EFFECT OF PRE-CONSTRUCTION PLANNING ON COSTS AND SUSTAINABILITY

By

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To my loved husband, my daughter, and my parents
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<td>actual cost of work performed</td>
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<td>BIM</td>
<td>building information modeling</td>
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<td>earned value of work performed</td>
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<td>IAQ</td>
<td>indoor air quality</td>
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<td>IPD</td>
<td>integrated project delivery</td>
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The construction industry involves many distinct processes and professionals that without planning, projects are bound to fail. For many years construction companies have used traditional scheduling approaches, but this process has proven to be insufficient. Several pre-construction planning methods have emerged in the last century and have made their way to be used on projects. These methods include, among others, design phase construction planning, building information modeling, project control systems and using past projects’ data to improve performance among others. The main goal of this study was to show how these relatively new approaches were effectively affecting cost savings, and how they are promoting sustainability. Additional objectives are to find which method is most widely used in the industry today and how these methods can help in the LEED Certification process. The data for this study was collected using an online survey, and the anonymity of the respondents was preserved.

The survey responses revealed that using data from past projects to improve performance still is the most used method. In addition, two other pre-construction planning methods were mentioned in the survey by the respondents – risk management.
and assembling a team. Companies that spent more on pre-construction planning are the ones that had more cost savings. Therefore, the study showed that profitable companies use pre-construction methods frequently and in combination.

The data showed that more than 97% of the respondents believed that pre-construction planning is an essential tool to achieve LEED Certification. In addition, the use of high performance materials is frequent even though the project does not have the intention to be LEED Certified. Moreover, companies which had more LEED Certified projects in their portfolio use pre-construction methods more frequently. Therefore, the data confirms that pre-construction planning methods promote sustainability.

Understanding how pre-construction planning affects the project cost and sustainability can encourage construction firms to use pre-construction planning more often and help the industry achieve better results.
CHAPTER 1
INTRODUCTION

Sustainability in the construction business today is measured by how “green” the building is in terms of energy and high performance materials used during its construction, operation, maintenance, and deconstruction. Software can be used to help optimize material selection, utilize the resources of the construction process more efficiently, and improve the maintenance of buildings by a diversity of applications. Most of the technology products for construction tasks such as financial management, project management, document management, bidding, project scheduling, and cost estimate were all built around the paper-based processes of design, communication, collaboration, and construction. It is difficult to change habits, but is not impossible. Business is not a static process; it needs to adapt and to be open to new approaches and technologies.

Pre-construction planning is a valuable strategy to achieve sustainability and it can help reduce construction costs. Therefore, construction companies are using some pre-construction approaches to increase savings and obtain better performance of their buildings.

Building Information Modeling (BIM) is one of these new approaches. So far BIM has been very much a tool for professionals, emphasizing the early part of a building’s life cycle. In the current changing scenario, the BIM models can be used to maximize energy efficiency and optimize material selection. Construction companies have been using numerous 3D tools for a long time but in isolation. True BIM as a process that supports integrated project delivery (IPD) is still in its infancy. It is not about availability of technology but rather the industry’s resistance to change. The initial investment is
considerable. Top construction companies in United States are using this process successfully. BIM is responsible for saving money on estimating, reducing waste materials, and minimizing unnecessary change orders. It is a process that makes the Design phase a little longer, but it can save money and time at the time of executions of the project. Different approaches also can be used like design-phase construction planning, establishing a project control system or unit, and using past projects data to improve productivity.

A survey of the top US green construction companies was conducted and in order to evaluate how costs can be reduced with the implementation of preconstruction planning methods and how these methods can promote a more sustainable environment. The survey analyzed the commercial, retail, and industrial construction sectors in order to test the following hypotheses:

$H_{01}$: The implementation of pre-construction planning in the commercial, retail, and industrial sectors of construction increases savings on costs considerably.

$H_{02}$: The implementation of pre-construction planning in the commercial, retail, and industrial sectors of construction promotes a sustainable environment.

The results of this research will help lead to a more comprehensive view of the impact that pre-construction planning can have in the construction industry.
CHAPTER 2
LITERATURE REVIEW

Pre-Construction Planning

The complexity of the construction industry requires the identification of work tasks and the coordination of interactions among them. As a result, construction planning is considered to be one of the most critical steps toward success.

Construction projects need planning professionals to ensure that the project meets its program, stays on schedule and within budget, and causes minimal change orders along the way. Preconstruction planners perform a number of specialized services that can yield significant cost savings: estimating, budget development, constructability reviews, value engineering, construction strategy and schedule development, risk analysis and contingency management, and procurement strategy development. They can help ensure that projects succeed by providing administrators and the design team with the tools needed to carry out a project.

The sooner preconstruction planners begin work on a project, the greater their ability to identify cost reductions, enhance quality, improve constructability and increase schedule efficiency. Cost savings realized through high-quality preconstruction planning often can be reinvested in project enhancements. Professional preconstruction planners also can help minimize the need for redesign by identifying construction issues early and collaborating with architects and engineers in developing solutions. Therefore, preconstruction planners should be involved in the project from the start of the programming phase (http://asumag.com/mag/university_planning_ahead 2003).

Detailed estimates can be useful at every stage of design documentation by explicitly defining the components, scope and cost of all building systems. Among the
estimating tools is benchmarking, which is used both for cost breakdowns and to verify that the estimated costs of each component of the project and system fall within the proper range for projects of that type and complexity. The benchmarking process isolates each major building component and system, and compares projected costs with those of projects that are of similar type, scope and geographic location. Typically, estimators look first at the building systems, then at the concepts behind the building design and, finally, at specific equipment and materials. This information is used to develop, verify and manage the project's budget.

In addition, development of a well-structured project cost estimate and schedule in the early planning phase sets the stage for wise decisions by the entire project team. The planning process requires that the decisions made by the institution and its design team are compared continually with project goals and cost estimates.

The pre-construction planning team should perform constructability reviews and conduct value-engineering workshops on every project to identify opportunities to build better facilities for less cost. This can free resources that can be reinvested in enhancements. For example, the team may identify opportunities to save money through simplified installation details, prefabrication or construction standardization. Recommendations may be made for achieving the best value for materials or for minimizing trade interdependencies and weather conditions.

Value-engineering workshops examine whether more cost-effective ways are available to meet the same performance goals without sacrificing scope, quality or architectural appeal. Taking this approach, the preconstruction planning team first looks at how individual components and systems meet a building's performance goals, then at
the design standards and sizes of those systems and components, and finally at the materials and finishes. An experienced construction manager maintains a database for projects of similar program scope and building type from which to draw, analyze and compare costs, and to develop value-engineering solutions.

Savings also may be realized through effective risk analysis and contingency planning. During the preconstruction planning process, the team also identifies any needs for early procurement of equipment and materials with long lead times, not only to ensure that the schedule is met, but also to reduce costs. The procurement of equipment and materials typically is spelled out in the project-execution strategy developed by the planning team, in order to coordinate the procurement of equipment and the arrival of materials at the optimal time in the construction process.

An initial investment in preconstruction planning can result in considerable cost savings. The key is to involve a construction manager as an integral member of the project team at the programming stage. Preconstruction planning is important to the success of any building project and is absolutely essential when undertaking the challenges of a renovation or expansion (Arsht 2003).

**Sustainable Design**

Sustainable design seeks to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments. (GSA 2010)

Moreover, green design is design that goes beyond being just efficient, on time, and on budget. Green design cares about how such goals are achieved, about their effect on people and on the environment. An environmentally responsible professional
makes a commitment to constantly try to find ways to diminish design's impact on the world around us. It is also a smart way of doing business: sustainable design is the fastest growing segment of our industry. (ASID 2009)

Sustainable buildings provide financial rewards for building owners, operators, and occupants. Sustainable buildings typically have lower annual costs for energy, water, maintenance/repair, churn (reconfiguring space because of changing needs), and other operating expenses. These reduced costs do not have to come at the expense of higher initial costs. Through integrated design and innovative use of sustainable materials and equipment, the cost of a sustainable building can be the same as, or lower than, that of a traditional building. Some sustainable design features have higher initial costs, but the payback period for the incremental investment often is short and the lifecycle cost typically lower than the cost of traditional buildings. In addition to direct cost savings, sustainable buildings can provide indirect economic benefits to both the building owner and society. For instance, sustainable building features can promote better health, comfort, and well-being of building occupants, which can reduce levels of absenteeism and increase productivity. Sustainable building features can offer owners economic benefits in terms of lower risks, longer building lifetimes, improved ability to attract new employees, reduced expenses for dealing with complaints, less time and lower costs for project permitting resulting from community acceptance, and support on sustainable projects, and increased asset value. Sustainable buildings also offer society as a whole economic benefits such as reduced costs for air pollution damage and lower infrastructure costs, e.g., for avoided landfills, wastewater treatment plants, power plants, and transmission/distribution lines (DOE EERE 2008).
LEED Certification

Leadership in Energy and Environmental Design (LEED) was launched in March 2000. LEED is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO$_2$ emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. LEED applies to all building types – commercial as well as residential. It works throughout the building lifecycle – design and construction, operations and maintenance, tenant fit out, and significant retrofit. (http://www.usgbc.org 2011)

LEED was designed to encourage and accelerate global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted standards, tools, and performance criteria. LEED promotes a whole-building approach to sustainability by recognizing performance in key areas:

**Sustainable Sites**

Site selection and development are important components of a building’s sustainability. The Sustainable Sites category discourages development on previously undeveloped land; seeks to minimize a building’s impact on ecosystems and waterways; encourages regionally appropriate landscaping; rewards smart transportation choices; controls storm water runoff; and promotes reduction of erosion, light pollution, heat island effect and construction-related pollution.

Healthy landscapes have the capacity to enhance and regenerate natural resources and ecosystem health.
Water Efficiency

Buildings are major users of potable water supply. The goal of the Water Efficiency category is to encourage smarter use of water. Water reduction is typically achieved through more efficient appliances, fixtures and fittings inside the buildings and water-conscious landscaping outdoors. Moreover, use of high-efficiency fixtures and dry fixtures such as composting toilet systems and waterless urinals to reduce wastewater volumes are some of the actions to achieve these criteria. In addition, the reusing storm water or grey water for sewage conveyance or on-site wastewater treatment systems (mechanical and/or natural) reduces water use. Therefore, options for on-site wastewater treatment include packaged biological nutrient removal systems, constructed wetlands, and high-efficiency filtration systems should be considered.

Energy and Atmosphere

According to the U.S. Department of Energy, buildings use 39% of the energy and 74% of the electricity produced each year in the United States. The Energy & Atmosphere category encourages a wide variety of energy-wise strategies: commissioning; energy use monitoring; efficient design and construction; efficient appliances, systems and lighting; the use of renewable and clean sources of energy, generated on-site or off-site; and other innovative measures.

Materials and Resources

During both the construction and operations phases, buildings generate a lot of waste and use large quantities of materials and resources. The Materials & Resources category encourages the selection of sustainably grown, harvested, produced and transported products and materials. This criteria promotes waste reduction.
In addition, it promotes reuse and recycling, and it particularly rewards the reduction of waste at a product’s source.

**Indoor Environmental Quality**

The U.S. Environmental Protection Agency estimates that Americans spend about 90% of their day indoors, where the air quality can be significantly worse than outside. The Indoor Environmental Quality category promotes strategies that improve indoor air as well as those that provide access to natural daylight and views and improve acoustics. Poor IAQ is a major concern as it can impact the health, comfort, and productivity of the building occupants. This category focuses on a building's strategies to improve indoor air quality and occupants’ comfort.

**Locations and Linkages**

The LEED for Homes rating system recognizes that much of a home's impact on the environment comes from where it is located and how it fits into its community. The Locations & Linkages category encourages building on previously developed or infill sites and away from environmentally sensitive areas. Credits reward homes that are built near already-existing infrastructure, community resources and transit – in locations that promote access to open space for walking and physical activity.

**Awareness and Education**

The LEED for Homes rating system acknowledges that a home is only truly green if the people who live in it use its green features to maximum effect. The Awareness & Education category encourages home builders and real estate professionals to provide homeowners, tenants and building managers with the education and tools needed to understand what makes their home green and how to make the most of those features.

Occupants play a substantial role in the resource use of a home over its lifetime.
Innovation in Design

The Innovation in Design category provides bonus points for projects that use innovative technologies and strategies to improve a building’s performance well beyond what is required by other LEED credits, or to account for green building considerations that are not specifically addressed elsewhere in LEED. This category also rewards projects for including a LEED Accredited Professional on the team to ensure a holistic, integrated approach to the design and construction process.

Regional Priority

USGBC’s regional councils, chapters and affiliates have identified the most important local environmental concerns, and six LEED credits addressing these local priorities have been selected for each region of the country. A project that earns a regional priority credit will earn one bonus point in addition to any points awarded for that credit. Up to four extra points can be earned in this way.

Building Information Modeling (BIM)

A Building information model is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. A basic premise of Building Information Modeling (BIM) is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the Model to support and reflect the roles of that stakeholder. The Model is a shared digital representation founded on open standards for interoperability (NBIMS 2007).

BIM involves integration of CAD drawings, geospatial data and other graphical and non-graphical data, and may represent the view of a building from any practitioner
perspective: architect, specification drafter, and engineer, fabricator, leasing agent, lender and general contractor. As such, it serves as a shared source of information on a building, forming a reliable basis for decision making during its lifecycle. Pushing users in the direction of discovering, accessing and 'fusing' information to support decision-making throughout this lifecycle is the technology enabler of network-based distributed computing. It shifts the focus from isolated drawings and project-specific data files and software systems to drawing, seemingly spontaneously, on information and software services residing on countless servers. Key to this development is interoperability and standards (Global Initiatives in Management 2010).

Buildings consume close to 40% of total energy used in the United States and account for 30% of greenhouse gas emissions. With the rising cost of energy and growing environmental concerns, the demand for sustainable buildings with minimal environmental impact is increasing. The most effective decisions related to the sustainable design of a building can be made in the early design and preconstruction stages. In this context, BIM can aid in performing complex building performance analyses to ensure an optimized sustainable building design. (Azhar and Brown 2009)

Building information modeling (BIM) offers yet another powerful capability to design teams: they can assess alternative energy strategies and systems in the earliest phases of design. New and emerging tools allow a user to submit data from project BIMs to test energy-saving ideas and see results quickly. This helps teams make energy-conscious decisions early in design – when those decisions have greatest impact on the building’s life cycle. This capability also helps project teams make cost effective retrofit decisions (Stumpf and Brucker 2006).
Integrated practice represents both an opportunity and a challenge for architecture and engineering professions. From a sustainable design perspective, the greatest potential is for increased collaboration and integration across design disciplines. (Vallero 2008)

At any stage of the design, BIM technology can extract an accurate bill of quantities and spaces that can be used for cost estimation. In the early stages of a design, cost estimates are based primarily on the unit cost per square foot. As the design progresses, more detailed quantities are available and can be used for more accurate and detailed cost estimates. It is possible to keep all parties aware of the cost implications associated with a given design before it progresses to the level of detailing required of construction bids.

Because the virtual 3D building model is the source for all 2D and 3D drawings, design errors caused by inconsistent 2D drawings are eliminated. In addition, because systems from all disciplines can be brought together and compared, multi-system interfaces are easily checked both systematically (for hard and soft clashes) and visually (for other kinds of errors). Conflicts are identified before they are detected in the field. While BIM offers new methods for collaboration, it introduces other issues with respect to the development of effective teams. Determining the methods that will be used to permit adequate sharing of model information by members of the project team is a significant issue. If the architect uses traditional paper-based drawings, then it will be necessary for the contractor (or a third party) to build the model so that it can be used for construction planning, estimating, and coordination etc. Creating a model after the design is complete adds cost and time to the project, but it may be justified by the
advantages of using it for construction planning and detailed design by mechanical, plumbing, other subs and fabricators, design change resolution, procurement, etc. (Eastman et al. 2008)

**Design-Phase Construction Planning**

During the planning and design phase, two major issues are addressed: design concepts and a budget. Wan (2011) explained how the design-phase works among design-build companies. Several steps are involved in the design-phase planning method: schematic design, conceptual design stage, design development stage, construction document stage, and design modifications stage.

**Schematic Design**

During the Schematic Design stage for buildings, a list of spatial requirements (number of offices, conference rooms, and special spaces) baseline the design. The goal during this phase is to acquire a complete and accurate understanding of project requirements. For example, a code analysis will establish specific zoning and environmental restrictions. Based on the program and code analysis a preliminary design sketch of a site plan (the proposed building located on the site), floor plans (layout) and elevations (exterior views of the building) will be produced. Then, an outline specification; a list describing the proposed products and materials to be used on the project will be prepared.

Depending on the size and complexity of the project, multiple schemes will be prepared and discussed to focus on the benefits and/or drawbacks of each scheme. Use of several different presentation methods such as 3D perspective drawings and/or models is encouraged. Upon completion of the Schematic Design phase, a preliminary cost estimate for each potential scheme is prepared.
Conceptual Design Stage

This stage should demonstrate compliance with the relevant codes and zoning, the space program identified in the programming phase, functional requirements, and the massing should respect the context for the project. Engineering systems must be defined in a narrative form in this phase. Building envelope should be defined and should respect and relate to the context of the project. A design narrative should be included describing the design approach and the rationale for it. The cost estimate should be consistent with the programming phase and should be included in the report.

Design Development Stage

Engineering systems must be defined in this phase and incorporated into the architecture. Engineering systems include civil, structural, heating, ventilation and air conditioning (HVAC), plumbing, electrical, fire protection, and security. All building elements and components must be selected, defined, and incorporated in this phase of the work. This includes building envelope, interior structure, service spaces, and elevators. Outline specifications should be produced and included in this package.

Construction Document Stage

This stage includes the production of working drawings that identify all the necessary details. Engineering disciplines should be well-coordinated and incorporated into the design. The drawings should also be consistent with the specifications. The notes on these drawings should result in a single interpretation of a specific set of data and become the basis of a competitive price proposal.

Design Modifications Stage

Modifications can be incorporated at any stage in the project. However, the more advanced the design, the higher the modification cost. Hence, it is best to conduct
modifications thorough programming and schematic design phases to avoid any modifications during the design development phase and the construction document phase. Modifications during construction phase will have to be negotiated with the architecture firm through construction and the architecture firm will prepare a cost estimate for the modification. The contractor will be required to submit a modification (variation order) cost. Modifications are common in every project, so the project manager should anticipate them and budget at least 10% of the construction budget as post award allowance. The project manager should expect a higher level of modifications in renovation projects due to unforeseen conditions.

**Project Control System**

During the execution of a project, procedures for project control and record keeping become indispensable tools to managers and other participants in the construction process. These tools serve the dual purpose of recording the financial transactions that occur as well as giving managers an indication of the progress and problems associated with a project. The problems of project control are aptly summed up in an old definition of a project as "any collection of vaguely related activities that are ninety percent complete, over budget and late." The task of project control systems is to give a fair indication of the existence and the extent of such problems.

For cost control on a project, the construction plan and the associated cash flow estimates can provide the baseline reference for subsequent project monitoring and control. For schedules, progress on individual activities and the achievement of milestone completions can be compared with the project schedule to monitor the progress of activities. Contract and job specifications provide the criteria by which to assess and assure the required quality of construction. The final or detailed cost
estimate provides a baseline for the assessment of financial performance during the project. To the extent that costs are within the detailed cost estimate, then the project is thought to be under financial control. Overruns in particular cost categories signal the possibility of problems and give an indication of exactly what problems are being encountered. Expense oriented construction planning and control focuses upon the categories included in the final cost estimation. This focus is particular relevant for projects with few activities and considerable repetition such as grading and paving roadways.

For control and monitoring purposes, the original detailed cost estimate is typically converted to a project budget, and the project budget is used subsequently as a guide for management. Specific items in the detailed cost estimate become job cost elements. Expenses incurred during the course of a project are recorded in specific job cost accounts to be compared with the original cost estimates in each category. Thus, individual job cost accounts generally represent the basic unit for cost control. Alternatively, job cost accounts may be disaggregated or divided into work elements which are related both to particular scheduled activities and to particular cost accounts. In addition to cost amounts, information on material quantities and labor inputs within each job account is also typically retained in the project budget. With this information, actual materials usage and labor employed can be compared to the expected requirements. As a result, cost overruns or savings on particular items can be identified as due to changes in unit prices, labor productivity or in the amount of material consumed (Hendrickson 1998). Businesses sometimes use formal systems development processes. A formal process is more effective in creating strong controls,
and auditors should review this process to confirm that it is well designed and is followed in practice. A good formal systems development plan outlines:

- A strategy to align development with the organization’s broader objectives
- Standards for new systems
- Project management policies for timing and budgeting
- Procedures describing the process
- Evaluation of quality of change

Project management control systems are the modern tools for managing project scope, cost and schedule. They are based on carefully defined process and document controls, metrics, performance indicators and forecasting with capability to reveal trends toward cost overrun and/or schedule slippage. Identifying those trends early makes them more amenable to successful management.

Traditionally, management systems have utilized data about planned and actual costs. Modern systems further incorporate, in their analysis of projects and tasks, the monetary value earned for actual work accomplished. They analyze the Planned Value of work scheduled (PV), Actual Cost of work performed (AC), and Earned Value of work performed (EV) (Lavine 2008).

**Case Study**

When Princeton University, Princeton, N.J., decided to renovate and expand the Marquand Library of Art and Archaeology, it immediately involved preconstruction planners. The 63,000-square-foot project calls for underground and third-floor additions, as well as the complete renovation of four stories, including all new mechanical systems, lighting and finishes with extensive millwork. The project also included installation of two new elevators, a new 12,000-square-foot plaza at the north entry of McCormick Hall, renovation of swing space on campus, and the temporary relocation of
the library staff and collections. Preconstruction planning began in 2000, and it was determined that before full-scale construction, McCormick Hall would need an elevator to allow access for those with disabilities.

The elevator was completed in November 2001, and full-scale construction began in March 2002. A tight site at the center of the campus requires ongoing construction sequencing and coordination to maintain a safe environment for the college community and construction workers. Close coordination of deliveries, work vehicles and debris removal is necessary daily. Emergency egress routes are maintained at all times. At Princeton's Robertson Hall, a recent 75,000-square-foot, two-phase renovation of a combined office, classroom and lecture facility involved the removal and replacement of all building systems, as well as an architectural reconstruction of the interior spaces, including extensive millwork and finishes.

The renovation included infilling of the second- and third-floor mezzanines to turn an existing three-story library into office space. It also included two new additions that house classrooms. All mechanical, electrical and life-safety systems were replaced with new systems. The exterior received new windows, skylights and repairs to the plinth and some existing window systems. Preconstruction planning began in November 1999, field construction began in May 2000, and the project was completed in August 2002.

The original design of the all-concrete structure presented many challenges, including access to existing utilities. This required preconstruction planners to work closely with architects on the design and construction methods necessary to replace systems. For example, fourth-floor pits housing piping and ductwork were fed from the third-floor ceiling but were not accessible from the third floor.
The design team was planning to replace all of the ductwork and piping. However, constructability reviews and testing revealed usable ductwork and piping that would have been expensive to remove and replace. Replacement of the piping would have required a design with many turns, creating potential maintenance problems. As a result, reusable elements were incorporated into the design. Working in an occupied building on a tight site required careful construction sequencing and coordination, maintenance of access and emergency egress, and the installation and maintenance of temporary structures and utilities. Effective preconstruction planning, including constructability reviews and value engineering, helped to reduce costs significantly (Arsht 2003).

Figure 2-1. Marquand library of art and archaeology - view of the plaza (http://marquand.princeton.edu/renovations.php).
Figure 2-2. Marquand library of art and archaeology – 1st floor reading room. (http://marquand.princeton.edu/renovations.php).

Figure 2-3. Marquand library of art and archaeology – 3rd floor Carrels (http://marquand.princeton.edu/renovations.php)
CHAPTER 3
METHODOLOGY

Overview

A survey was conducted among architects, engineers, contractors, and builders all members of USGBC in commercial, institutional, and industrial sectors. Invitations to participate were sent to 1,462 e-mail addresses of architects, engineers, contractors, and builders, all members of the USGBC. The emails were randomly selected and collected from the USGBC website. An additional 84 emails were sent to the ENR 2010 Top Green Contractors, resulting in a total of 1546 emails being sent out.

A total of 26 e-mails bounced back as either a wrong address or no longer existing. The net total of 1520 valid emails invitations resulted in 80 completed responses. The response rate was 5.3%.

The survey was divided in two major categories: demographics and past projects’ data. The first set of responses was demographics questions. The demographic section of the survey was intended to categorize the target population in a way to better understand the construction industry. The second half of the survey referred to past project data which reflects better on how the construction industry is facing this economic crisis period.

Scope

The results of this research help lead to more comprehensive view of the possibilities and implications that these pre-construction planning approaches can cause in the construction industry. The collection technique involved web-based-surveys because it is the most practical and flexible way to conduct a survey among the population chosen.
Web based surveys are faster and could be done without revealing the respondent identity. A significant number of responses were crucial for the success of this study. The comparison of similar projects in relation to size, initial investment, nature, and location are the key to have very accurate results. A study was conducted in each construction sector – commercial, institutional, and industrial, and the parameters looked at were – size, cost, and location.
CHAPTER 4
RESULTS

The survey was sent to an equally number of professionals per discipline spread among U.S. states. However, as shown in Figure 4-1 and Table 4-1, general contractors and architects were the main professionals that responded to this study with 41.3% (33) and 37% (30) responses respectively. The rest of the responses came from subcontractors (7), engineers (5), developers (3), construction manager (1), and consultant (1).

Figure 4-1. Company role (n=80)

<table>
<thead>
<tr>
<th>Construction Industry Disciplines</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Contractors</td>
<td>33</td>
</tr>
<tr>
<td>Subcontractors</td>
<td>7</td>
</tr>
<tr>
<td>Engineers</td>
<td>5</td>
</tr>
<tr>
<td>Architects</td>
<td>30</td>
</tr>
<tr>
<td>Developer/Contractor</td>
<td>3</td>
</tr>
<tr>
<td>Consultant</td>
<td>1</td>
</tr>
<tr>
<td>Construction Management</td>
<td>1</td>
</tr>
</tbody>
</table>
The respondents were also asked about their industry experience and 56.3% of the professionals have from 20 to 40 years of experience in the construction industry. The majority of respondents have a large number of years of experience in the industry, which indicates a better view of the industry over the years. In addition, respondents with 1 to 10 years of construction experience sum 5.1%. In contrast, 7.5% of the respondents have more than 40 years of construction experience. Figure 4-2 shows the professional experience data collected from the survey.

![Professional Experience Chart](image)

**Figure 4-2. Professional experience (n = 80)**

In addition, the respondents were asked about the company’s headquarters location. The survey was sent out to more than 20 states spread equally among regions in the USA, and 62% of the respondents are from the South. Northeast (New England) comes right after with 16% of the answers. Midwest region and West (Pacific) region were tied with 8% of the respondent’s answers. Finally, West (mountains) comes with 4% of the answers, and Northeast (Mid-Atlantic) had 2% of the total answers. The percentage of responses divided per area is shown on Figure 4-3.
Next, responses on what types of projects were executed by the respondent’s companies. Commercial jobs lead the study with 40.6% followed by residential projects with 22.4%, and next industrial projects with 19.4% of the answers. In addition, other types of projects were mentioned on the study. Transportation and heavy civil projects had respectively 6.7% and 3.6% of the answers. In addition, it was observed that many companies executed more than one type of project. Many of the respondents performed a combination of two or more types of projects. Figure 4-4 shows the number of answers on each type of project.

Figure 4-3. Location of company’s headquarter (n = 76)

![Location of company's headquarter](chart)

Figure 4-4. Company project types (n = 165)

![Company project types](chart)
The responses to the question regarding the company’s size in the survey showed that 56% of the respondents indicated that their business has an average annual income that range from $1 million to $49 million (Figure 4-5). Companies with annual revenue ranging from $100,000 to $499,000 comprised 13.3% of the total responses.

These answers were cross-tabulated with the respective total number of architects and contractors listed in Table 4-2. As shown in Figure 4-6, the contractors in the annual revenue range from $25 million to $99 million were the largest group in the study with 34% of the total answers by contractors. In addition, as shown in Figure 4-7, architects with an annual revenue range from $1 million to $25 million formed the largest group in the study with 40% of the total answers by architect.

Figure 4-8 shows that 35% of the respondent’s companies have from 1 to 10 employees, followed by 14% of the companies with 10 to 20 employees, and finally 9% of the respondents came from companies with 20 to 30 employees.

**Annual Revenue**

![Bar Chart]

**Figure 4-5.** Annual revenue (n =76)
Figure 4-6. Annual revenue – Contractors (n =33)

Figure 4-7. Annual revenue – Architects (n =30)
Figure 4-8. Number of employees (n = 78)

The data reveal that construction companies with annual revenues that range from 1 to 49 million dollars had an average of 15 employees (Figures 4-5 and 4-8). Therefore, based on this data the majority of the work by these companies was performed by third parties such as subcontractors and not their own personnel.

**Types of Pre-Construction Methods and Their Relationship**

The survey respondents had to choose out of four major groups of pre-construction planning methods: design-phase construction planning, BIM, establishing a project control system and using past projects’ data to improve performance. In addition, they had an option to add any other method they used and that they did not think belonged to any of the mentioned ones. Therefore, two other categories were added: risk management tools and assembling a team. The objective of this survey section was to find out which of these methods, or others if any, were more widely used in addition to which were more effective in terms of saving cost. Past projects’ data still is the most used method with 29.6% of responses followed by design phase planning.
(27.5%), BIM (22.2%), and project control (18.5%). Figure 4-9 shows the frequency of these methods used in construction industry. It was observed that all the four major methods had a very similar number of answers. This occurred because companies, in general, do not use only one method, but a combination of them.

**Pre-Construction Planning Methods**

The survey data were analyzed to reveal which construction sector uses which pre-construction method more often. Contractors, architects, and subcontractors are the main disciplines that frequently use pre-construction planning methods. Contractors had a total of 95 selections, followed by architects (61), and subcontractors (20). The data reveal that past project's data was selected 52 times followed by design-phase (47) and BIM (38) among contractors, subcontractors, and architects. Figure 4-10 shows the number of respondents that use each method and what sector they belonged to. In addition, Table 4-2 shows the number of responses for each method of pre-construction planning by company role. A total of 204 responses were received. Engineers, construction managers, developers, and consultants had respectively 10, 9, 6, and 3 answers each.
Using past projects’ data to improve performance is the most used method based on all the responses.

Table 4-2. Number of responses for each method of pre-construction planning by company role (n=204) (refer to Survey Questions 1 & 8)

<table>
<thead>
<tr>
<th>Company Role</th>
<th>BIM</th>
<th>Design Phase</th>
<th>Project Control</th>
<th>Past Projects' Data</th>
<th>Risk Management Tools</th>
<th>Assembling a Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor</td>
<td>15</td>
<td>28</td>
<td>21</td>
<td>29</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Subcontractor</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Engineers</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Architect</td>
<td>19</td>
<td>15</td>
<td>9</td>
<td>16</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Developer</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Consultant</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction Management</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4-10. Methods of pre-construction planning per company role

In addition, the survey asked the respondents about the amount of time spent on pre-construction planning. Thirty-four percent of the respondents said that they spent
from 1% to 5% of the total project time on pre-construction planning, followed by 21.5% of respondents who spent from 10% to 20% of the total project time on pre-construction planning (Figure 4-11).

**Percentage of time spent on pre-construction planning phase**

![Bar Chart](image)

% of time spent on pre-construction planning
Figure 4-11. Percentage of time spent on pre-construction planning phase.

**Relationship between Pre-Construction Planning and Annual Revenue**

The size of a company has an impact on how much the company is willing to spend on pre-construction planning. However, just because a company is spending more on planning does not necessarily mean that it will make a higher profit. Figure 4-11 shows how often the respondent’s companies use Pre-Construction Planning in their projects. The data shows that more than 50% of the companies surveyed use pre-construction planning in their projects all the time followed by companies that use some method of pre-construction planning regularly (29.9%), and finally companies that rarely use pre-construction planning methods sum 16.9%. When comparing the size of businesses with their corresponding frequency of using pre-construction planning in
their projects, the data indicates that the relationship of how profitable the company is and how often the company uses pre-construction planning in its projects is directly proportional. Table 4-3 and Figure 4-13 show how the implementation of pre-construction planning is beneficial for business.

Frequency of pre-construction planning on projects

![Frequency of pre-construction planning on projects](image)

Figure 4-12. Frequency of pre-construction planning on projects

<table>
<thead>
<tr>
<th>Annual Revenue</th>
<th>Rarely</th>
<th>%</th>
<th>Regularly</th>
<th>%</th>
<th>All the time</th>
<th>%</th>
<th>Total Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 100K</td>
<td>1</td>
<td>20.0%</td>
<td>1</td>
<td>20.0%</td>
<td>3</td>
<td>60.0%</td>
<td>5</td>
</tr>
<tr>
<td>100K - 499K</td>
<td>6</td>
<td>54.5%</td>
<td>1</td>
<td>9.1%</td>
<td>4</td>
<td>36.4%</td>
<td>11</td>
</tr>
<tr>
<td>500K - 999K</td>
<td>2</td>
<td>25.0%</td>
<td>2</td>
<td>25.0%</td>
<td>4</td>
<td>50.0%</td>
<td>8</td>
</tr>
<tr>
<td>1M - 25M</td>
<td>4</td>
<td>15.4%</td>
<td>12</td>
<td>46.2%</td>
<td>10</td>
<td>38.5%</td>
<td>26</td>
</tr>
<tr>
<td>25M - 99M</td>
<td>0</td>
<td>0.0%</td>
<td>4</td>
<td>23.5%</td>
<td>13</td>
<td>76.5%</td>
<td>17</td>
</tr>
<tr>
<td>100M - 499M</td>
<td>0</td>
<td>0.0%</td>
<td>1</td>
<td>20.0%</td>
<td>4</td>
<td>80.0%</td>
<td>5</td>
</tr>
<tr>
<td>500M - 1 Billion</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>1</td>
<td>100.0%</td>
<td>1</td>
</tr>
<tr>
<td>1 - 5 Billion</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>2</td>
<td>100.0%</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 4-13. Frequency of using pre-construction planning based on company annual revenue.

Relationship between Pre-Construction Planning and Cost Savings

One of the main aims of this research can now be accomplished after answering all the other objectives leading to it. It is very important to have a clear understanding of how pre-construction planning affects the cost savings of a project. The survey asked on question 10 and 11 how much was invested in pre-construction planning and how much were the cost savings. The survey data showed a very scattered relationship since respondents spent different percentages on the planning. Figure 4-14 shows a scattered graph of all the respondents’ data. The companies that invested more in the implementation of some type of pre-construction planning method had more cost savings in their projects. A linear relationship was found based on the average of responses to express the increase in profits when compared with the use of pre-construction planning.
Effect of Pre-Construction Planning on Sustainability

The second main aim of this research was to demonstrate how the use of pre-construction planning helps promote sustainability. Respondents were asked what percentage of the total projects were LEED certified projects. Figure 4-15 shows that 28.2% of the respondents’ companies did not have any LEED certified project last year. In contrast, 17.9% of the companies had more than 40% of their projects LEED certified. In addition, 24.4% of the respondents had from 1% to 10% LEED certified projects. Next, 10.3% of the respondents had from 10% to 20% LEED certified projects, followed by 11.5% of the respondents that had from 30% to 40% LEED certified projects from the total amount of projects.
The survey also asked about the use of high performance products and/or eco-products on their projects (Figure 4-16). The results show that more than 80% of the respondents used high performance products on their projects. By taking the results shown in Figure 4-15 and comparing them with the data shown on Figure 4-16, it can be concluded that even though in many instances the projects do not have the intention to be LEED certified, the frequency of use of high performance products in the respondent’s projects was very high.

Figure 4-15. Percentage of LEED certified projects (refer to survey question 16).

Figure 4-16. Use of high performance materials and/or eco-products (refer to survey question 15).
The survey asked the respondents whether they believed that the implementation of pre-construction planning methods could help in the LEED certification process and the answers were almost unanimous. The study revealed that 97.4% of the respondents believed that pre-construction planning can help with the LEED certification process (Figure 4-17).

![Pre-Construction Planning help in the LEED Certification Process](image)

Figure 4-17. Pre-construction planning helps in the LEED certification process (Appendix - survey question 17).

The scatter plots shown in Figures 4-18, 4-19, and 4-20 are based on the data previously shown in Figure 4-12 about how often companies use pre-construction planning methods in their projects. This information was crossed referenced with the data collected from the responses to the question about what percentage of the previous year’s project were LEED Certified projects. For each of the three main methods chosen – BIM, Design-Phase Construction Planning, and Past Project’s Data – a scattered graph was created to visualize the relationships. In addition, the data reveal that 59% of the respondents used BIM all the time followed by 38% that used it regularly, and 3% that rarely used this method. This data was compared with the percent of LEED certified projects, and a linear relationship shows that companies that had more LEED certified projects in their portfolio were the ones that used BIM more
frequently in projects (Figure 4-18). The same occurred with design-phase planning method where 64% of the respondents used this method all the time followed by 33% that used regularly, and 3% rarely used this method. This data was compared with the percent of LEED certified projects, and the linear relationship shown in Figure 4-19 indicates that companies that had more LEED certified projects in their portfolio were the ones that used design-phase more frequently in projects. The past projects’ data method had similar results, with 61% of the respondents indicating that they have used past projects’ data all the time followed by 36% that used regularly, and 3% rarely used this method. Past project’s data were also compared to the percent of LEED certified projects, and a linear relationship show similar results from the two previously mentioned pre-construction methods (Figure 4-20). Table 4-4 shows this relationship.

Table 4-4. Frequency of use of pre-construction planning per method (survey questions 7 and 8 in appendix).

<table>
<thead>
<tr>
<th>Method</th>
<th>Rarely (%)</th>
<th>Regularly (%)</th>
<th>All the time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM</td>
<td>3%</td>
<td>38%</td>
<td>59%</td>
</tr>
<tr>
<td>Design-phase</td>
<td>3%</td>
<td>33%</td>
<td>64%</td>
</tr>
<tr>
<td>Past project’s data</td>
<td>3%</td>
<td>36%</td>
<td>61%</td>
</tr>
</tbody>
</table>

Figure 4-18. Frequency of pre-construction methods - BIM vs. LEED projects.
Figure 4-19. Frequency of pre-construction methods (design phase) vs. LEED projects

Figure 4-20. Frequency of pre-construction methods (past project’s data) vs. LEED certified projects
Knowing how pre-construction planning affects cost savings and how these methods promote sustainability is valuable information to investors and owners. Studies like this one, lead to look forward to more effective methods that can improve projects quality and profits. In addition, well implemented pre-construction planning methods can make the difference between success and failures in a fragile economy. The survey data collected in this study revealed how pre-construction planning is being used and how it is making a difference. The data collected in this study reflects the current understanding of pre-construction planning in the United States. Hence, the findings were analyzed and the information was crossed referenced with the intention to get essential conclusions about pre-construction planning methods. To sum up the findings of this research, there are many different pre-construction planning methods that comprise the four major methods described in this study – BIM, design-phase, project control, and past projects’ data.

BIM, design-phase planning, project control, and past projects’ data are the main pre-construction planning methods used today in the construction industry. The data revealed that successful companies not only use pre-construction methods frequently in their daily projects, but in many instances, these planning methods are used in combination. The study also revealed that past projects’ data still is the most used method.

The study confirmed hypothesis $H_{01}$ and $H_{02}$ presented previously in the introduction, stating that the implementation of pre-construction planning in the studied sectors of construction increases savings on costs and it promotes a sustainable
environment. Companies that spent more on pre-construction planning are the ones that had more cost savings. In addition, this economy reduced considerably companies’ profits, but still, pre-construction planning methods were proven to be helpful in difficult times like this one.

The second main objective of this research revealed that the use of pre-construction planning can help promote sustainability. Sustainability is not being considered optional anymore; it is a concept that is already part of the companies' values. The data shows that even though the project does not have the intention to be LEED certified, the use of high performance materials is frequent. Moreover, pre-construction planning is seen as an essential tool to achieve LEED certification. Hence, 97.4% of the responders believed that these methods contributed to the LEED certification process. In addition, it was found that companies which have more LEED certified projects in their portfolio were the ones that used pre-construction methods more often.

The analysis the data of the second section of the survey, an industry weakness was revealed in this study. When the respondents were asked about waste management and control, they were unanimous in saying that there was no record kept of how much construction waste were saved with the use of these methods.

There were many additional comments in the survey about how profits were considerably decreased because of the economic crisis. Therefore, one recommendation for future study is to conduct a survey among construction companies in the U.S. about how much of the companies ‘profits were reduced in the advent of the actual economic crisis which is affecting so much our industry.
Another recommendation is to conduct a whole survey dedicated to the control and management of construction waste that has been revealed to be a great weakness of the construction industry. Waste is one of the major concerns when talking about sustainability. In addition, millions of dollars could be saved with a more rational use of resources. However, this second recommendation requires a larger number of respondents and a couple of cases studies analysis.

Future studies should also include more specific questions about each of the main pre-construction methods. For example, questions referring to how much were expended in the implementation of these methods and what was the return on investment.

In closing, it is our responsibility as professionals to “do the right thing”. Moreover, doing the right thing is not only an ethical issue, but it is a matter a choice. The use of pre-construction planning methods that helps companies reduce costs and promote a better environment for our future generations is a way to achieve this goal.
APPENDIX
SURVEY QUESTIONNAIRE

Impact of Preconstruction Planning on Sustainability Study

Question 1 - Choice - Multiple Answers
Demographics: The next questions are for classification purposes only and will be used to group your answers with others like yourself.
Company/Organization Role:

☐ General Contractor
☐ Subcontractor
☐ Engineer
☐ Architect
☐ Other, please specify

Question 2 - Open Ended
Number of years working as a professional: (Please fill the total combined numbers of years working in the current industry)

Question 3 - Choice - Multiple Answers
Company/Organization Projects Types: (Please select all that apply)

☐ Commercial
☐ Residential
☐ Industrial
☐ Transportation
☐ Heavy Civil
☐ Other, please specify

Question 4 - Open Ended
Annual Company/Organization Revenue:

Question 5 - Open Ended
Number of Company/Organization Employees:
Question 6 - Choice - Multiple Answers

What is the location of your Company/Organization Headquarters:

- Northeast (New England)
- Northeast (Mid-Atlantic)
- Midwest
- South
- West (Mountains)
- West (Pacific)

Question 7 - Choice - Multiple Answers

How often do you use pre-construction planning in your projects?

- Rarely
- Regularly
- All the time

Question 8 - Choice - Multiple Answers

Which method(s) of pre-construction planning, other than the traditional scheduling, have you used: (Select all that apply)

- Building Information Modeling/Virtual Design and Construction
- Design-Phase Construction Planning
- Establishing a Project Control System
- Using Past Projects' Data to Improve Performance
- Other, please specify

Question 9 - Open Ended

Past Project Overview: The questions below refer to your 2010 projects. What percentage of the total project completion time is approximately taken by the pre-construction planning phase of your projects?

Question 10 - Open Ended

What percentage of the total project cost was spent on pre-construction planning?

Question 11 - Open Ended

Approximately what was the savings or additional profit as a percent of the total project cost?
Question 12 - Open Ended
What percentage of that cost saving or additional profit do you believe was attributed to pre-construction planning?

Question 13 - Open Ended
What was the percentage reduction in waste materials in comparison with previous projects?

Question 14 - Open Ended
What percentage of the reduction of waste materials do you believe was attributed to pre-construction planning?

Question 15 - Yes or No
Were High Performance Materials and/or eco-products used in your projects?
- Yes
- No
- Additional Comment

Question 16 - Open Ended
Approximately what percentage of your projects was LEED Certified?

Question 17 - Yes or No
Do you believe that pre-construction planning can help in the LEED certification Process?
- Yes
- No
- Additional Comment
LIST OF REFERENCES


Harris, J. (2000). Rethinking sustainability: power, knowledge, and institutions, Ann Arbor, University of Michigan Press, MI.


BIOGRAPHICAL SKETCH

Cristiane Kreitler graduated in Architecture and Urban Design in Brazil at “Universidade Tuiuti do Parana” in July 2002. Immediately following graduation, Cristiane started to work for Phillips Lighting from Brazil as an Architect Consultant. This position gave her the opportunity to work with professionals from different disciplines and promote speeches at universities and construction offices. In addition, one year after her graduation, she finished her Certificate program in Construction Management at UTFPR University – Brazil, and she got married in July 2004. After that, her husband was transferred from his work, and they moved to the USA, where she worked for CMC Joist and Deck as a structural detailer for over 3 years. It was a great experience because she had the opportunity to learn more about the American construction processes, and she established many good friendships. Although, the desire to learn more about sustainable construction and effective management processes led her to apply to the Master of Science in Building Construction program at the University of Florida. Dr. Raymond Issa (Director of the Graduate Programs) at that time encouraged her and said: “Don’t give up!” and she did not. She was eventually accepted into the MSBC program, and she is now graduating. She will forever be a proud Gator!