projects can demonstrate competitive integration if they involved the contractor either informally or formally for preconstruction services. However, this flaw is understandable because the data set was too large to pursue an in depth analysis. The second finding seems flawed as the sample selected by Molenaar et al. (2009) seems to be biased towards CMR projects by including 54 DBB and 56 DB projects versus 120 CMR projects.

3. *Assignment of the Green Responsibility*

Molenaar et al. (2009) reports that *"if an owner desires a highly sustainable building, i.e. gold or platinum, it should assign the responsibility for obtaining* LEED® *certification as early as possible."* The study also reports that *"if an owner would like to maximize the sustainability within the constraints of budget and schedule, it is better to use DB-Lump Sum (LS) or DBB to specify the LEED® level in the procurement documents*." The current study completely aligns with the first finding; however, for the second result the current study did not observe any patterns therefore this study cannot conclusively support the finding.

4. *Green Liability*

Molenaar et al. (2009) defines green liability as an issue in failed certifications or certification below the contractually defined level. The survey found that the performance of the DB and the DBB delivery methods in achieving or exceeding the desired certification level (contractually opposite ways of specifying sustainable objectives) was approximately the same. In the current study, except for one project all the others either exceeded or achieved their intended targets. The data set was a balanced distribution between the three delivery methods. Therefore, this study cannot refute or support this finding.

5. *Green Procurement Approaches*

In Molenaar et al. (2009) sample population, quality based selection procurements enjoyed the highest success rate which was more common in DB-GMP and CMR projects. The report suggested that this was because contractor design input and integration were thought to be aspects most critical to LEED® success within the DB and CMR delivery methods. The current study does not align or refute this finding as participants for the majority of the current study were selected through sole source method. Due to the differing type of projects (i.e., public vs private) in the sample led to deviating results.

However, the current study does not align with the proposition that integration can only happen within CMR and DB methods in Molenaar et al. (2009). As mentioned earlier DBB has the potential to display competitive level of integration and contractor input for LEED® success. The study observed that contractors can be involved in the design phase informally or contractually for pre-design services allowing upto medium level of integration.

6. Contract Payment Provisions

Molenaar et al. (2009) suggests that success rates favor those project delivery methods that use GMP payment provisions. It is suggested by the author that GMP is negotiated and therefore owner and designer can negotiate which credits the project will accrue while getting real-time pricing for those features from the entity that will actually complete the construction. The current study showed cost plus fee to be the most effective payment method leading to successful outcomes. It was observed that the respondents preferred cost plus fee because it helps the project team (designer and contractor) to focus towards the project goals rather than deviating to protect their own financial interests.

The discussion above shows that there although there are deviations in the results of the two studies; there are also many points of alignments. The main reason for the deviant results can be owed to the differing sample type and size. Molenaar et al. (2009) database consisted of mostly public projects where as the current study included mostly private projects. This resulted in deviant results under attributes such as project team procurement and contract conditions. Also, the sample population for Molenaar et al. (2009) was too big to be analyzed in detail where as the sample population of the current study was too small to generate generalizable results by itself. Therefore, a discussion of results has helped bolster results of both studies.

6.4 Guidelines and Lessons Learned on Sustainable, High Performance Building Project Delivery

In the current study, some practices leading to exemplary projects were observed. However, outliers to these exemplary practices were also seen i.e., projects that did not follow the exemplary practices to their entirety and still achieved exemplary results. On the contrary, the common practices in flawed projects were seen as red flags throughout the delivery process that if crossed would increasingly reduce the probability of achieving exemplary results. Therefore, the common practices in the flawed projects were seen to be more generalizable than the exemplary ones. To avoid achieving less than optimal results the guidelines below should be prioritized.

Practices leading to flawed projects:

- If the owner commits to green strategies as late as design development phase, it is less likely that the process would lead to successful outcomes;
- Mandating the green verbally lessens the probability for successful outcomes as it indicates towards the unclear mind set of the owner which could eventually reflect on the project team;
- Contractor is one of the key members of a project and if involved later than construction documents or bidding phase would not be able to provide constructive suggestions that can eventually lead to rework and consequently to a cost growth;
- If the green design coordinator is not directly contracted to the owner it tends to reduce the priority of green for the project team leading to probable under

achievement in the level of sustainability as the motivation to pursue a green building is not coming directly from the owner;

- Construction is dynamic process that is prone to change. Low bid procurement method should not be followed as it inherently cannot accommodate such changes and generally leads to contention between participants.

Practices leading to exemplary projects:

The practices listed in this section were observed in exemplary projects. Although following these practices can lead to potentially successful outcomes, not following them will not necessarily lead to flawed outcomes. Therefore, these results were not completely generalizable.

- Owner must display high commitment towards green strategies and the project by including green early in the project process starting as early as pre-design stages;
- Contention between the participants to protect their own interest needs to be eliminated from project to pursue successful outcomes;
- The presence of a green design coordinator is imperative in a sustainable project. Also direct contract between the LEED® A.P. and owner seem to yield better outcomes especially in terms of sustainability as the former orchestrates the inclusion of green with strong owner support;
- Timing of participant involvement (contractually or informally) especially contractor's should be as early as pre-design or schematic phase in the design process;

- Design charrette and collaborations session should be conducted to align the project team towards common goals and deliverables;
- Prior experience of team members with each other can be an important factor for the success of the project.

6.5 Conclusions

This research aimed to understand the extent of the effect of project delivery methods and practices on the level of integration achieved by the project team and further its effects on project outcomes with a focus on sustainability goals. After conducting a comprehensive case study protocol the following is concluded.

1. The level of design integration in a project achieved can strongly affect the accomplishment of sustainability goals. Timing of participant's involvement, timing and methods of communication, and level of collaboration among participants are the most vital attributes to complement the level of integration achieved in a project.
2. Project delivery attributes were found to be more influential on the level of design integration achieved by a project than the PDM's adopted. These include timing of participant's involvement, the level of collaboration they share and the procurement methods adopted.
3. Project delivery attributes, in particular integration in the delivery process, contractual terms, contractual conditions, owner commitment, have strong effects on the final project outcomes such as schedule and cost performance.

4. Any PDM can achieve any level of sustainability i.e., LEED® certified to platinum. However, DB and CMR delivery methods have higher potential to achieve the same at lower cost and schedule growth.

6.6 Limitations

This section discusses the limitations of this study with potential remedies.

1. Due to the relatively small sample size, statistical validation of the results was not possible. However, the generalizability of the results was established through external validation i.e., by comparing the results with previous research study findings from the same field;

2. Due to the intense focus of the research on sustainable office buildings that were new construction and fairly small sample size, the results could not be generalized over all building types, locations, functions, sizes. However, certain results could be generalized that were seen as red flags to compromise the success of projects along the project delivery phase. Under most circumstances these should not be followed as they could lead to potentially flawed projects;

3. In a qualitative study any sample is limiting as increasing number of respondents can provide more perspectives, and a broader understanding of the same topic. Also with the time lag, respondent's memory gets skewed leading to inaccurate responses. A potential remedy to this problem can be including various projects participants (e.g. owner, designer, and contractor) in the data collection process and cross referencing their responses. Archival documents and cross referencing

can also be utilized for minimizing the response bias which were all utilized in this study however, alternate methodologies may be adopted (e.g. ethnography to fully eliminate this limitation); where a researcher is embedded to the project delivery process where they perform in time recording.

4. Majority of the projects selected for this research were private and therefore skewed the results. For example the procurement methods utilized in the study were mostly sole sourced selection. A balanced mix of public and private projects could have provided a broader perspective of certain metrics such as timing of participant involvement, project delivery methods, and the reason to build green and its timing of intro to the project. There were no restriction for the selection of alternative delivery methods and the potential affect of legislation was not detected.

5. Handpicking case studies threatens the external validity of the research and it is not considered as strong as random selection. Although, the case study selection criteria adopted for this study introduced a bias in the sample this bias was important to control external variables such as size scope and complexity of buildings. This procedure minimizes the effects of such variables and therefore leads to more generalizable results towards the project delivery attributes. Additionally the case study selection procedure allowed for a good balance in the sample for all PDM's and level of LEED® certification.

6. This study is using projects only from the USGBC's LEED® certified projects database that is available on the web which can be seen as a limitation to the study. however, there are extreme numbers of projects in the market that are built according to sustainability standards that have not attempted to receive certification or has adopted other green buildings assessment system than LEED®. However, LEED® is the most widely accepted national standers for the U.S. and a well known tool in the world market. Therefore, LEED® certified buildings are considered as good representatives of the green building population in the U.S. This system also provides a good sustainable, high performance assessment basis for the objectives of this research.

7. Cost and schedule metrics are very complex and difficult to collect data on and analyze as they include many aspects such as design, construction, and material cost and market changes resulting to inflation. Their evaluation is a limitation to this study. Also even if the data is collected, it is very difficult to find an exact comparison between projects as they differ in terms of their systems, locations, complexities, and scope changes along the delivery process. Even more importantly, the objective reflection of cost on project performance may not be representative of the real project success. For example, an owner might accept cost growth in return for high LEED® certification if added it later to the scope, in which case it becomes an acceptable cost growth. On the contrary, another owner might decline higher LEED® certification due to the rising cost. To realistically

take these factors in to account, this study coded cost and schedule metrics based on respondent evaluations (e.g., as high cost growth, on target, and under budget).

8. Although, safety is one of the critical factors in construction project, responses were provided by the study participants. Therefore, this metric was excluded from the analysis stage.

9. Certain metric such as project team characteristics, evaluation of prior team experience and project team chemistry and compatibility that were evaluated via Likert scale, were prone to response bias. The bias was based on the respondents experience with the project and other members. Therefore, to eliminate this bias, all project participants for each project (the owner, designer, and contractor) were included in the data collection process for the team characteristics evaluation questions. The responses were eliminated when the participants evaluated themselves. The other responses were coded and their average generated the final response for these questions.

6.7 Recommendations for Future Research

Based on its results and limitations this study recommends the following areas for future research:

1. Due to the changes in the followed practices the learning curve of the industry is also constantly changing. Therefore, in time this topic should be revisited in form of a longitudinal study with mixed methods (quantitative and qualitative) as the

results may not, stay the same. It is expected that the associations between attributes might in fact become even stronger.

2. Throughout the study it was seen that the time lag skewed the memory of the participants. Also different respondents had different understanding of the concepts such as PDM's and integration. Therefore, to understand the relationships, communications, and compatibility levels within team members and in depth field study should be conducted. This study should attempt an ethnography methodology to record the actual activities in delivery processes or through a data base entry by project team members (e.g. designer, contractors, and subcontractors) as they occur;

3. Over time methods of communications have evolved future research could look at the potential effects of different communication methods such as building information modeling, and project management software's on integration and further on project outcomes;

4. Due to lack of resources and data sharing enthusiasm from the participant's safety metric could not be included in this study. However, safety is a very important metric having significant affects on the outcomes. Therefore, future research should attempt a study by defining a data collection tool and evaluation guideline for this metric.

5. It was seen within this study that the "project team characteristics metric" could not be evaluated efficiently due to the inherent response bias. A study should attempt to find a more subjective evaluation method such as application of entry and exit surveys of project delivery processes for project team characteristics, which would potentially eliminate the inherent bias from respondents.

6.8 Concluding Remarks

Sustainability is a growing trend in the building market. Currently, most sustainability assessment systems available in the literature and market are product-based. However, recently a need for rigorous process guidelines is recognized. Therefore, this study aimed to understand the extent of the effect of projects delivery methods (PDM) and practices on the level of integration achieved in the project delivery and further their effects on project performance with a specific focus on sustainability goals. This study followed a case study approach and qualitative methods of analysis. The primary findings of the study showed that the level of integration in the delivery process has significant affects on the final project outcomes especially on sustainability goals. Also, the study determined that level of integration is more affected by project delivery attributes such as owner commitment and timing of participant involvement, rather than project delivery method selected. Even though the sample population for this study was limited to 12 case studies, the majority of the results were generalized through external validation with recent research findings. The verified findings included:

- Early inclusion of green (Pre-design) in the project;
- The reason to pursue green should be an owner driven factor;

- Green should be mandated contractually with the team members;
- Projects delivered by the CMR and DB outperformed DBB projects;
- LEED® A.P. should be directly contracted to the owner;
- Contractor is a key factor in the success of a project and should be involved in the early design phases;
- Design charrettes and collaboration sessions should be conducted to assist the project team focus towards a single goal.

Appendix A

HIGH PERFORMANCE GREEN BUILDING PROJECT DELIVERY SURVEY

RESPONDENT INFORMATION

Name : ______________________

Position/Title : ______________________

Company : ______________________

E-Mail Address : ______________________

Phone Number : ______________________

Case Study Project Name : ______________________

PROJECT PROFILE

1. Please provide following information about the project:

(a) Building Size: __________ / __________ SF (Total / Garage)

(b) Number of Floors: ______________

(c) Building Location: ______________ (City / State)

(d) Who is the owner of the project? ______________

(e) Type of Owner: □ Public □ Private □ K-12 □ Higher Education □ Developer □ Other _____

OWNER COMMITMENT

1. Who initially proposed the idea of incorporating "green" or "sustainable" building attributes/requirements?

□ Owner □ Developer □ Designer / Design-Builder □ Other ________

2. What is the primary reason for the project team to pursue green building objectives?

□ Mandated by client or state □ Owner Driven Factor (Vision Statement)
□ Energy Use / Cost □ Productivity of Occupants
□ Other ______________________ (Please list)

(a) If mandated by the client. How?

3. If asked for any, what green metric did the owner asked the project team to follow?

- ☐ USGBC's LEED certification level
  - ☐ Platinum
  - ☐ Gold
  - ☐ Silver
  - ☐ Certified
  - ☐ Does not matter
- ☐ Green Globes
  - ☐ 4 Globes
  - ☐ 3 Globes
  - ☐ 2 Globes
  - ☐ 1 Globes
  - ☐ Does not matter
- ☐ Other ______________________________ (Please list)

4. If mandated, How did the owner mandate the green metric?

☐ Contractually ☐ Verbally

5. At what point during the design process was the notion of a green building introduced? (Please base your timing definition on the level of design completed.)

☐ Conceptual Design (0-15%) ☐ Schematic Design (15-30%)
☐ Design Development (30-60%) ☐ Construction Documents (60-99%)
☐ Bidding (Full CD)

6. Did the project program undergo a Scope Creep? ☐ No ☐ Yes

Scope Creep: The increase in scope due to the introduction of more requirements (eg:technology usage for construction/material/design/ function/user ratio) that were not included in the initial planning of the project whilst maintaining the same time frame for project delivery

(a) If *yes,* what was the reason?

(b) If *yes,* then who would you consider responsible for it?
(You can choose more than one or add to the list)

☐ Owner ☐ Developer ☐ Design-Builder ☐ Designer
☐ Contractor ☐ Green Design Facilitator ☐ Other ____________

(c) Please describe in detail the extent of the scope creep in terms of cost, schedule, quality, and level of sustainability achieved.

7. If *you* are the *Owner* please answer the following questions?

(a) Are you satisfied with the increase in scope? ☐ No ☐ Yes
(b) Are you satisfied with the:
(b-1) Schedule growth (if any) caused by the increase in scope? ☐ No ☐ Yes

(b-2) Cost growth (if any) caused by the increase in scope? ☐ No ☐ Yes

(c) If answered *no* to b what do you consider responsible for the increase? (Circle more than one if needed)

□ Change orders □ Incomplete Project program □ Other

(d) If answered *no* to b & c who do you consider responsible for the increase? (Circle more than one if needed)

□ Owner □ Developer □ Design-Builder □ Designer
□ Contractor □ Green Design Facilitator □ Other ____________

PROJECT DELIVERY METHOD

1. Mark the appropriate box for the project delivery system (PDM) which best describes that used on your project. (Please use the definitions of project delivery method's below.)

□ Construction Management at risk
□ Design-Build
□ Design-Bid-Build

CM at Risk : The owner contracts with a design company to provide a facility design. The owner separately selects a contractor to perform construction a management services and construction work in accordance with the plans and specifications for a fee. The contractor usually has significant input in the design process and generally guarantees the maximum construction price.
Design Build : This is a single agreement between an owner and a single entity to perform both design and construction under a single design build contract. Portions or all of the design and construction may be performed by the entity or subcontracted to other companies.
Design Bid Build : This is a traditional process in the US construction industry, where the owner contracts separately with a designer and a contractor. The owner normally contract with a design company to complete design documents. The owner or his/her agent then solicits fixed price bids from contractors to perform the work. One contractor is usually selected and enters into an agreement with the owner to construct a facility in accordance with the plans and specifications.

2. Please describe in detail how did this PDM hinder or add to your efficiency?

3. Can you explain in detail the reasons for the choice of this PDM.

4. Will you use this PDM on a similar project again? □ No □ Yes

5. If *no* can you describe in detail that under what circumstances *you* may consider to use this PDM again.

6. How would you rate the current PDM in terms of :

General Satisfaction				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Cost:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Schedule:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Quality of Constructed Product:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Safety:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)

7. Do you think another PDM from the above list could have been more efficient?
If yes which one?

General Satisfaction:	□ No	□ Yes
□ CM at Risk	□ Design-Build	□ Design-Bid-Build
Cost:	□ No	□ Yes
□ CM at Risk	□ Design-Build	□ Design-Bid-Build
Schedule:	□ No	□ Yes
□ CM at Risk	□ Design-Build	□ Design-Bid-Build
Quality of Constructed Product:	□ No	□ Yes
□ CM at Risk	□ Design-Build	□ Design-Bid-Build
Safety:	□ No	□ Yes
□ CM at Risk	□ Design-Build	□ Design-Bid-Build

PROJECT TEAM PROCUREMENT

1. Mark the appropriate box for the procurement method used for the designer and contractor or design builder. (Use the definitions of procurement methods below.)

Designer	□ Sole source selection	□ Qualifications-based selection
	□ Best value selection	□ Fixed budget/best design □ Low bid
	□ Design Competition	
Contractor	□ Sole source selection	□ Qualifications-based selection
	□ Best value selection	□ Low bid
Design-Builder	□ Sole source selection	□ Qualifications-based selection
	□ Best value selection	□ Fixed budget/best design □ Low bid

Sole source selection : Direct selection without proposals.
Qualifications-based selection : Through an RFQ, the owner selects the most qualified designer/contractor and negotiates only with that entity to a "fair and reasonable" price.
Best value selection : The designer/contractor entities respond with proposals that contain technical aspects and price; the owner selects the proposal it deems to be of best value.
Fixed budget/best design : The owner announces the budget for the project and the design-build teams compete by submitting proposals containing as much scope as they can place in their package.
Competition : Design only through competition w/out budget concerns.

2. Was the primary process for selecting the designer and contractors competitive or negotiated?

Designer	□ Competitive	□ Negotiated
Contractor	□ Competitive	□ Negotiated
Design-Builder	□ Competitive	□ Negotiated

3. Mark the appropriate box that defines the attributes of your project team:

(a) Was there an attempt to restrain the pool of:

Designer:	□ No	□ Yes
Contractor:	□ No	□ Yes
MEP Consultant:	□ No	□ Yes

(b) If yes,What was the ability to restrain the pool:

Designer:	□ Low	□ High
Contractor:	□ Low	□ High
MEP Consultant:	□ Low	□ High

(c) What was the primary benchmark of the restrained pool?

□ Qualifications □ Proximity □ Previous work experince
□ Number of LEED previously completed □ Other ______________

4. Mark the appropriate box for the **contractual terms** used for the design-builder or designer and contractor.

Architect/Designer	□ Lump-Sum	□ GMP	□ Cost Plus fee	□ Not Applicabl(
Contractor	□ Lump-Sum	□ GMP	□ Cost Plus fee	□ Not Applicabl(
Design-Builder	□ Lump-Sum	□ GMP	□ Cost Plus fee	□ Not Applicabl(

CONTRACT CONDITIONS

1. Were *'green features'* a part of the contract? Which party was responsible for conducting these requirements?

- □ No, sustainability requirements were not listed in the contract.
- □ Yes, designer was primarily responsible for it.
- □ Yes, contractor was primarily responsible for it.
- □ Yes, design-builder was primarily responsible for it.
- □ Yes, owner's LEED AP was responsible for it.

2. Was onsite safety requirements a part of the contract and which party was responsible for conducting these requirements

- □ No, safety requirements were not listed in the contract.
- □ Yes, designer was primarily responsible for it.
- □ Yes, contractor was primarily responsible for it.
- □ Yes, design-builder was primarily responsible for it.
- □ Yes, owner was primarily responsible for it.

3. What incentive clauses and/or penalties were included in the project? (***Circle** choices in parenthesis that apply.)*

- □ Quality (Incentive / penalty)
- □ Schedule (Incentive / penalty)
- □ Cost (Incentive / penalty)
- □ Safety (Incentive / penalty)
- □ LEED certification (Incentive / penalty)
- □ Energy Performance (Incentive / penalty)
- □ Other ______________ (Incentive / penalty)
- □ None

4. When were the project participants contracted to the project team? (Please base your timing definition on the level of design completed.) (Please write C- CONTRACTUALLY or I- INFORMALLY)

Project Participants	Predesign	Conceptua Design (0-15%)	Schematic Design (15-30%)	Design Development (30-60%)	Construction Documents (60-99%)	Bidding (Full CD)
Core Team						
Designer						
Contractor						
Design-Builder						
Mechanical Sub.						
Electrical Sub.						
Consultants						
Green Design Facilitator (eg. LEED AP)						
Energy Consultant						
Lighting Consultant						
Indoor Air Quality Consultant						
Commissioning Agent						

5. If applicable, who held the contracts for the project participants listed below? (Please check the relevant boxes)

	Contract Held by				
Project Participants	Owner	Designer	Contractor	Design-Builder	N/A
Green Design Coordinator (eg.					
Energy Consultant					
Lighting Consultant					
Mechanical Contractor					
Electrical Contractor					
Commisioning Agent					

INTEGRATION IN THE DESIGN PROCESS

1. Does the project have a designated "Green Design Coordinator" with relevant credentials or experience?

□ Yes □ No □ Not sure

2. Was a collaboration session/ Design charrete held during the design initiation stage to discuss sustainable goals?

□ Yes □ No □ Not sure

3. If yes, who attended the session?

□ Owner or owner's representative
□ Green Design Coordinator
□ Designer
□ Mechanical Engineer
□ Electrical Engineer
□ Civil Engineer
□ Contractor
□ Other ____________________ (Please list)

4. Were at least two collaboration sessions held before the preparation of construction documents (not including the project initiation stage session)?

□ Yes □ No □ Not sure

5. When did the project team communicate with each other?
(Please check all applicable choices.)

□ At prescribed milestones (as part of the contract)
□ Only during design clashes
□ At regular intervals regardless of clashes

6. What were the methods of communication used amongst the team members?
(Please check all applicable choices.)

□ Email/ Fax/Phone
□ Project Management Softwares
□ Building Information Modelling
□ Other _______________
□ Online databases

7. Please evaluate the effectiveness of the communication methods used using a 1 to 5 scale.

□ 1 (None) □ 2 □ 3 (Limited) □ 4 □ 5 (Excellent)

8. What quantitative performance metrics does your team use to measure the sustainable performance of the project?

□ Building Energy Use Intensity
□ New PV System Production
□ Lighting Power Density
□ LEED points or certification level
□ Other ________________________ (Please list)

9. To what extend were the construction documents (drawing and performance specifications) completed at the time of envelope and mechanical-electrical-plumbing (MEP) systems' construction? ________________________ (%)

10. Were the subcontractors educated for specific applications and practices needed for green rating and certification systems such as LEED? □ Yes □ No □ Not sure

PROJECT TEAM CHARACTERISTICS

1. According to your experience please mark the appropriate box for each of the following attributes of your project team at the time of the project ((on a scale of 1(none) to 5 excellent)

(a) Individual experience of team members with **similar facilities**

Owner's Representative	□	1	□	2	□	3	□	4	□	5
Design-Builder	□	1	□	2	□	3	□	4	□	5
Designer/Designer	□	1	□	2	□	3	□	4	□	5
Contractor	□	1	□	2	□	3	□	4	□	5
Mechanical Subcontractor	□	1	□	2	□	3	□	4	□	5
Electrical Subcontractor	□	1	□	2	□	3	□	4	□	5

(b) Individual experience of team members with **high performance green buildings**

Owner's Representative	□	1	□	2	□	3	□	4	□	5
Design-Builder	□	1	□	2	□	3	□	4	□	5
Designer/Designer	□	1	□	2	□	3	□	4	□	5
Contractor	□	1	□	2	□	3	□	4	□	5
Mechanical Subcontractor	□	1	□	2	□	3	□	4	□	5
Electrical Subcontractor	□	1	□	2	□	3	□	4	□	5

(c) Individual experience of team members using your project's **delivery system**

Owner's Representative	□	1	□	2	□	3	□	4	□	5
Design-Builder	□	1	□	2	□	3	□	4	□	5
Designer/Designer	□	1	□	2	□	3	□	4	□	5
Contractor	□	1	□	2	□	3	□	4	□	5
Mechanical Subcontractor	□	1	□	2	□	3	□	4	□	5
Electrical Subcontractor	□	1	□	2	□	3	□	4	□	5

2. Please evaluate the following project characteristics (on a scale of 1(none) to 5 (excellent):

(a) Team's prior experience as a unit:	□	1	□	2	□	3	□	4	□	5
(b) Project team communication:	□	1	□	2	□	3	□	4	□	5
(c) Project team chemistry:	□	1	□	2	□	3	□	4	□	5
(d) Owner representative's capability:	□	1	□	2	□	3	□	4	□	5
(e) Owner's ability to define scope:	□	1	□	2	□	3	□	4	□	5
(f) Owner's ability to make decisions:	□	1	□	2	□	3	□	4	□	5
(g) Project complexity:	□	1	□	2	□	3	□	4	□	5
(h) Regulatory/ legal constraints:	□	1	□	2	□	3	□	4	□	5
(i) Onerous contract clauses:	□	1	□	2	□	3	□	4	□	5

3. How many LEED certified projects have you completed.

□ 0 □ 1-3 □ 3-5 □ 5+

4. Please categorize the number of projects according to their certification level.

□ Platinum ________ □ Gold ____________

□ Silver __________ □ Certified ____________

LEVELS OF HIGH PERFORMANCE GREEN

1. Please attach your preliminary and final LEED Checklist/ Scorecard.

2.. How important were the project's green goals for the project team?
□ Very Important □ Fairly Important □ Not Important

3. Did the project meet the green goals that the team had set at the beginning of the project?
□ Yes □ Exceeded □ Below Target □ Don't Know

4. What was the intended certification level?
□ Platinum □ Gold □ Silver □ Certification

5. Why was the project below target or how did the project exceed the intended target.
(Please answer the relevant option in detail)

PROJECT SCHEDULE PERFORMANCE

1. Please provide the following schedule information. (D/B/B and CMR)

Item	**As Planned (mm/dd/yy)**	**As Built (mm/dd/yy)**
Design Start Date (Notice to proceed)		
Construction Start Date (Notice to proceed)		
Construction End Date (Substantial Completion)		

2. Please provide the following schedule information. (D/B)

Item	**As Planned (mm/dd/yy)**	**As Built (mm/dd/yy)**
Start of Request for Proposal		
Start of Design Build		
Construction End Date (Substantial Completion)		

3. If *you* are the *Owner* how satisfied are you with the schedule performance of the project?

□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

PROJECT COST PERFORMANCE

1. What are the following total project costs? Indicate whether estimated (E) or actual (A). Please deduct all property costs, owner costs of installed process or manufacturing equipment, furnishings, fittings and equipment, or items not a cost of the building.

Stage / Cost	Design Costs	Construction Costs	Total Project Costs
Contract Award			
Final Cost			

2. If *you* are the *Owner* are you satisfied with the cost performance if any?

□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

3. What percentage of construction cost was the design fee? ____________________

4. Approximately, what percentage of cost growth related to external factors (e.g. weather,material delay, government. regulations)?

____

PROJECT QUALITY PERFORMANCE

1. If you are the owner please complete this section. If not please proceed to next section. Please evaluate the **quality** of the project compared to your expectations using a 1 to 5 scale.

Difficulty of facility start up:
□ 1 (High) □ 2 □ 3 (Medium) □ 4 □ 5 (Low)

Number and magnitude of call backs:
□ 1 (High) □ 2 □ 3 (Medium) □ 4 □ 5 (Low)

Did the quality of envelope/ roof/ structure/ foundation meet your expections?
□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

Did the quality of interior/ space/ layout/ meet your expectations?
□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

Did the quality of environmental systems (light/ HVAC) meet your expectations?
□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

Did the quality of process equipment/ layout meet your expectations?
□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

Did the project meet your expectations overall?
□ 1 (Did not meet) □ 2 □ 3 (Met) □ 4 □ 5 (Exceeded)

If the building has received a green certification (e.g. LEED, Green Globes), please rate the **difficulty** of the submittal review process.
□ 1 (High) □ 2 □ 3 (Medium) □ 4 □ 5 (Low)

SAFETY

1. If available please provide the safety records of the project on the following:

OSHA Recordable Incident Rate (RIR): ______________________________
DART Rate (Days Away/Restricted or Job Transfer Rate): ______________
Lost Time Case Rate (LTC): ______________________________
Lost Work Day Rate (LWD): ______________________________

POST OCCUPANCY EVALUATION

1. Please evaluate the **quality** of the project compared to *your previous experience of other facilities* on 1 to 5 scale

Average water consumption:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Average energy consumption:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Occupant turnover rate:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Occupant absenteeism:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)

2. How would your users rate this building?

General Satisfaction:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Acoustic quality:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Ventilation:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Controllability:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Lighting:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)
Thermal Comfort:				
□ 1 (High)	□ 2	□ 3 (Medium)	□ 4	□ 5 (Low)

3. What were the number of callbacks in terms of:

(a) Acoustic: ____________________
(b) Ventilation: ____________________
(c)Controlability: ____________________
(d) Lighting: ____________________
(e) Thermal Comfort: ____________________

4. Which system has been subject to most complains? What were the complaints?

____

5. Did the project meet the modelled performance v/s the final performance?

□ Yes □ Exceeded □ Below Target □ Don't Know

LESSONS LEARNED

1. Please answer the following questions in detail

(a) Could this project have been **delivered** better or more successful? How?
(b) Did the project meet intended needs?
(c) Describe any unique features about this building that influenced its cost, schedule or quality.
(d) How did the project delivery method chosen had an affect on the level of integration achieved by the project?
(e) Did you have any problems along the way? What type and measures were taken to eliminate them?
(f) What were the specific steps you took for the building to achieve its goals?
(g) In terms of process were there any specific problems affecting the performance?
(h) If you were to do this project again what would you do to make this project more efficicent?
(f) How did external factors (e.g. weather,material delay, regulations) affect the project (eg. in terms of cost schedule quality or achievement of LEED points)?

Appendix B

Institutional Review Board Approval Letter

January 5, 2009

To: Sinem Korkmaz
111-A Human Ecology Building
East Lansing

Re: **IRB# X08-1185** Category: EXEMPT 1-2
Approval Date: January 5, 2009

Title: Influence of Project Delivery Method on Achieving Sustainable, High Performance Buildings

The Institutional Review Board has completed their review of your project. I am pleased to advise you that your **project has been deemed as exempt** in accordance with federal regulations.

The IRB has found that your research project meets the criteria for exempt status and the criteria for the protection of human subjects in exempt research. **Under our exempt policy the Principal Investigator assumes the responsibilities for the protection of human subjects** in this project as outlined in the assurance letter and exempt educational material. The IRB office has received your signed assurance for exempt research. A copy of this signed agreement is appended for your information and records.

Renewals: Exempt protocols do not need to be renewed. If the project is completed, please submit an ***Application for Permanent Closure***.

Revisions: Exempt protocols do not require revisions. However, if changes are made to a protocol that may no longer meet the exempt criteria, a new initial application will be required.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants regarding the risk and benefits of the project must be reported to the IRB.

Follow-up: If your exempt project is not completed and closed after three years, the IRB office will contact you regarding the status of the project and to verify that no changes have occurred that may affect exempt status.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

Dan Ilgen, Ph.D.
SIRB Chair

c: lipika swarup
916 cherry lane appt h
east lansing
michigan-48823

Appendix C

Consent Form

The research on *"The Influence of Project Delivery Method on Achieving Sustainable, High Performance Buildings"*, is being conducted by the construction management Program at Michigan State University. This project is funded by the Charles Pankow Research Foundation.

The main theme of the research is to understand the influence of different project delivery methods on the level of interdisciplinary integration in projects and consequently its affect on pre and post occupancy project performance. Goals for this project are to provide building owners, planners, designers, constructors and operators with recommendations, tools and guidelines for (a) determining the most effective delivery and project management strategies, and for (b) applying best practices by which project teams can capitalize on the delivery method selected.

Your participation in this research is in the form of structured interviews that will be voice recorded and transcribed verbatim later. Each interview conducted would take approximately 40-50 minutes. All information collected through interviews will be kept confidential in the principal's investigators office and would only be accessible to the research team involved with this project. The information collected will only be used to achieve the research objectives as well as for written or oral reports and published papers. Your name and other critical information (such as cost, schedule or any other information as per the discretion of the interviewee) received about the project will be kept confidential in all public references to this research and your confidentiality will be maintained to the maximum extent allowable by law (unless the interviewee agrees to the inclusion of his/her name and/or professional affiliation and/or critical project information in the study). There are no known risks associated with participation in the study.

As a possible benefit of your participation, you could gain a better understanding of your facilities overall performance. This work may also help in advancing the ongoing sustainable construction research in the county. Also as a participant we will be glad to share with you a copy of YOUR interview and the final report.

Your participation is voluntary i.e., you may choose not to participate at all, or refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without consequence. One copy of this document will be kept together without research records at Michigan State University for 3 years after the project completion. If at any time, you would like to discuss questions regarding this research, you may do so by contacting Dr. Sinem Korkmaz (517-353-3252) or Lipika Swarup (630-701-5715). Also, if you have any questions or concerns about your roles and rights as a research participant, or would you like to register a complaint about this study, you may contact anonymously if you wish to the director of MSU's Human Research Protection Program at 517-355-2180 or email at irb@msu.edu or regular mail at 202, Olds Hall, East Lansing, Mi- 48824.

Research team contacts

Primary Investigator :

Dr. Sinem Korkmaz
Asst. Professor
(Construction Management)
201-D Human Ecology Building
Michigan State University
Office: (517) 353-3252

Secondary Investigator:

Lipika Swarup
Graduate Student,
(Construction Management)
Room no. 405, Human Ecology
Michigan State University
Ph- 517-432-3968, 630-701-5715

I voluntarily agree to participate in this study.

-------------------	-------------------	-------------------
Please print your full name	Signature	Date

I voluntarily give the permission to use my name and designation in the published report.

-------------------	-------------------	-------------------
Please print your full name	Signature	Date

Appendix D

E-mail to the Respondents

Dear Sir/Madam
We, in construction management Program at Michigan State University, are conducting research on the Influence of Project Delivery Method on Achieving Sustainable, High Performance Buildings. This project is funded by the Charles Pankow Research Foundation.

The main theme of the research is to understand the influence of different project delivery methods on the level of interdisciplinary integration in projects and consequently its affect on pre and post occupancy project performance. Goals for this project are to provide building owners, planners, designers, constructors and operators with recommendations, tools, and guidelines for (a) determining the most effective delivery and project management strategies, and for (b) applying best practices by which project teams can capitalize on the delivery method selected.

Your participation in this research will be highly appreciated and would add highly to the construction research. Participation will be in the form of structured interviews that would take approximately 30-40 minutes. All the information collected and your name will be kept confidential in all public references to this research.

If you agree to participate in this research please respond to us on swarupli@msu.edu. We would appreciate if you could include your contact information and a convenient time for us to conduct the interview.

At this point we wish to inform you that your participation is voluntary i.e., you may choose not to participate at all, or refuse to participate in certain procedures or answer certain questions or discontinue your participation at any time without any consequence. If at any time, you would like to discuss questions regarding this research, you may do so by contacting Dr. Sinem Korkmaz (517-353-3252) or Lipika Swarup (630-701-5715). Also, if you have any questions or concerns or complaints as a research participant you may contact anonymously if you wish to the director of MSU's Human Research Protection Program at 517-355-2180 or email at irb@msu.edu or regular mail at 202, Olds Hall, East Lansing, Mi- 48824.
Thank you

Research Team Contacts

Primary Investigator:

Dr. Sinem Korkmaz
Asst. Professor
(Construction Management)
201-D Human Ecology Building
Michigan State University
Office: (517) 353-3252

Secondary Investigator:

Lipika Swarup
Graduate Student,
(Construction Management)
Room no. 405, Human Ecology
Michigan State University
Ph- 517-432-3968, 630-701-5715

Appendix E

Outline of the Phone Conversation with Respondents

Hello… Good Morning/afternoon/evening…. My name is Lipika Swarup, I'm graduate student from MSU, I was hoping if you would have a minute to talk to me....

Thank you….

I'm a student of the construction Management program we are conducting a research on the Influence of Project Delivery Method on Achieving Sustainable, High Performance Buildings. This project is funded by the Charles Pankow Research Foundation.

We received your contact information from Mr/Miss Website XYZ.

We are very interested in studying you facility. The main theme of the research is to understand the influence of different project delivery methods on the level of interdisciplinary integration in projects and consequently its affect on pre and post occupancy project performance.

If you agree to participate in this research we would be conducting structured interviews with you and the project team. The interviews should not take more than 40-50 minutes. All the information we collect and your name will be kept confidential in all public references to this research. This is completely voluntary and you choose to opt out at any time. There is minimal or no known risk associated with this research.

(If the respondent agrees)

Thank you so much for agreeing to take part in this research. We greatly appreciate your assistance. I was wondering when will be a good time to contact you again or will you like to schedule an interview right now…

Thank you!!

Can we please have your email id so that we can confirm the interview slot? I would include my contact information in the email if you need to contact me for anything.

Thank you once again

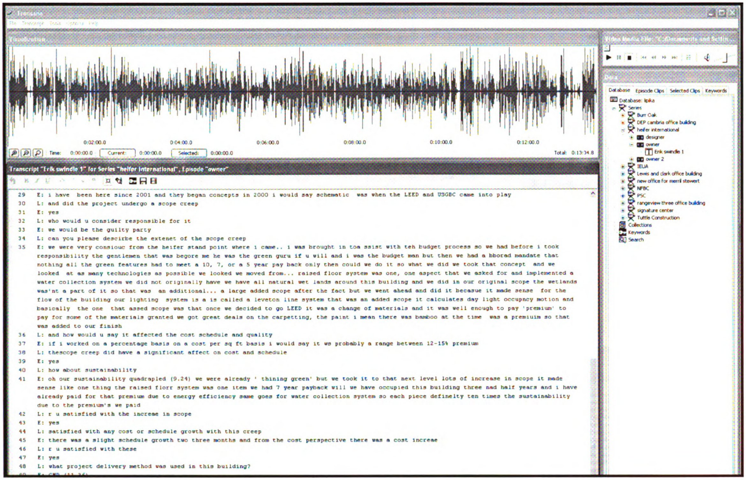
See you on……..

(If the respondent disagrees)

We understand your reluctance to participate in his research. Thank you and have a nice day!!!

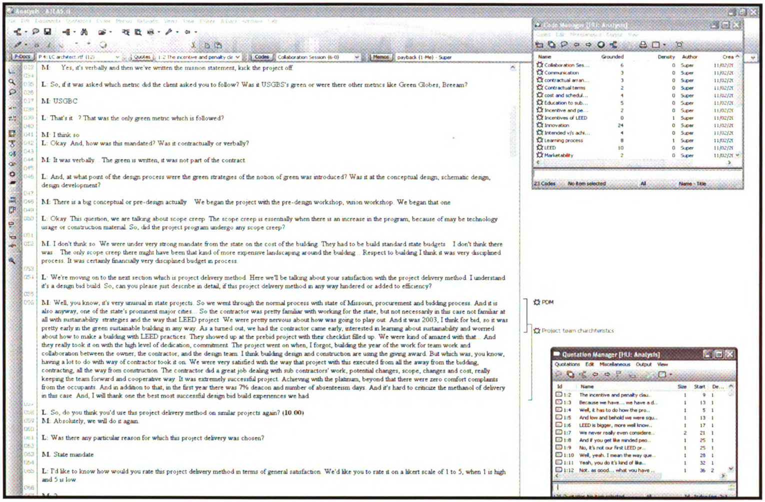
Appendix F

Snapshot of Transana 2.12® used for transcription of the telephonic interviews.



Appendix G

Snapshot of ATLAS. ti® used for transcription of the telephonic interviews.



Appendix H

Coding for the Level of Sustainable High Performance Achieved by Using LEED® Score Card

Project	Total ach.	Total poss.	Total %	Green	Energy	Energy possible	Energy %	Energy	IEQ	Poss. IEQ	IEQ %	IEQ	Energy + IEQ	Energy + IEQ Total	Energy + IEQ %	HPG
A1	26	69	37.68	-1	5	17	29.41	-1	11	15	73.33	0	16	32	50	-1
A2	26	69	37.68	-1	3	17	17.64	-1	8	15	53.33	-1	11	32	34.37	-1
A3	30	69	43.47	-1	6	17	35.29	-1	9	15	60	-1	15	32	46.87	-1
B1	30	61	49.18	-1	2	14	14.28	-1	6	11	54.54	-1	8	25	32	-1
B2	33	69	47.82	-1	4	17	23.52	-1	12	15	80	1	16	32	50	-1
C1	40	69	57.97	0	11	17	64.70	1	9	15	60	-1	20	32	62.5	1
C2	45	69	65.21	1	14	17	82.35	1	13	15	86.66	1	27	32	84.37	1
D1	46	61	75.41	1	12	16	75	1	11	13	84.61	1	23	29	79.31	1
D2	52	69	75.36	1	12	17	70.58	1	12	15	80	1	24	32	75	1
D3	52	69	75.36	1	15	17	88.23	1	10	15	66.66	0	25	32	78.12	1
D4	53	69	76.81	1	15	17	88.23	1	12	15	80	1	27	32	84.37	1

Appendix I

Coding for the Owner Commitment Using Survey Responses

Project	Initial Idea	Primary Reason	Green Metric	Mandated	Timing of Green	Scope Creep	Responsibility	Satisfied with Scope	Satisfied with Schedule	Satisfied with Cost
A1	Designer	Grants	USGBC	Verbally	Design Development	NO	*****	*****	*****	*****
A2	Owner	Learning grounds	USGBC	Verbally	Schematic Design	NO	*****	*****	*****	*****
A3	Owner	LEED®	USGBC	Contractually	Conceptual Design	YES	Owner	YES	NO	YES
B1	Owner	LEED®	USGBC	Verbally	Conceptual Design	YES	Owner	YES	YES	YES
B2	Owner	Vision Statement	USGBC	Verbally	Design Development	YES	Owner	NO	NO	NO
C1	Owner	Vision Statement	USGBC	Verbally	Conceptual Design	YES	Owner	YES	YES	YES
C2	Owner	Vision Statement	USGBC	Contractually	Conceptual Design	YES	Designer	YES	*****	*****
D1	Owner	Vision Statement	none	Contractually	Conceptual Design	NO	*****	*****	*****	*****
D2	Owner	Vision Statement	USGBC	Contractually	Schematic Design	YES	Owner	YES	YES	YES
D3	Owner	Vision Statement	USGBC	Contractually	Schematic Design	YES	Owner	YES	YES	YES
D4	Owner	Vision Statement	USGBC	Contractually	Conceptual Design	YES	Owner	YES	YES	YES

Appendix J

Coding for the Project Team Procurement Using Survey Responses

Project	Procurement Method			Process to select			Pool restrain			Ability to Restrain			Contractual Terms		
	Des.	Cont.	D-B	Des.	Cont.	D-B	Des.	Cont.	MEP	Des.	Cont.	MEP	Des.	Cont.	D-B
A1	SOLE	BEST	****	NEGO	COMP	*****	YES	YES	YES	LOW	HIGH	*****	LUMP	LUMP	*****
A2	SOLE	SOLE	****	NEGO	NEGO	*****	NO	YES	NO	*****	HIGH	*****	*****	LUMP	*****
A3	QUAL	BEST	****	NEGO	COMP	*****	YES	YES	YES	HIGH	HIGH	HIGH	LUMP	GMP	*****
B1	SOLE	SOLE	****	NEGO	NEGO	*****	YES	YES	****	HIGH	HIGH	*****	LUMP	LUMP	*****
B2	SOLE	SOLE	****	NEGO	NEGO	*****	****	****	****	*****	*****	*****	LUMP	GMP	*****
C1	*****	*****	SOLE	NEGO	NEGO	NEGO	YES	NO	NO	HIGH	*****	*****	*****	*****	COST
C2	*****	*****	DES COMP	NEGO	NEGO	NEGO	YES	YES	YES	HIGH	HIGH	HIGH	*****	*****	COST
D1	SOLE	SOLE	****	*****	*****	*****	****	****	****	*****	*****	*****	COST	COST	*****
D2	SOLE	BEST	****	NEGO	COMP	*****	NO	NO	NO	HIGH	HIGH	*****	COST	COST	*****
D3	****	****	BEST	COMP	*****	COMP	NO	****	NO	HIGH	*****	*****	*****	*****	LUMP
D4	QUAL	LB	****	COMP	COMP	*****	YES	NO	YES	HIGH	LOW	HIGH	COST	LUMP	*****

Des. : Designer	DES COMP : Design Competition	QUAL: Qualification Based Selection
Cont. : Contractor	BEST: Best Value Selection	COMP: Competitive
D-B : Design Builder	LB: Low Bid	GMP: Guaranteed Maximum Price
MEP : Mechanical Electrical and Plumbing	SOLE: Sole Sourced Selection	COST: Cost Plus Fee
NEGO : Negotiated	LUMP: Lump sum	

Appendix K

Coding for the Integration in the Delivery Process Using Survey Responses

Project	Green Design crdinator	Design Chartte	Clboration session	How Cmnicted*	Quntative Metrics*	Sub cont Educated	Prior ex	comm	chem
A1	NO	NO	NO	R1, R4	S2	NO	1	3	3
A2	YES	YES	YES	R1	S2	YES	4	4	4
A3	YES	YES	YES	R1	S2	YES	3	4	4
B1	YES	YES	YES	R1	S2	YES	4	4	4
B2	YES	NO	YES	R1	S1,2,4	YES	3	3	3
C1	YES	YES	YES	R1, R2, R4	S1, S2	YES	4	4	4
C2	YES	YES	YES	R1,2,4	S2	YES	2	3	3
D1	YES	NO	YES	R1,3, 4	S2, 5	YES	5	5	4
D2	YES	YES	YES	R1, R3, R4	S1, 2, 5	YES	4	4	4
D3	YES	YES	YES	R1	S1, S2, S4	YES	3	4	3
D4	YES	YES	XXXX	R1,2,4	S1-4	YES	3	3	4

*Response Codes

Email/ Fax/Phone	R1	Building Energy Use Intensity	S1
Building Information Modelling	R2	LEED® points or certification level	S2
Online databases	R3	New PV System Production	S3
Project Management Softwares	R4	Lighting Power Density	S4
Other	R5	Other	S5

Appendix K

Coding for the Integration in the Delivery Process Using Survey Responses

Project	Timing of Entry								
	Designer	Contractor	D-B	MEP	LEED® A.P.	Energy Con.	Light Con.	IAQ Con.	Comm Ag.
D3	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Sch. D (C)	Pre. D. (C)	******	******	******	Pre. D. (C)
A1	Pre. D. (C)	Bid	******	Bid	******	Pre. D. (C)	******	Bid	CD
A2	Pre. D. (C)	Pre. D.. (I) Bid (C)	******	Bid (C)	Pre. D.. D (C)	******	******	******	******
A3	Pre. D. (C)	Sch. D (C)	******	Pre. D.. (I)	Con. D (C)	******	******	******	******
B1	Con. D (C)	Pre. D. (I), Bid (C)	******	Con. D	Con. D	Con. D	Con. D	******	Bid
B2	Sch. D (C)	Pre. D. D. D (C)	******	CD (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Sch. D (C)	Sch. D (C)
C1	Pre. D. (I), Con. D (C)	Pre. D., DPre. D.. D (I) (C)	******	Bid (C)	Con. D (I), Sch. D (C)	Pre. D., Con. D (I) (C)	Pre. D. (I) , Con. D (C)	Pre. D.(I) , Con. D (C)	Con. D (I), Sch. D (C)
C2	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)
D1	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)
D2	Pre. D. (C)	Sch. D (C)	******	Sch. D (C)	Sch. D (C)	Sch. D (C)	Sch. D (C)	Sch. D (C)	Sch. D (C)
D4	Pre. D. (C)	Bid (C)	******	Bid (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)	Pre. D. (C)

Pre. D. : Predesign	D.D : Design Development	CD: Construction Documents
Con. D : Conceptual Design	(c) : Contractually	
Sch. D : Schematic Design	(I): Informally	

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