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The Pennsylvania State University

The Graduate School

College of Engineering

PROCESS TRANSPARENCY FOR SUSTAINABLE BUILDING DELIVERY

A Dissertation in

Architectural Engineering

by

Leidy Klotz

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

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ABSTRACT

The construction and operation of buildings have considerable impacts, accounting for more than one third of all material and energy flows worldwide. A greater market share of sustainable buildings, which seek to reduce the associated negative impacts, is an essential part of plans to address global problems such as energy and water shortages, and climate change. Proven strategies and technologies exist today for more sustainable buildings, yet a pressing need to improve their implementation remains. The processes for planning, designing, building and operating, or “delivering,” these sustainable buildings are often complex and unfamiliar to the stakeholders (e.g., owners, designers and constructors) whose collaboration is essential to sustainable solutions.

In other industries, process transparency helps facilitate complex, unfamiliar processes by making situations; including status, goals and rules; visible to all stakeholders. This research revealed the possibility of cost savings for sustainable buildings through increased process transparency by comparing the delivery of recently completed sustainable building projects to hypothetical, “counterfactual,” delivery of the same projects with complete process transparency. Building on this finding, one strategy for enhancing process transparency was also studied. Process maps, which are visual aids for picturing work processes, were developed. Then, quizzes and surveys were used to study the influence of process mapping on transparency.

Primary contributions of this research include a rigorous method for applying counterfactual analyses to project delivery, evidence that reduced costs for sustainable buildings are possible by increasing delivery process transparency, and evidence that process mapping may be considered as a method to enhance process transparency.

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Chapter 1

Introduction

1.1 Context

Global climate change and shortages of critical resources including energy and water are among the most important issues facing humanity at the beginning of the 21st century (Smalley 2004). Expanding population and continued development necessitates visionary research and development efforts seeking groundbreaking solutions (e.g., novel sources of clean energy and economically feasible carbon sequestration strategies) for future application. In the meantime, proven solutions already exist and their broad application could immediately address these issues in a significant way. For example, using existing strategies and technologies, the United States could reduce its global warming emissions 50% by 2050 (Pacala 2004).

Reducing the environmental impacts of our buildings is a critical part of the current response. The construction and operation of buildings have massive worldwide impacts, accounting for 40% of all material and energy flows (EPA 2007). This represents more energy usage and global warming emissions than automobiles and planes combined (Worldwatch 2007), over 10% of waste streams, and over 10% of potable water use (Barnett 2005). Sustainable buildings are those designed to reduce these impacts, and there is great potential for the worldwide application of sustainable building, which currently represents only a small fraction of the total building market. Sustainable

buildings are defined for this research as those seeking to: optimize site potential and energy use, protect and conserve water, use environmentally preferable products, enhance indoor environmental quality, minimize volatile organic compound (VOC) emissions, and optimize operational and maintenance practices (NIBS 2006).

1.2 Problem

Traditional building projects are a complex endeavor, bringing together talented stakeholders from various disciplines to plan, design, build, and operate, or “deliver,” the building. Delivery of a single building involves many stakeholders (e.g., architects, engineers, contractors, construction managers, owners, building occupants, building operators and government agencies) performing many processes (e.g., planning, design, construction and operations). Separation between stakeholders and disconnects in processes mean that few, if any, stakeholders understand all aspects of the delivery process outside their specific area of expertise.

Delivery of sustainable buildings adds unfamiliarity to this complexity. Sustainable building requires the addition of a new criterion, sustainability, to the traditional project success measures of time, cost and quality. As a result, new stakeholders are involved in sustainable building delivery, and traditional stakeholders have new roles. Processes unique to sustainable building delivery, such as energy modeling, also contribute to a delivery process that is unfamiliar to many project stakeholders. Further, effective sustainable project delivery requires an integrated process where intricate, multidisciplinary collaboration between a wide range of stakeholders

helps generate sustainable solutions (Vanegas 2003). While essential, this integrated process is not well understood, and therefore contributes to the unfamiliarity (Magent 2005).

Successfully negotiating the complexity and unfamiliarity of sustainable building delivery can be rewarding. Exemplary sustainable buildings, such as the office facility for the lighting and electrical consulting firm Integrated Design Associates (IDeAs), produce more energy than they consume at minimal first cost premiums, which are quickly offset by energy cost savings (Lewers 2008). Buildings are also achieving more modest, but still significant, sustainable objectives with no first cost premium at all (Matthiessen 2007). For instance, Toyota Motor Sales avoided any first cost premium on their South Campus development where 95% of construction waste was diverted from landfills and energy consumption and potable water use were reduced 60% and 94%, respectively, below state requirements (Lapinski 2005). Despite these success stories, sustainable buildings remain a small fraction of the overall construction market.

Strategies and technologies for more sustainable buildings are here now, but there is a need to get better at implementing them. To do this, awareness of the sustainable building delivery processes is essential for stakeholders at all phases and levels of a project. With this awareness, these stakeholders can apply their expertise and perspective to make decisions that benefit the project as a whole and generate sustainable solutions. For instance, when building maintenance staff sees their opportunity to contribute during design, or designers see that they should consult with the maintenance staff, the maintenance staff is more likely to provide valuable input during the design phase. The resulting insight into maintenance costs for and observed performance of different

technologies under consideration is especially important for sustainable projects, where unfamiliar technologies ranging from waterless urinals to the next generation of heating, ventilation and air conditioning (HVAC) control systems are vital to achieving sustainable goals.

Research is beginning to show the potential for improving the delivery of sustainable building projects, which is essential to more widespread implementation of sustainable buildings (Lapinski 2005). Increased integration and participation are recognized as valuable attributes for sustainable projects and, increasingly, these attributes are a focus throughout the delivery process (Magent 2005). However, these attributes alone do not fully characterize the sustainable building delivery process and a key research opportunity involves learning more about the attributes of sustainable delivery processes. Without this understanding, the sustainable delivery process is not as clear as it could be to the various stakeholders whose coordinated knowledge could help produce buildings that maximize benefits to occupants and minimize negative impacts on the world.

1.3 Process Transparency: A Potential Solution

Other industries have faced similar problems related to complex, unfamiliar processes. In these industries, successful companies have negotiated this complexity to see the big picture, resulting in better processes and consequently, better products. Striving for process “transparency” is one practice applied by these successful companies. Complete transparency is present in a process when “situations are visible to

everyone; goals and rules are visible to everyone; and each person participates and considers themselves (sic) involved” (Greif 1991). The process-focused transparency theory applied to this research is part of Toyota Motor Company’s culture, which has helped the company grow from making dinnerware and fish paste immediately following World War II to become the top automaker in the world today (Maynard 2007). For Toyota, transparency enables increased participation and provides decision-making ability to more stakeholders. If transparency has this same impact on sustainable building delivery, it could help stakeholders negotiate the unfamiliarity and complexity of the delivery process to enhance integration and improve the final product. Those studying the success of Toyota describe transparency as enabling “massive and continuing amounts of problem solving... by teams of employees who historically have not even talked to each other, much less treated each other as equals” (Womack 2003). This quote also describes the ideal integrated process for delivering a sustainable building.

Since the value of transparency was initially recognized, evidence from its application in various manufacturing environments has accumulated supporting the theory’s validity (Greif 1991, Womack 2003). Figure **1-1** shows examples of process transparency in a factory (e.g., uncluttered workspaces, the sign showing production information and an open environment), all of which contribute to making the status of production transparent to anyone in this factory. Other examples of efforts to increase transparency in manufacturing environments include clear instructions posted where work activities take place and tools allowing workers to quickly recognize standards and deviations from them (Greif 1991).



Figure 1-2: Transparency in the Factory (From Brill, 2008)

Transparency is also valuable for business processes outside of the factory environment. Showing the status of a fundraising campaign using a thermometer poster is a classic application of transparency, immediately making the goals and status of the fundraising process visible to viewers (Figure 1-3). Other examples of efforts to increase transparency outside of the factory environment include using measurements to make invisible attributes of the process visible (Figure 1-3) and charting processes themselves to make them visible.



Figure 1-3: Transparency Outside the Factory

Based on its value in other fields, sustainable building experts hypothesize that process transparency is valuable for delivering these buildings (Pearce 1998, Kibert 2004). An example illustrates the logic behind this hypothesized value. Commissioning is a fundamental component of sustainable building delivery, helping to ensure that the building operates as designed. Because the commissioning process has not been in widespread use in the building industry, there is often confusion regarding responsibilities and interactions related to commissioning. Increasing transparency could help reinforce responsibilities and interactions, making the commissioning process more effective.

The current research project builds on the expert hypothesis with a detailed exploration of the relationship between transparency and sustainable building delivery. Potential measures of this relationship may consider how transparency affects the building's level of sustainability, schedule and cost. Cost is the focus for the current research as owners are more likely to build sustainably if costs can be lowered while

other variables (e.g., quality, schedule and level of sustainability) remain constant.

Therefore, the primary research question becomes, “Does increased delivery process transparency have a relationship to the cost for delivering sustainable buildings?”

1.4 Research Goal and Objectives

The goal for this research project is to determine whether process transparency has a relationship to costs for sustainable buildings. Showing potential for reduced costs would raise awareness of the importance of striving for process transparency, which is the first step in efforts to enhance process transparency during sustainable building delivery. To achieve the research goal, the following objectives are pursued:

1. **Investigate background supporting a relationship between transparency and sustainable building delivery.**

A literature review does not reveal any empirical studies of the impact of process transparency on sustainable building delivery.

However, the review provides sufficient information to develop the background necessary to support the empirical portion of this research project. Beginning at the broad level of Lean theory and sustainable development and funneling to the focused level of sustainable building delivery, anecdotal evidence of the relationship between transparency and sustainable building delivery is synthesized.

2. **Develop a research method for studying delivery of unique projects.**

Counterfactual analysis, where an actual scenario is compared to a hypothetical, counterfactual scenario has been applied successfully to solve research problems

in fields including economics, history, and political science (Fogel 1964, Belkin 1996). For the current research, counterfactual analysis is adapted to project delivery to study whether there is a relationship between delivery process transparency and costs for sustainable buildings. Using counterfactual analyses, costs of actual sustainable buildings are compared to the costs of identical, hypothetical sustainable buildings with complete delivery process transparency. Application of counterfactual analyses helps satisfy the goal of the current research project by developing theory regarding the relationship between transparency and sustainable building delivery.

3. **Examine one approach with potential to enhance process transparency.**

Process maps, which are a visual aid for picturing work processes, show links between inputs, outputs, and tasks. These maps are considered a strategy that supports transparency (Womack 2003, Bauch 2004). Process maps are developed for a construction organization, and the influence of their use on transparency is evaluated.

4. **Classify and prioritize the research results to emphasize implications for**

industry and academia. The research results show that reduced costs for sustainable buildings are possible by increasing delivery process transparency. Further classification and prioritization of these results reveal practical implications for industry and academia. Particular attention is paid to delivery phases where increasing process transparency appears most beneficial, and types of interactions where process transparency is lacking.

1.5 Research Approach

Empirical investigation of the impact of process transparency on sustainable buildings was undertaken by examining recently completed LEED-Gold and LEED-Silver certified projects at Penn State¹. These building projects were managed by Penn State's Office of Physical Plant (OPP), and OPP employees and project files were made available for this study. Applying the counterfactual analysis adapted to project delivery that was developed for this research, costs associated with each project's actual delivery were compared to costs associated with a "counterfactual" delivery of the same project with complete process transparency.

To supplement the investigation of the relationship between process transparency and sustainable building costs, a strategy with the potential to enhance transparency was investigated. Process maps show the activities and procedures of organizations in a graphical form and a literature review provides partial evidence of the ability of process maps to positively influence process transparency. Building on this literature review, quizzes and surveys were used to study the influence of process maps on transparency when used in a training session for OPP employees.

The overall research approach is shown in Figure 1-4. Throughout this approach, data collection was designed to follow two primary principles.

- Both quantitative and qualitative measures were collected for each research question examined, enabling triangulation during analysis of results. Because

¹ LEED is an abbreviation for Leadership in Energy and Environmental Design, which is the rating system used by the United States Green Building Council to classify sustainable buildings. Further description of the LEED rating system is provided in Chapter 2.

analysis shows that these quantitative and qualitative measures support each other, there is greater certainty of results.

- Rigor was achieved while requiring a minimal amount of time and resources from project stakeholders. Hopefully, this straightforwardness will encourage similar data collection by construction organizations and by other researchers.

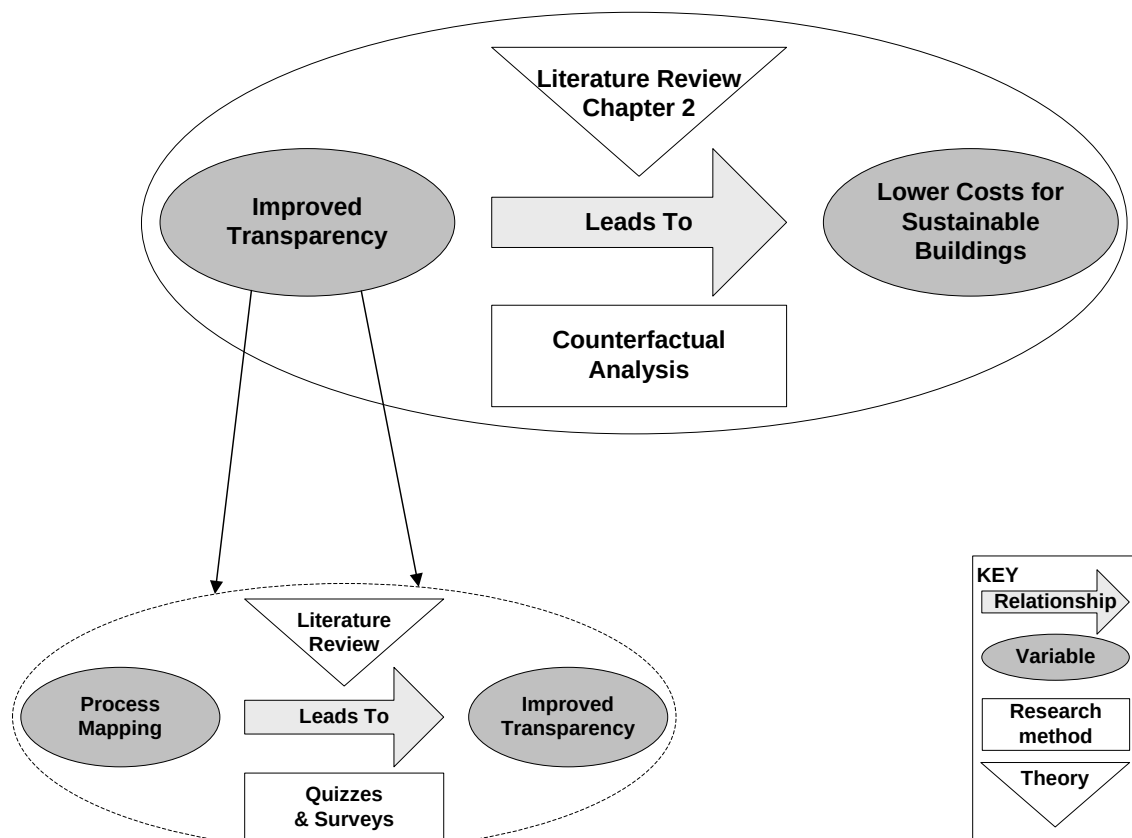


Figure 1-4: Research Relationships Overview

1.6 Primary Results and Implications

This research found that reduced costs for sustainable buildings are possible by increasing delivery process transparency. The evidence supporting this statement satisfies

the main goal of this research project by identifying the relationship between transparency and sustainable project delivery. In addition, several noteworthy implications are derived from this study:

- Stakeholders delivering sustainable building projects should understand the value of process transparency;
- The majority of costs related to a lack of process transparency appeared during the construction phase of project delivery and could have been avoided during design;
- Efforts to enhance process transparency represent a fraction of the costs related to rework and other costs resulting from a lack of process transparency;
- Delay costs make up a significant proportion of costs related to a lack of process transparency; and
- Cost impacts result from a lack of process transparency both between stakeholder groups and also within these groups.

Addressing the finding that reduced costs for sustainable buildings are possible by increasing delivery process transparency, process mapping was examined as a potential strategy for enhancing process transparency. Process mapping led to increased transparency, on average, for the application at OPP discussed in Chapter 6,

1.7 Reader's Guide

The organization of this dissertation is shown in Figure 1-5. This chapter introduces the research, including the problem and proposed solution, goals and

objectives, research approach, and primary results and implications. In Chapter 2, the literature review and point of departure for this research are described. Next, the rationale for selecting counterfactual analysis as the primary research method is explained in Chapter 3. This counterfactual analysis is tailored to project delivery in Chapter 4, including examples and results from its application to study LEED-Gold and LEED-Silver certified buildings. Results and analyses from the application of counterfactuals are discussed in Chapter 5. In Chapter 6, process mapping is examined as a potential strategy to enhance transparency. Chapter 7 contains discussion of conclusions resulting from this research project including theory developed, practical implications, intellectual merit, limitations, and areas of research uncovered. The appendices include background information about the buildings studied, complete data sets from the counterfactual analysis for each building, example process maps, and data collection instruments used to study the relationship between process mapping and transparency.

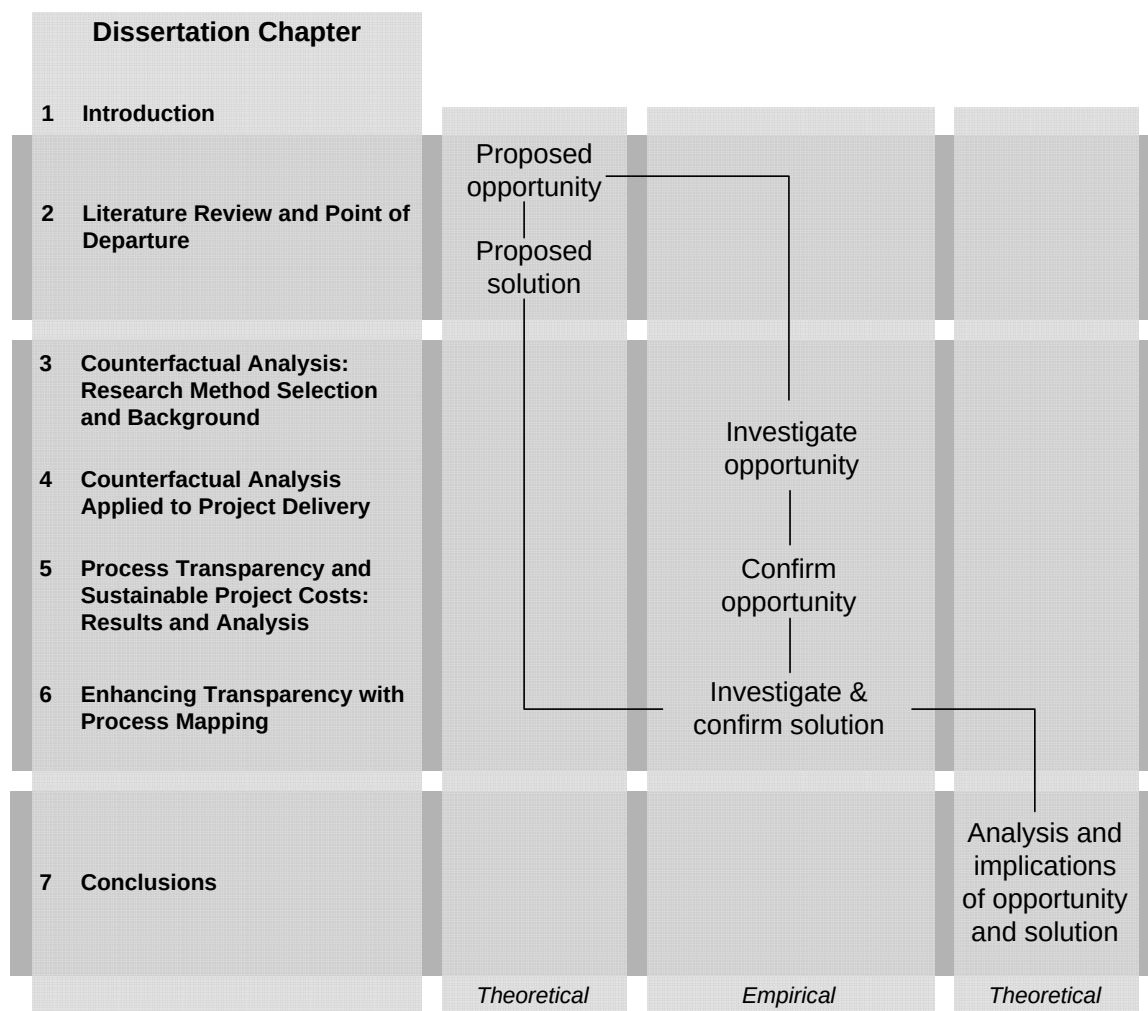


Figure 1-5: Reader's Guide

Chapter 2

Literature Review and Point of Departure

A review of literature exposes the potential value of process transparency for sustainable project delivery. This review begins with Lean theory and sustainable development and funnels to a more focused level, where the relevance of transparency to sustainable building delivery is considered (Figure 2-1). Throughout, connections between Lean theory, sustainability, and transparency are prevalent. At the broad level, Level 1 of the literature review, transparency is recognized as a valuable attribute in both Lean and sustainability theory. Both of these theories influence the building industry, where sustainable building and Lean construction are established and continue to develop (Level 2). The “how” and “who” of sustainable building and Lean construction are discussed in Level 3 as sustainable building delivery and Lean product development, respectively. Finally, at the point of departure for this research are identified relationships between transparency and sustainable building delivery.

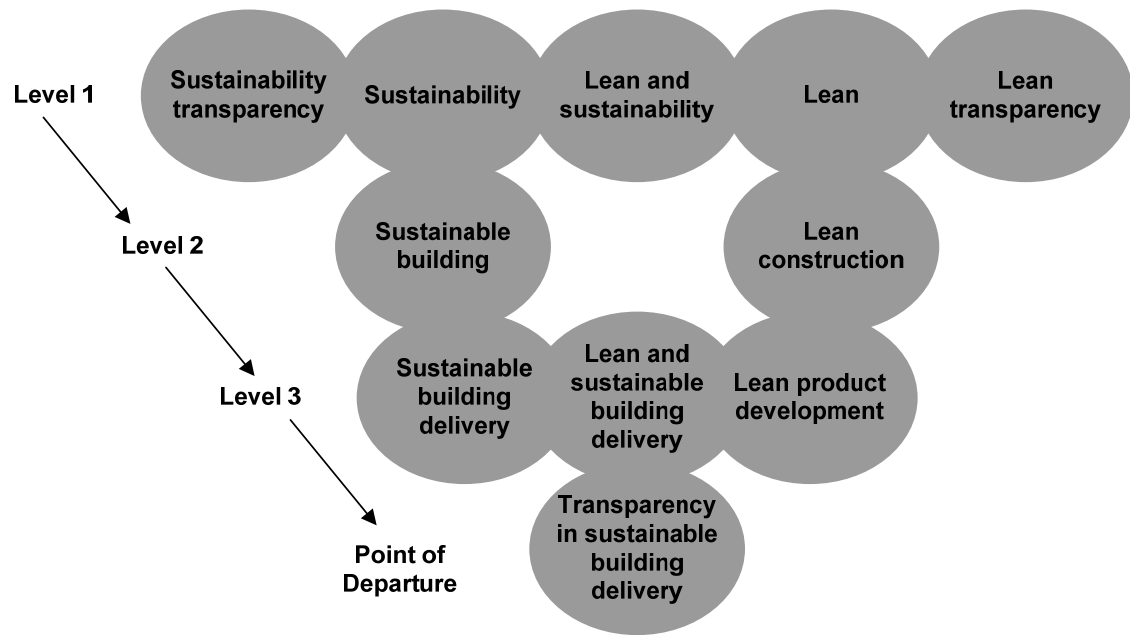


Figure 2-1: Literature Review Format

2.1 Literature Review Method

Several strategies are utilized to conduct the literature review. Where the goal is explanation of background theory, an exhaustive account of references is not required. Namely, background provided on Lean and sustainability theory draws from a review of important references, but does not discuss all works in each field. In other cases, every effort was made to review all relevant literature. For instance, examination of transparency as applied to sustainable project delivery and to Lean product development included a thorough search intended to cover all applicable references. To ensure a current understanding of the evolving topics related to transparency in sustainable building delivery, the literature review was ongoing throughout this research project.

2.2 Level 1: Sustainability and Lean

In Level 1 of the literature review, Lean and sustainability are discussed at the theoretical level. Integral to this research project are the synergies between Lean and sustainable theory, and the recognition of transparency as a valuable attribute for both (Figure 2-2).

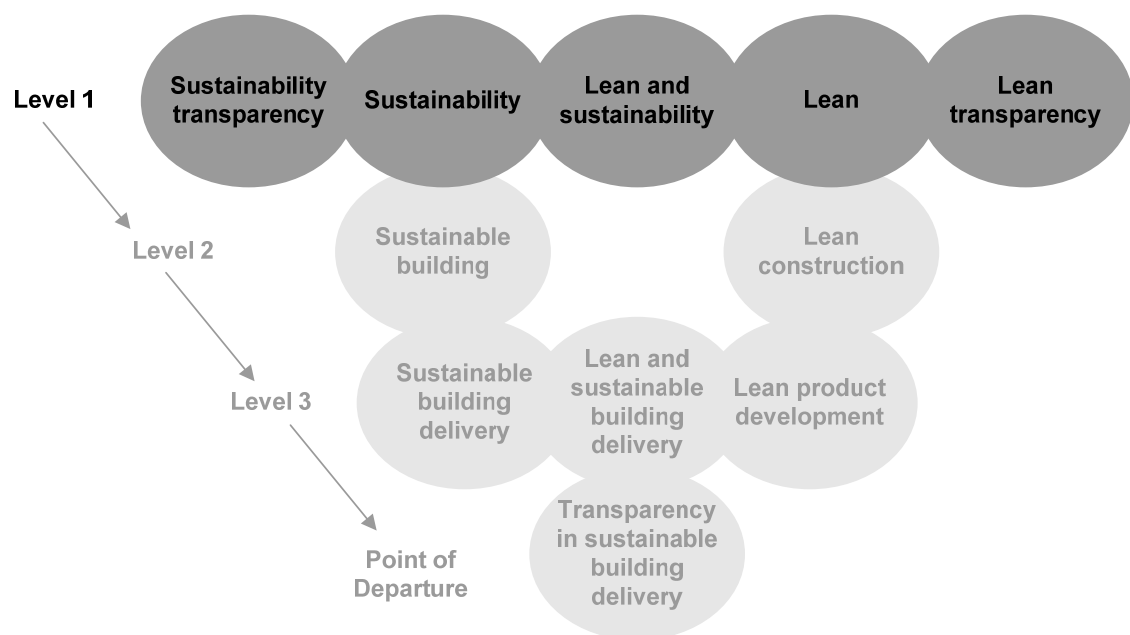


Figure 2-2: Literature Review Level 1

2.2.1 Sustainability

Sustainable development is defined as meeting the “needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987), and considered “the framework for our efforts to achieve a higher quality of life for all people” (UN 1995). While there are varying detailed definitions of sustainable

development, any accurate definition includes environmental or ecological considerations, economic considerations, and community values. Sustainability directly addresses most of the top 10 problems humanity will likely face over the next 50 years (Smalley 2004) and recognition of sustainability as necessity continues to increase as issues such as energy costs and global warming move to the forefront of the public's consciousness.

2.2.2 Sustainable transparency

Programs to achieve sustainable development suggest dealing transparently and systematically with risk, uncertainty and irreversibility (Hargroves 2005). Agenda 21, the United Nation's blueprint for achieving sustainable development, states that as part of sustainable development, countries should promote transparency as a vital objective for their administration and decision-making (UN 1992). Transparency of, and the corresponding public participation in, decision-making processes are recognized as essential elements of sustainable development projects (Cutcher-Gershenfeld 2004, Halle 2007, Jansky 2007).

2.2.3 Lean

Many methodologies and theories focus on increasing resource productivity. Quality Circles, Six Sigma, Lean, Total Quality Management, Business Process Reengineering, and ISO 9000 are well-known examples. For this research project, Lean

is selected as a guiding theory based on its attributes; including its focus on waste elimination, service, and flow; and its relationship to sustainability and to the building industry. However, the method selected is less important than the fact that improvement is being pursued using a scientific approach. Even James Womack, chair and founder of the Lean Enterprise Institute, and author of *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, concedes:

"None of us, of course, have created any perfect value streams. Probably, we never will. But energy expended on comparing and criticizing improvement methods rather than pursuing the perfect value stream is surely type 2 muda (waste). That's the type of waste we can get rid of immediately (Womack (2) 2003)."

The principles of Lean developed over time at Toyota Motor Company in Japan and are currently imitated by organizations around the world. Focused on the elimination of waste by streamlining systems, Lean theory advocates the following five principles:

- Value – as defined by the customer, in terms of the final product, and provided by the producer,
- The Value Stream – consisting of all of the steps required to bring a product through the producer to the customer,
- Flow – focusing on the product and its needs and reduction of batch and queue processing to make value flow,
- Pull – producing only when something is requested, and
- Perfection – working continuously on the first four principles to get better and better (Womack 2003).

Although Lean principles are straightforward conceptually, most organizations attempting to imitate Toyota fail to duplicate their success. Commonly, organizations

confuse Toyota's tools and actions with the system itself. Importantly, the scientific method permeates Toyota, making the company a learning organization. In addition: all work at Toyota is highly specified; customer-supplier connections and product pathways are simple and direct; and improvement occurs, under teacher guidance, at the lowest levels in the organization. Companies seeking to imitate Toyota often overlook these key process features (Spear 1999).

Valuable efforts to distill Toyota's underlying culture separate the total process from the tools used. The starting point in Toyota's business culture is generation of value for the customer, society and economy. Toyota then pursues creation of a process with continuous flow that matches customer demand and exposes problems for solving. Finally, through reflection and improvement, Toyota remains a learning organization (Liker 2004). Principles embedded at Toyota that have either a direct or an indirect relationship to transparency are shown in Table 2-1.

Table 2-1: Principles Embedded at Toyota and their Relationship to Transparency

Toyota Principle	Relationship
Applying Toyota culture to workers, enabling constant improvement	Indirect
Going and seeing for yourself to thoroughly understand the situation	Indirect
Using visual concepts to prevent hidden problems	Direct
Empowering employees and management	Indirect
Respecting suppliers and producers by helping them improve	Indirect
Organizing meetings with visual aids	Indirect

2.2.4 Lean transparency

Transparency is a key Lean principle. Lean transparency describes the ability to see processes as a means for identifying problems quickly and efficiently. By providing a

transparent informational and process environment, Lean systems enable decentralization of decisions about the project because ground-level decision-makers have the required tools to make decisions. Substantial evidence from various companies has accumulated over the years supporting the validity of Lean transparency theory (Greif 1991, Womack 2003).

2.2.5 Lean and sustainability

Relationships between Lean and sustainability are fundamental to this research project. James Womack identifies a connection where Lean is a “critical enabler” to reduce the massive amounts of waste in current industrial practices. Womack recognizes that waste reduction will free up resources and allow addition of sustainable aspects at no cost to the customer. He refers to this as a “green is free” concept (Womack (1) 2003).

While Womack views the connections between Lean and sustainability as emerging from necessity rather than convenience, others recognize that the two really act synergistically and strengthen each other’s application. For instance, The United States Environmental Protection Agency (EPA) recognizes the Lean principles of flow and pull as helpful in eliminating overproduction. Elimination of overproduction has direct sustainable benefits related to reduced use of energy and raw materials including: less inventory; reduced damaged, spoiled, or deteriorated products; less need to construct new facilities because less floor space is needed; and reduced energy use from transport and reorganization of unsold inventory.

Natural Capitalism, a groundbreaking work presenting practical approaches to sustainable development, also recognizes the synergy between Lean and sustainability.

The four primary approaches to sustainability identified in *Natural Capitalism* are:

- radical resource productivity increase,
- biomimicry (design and engineering that imitates nature),
- service and flow economy, and
- investment in natural capital (Hawken 1999).

While greater sustainability is possible with investments in natural capital and increased biomimicry, a service and flow economy and radical resource productivity increase both promote Lean practices. To address issues such as global climate change and excessive energy use, *Natural Capitalism* recommends application of both sustainable and Lean concepts to change traditional accounting methods. Sustainability influences the recommendation to include the typically neglected value of natural capital, which is the value associated with ecosystem services (e.g., providing clean water or filtering air).

Lean theory influences the recommendation to stop counting wastes (e.g., pollution, crime, auto accidents and divorces) in our measures for economic “growth.” In practice, the synergistic benefits identified in *Natural Capitalism* and by the EPA could supplement Womack’s concept of using waste reduction to free up resources and add environmental aspects at no cost to the customer.

2.3 Level 2: Sustainable Building and Lean Construction

Sustainable development and a shift to Lean practices are broad goals that will require widespread application to address such as global climate change and excessive energy use. In the building construction industry, efforts to adapt and apply both Lean and sustainability continue to develop. The associated fields of sustainable building and Lean construction are described in Level 2 of the literature review (Figure 2-3).

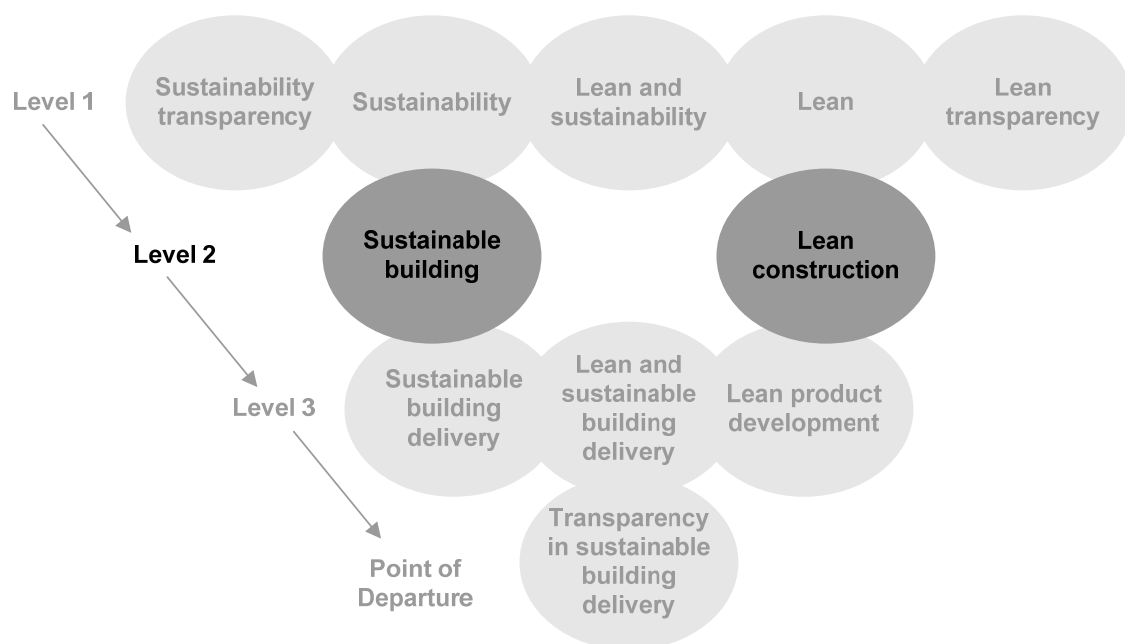


Figure 2-3: Literature Review Level 2

2.3.1 Sustainable building

With their 40% impacts on worldwide material and energy flows, buildings are an excellent target for sustainable approaches (Roodman 1995). Those who build sustainably seek to minimize, and eventually eliminate, these impacts through

efficiencies and innovations in building design, construction, and operation. While numerous definitions for sustainable building exist, prominent definitions generally include fundamental principles outlined in *The Whole Building Design Guide* (NIBS 2006). Sustainable buildings are those which:

- Optimize Site Potential (reduce impact on ecosystems, required transportation, and energy use through considerations of location, orientation, and landscaping),
- Optimize Energy Use (reduce loads, increase efficiency, and consider renewable energy),
- Protect and Conserve Water (minimize runoff, use efficiently, and consider reuse),
- Use Environmentally Preferable Products (select materials which have a reduced impact on human health and environment),
- Enhance Indoor Environmental Quality (maximize day-lighting and views, control moisture and ventilation, and minimize Volatile Organic Compounds (VOCs)), and
- Optimize Operational and Maintenance Practices (ensure the building operates as intended and minimize the environmental impacts of building maintenance).

2.3.1.1 Growth of the sustainable building market

Sustainable buildings' percentage of the overall building market is growing rapidly. Sustainable buildings appeal to the increasing social-consciousness of owners, lead to life-cycle energy savings, and promise improved indoor environmental quality,

which may lead to gains in labor productivity, retail sales, and manufacture quality (Hawken 1999). In some instances, sustainable buildings also appeal to those focused only on initial costs. Sustainable buildings can sell and lease faster, and for higher amounts than traditional buildings (McGraw Hill Editors 2006) and insurance companies now offer reduced insurance premiums for sustainable buildings (Fund 2006).

A key enabler for the growth of sustainable building in the U.S. is the Leadership in Energy and Environmental Design (LEED) rating system. The U.S. Green Building Council (USGBC) developed LEED in 1998 as a method for certifying that a building achieves certain sustainable building guidelines. The most recent LEED Version 2.2 includes a total of 69 points available in the categories of Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design. To become LEED certified, a building must achieve at least 26 points and satisfy prerequisites in each category. Depending on the number of additional points achieved, buildings may also achieve Silver, Gold and Platinum LEED certifications (USGBC 2008).

2.3.1.2 Barriers to growth of the sustainable building market

Despite their benefits and recent rapid growth, sustainable buildings represent only 2% of the nonresidential construction market in the U.S. (McGraw Hill Editors 2006). Primary barriers to more widespread application of sustainable building include:

- lack of demand from clients,
- lack of education on the benefits of sustainable buildings,

- failure of service fee structures to account for the recovery of long-term savings, and
- higher costs (both real & perceived) of sustainable building (Landman 1999).

This increased first cost, whether real or just perceived, is the primary barrier to sustainable building (BD&C 2006).

In studies examining first cost differences for sustainable buildings, the largest estimated first cost increase is between 8% and 15% compared to a typical building. However, this estimate is generated by a study where researchers experienced difficulty obtaining accurate cost information for sustainable projects and recognize uncertainties in their “value analysis methodology” (Blue 2004). A more extensive study employs a database of one consulting firm’s projects to compare the cost of LEED-certified projects to those not pursuing certification, finding no statistically significant difference between the two groups (Matthiesson 2004, Matthiesson 2007). Supporting these findings, a separate study of 33 sustainable buildings in California also finds a negligible first cost difference between sustainable and traditional buildings, estimating an average first cost premium of less than 2% (Kats 2003).

One possible explanation for the different findings is the level of sustainability pursued by the building. While the studies finding negligible cost increases used databases based on LEED certification, the study finding the highest increases examined Battery Park City in Lower Manhattan, a building that surpassed the minimum requirements of LEED. There are many factors contributing to the first costs of buildings and determining the costs solely attributed to sustainability is unrealistic. Further, the level of sustainability pursued and the effectiveness of planning, design, and construction

significantly influence the costs associated with sustainability. As a result, there is no universal first cost premium for sustainable buildings.

More important, and realistic, than determining a first cost premium for sustainable buildings is recognizing opportunities for “tunneling through” the first cost barrier. There are scenarios during planning and design where going past the cost effective limit (budget) into diminishing returns (over-budget) is necessary before coming back to a lower cost (below-budget). For instance, adding highly insulated windows may initially increase building cost, even when considering energy saved over the building’s life. However, these windows may permit downsizing of heating ventilating and air conditioning (HVAC) equipment, resulting in a cost savings greater than the cost increase of the windows. When considering the costs of a sustainable building, optimizing the entire building and accurately counting all measurable benefits is essential (Hawken 1999).

2.3.1.3 Future directions

Realization of true sustainability, where buildings have no negative impacts, will require continued evolution and improvement of buildings. Suggestions for buildings making the next step towards sustainability include greater integration with local ecosystems, closing loops of materials systems, maximizing use of passive design and renewable energy, optimizing building hydrologic cycles, and fully implementing indoor environmental quality measures (Kibert 2005). Even after implementing these

suggestions, buildings are truly sustainable only when they have no negative impact.

Long-term strategies aimed at this true sustainability include:

- taking the next technology leap,
- developing new construction processes that minimize environmental impact,
- re-educating professional and blue collar workers,
- redesigning fee structures for designers and builders, and
- rethinking the products of construction (e.g., leasing materials such as steel and concrete or utilizing buildings as net power generators) (Plessis 2003).

2.3.2 Lean construction

Lean construction applies Lean theory and principles to the building industry.

Project management in Lean construction is conceptually different from traditional project management due to shifts in six primary areas as shown in Table 2-2 (Ballard 2000, LCI 2004). The advocated shifts in coordinating action and decision-making align with management that focuses on openness, listening, and commitments produced through promises and requests “allowing for the autonomy of the productive unit (Howell 2004).”

Table 2-2: Lean Project Management Shifts (Adapted from LCI 2004)

Area	Shift From	Shift To
Control	monitoring results	making things happen
Performance	optimizing individual activities	maximizing value at the project level
Project Delivery	a linear, sequential process	simultaneous design of the building and the production process
Value	owner definition at the outset	customer-defined and evolving
Coordinating Action	central authority and pushing of resources	continuous flow and pulling
Decision Making	central authority	ground-level stakeholders through transparency

2.3.3 Lean construction transparency

In Lean construction theory, insufficient process transparency increases the chance for errors, reduces the visibility of errors, and decreases motivation for improvement. Processes that are directly observable, standardized, and measured can help prevent this lack of transparency (Koskela 2000). While transparency for field operations is discussed in Lean construction literature (Santos 1998, Heineck 2002), no references were identified with detailed investigation of delivery process transparency.

2.4 Level 3: Sustainable Building Delivery and Lean Product Development

Background information about *what* makes a building sustainable or construction Lean is provided in Level 2 of the literature review. This research project examines *how* a sustainable building is created. Accordingly, sustainable building and Lean construction from Level 2 of the literature review are adapted in Level 3 (Figure 2-4) to sustainable building delivery and Lean product development, respectively. Just as Lean and

sustainability reinforce each other at the broad level, synergies are present on this more detailed level, between Lean and sustainable building delivery.

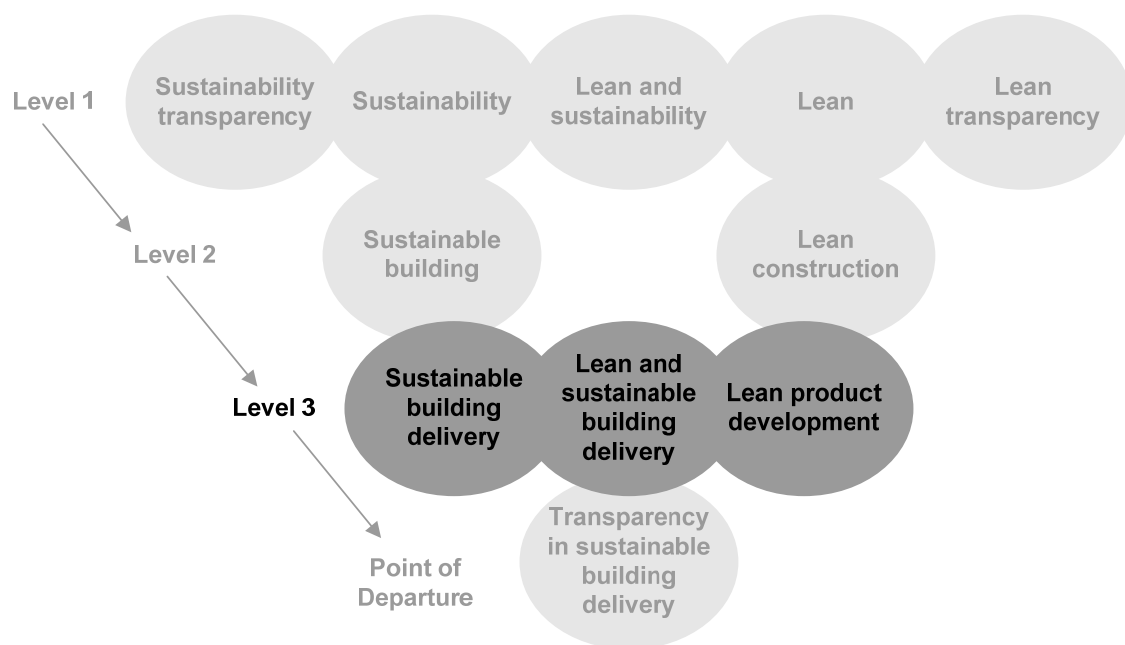
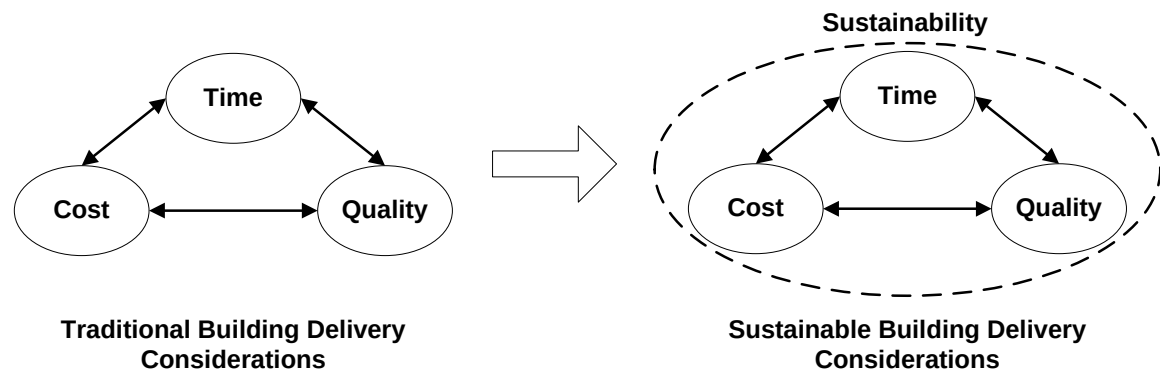


Figure 2-4: Literature Review Level 3

2.4.1 Sustainable building delivery

On traditional building projects, decisions made during project delivery (planning, design, construction, and operations) attempt to optimize time, cost and quality (including safety) for the project as a whole. For sustainable building projects, sustainability is an added criterion in all decisions (Figure Error! Reference source not found.). Instead of optimizing at a project level, sustainable building delivery attempts to optimize on a global level, making decisions that are best for the entire world.



Optimal delivery of sustainable buildings requires modification of the traditional building process to integrate sustainability into daily decision-making processes. Accordingly, strategies specific to sustainable building are present throughout the delivery continuum as shown in Figures 2-6 and 2-5. These modifications and new strategies, geared towards delivering sustainable buildings, result in a process that is more complex than traditional building delivery and unfamiliar to many stakeholders. To make decisions that optimize globally, sustainable projects require an integrated process with intense, interdisciplinary collaboration between a wide-range of stakeholders. This increased stakeholder involvement is crucial to development of sustainable solutions, but also contributes to a more complex delivery process. Stakeholders must understand this process to best apply their expertise and perspective when generating sustainable solutions.

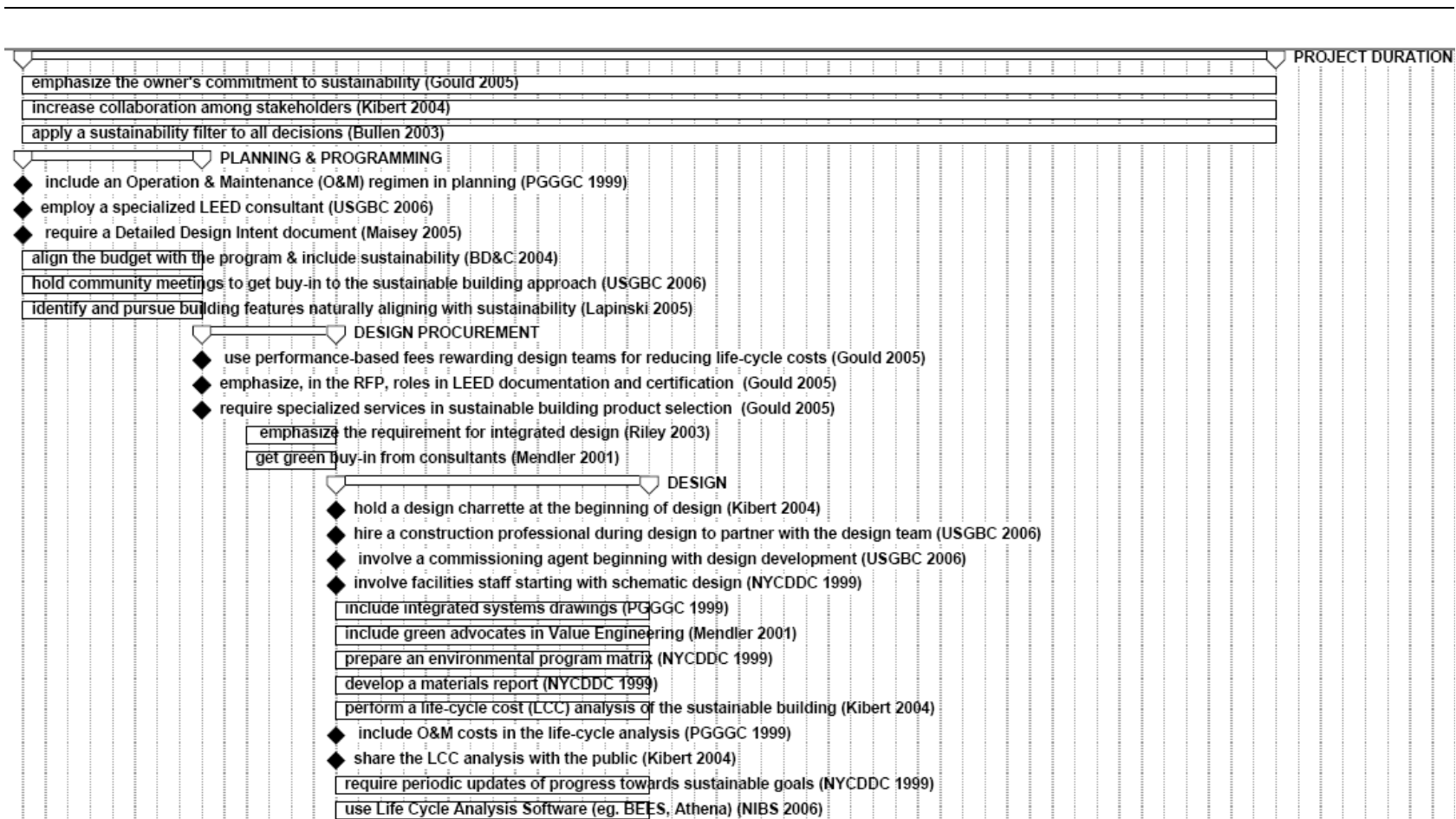


Figure 2-6: Specific Changes for Sustainable Building Delivery (Planning through Design Phases)

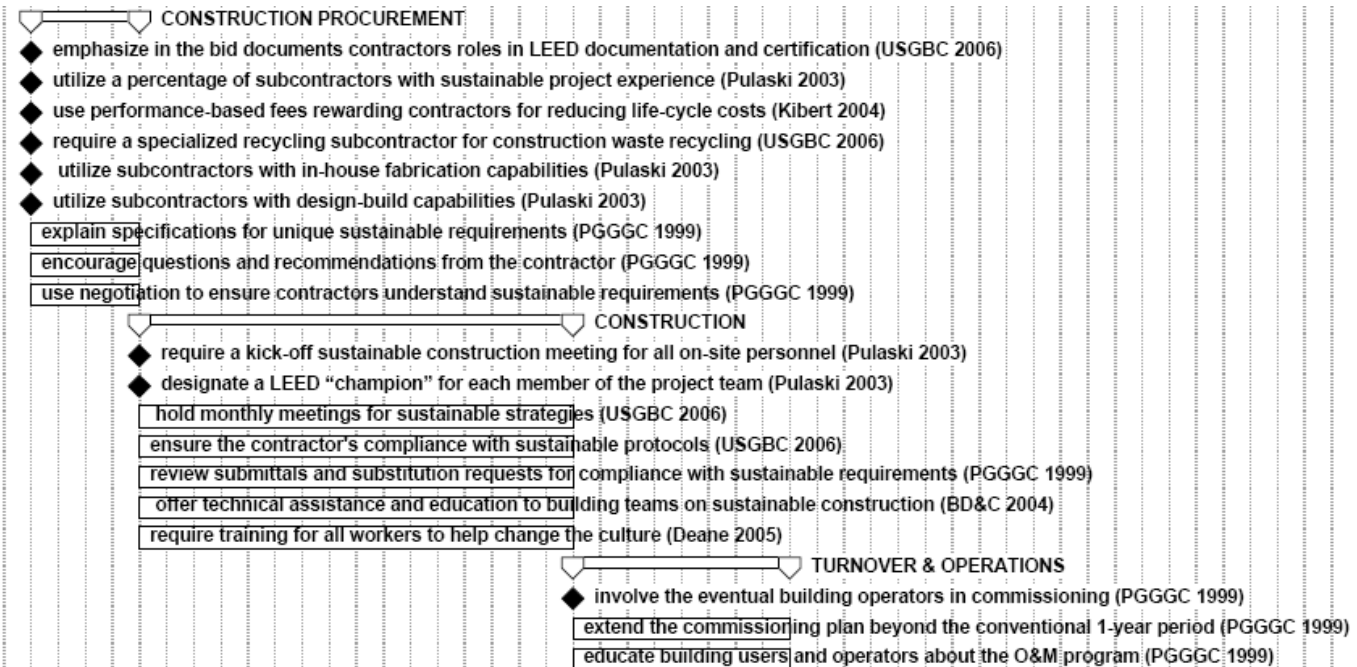


Figure 2-7: Specific Changes for Sustainable Building Delivery (Construction Procurement through Operations Phases)

General process change requires integrating sustainability issues into the project selection process and into smaller, daily decision-making processes (Bullen 2003). Other suggested general strategies include: leaving time for research of new sustainable technologies (Mendler 2001), utilizing an energy toolkit procedure map describing energy decisions for each project phase, including sustainability issues on the agenda of project team meetings, performing periodic evaluations of the project's predicted performance to monitor progress towards the sustainability targets, and providing reports on sustainability to the client and full project team showing how the project performs compared with the client's general sustainability policy (Addis 2001). In addition to the general process change, specific differences in the sustainable building process are present throughout the delivery continuum.

Beginning with the *capital planning/budgeting phase*, a key, but frequently overlooked, first step in sustainable building delivery is the decision to build. “Build it small if at all” is a reminder of the necessity to determine whether a new building is really needed, or whether renovations of existing space could meet these needs (Simpson 2001). Other sustainable strategies for the capital planning/budgeting phase include early adoption of sustainable objectives, and alignment of sustainable objectives with the project's business needs (Lapinski 2006).

In the *programming phase*, suggested strategies include: holding community meetings with interested stakeholders to obtain public buy-in to the sustainable building approach (USGBC 2006); making clear the owner's commitment to sustainable objectives (Gould 2005); employing a specialized LEED consultant to coordinate the sustainable building effort (USGBC 2006); aligning the budget with the program

(including sustainability) (BD&C 2004); requiring a Detailed Design Intent (DDI) document explaining, in simple language, how and why systems were selected and sized to meet the owner's life-cycle requirements, (Maisey 2005); and identification and pursuit of building features that naturally align with sustainability (Lapinski 2006).

Strategies for *design procurement* include: using performance-based fees that reward design teams for reducing building life-cycle costs, emphasizing in the RFP the roles of prospective design firms in LEED documentation and certification (Gould 2005), emphasizing the requirement for integrated design (Riley 2003), requiring specialized services from the designer in the use of LEED to guide project design (Gould 2005), and getting green buy-in from consultants (Mendler 2001).

During the *design phase*, suggested strategies include: holding a design charrette at the beginning of design (Kibert 2004), preparing an environmental program matrix, developing a materials report (NYCDDC 1999), hiring a general contractor or construction manager during design to partner with the design team (USGBC 2006), performing a life-cycle cost analysis of the sustainable building and sharing this analysis with the public to show how the sustainable building will save them money over time (Kibert 2004), including integrated systems drawings, explaining specifications for unusual or unique sustainable requirements (PGGGC 1999), requiring the design firm to provide an update of progress towards sustainable goals at each phase of design (NYCDDC 1999), having sustainable advocates in the value engineering process (Mendler 2001), involving facilities staff starting with schematic design (NYCDDC 1999), and using Life Cycle Analysis Software (e.g., BEES or Athena) where appropriate (NIBS 2006).

Integrated design is a primary feature of sustainable building delivery. Sustainable projects are best served by integrated teams where all types of building designers (e.g., architects, mechanical engineers, site engineers and structural engineers) as well as contractors and appropriate owner representatives are involved in the design process from the beginning (Riley 2003, DOE 2004). For example, in an integrated design process, the mechanical engineer can calculate energy use and cost early in the design process. The mechanical engineer can then inform the other design team members of the implications of their decisions; regarding building orientation, configuration, fenestration, mechanical systems and lighting options; on the building's energy use (DOE 2004).

Suggested strategies during *construction procurement* include: negotiating with contractors to ensure they understand sustainable requirements prior to contract award (PGGGC 1999), emphasizing in the bid documents the roles of prospective contractors in LEED documentation and certification (USGBC 2006), utilizing a percentage of subcontractors that have completed sustainable projects in the past (Pulaski 2003), encouraging questions and recommendations from the contractor (PGGGC 1999), using performance-based fees that reward contractors for reducing building life-cycle costs (Kibert 2004), requiring a specialized recycling subcontractor to handle construction waste recycling (USGBC 2006), and utilizing subcontractors with design-build capabilities or in-house fabrication capabilities (Pulaski 2003).

Strategies during *construction* include: requiring a kick-off sustainable construction meeting for all on-site personnel, designating a LEED “champion” for each member (e.g., general contractor, designer and owner) of the project team (Pulaski 2003), holding monthly meetings for sustainable strategies throughout the construction phase

(USGBC 2006), paying special attention to ensure the contractor's compliance with sustainable protocols (USGBC 2006), carefully reviewing submittals and substitution requests to ensure compliance with sustainable requirements (PGGGC 1999), offering sustainable construction technical assistance and education to building teams (BD&C 2004), and requiring training for all workers to help incorporate sustainability into the culture of the building industry (Deane 2005).

Finally, strategies associated with *turnover and operations* include: involving the eventual building operators in the commissioning process (PGGGC 1999), involving a commissioning agent beginning with the design development phase (USGBC 2006), extending the commissioning plan beyond the conventional one-year period, including an Operation & Maintenance (O&M) regimen in the early planning phases, including O&M costs in the life-cycle analysis, and educating building users and operators about the O&M program (PGGGC 1999).

2.4.1.1 Sustainable building delivery costs

The primary influence for sustainable building costs is process, and opportunities to reduce costs on sustainable projects are even earlier in the delivery process than on traditional projects (Mogge 2004). Interviews with practitioners confirm the possibility of first cost savings for sustainable projects due to process alteration. Specifically, reducing the uncertainty between phases of project delivery decreases perceived risk and the associated cost. For instance, pre-bid meetings that clarify scope for contractors can decrease costs by reducing risk and increasing clarity (Mogge 2004).

2.4.2 Lean product development

Product development is “the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product (LAI 1999).” Because of the similarities between product development and project delivery, the principles of Lean product development offer a template for adopting Lean principles to sustainable building delivery. In their implementation of Lean product development, Toyota follows several strategies. They use early detailed scheduling, examine multiple alternative solutions, front-load the process, and standardize the process to create flexibility. Toyota applies standardized process lists and checklists to limit the amount of approvals needed, as decisions are made only once with the right people (Morgan 2002). When adapting Lean to product development, accounting for the risk and variation in a creative and iterative design process is imperative (Millard 2001). The process must be managed, standardized, and improved without sacrificing creativity (Morgan 2002).

2.4.3 Lean product development transparency

For Lean product development, transparency is a concept of equal importance to value and waste (Bauch 2004). Due to the increasing complexity and need for creativity in product development processes, keeping processes transparent to all employees in a consistent way is important. Deficient transparency is a primary cause of rework and iterations in product development (Bauch 2004) and deficient transparency can lead to flawed information transfers (Graebisch 2005). Conversely, abundant transparency helps

identify and eliminate wastes from the product development process including poor information quality, ineffective communication, and unnecessary detail and accuracy.

2.4.4 Lean sustainable building delivery

Just as Lean and sustainability reinforce each other on a broad level, connections are also present on a more detailed level, between Lean and sustainable building delivery. Again, there are those who recognize Lean and sustainability, without identifying the synergism (Bidarianzadeh 2002), and others who recognize Lean and sustainable project delivery as reinforcing each other.

Huovila (2002) offers insights into adjustments for sustainable delivery, identifying Lean as applicable to design and construction processes. The specific focus for design is a minimization of value lost for the customer, while focus during construction is literally on elimination of waste. To account for sustainability in a Lean manner, the environment is added as a customer in an attempt to appropriately consider environmental burdens (Huovila 2002). Horman builds on these insights, pointing out that, while sustainability focuses on building design, and Lean focuses on the building delivery processes, both focus on waste and resource minimization (Horman 2004). Lean improvements identified for sustainable building delivery include:

- provision of methods in execution that streamline project processes (e.g., reducing design activities by scheduling based on information flows),
- expansion of focus on waste reduction outside of construction (e.g., design cycles, rework, document quality and incorrect decisions),

- forcing an emphasis on value (determine what the owner really wants), and
- adding the environment as a customer to help in value determination (Horman 2004).

2.5 Point of Departure: Transparency in Sustainable Building Delivery

At the culmination of the first three levels of the literature review, the point of departure for this research is previous work identifying process transparency as valuable for sustainable building delivery (Figure 2-8). Limited work covers this specific subject, none of which empirically examines the relationships between process transparency and sustainable building delivery. Still, the previous work provides valuable building blocks for this research project.

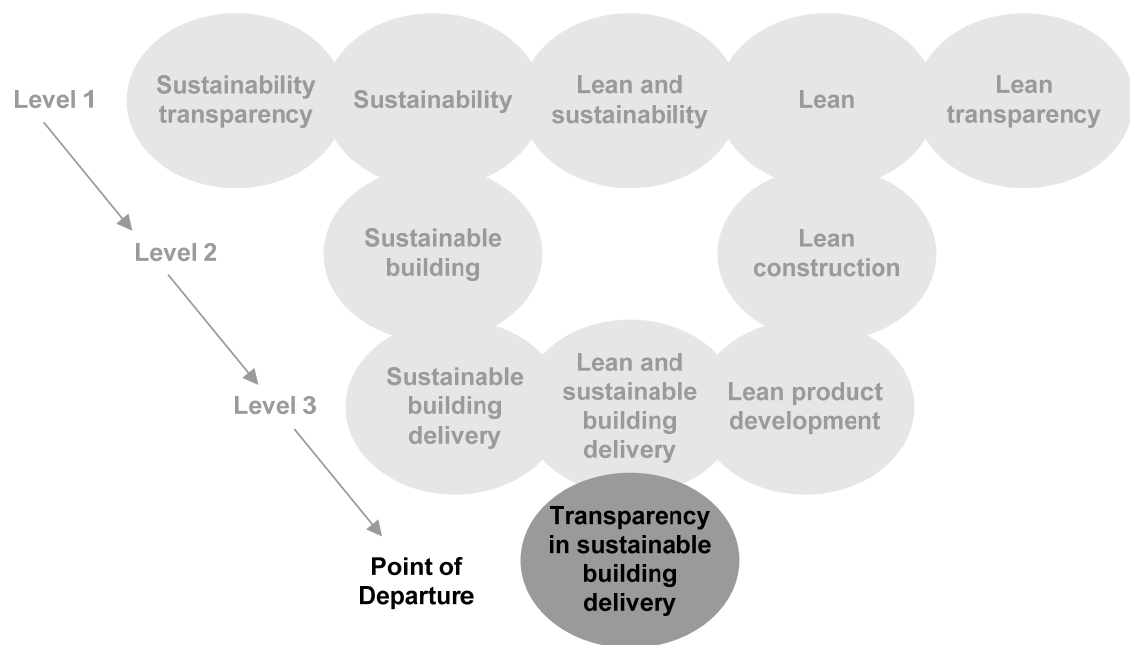


Figure 2-8: Point of Departure

2.5.1 Sustainable building delivery transparency

Transparency is an important concept for sustainable building processes. Initial development of a methodological framework for sustainable building (Figure 2-9) includes axes showing the system (boundary), process (actor) and aspect (sustainability) (Pearce 1998). Transparency is an integral concept on the process axis, which measures process effectiveness based on how stakeholders work together to meet sustainability objectives, especially at system boundaries. Referring to sustainable building:

“transparency of objectives and tasks across system boundaries at different system levels is a key performance requirement, since many mistakes of the past can be traced back to a lack of task and objectives coordination (Pearce 1998).”

More recent references also recognize the importance of transparency in sustainable building, pointing out that delivery methods which inhibit process transparency are not optimal (Kibert 2004).

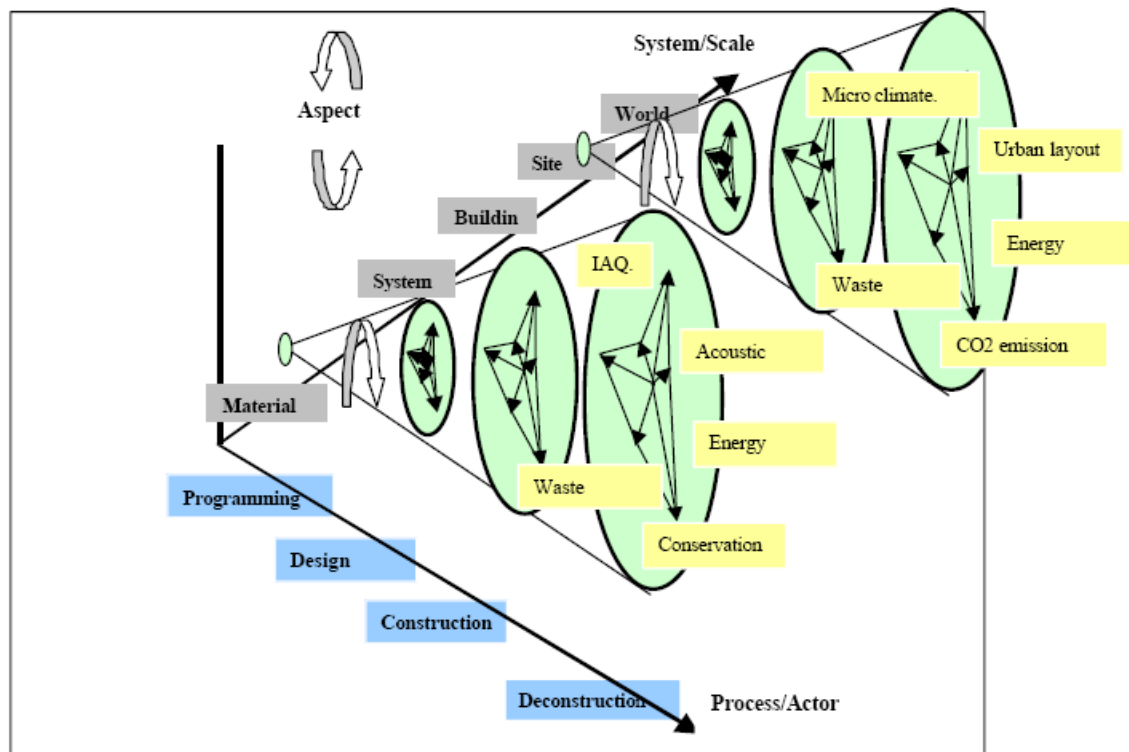


Figure 2-9: A Framework to Identify Performance Aspects in Relation to Process and System (From Pearce, 1998)

2.5.1.1 Transparency in building assessment

Recognizing the value of process transparency in sustainable building delivery, researchers are designing the next generation of building assessment tools to enhance process transparency (Cole 2005, Kaatz 2006). Currently, assessment tools, such as LEED, focus primarily on environmental performance of the building. The proposed sustainable assessment also addresses the need to adapt the practices and processes of construction. Ensuring stakeholder participation in assessment will create greater participation and broaden sustainability considerations made in the building delivery

process. To facilitate this participation, the presence of process transparency is imperative to meet the information demands of decision makers, help communicate sustainability efforts, and support documentation and record-keeping (Kaatz 2006).

2.6 Chapter Summary

Providing the foundation for this research project, the literature review begins at the broad level of Lean theory and sustainable development. Throughout the review, connections between Lean theory, sustainability, and process transparency are prevalent. At the point of departure for this research project, anecdotal evidence illustrates the potential value of process transparency for sustainable building delivery. The foundation provided by the literature review supports the empirical study described in the following chapters, which investigates whether reduced costs for sustainable buildings are possible by increasing delivery process transparency.

Chapter 3

Counterfactual Analysis: Research Method Selection and Background

To supplement the limited, anecdotal evidence in the literature review, empirical research is needed to answer the question “Are reduced costs for sustainable buildings possible by increasing delivery process transparency?” Asking this question is like asking, “What is the impact of a national railway system on the country’s economic development?” Or, “What is the impact of poor interoperability on the cost of construction?” It is impractical to answer any of these questions using only traditional construction research methods. Controlling the countless variables involved in these types of problems is nearly impossible. No two scenarios are identical and some variables may have greater impact on one scenario and less on another. To answer the question concerning the impact of a railway system on the economy, Robert Fogel pioneered use of the counterfactual analysis research method, winning a Nobel Prize in the process (Fogel 1964, Frangmyr 1994). Using a version of this same method, the National Institute of Standards and Technology measured the cost of poor interoperability in the U.S. capital facilities industry at nearly \$16 Billion each year (NIST 2002).

To address the novelty of applying counterfactual analysis to construction research, background information is drawn from applications of counterfactual analysis to study problems in fields including economics, history and political science. This background information includes:

- a definition of counterfactual analysis,

- types of counterfactual analysis,
- rationale for using counterfactual analysis on this project,
- criteria for developing a rigorous counterfactual analysis,
- strategies for preventing biases when developing counterfactual scenarios, and
- notable applications of counterfactual analyses including applications from Nobel Prize-winning research.

This background information supports selection of counterfactual analysis as the primary research method for determining whether reduced costs for sustainable buildings are possible by increasing delivery process transparency. The application of counterfactual analysis to study project delivery is described in the following Chapter 4.

3.1 Definition of Counterfactual Analysis

In a counterfactual analysis, researchers think back in time to specify an independent variable of interest, the *antecedent*. The goal is to determine the effect that changing the antecedent has on a dependent variable, the *consequent*. Specifying the *connecting principles* is also important, as the counterfactual analysis will rely on these principles to link the antecedent and consequent. The validity of connecting principles is central to the validity of the counterfactual scenario (Lebow 1996).

An example of a straightforward counterfactual analysis illustrates these fundamental concepts. In 2005, Penn State's football team finished the regular season with a record of eleven wins and one loss. Their only loss came at the University of Michigan in the seventh game of the season. A common counterfactual analysis used that

season by Penn State students was some version of “If Penn State had beaten Michigan, they would have finished the regular season undefeated.” Here, the student creates the antecedent by going back in time and changing Penn State’s loss against Michigan to a win. The student’s expected consequent is that Penn State would finish the season undefeated. To realize this consequent, the student is relying on the connecting principles that the results from Penn State’s games after the Michigan game would remain unchanged. These connecting principles are subject to argument as Penn State may have been overconfident in the following games had they beaten Michigan, or other teams may have been more motivated and prepared to play Penn State.

3.2 Types of Counterfactual Analysis

Counterfactual analyses may be idiographic or nomothetic. Studying or clarifying individual cases or events, idiographic counterfactual analyses show points of indeterminacy at particular moments in time and illustrate how the situation could easily have developed differently (Belkin 1996). For example, a Penn State student is relying on an idiographic counterfactual analysis when arguing that Penn State’s football team would have finished the 2005 season undefeated had they beat Michigan. On the other hand, nomothetic counterfactual analyses involve the study or formulation of general laws. The nomothetic type of counterfactual analysis applies well-defined theoretical or empirical generalizations to well-defined antecedent conditions (Belkin 1996). For instance, a Penn State student is relying on a nomothetic counterfactual scenario when arguing that Penn State’s football team would have beat Michigan in 2005 if the game

were in Beaver Stadium at Penn State. In this case, moving the game to Beaver stadium represents the antecedent, while Penn State's home-field advantage is the student's well-defined theoretical generalization.

The joint idiographic-nomothetic counterfactual analysis is a widely-used, hybrid style of counterfactual analysis (Belkin 1996). By combining idiographic and nomothetic styles, joint counterfactual analyses show what was possible in particular cases (idiographic) while identifying or applying theories suitable for application to many cases (nomothetic). Continuing with the Penn State football analogy, a student is applying a joint idiographic-nomothetic counterfactual analysis when arguing that Penn State would have finished the 2005 regular season undefeated had their game against Michigan been at Penn State.

This joint idiographic-nomothetic counterfactual analysis is well-suited to study whether reduced costs for sustainable buildings are possible through increased process transparency. The idiographic portion of this counterfactual analysis provides insight into how the delivery of the sustainable building under investigation would differ if there were complete process transparency. Complementing this idiographic study, a nomothetic component of the analysis applies the process transparency definition (Table 4-1), based on established theory, to the sustainable building being analyzed. Interestingly, a second nomothetic component will result from the completed counterfactual analysis in the form of evidence supporting the general principle that reduced costs for sustainable buildings are possible through increased process transparency.

3.3 Rationale for Using Counterfactual Analysis

Counterfactual analysis, rigorously applied, offers a practical method for studying whether reduced costs for sustainable buildings are possible through increased process transparency. Because no two buildings are delivered exactly the same way, running experiments where hypothesized causes are manipulated while holding all other variables constant is impossible. This type of experimentation would require identifying additional building projects that are similar to the project under investigation but have different values of the variable being studied, in this case process transparency. Assuming these similar building projects are identified, differences other than process transparency would still exist between the buildings being studied. Addressing these differences (confounding variables) would require control using statistical tools.

Gaining insight from the application of these statistical tools depends on obtaining a certain number of case studies similar to the building being studied. If a \$30 million, LEED-Gold rated, architecture building on a University campus is studied, any proper statistical analysis of process transparency impacts would require projects that, among other similarities, had comparable cost, function, and level of sustainability. Most likely, no other building fitting this description exists, let alone enough cases to allow control for other confounding variables.

For the sake of argument, assume that one million buildings similar to our \$30 million, LEED-Gold, architecture building exist. If this were the case, the statistical analysis could probably be performed to determine whether reduced costs for sustainable buildings are possible through increased process transparency. Still, this statistical

analysis relies on counterfactual assumptions that explanatory variables (process transparency) and the error variables (e.g., location, date and bidding climate) are uncorrelated (Fearon 1991). In an actual experiment, the use of random assignment would prove this assumption. In our statistical analysis of the architecture building, where random assignment is impossible, a counterfactual analysis satisfies the assumption of no correlation. Implied in this statistical analysis is the counterfactual scenario that variables such as location, date of construction, and bidding climate are unrelated to process transparency.

On the other hand, explicitly using the counterfactual analysis to study the delivery of this same architecture building is an attempt at a perfect experiment, where all variables except process transparency are equal. Here, the counterfactual assumption is what would have happened on the delivery of the architecture building if there were greater process transparency. The credibility of the counterfactual scenario relies on application of accepted theories separate from the hypothesis being tested, and on application of knowledge and evidence of the facts relevant to the delivery of the architecture building. So, the primary difference between the statistical experiment and the explicit counterfactual analysis is not whether counterfactual scenarios are applied (Dawes 1996). Rather, both instances rely on counterfactual analyses, and the primary difference is in how these analyses are applied.

The Penn State football example can help illustrate this important point. Assume researchers wish to show that Penn State would have beaten Michigan in 2005 were the game at Penn State.

Performing the statistical experiment requires identifying other instances where similar college football teams played against each other. Then, implicit use of counterfactual analysis determines which variables require control (e.g., location, team rankings, weather, injuries and attendance) and which variables do not (e.g., the cheerleaders' uniform colors or the number of hot dogs sold at the game). This allows testing of the effect of home-field advantage on the game's outcome, and this effect is then compared to the impact identified for the controlled variables. Assuming enough cases were examined to satisfy the statistical requirements, the credibility for this experiment relies primarily on the *implicit* counterfactual analysis utilized to select the variables requiring control.

In contrast with the statistical experiment, a second option is application of an *explicit* counterfactual analysis. Here, our study for comparison is Penn State's 2005 game against Michigan with all variables equal except the location of the game, now changed to Penn State. Using counterfactual analyses to control for other variables is unnecessary, as these variables do not exist. Instead, the application of counterfactual analysis emerges when estimating the effect of home-field advantage on the game's outcome. The credibility of this explicit counterfactual analysis relies on the theory and facts used to support the estimated effect of home-field advantage.

Discussion of the relative merits of counterfactual analyses and experiments that are more traditional is extensive and this section has outlined the primary arguments

applicable to this research project². Perhaps the most compelling rationale for applying counterfactual analysis to study whether reduced costs for sustainable buildings are possible through increased process transparency is the recognition of counterfactual analysis as:

“unavoidable in any field in which researchers want to draw cause-effect conclusions but cannot perform controlled experiments in which they randomly assign “subjects” to treatment conditions that differ only in the presence or absence of the hypothesized cause (Kiser 1996).”

3.4 Developing a Rigorous Counterfactual Analysis

As with any rigorous research method, criteria exist for counterfactual analysis that, when satisfied, add to the credibility of the research results. There are also potential biases that, when present, can subtract from the credibility of these same results. This section includes a description of these criteria and biases.

3.4.1 Criteria for rigorous counterfactual analyses

Six general criteria can assist evaluation of the credibility of counterfactual arguments (Belkin 1996). These criteria are clarity; logical, theoretical, historical, and statistical consistency; and projectability. In addition to these general criteria, which are fundamental to the development of all counterfactual analyses, two additional criteria, proximity, and possibility of additional consequents, are appropriate specifically for

² Interested readers are encouraged to consult Fearon (1991) for an in-depth discussion of the use of counterfactuals.

project delivery (Fearon 1996, Lebow 1996). Criteria for rigorous counterfactual analyses, and how these criteria are satisfied, are summarized in Table 3-1 and discussed in the following sections.

Table 3-1: Satisfying the Criteria for a Rigorous Counterfactual Analysis	
Criterion	How Satisfied
Clarity	Define the antecedent and consequent
Logical consistency	Define the connecting principles
Theoretical consistency	Define connecting principles in accordance with existing theory
Historical consistency	Define the antecedent to remain within the realm of possibility
Statistical consistency	Define connecting principles in accordance with accepted statistical generalizations
Projectability	Verify connecting principles on another scenario
Proximity	Minimize time and causal steps between the antecedent and consequent
Possibility of additional consequences	Consider negative and positive impacts of increased process transparency

3.4.1.1 Clarity

Openly defining the antecedent and consequent used in the counterfactual scenario satisfies the requirement for clarity in counterfactual analysis (Belkin 1996). To study whether reduced costs for sustainable buildings are possible through increased process transparency, the antecedent is clearly defined as the delivery of the sustainable building with complete process transparency. Further description of this antecedent is provided in Chapter 4 in Step 2 of the application of counterfactual analysis to project delivery. The resulting consequent is the impact on costs of the sustainable building.

3.4.1.2 Logical consistency

The logical consistency requirement for counterfactual analysis is satisfied by precisely defining the principles connecting the antecedent and consequent (Belkin 1996). These principles should not contradict each other or the antecedent and consequent. For this research project, the specific connecting principles defined to satisfy the logical consistency criterion are specified in Chapter 4 in Step 2 of the application of counterfactual analysis to project delivery. Changing only one variable, process transparency, minimizes the reliance on these connecting principles when developing the counterfactual scenario.

3.4.1.3 Theoretical consistency

Like the requirement for logical consistency, the theoretical consistency criterion addresses connecting principles. To achieve theoretical consistency, connecting principles should agree with established theoretical generalizations (Belkin 1996). For the study of whether reduced costs for sustainable buildings are possible through increased process transparency, one example of a connecting principle is that a change order during the construction phase will cost the owner some premium over the same change made during the design phase. The theoretical generalization at work in this example is the building industry standard that change order pricing is higher than pricing for work that is part of the original contract. Theoretical consistency is ensured by consulting existing literature, soliciting input from industry experts, and applying the researcher's experience in the building industry.

3.4.1.4 Historical consistency

Defining the antecedent to remain within the realm of possibility satisfies the historical consistency or “minimal-rewrite rule” (Belkin 1996). For example, studying the cost savings possible if aliens helped construct a sustainable building would fail the historical consistency criterion because the antecedent, aliens constructing the building, would require a substantial rewrite of the history leading up to the antecedent. However, specifying complete process transparency for the building’s delivery requires no additional rewrite and therefore passes the historical consistency criterion.

3.4.1.5 Statistical consistency

To satisfy the statistical consistency requirement, connecting principles between the antecedent and consequent are defined in accordance with established statistical generalizations (Belkin 1996). A lack of statistical generalizations related to building project delivery renders this requirement inapplicable.

3.4.1.6 Projectability

The projectability criterion is satisfied by separating out specific connecting principles from the counterfactual analysis to ensure real-world observations reflect these principles (Belkin 1996). For example, the projectability criterion is satisfied for the several connecting principles by consulting industry experts who did not participate in the delivery of the sustainable building being studied. This strategy provides independent

evidence to verify the connecting principles, which are integral to the counterfactual analysis.

3.4.1.7 Proximity

The proximity criterion deals with the distance between the antecedent and the consequent. Ideally, both the time and the number of causal steps are minimized between the antecedent and consequent (Fearon 1996). Time is an issue when using counterfactual scenarios to study history if hundreds of years separate the antecedent and consequent. Time is less likely an issue for the delivery of building projects, where the entire project typically spans less than five years.

On the other hand, the proximity requirement to minimize the number of causal steps between the antecedent and consequent does require careful consideration in this study. For the delivery of sustainable buildings, process transparency affects numerous steps. Minimizing these steps is one reason why this research project focuses on whether reduced costs for sustainable buildings are possible through increased process transparency, and does not measure other impacts transparency may have. While studying whether increased process transparency may result in a better, more sustainable, building is certainly worthwhile; this type of study would introduce additional causal steps and decrease the validity of the counterfactual analysis. For example, increased process transparency could lead to operations input during design, which could result in a change in the type of HVAC system selected for sustainable building. This type of design change could lead to other impacts such as changes to windows, spaces, and structural

systems. Accurately anticipating how these changes would play out in the completed sustainable building is impossible. Limiting the scope of this research project to whether reduced costs for sustainable buildings are possible through increased process transparency minimizes the number of causal steps and still permits important insight into the impact of transparency.

3.4.1.8 Possibility of other consequents

The final criterion against which the counterfactual analysis is judged is recognition of the possibility of additional consequents. When introducing the antecedent, there is potential that consequents, in addition to the one being studied, may result (Lebow 1996). Additional positive consequents, such as improved customer satisfaction, would reinforce the consequent being studied, in this case project costs. On the other hand, additional negative consequents may outweigh the benefits realized in the expected consequent. For example, competing organizations may gain a competitive advantage because of the process transparency on the sustainable building project. Consideration of additional consequents is included in Chapter 4 as part of Step 2 of the application of counterfactual analysis to project delivery.

3.4.2 Potential biases in counterfactual analyses

There are unique biases to guard against when performing counterfactual analyses. Satisfying the eight criteria for rigorous counterfactual analyses helps to prevent

these biases. Still, as with any rigorous research method, it is important in counterfactual analysis to recognize and take steps to eliminate these biases. Potential biases for the SALA and Forest Resources counterfactual analyses are summarized in Table 3-2 and outlined below.

Table 3-2: Addressing Potential Biases in Counterfactual Analyses

Potential Bias	How Addressed
Need to avoid blame or claim credit	Researcher is an outside observer
Need for cognitive consistency	Identify both positive and negative consequents of increasing process transparency
Cognitive bias	Select a typical scenario

3.4.2.1 The need to avoid blame or claim credit

This bias may occur if the researcher performing the counterfactual analysis was involved in the scenario being analyzed (Belkin 1996). For instance, if the project manager for the sustainable building project being studied were performing the counterfactual analysis, they might be less likely to point out a lack of process transparency that reflects poorly on their performance. Because the researcher for this project is an outside observer, with no stake in the delivery of the projects being studied, this type of bias is negligible.

3.4.2.2 The need for cognitive consistency

This bias occurs when researchers are hesitant to rule out counterfactual scenarios that link negative antecedents to positive consequents or vice versa (Belkin 1996).

Arguing that slavery was integral to economic growth in the South is subject to this type of bias. In this research project, bias resulting from the need for cognitive consistency is reduced by taking care to identify both positive (cost decreases) and negative (cost increases) consequents which result from increased process transparency.

3.4.2.3 Cognitive bias

This bias results from a tendency to apply antecedents that undo scenarios representing a change from routine (Belkin 1996). A classic example of cognitive bias is the person who takes a different route to work and gets in a minor car accident. For most people, the response to this scenario is, “if only they had taken the usual route, the accident would not have happened.” The accident would also have been avoided if the person left for work five minutes later or if they took the bus, but these antecedents do not immediately come to mind. Cognitive bias is not a major issue for the study of process transparency and project costs for sustainable building delivery. Transparency is never complete on any building project, so introducing complete process transparency as an antecedent does not undo a change from the routine.

3.5 Notable Applications of Counterfactual Analysis

Application of counterfactual analysis has assisted rigorous research on subjects ranging from political science (Fearon 1991) to history (Winter 1986) to economics (Fogel 1964). Counterfactual analysis has become more broadly accepted after its use by

Economist Robert Fogel to examine the impacts of railroads on U.S. economic development (Fogel 1964). Fogel's application of counterfactual analysis contributed to his winning a Nobel Prize in 1993 (Frangsmyr 1994), and counterfactual analysis is now a research method of choice for researchers at leading U.S. institutions (Belkin 1996).

In the building construction industry, the application of counterfactual analysis was integral to an influential study of the cost impacts of poor software interoperability in the U.S. construction industry (NIST 2002). In this study, the actual cost impacts experienced were compared to a hypothetical counterfactual scenario with flawless exchange and availability of electronic information. Performed by the National Institute of Standards and Technology (NIST), this study conservatively estimates the cost impacts of the incompatible systems at nearly \$16 billion dollars a year. To arrive at this estimated cost impact, researchers surveyed and/or interviewed 70 different organizations representing the major stakeholders on building projects (e.g., owners, contractors, architects, engineers, fabricators, suppliers and vendors). The surveys and interviews were used to solicit data from organizations regarding impacts experienced resulting from incompatible systems. For example, architecture firms were asked how much time their employees spent transferring contractor requests for information to a different file format. Hourly wages were used to convert this time to a cost impact, which was extrapolated to the national-level using U.S. Census data.

While the NIST study applies counterfactual analysis to examine the building industry, no studies were identified explicitly applying counterfactual analysis to study building project delivery. A primary contribution of this research project is the method

and example for applying counterfactual analysis to building project delivery, which is described in Chapter 4.

3.6 Counterfactual Analysis and Theory Development

Readers may remain unconvinced of the validity in using counterfactual analysis to test theories. If this is the case, you are not alone (Weber 1996) and the purpose of this dissertation is not to convince you otherwise. Because, while there is some dispute over the validity of counterfactual analysis for theory testing, there is nearly complete agreement that counterfactual analyses are valuable when applied as they are in this dissertation, to help *develop* theories. Even a critic of using counterfactual analysis for theory testing concedes that:

“I am pessimistic about our chances of making counterfactuals into powerful and widely accepted tools for theory testing in social science. The implicit assumption underlying efforts to do so is that data are the most important scarce resource in social science... Of course, good data are hard to come by, but I doubt that counterfactuals can count as good data in more than a few isolated cases about which we already know an enormous amount and have a high degree of confidence. I want to emphasize another key point about counterfactuals: theories, arguments, and ideas are another scarce resource, and counterfactuals can be very useful in generating them (Weber 1996).”

By design, the application of counterfactual analysis for this research project will not generate complete certainty about the exact magnitude of the relationships between the dependent (sustainable project costs) and independent (process transparency) variables. Still, the method will satisfy the goal of this research project and help develop theory regarding the relationship between process transparency and sustainable building delivery.

3.7 Chapter Summary

Counterfactual analysis is selected as the primary research method to study whether reduced costs for sustainable buildings are possible through increased process transparency. Relevant background information and criteria for rigorous counterfactual analyses support the method's appropriateness for project delivery research in general, and this research in particular. This background information informs the method for and example of applying counterfactual analysis to project delivery, which are described in the following Chapter 4.

Chapter 4

Counterfactual Analysis Applied to Project Delivery

A step-by-step method for applying counterfactual analysis to study project delivery was developed to study whether reduced costs are possible for sustainable buildings by increasing process transparency. This counterfactual method is designed to be straightforward and comprehensive and to work with available resources and references within construction industry organizations. The method was applied to study the delivery of the recently completed School of Architecture and Landscape Architecture (SALA) and Forest Resources buildings on Penn State's University Park campus. Each of the method's six steps are described in this chapter, including an example of each step from the study of the SALA and Forest Resources buildings. Based on its application to study these buildings, it is apparent that counterfactual analysis is a suitable research method for developing theories regarding project delivery. It is also apparent, as discussed in more detail in the following Chapter 5, that reduced costs for sustainable buildings are possible by increasing delivery process transparency.

4.1 Introduction

Examination of two recently completed, sustainable building projects reveals that reduced costs for sustainable buildings are possible by increasing delivery process transparency.

- Penn State's SALA building is an 111,000-square foot facility completed in August of 2005, which earned a LEED-Gold rating. Gold is the second-highest rating a building can receive from the United States' Green Building Council (USGBC), which maintains and oversees a national rating system for environmentally sustainable building.
- Penn State's Forest Resources building is a 92,000-square foot facility, which earned LEED-Silver certification and was completed in January 2006.

The SALA and Forest Resources buildings are shown in Figure 4-1, and detailed project information is provided in Appendix A, including: scope, costs, delivery schedule, delivery method, pictures, maps, and specific sustainable features of each project.



Figure 4-1: Penn State's SALA (Left) and Forest Resources (Right) Buildings

To empirically investigate the impact of process transparency on costs for the SALA and Forest Resources buildings, the counterfactual analysis research method discussed in Chapter 3 was tailored to project delivery. Figure 4-2 shows this adapted method, and expanded descriptions and examples for each step of the method provide the

structure for this chapter. The step-by-step presentation of the method is meant to support use of counterfactual analysis by others studying project delivery.

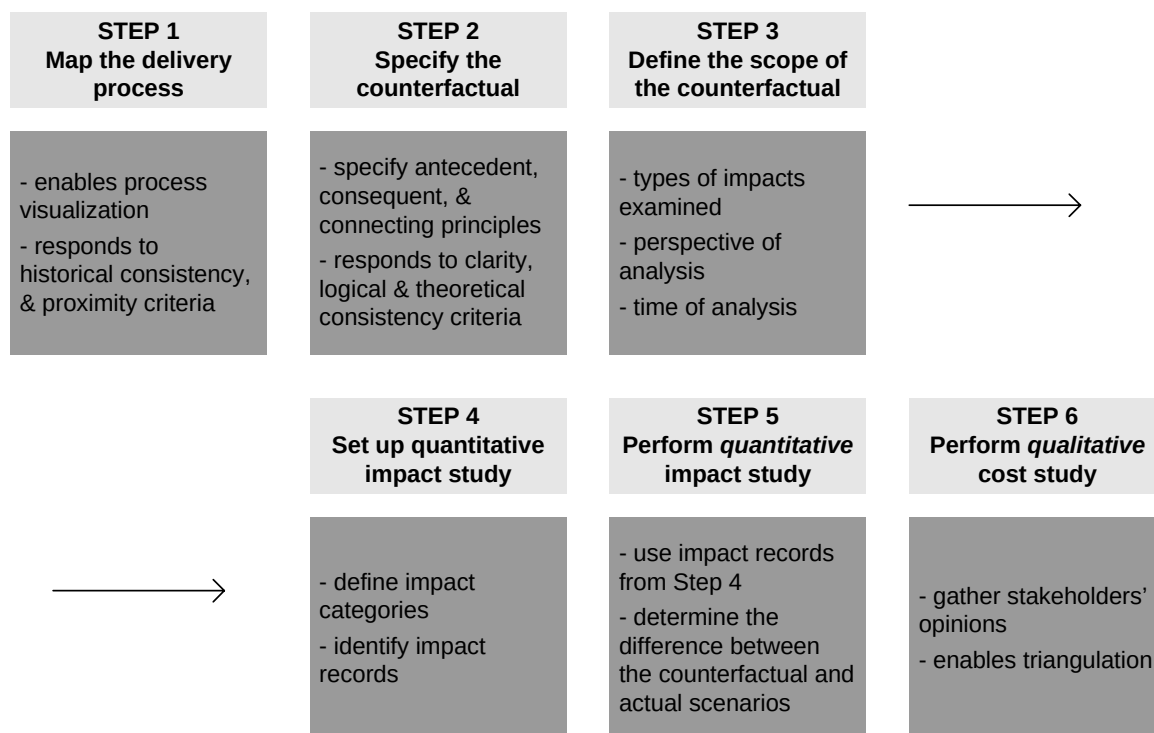


Figure 4-2: Counterfactual Analysis Applied to Project Delivery

4.2 Step 1: Map the Delivery Process

When applying counterfactual analysis to project delivery, the initial step is to map the delivery process being studied. Process maps show the activities and procedures of business entities as pictorial images, or “maps,” that convey considerable information (Curtis 1992). Mapping the delivery process is fundamental to developing a rigorous counterfactual analysis as the process map(s) allows the researcher to visualize the delivery process. This ability to visualize the process is essential to subsequent steps of

the counterfactual analysis, including location of the antecedent and consequent (Step 2), identification of connecting principles (Step 2), and revelation of cost windows (Step 4). The required level of detail of the process mapping depends on the desired findings of the counterfactual analysis. Mapping approximately forty activities and associated information flows for the delivery process was sufficient detail for the applications in this research project.

Mapping the delivery process contributes to satisfying the historical consistency and proximity criteria for rigorous counterfactual analyses (Table 3-1). The historical consistency or “minimal re-write” criterion is addressed by ensuring that only the antecedent is changed from the actual delivery process. Because the actual and counterfactual scenario maps are identical with the exception of the changed antecedent and because the antecedent is realistic, the counterfactual scenario remains within the realm of possibility. Mapping also contributes to satisfying the proximity criterion since locating the antecedent and consequent on a process map assists identification of causal steps between these variables.

4.2.1 Step 1 example

Process map development to study delivery of the SALA and Forest Resources buildings followed the Lean and Green (L&G) modelling protocol (Klotz 2007). Maps showing the delivery process at a macro-level, Level I and Level II maps, provided the necessary detail to satisfy Step 1. Map development began with review of applicable documents, including: organizational procedure manuals, standard forms, project records,

and schedule templates. Next, interviews with OPP's Director of Design and Construction, who is familiar with the entire delivery process, helped finalize the level I map. Following development of the level I map, other OPP employees familiar with each sub-process verified the level I map and developed the level II maps. Figure 4-3 shows the level I map, representing an overview of the entire delivery process. The remaining level I and level II maps developed are available in Appendix A (Figures A-10 through A-17). Additional process maps developed at OPP are available online³, and detailed descriptions of the L&G protocol and map development are available to readers interested in process mapping methods (Klotz 2007).

³ <http://www.opp.psu.edu/about/divisions/dc/manual/index.html> (Accessed 12/22/07)

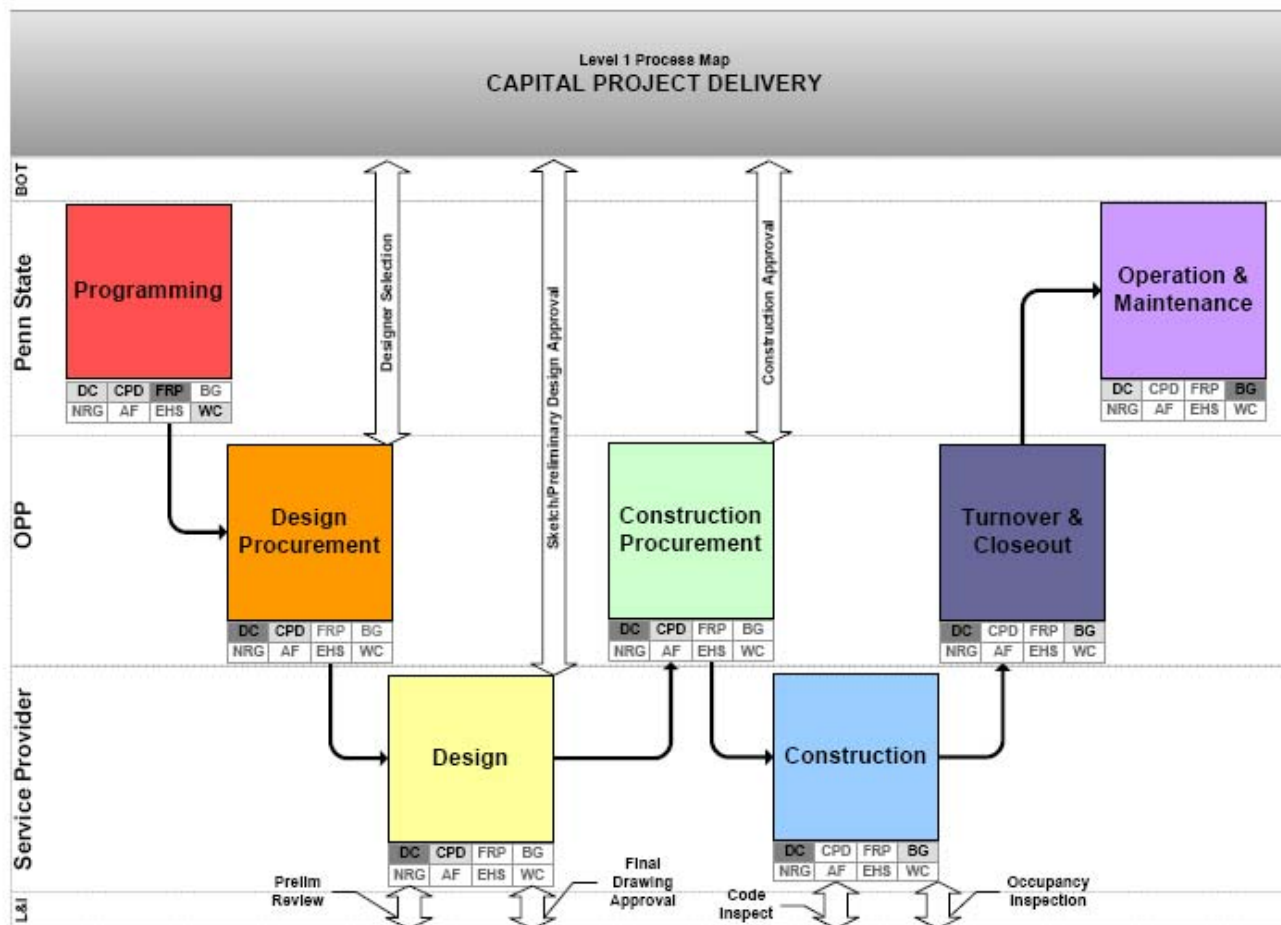


Figure 4-3: Level 1 Process Map

4.3 Step 2: Specify the Counterfactual Scenario

After mapping the delivery process, the next step in the application of counterfactual analysis to project delivery involves clearly specifying the counterfactual scenario, including the antecedent, consequent, and connecting principles. Specifying connecting principles is one of several steps where iteration will probably be required. Researchers can hypothesize key connecting principles when initially completing this step, but identification of additional connecting principles is likely when performing the quantitative cost analysis (Step 5). When practical, review of the counterfactual scenario by other researchers and industry members familiar with similar project types is encouraged. This review can help with accurate specification of the antecedent and consequent and appropriate application of connecting principles.

Specifying the counterfactual scenario helps satisfy five of the criteria for rigorous counterfactual analyses (Table 3-1). Clarity, logical consistency, and possibility of additional consequents are each explicitly satisfied. Specifying the antecedent and consequent provides clarity, while specifying the connecting principles provides logical consistency. The possibility of additional consequents is addressed by hypothesizing unintended impacts that may result from the introduction of the antecedent. Theoretical consistency is addressed through the independent review of the counterfactual scenario. Finally, the projectability criterion is addressed by confirming connecting principles. A review of literature is frequently most appropriate to perform this confirmation for broad, well-established principles, such as the decreased level of influence on costs as a building project progresses (Paulson 1976). For more specific connecting principles, consulting

with industry experts familiar with similar projects is more feasible. Ideally, researchers confirm all connecting principles with significant impacts on the counterfactual analysis.

4.3.1 Step 2 example

For the study of the SALA and Forest Resources buildings, the antecedent and consequent result directly from the research question: “Can complete process transparency lead to decreased sustainable project costs?” Therefore, the antecedent is “complete process transparency,” and the consequent is “sustainable project costs.” Using the process maps developed in Step 1, the antecedent was introduced after capital planning and prior to the programming phase of each building’s delivery and the consequent was measured immediately prior to the operations phase of project delivery (Figure 4-4). Operations costs were not part of the cost analysis because very little operations cost information is available for either of these recently completed buildings.

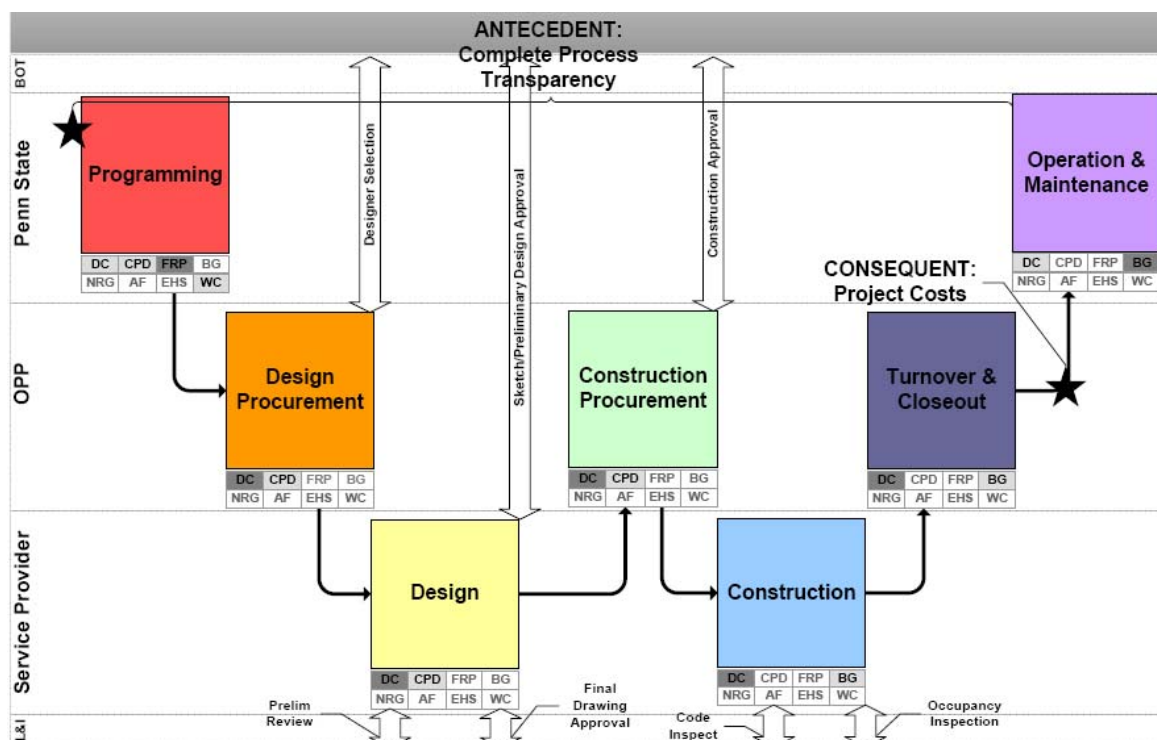


Figure 4-4: Location of the Antecedent and Consequent in the Level 1 Process Map

The primary connecting principle for this research project requires that cost impact consequents are considered only when the information required to avoid this impact existed at the time the impact occurred, and when this information could have been accessed if there were perfect process transparency. This connecting principle prevents “Monday morning quarterbacking” by ruling out cost impacts resulting from a lack of process information as opposed to a lack of transparency of process information. For instance, costs associated with approval delays resulting from the last-minute cancellation of a Board of Trustees’ meeting would not be included in the analysis due to the lack of process information (i.e., no one could have reasonably anticipated the cancellation of the meeting). However, a similar approval delay would be included in the analysis if the delay resulted from the project team’s failure to recognize that they needed

to attend the Board of Trustees' meeting. In this instance, the necessary process information existed at the time of the cost impact, most likely with the Board of Trustees and other Penn State representatives, and this information could have been accessed if there were perfect process transparency.

4.3.1.1 Antecedent

The process-focused definition of transparency applied to this research was adapted from manufacturing and product development. Lean theory recognizes transparency as the most important “spur to perfection” and defines transparency as the ability of all stakeholders in a system to see everything, making it “easy to discover ways to create value” (Womack 2003). Because traditional Lean theory is based on manufacturing processes, researchers studying product development processes have adapted the Lean definition of transparency (Bauch 2004). These adapted definitions are the foundation for the process transparency definition that forms the antecedent for this counterfactual analysis.

Transparency is most simply defined as process visibility. More specifically, transparency is defined by the degree to which the following elements are present for a process: recognition of status, problems, responsibilities, and interdependencies; facilitation of understanding, feedback, communication, and improvements; and, enabling decision-making. Table 4-1 lists each attribute of the process transparency definition, an example of the attribute and the primary reference supporting inclusion of the attribute in this definition.

Table 4-1: Attributes of the Process Transparency Definition

Attribute	Example
<i>Recognition</i>	
Of status	stakeholders understand the position of the process (Bauch 2004)
Of problems	stakeholders can identify areas of concern in the process (Womack 2003)
Of responsibilities	stakeholders understand their role in the process (Bauch 2004)
Of interdependencies	stakeholders understand how they will impact and be impacted by others for the process (Bauch 2004)
<i>Facilitation</i>	
Of system performance understanding	stakeholders can evaluate process efficiency (Womack 2003)
Of feedback on performed activities	stakeholders can determine whether their actions are correct (Bauch 2004)
Of communication	stakeholders are given tools allowing effective communication (Graebisch 2005)
Of improvements	stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement (Bauch 2004)
<i>Enabling</i>	
Decision making	stakeholders are given the necessary tools to be comfortable making decisions based on a total process understanding (Womack 2003)

This process transparency definition was applied to clearly specify the antecedent. In the counterfactual delivery process for the SALA and Forest Resources buildings, stakeholders have perfect understanding of their positions, roles and interactions in the process. These stakeholders can identify areas of concern, determine the correctness of their actions, evaluate process efficiency, and identify methods to eliminate waste and create value. Stakeholders are also able to effectively communicate and make decisions based on an understanding of the total process.

Process transparency is a subset of the more broad information transparency. On building projects, documentation throughout the project's delivery provides product transparency, which is a different subset of information transparency. Examples of documentation aimed at transparency of the product (the building) include: the capital plan, the building program, requests for proposals, design drawings and specifications,

physical and virtual 3D models, budgets, invoices, requests for information, and submittals. To illustrate, the construction drawings and specifications attempt to make product information provided by the designer transparent to the builder. As defined for this research, process transparency is the subset of information transparency that specifically provides information about the sequence and organization of the process itself (Table 4-2). A schedule, organization chart or responsibilities matrix are all efforts at increasing process transparency. Simply put, information transparency helps define what a building will be, while process transparency helps show how the project stakeholders will deliver the building.

Table 4-2: Types and Examples of Transparency (Adapted from Garcia 2003)

Type of Transparency	Example of efforts to add this type of transparency
Process (Organization)	organization charts, project team structures, contracting relationships
Process (Sequence)	schedules, process maps, work sequences, status updates
Product	drawings, specifications, 3D models, virtual models

Definition of the antecedent increases construct validity, i.e., the degree to which conclusions drawn from the results of this study actually reflect the theoretical foundation on which the study was based (Trochim 2006). The definition of process transparency was developed based on established literature and provides the theoretical basis for this research project (Womack 2003, Bauch 2004).

4.3.1.2 Consequent

Sustainable project costs are the consequent examined in this research project. To satisfy the criteria for rigorous counterfactual analyses, the possibility of additional

consequents is also considered (Table 3-1). There are numerous additional positive consequents possible by increasing process transparency, including improved relationships between stakeholders, a better (more sustainable) building due to opportunities recognized through improved process transparency, and increased user-group satisfaction with the final product. Any of these possible additional consequents would reinforce the positive impact of complete process transparency on the intended consequent, sustainable building costs. Of greater concern are possible additional consequents with negative impacts. Notably, project stakeholders may worry that increased process transparency will reveal proprietary information, causing their companies to lose competitive advantages. This concern is considered. However, the antecedent is complete *process* transparency, and organizations are less likely to realize negative impacts from sharing process information than from sharing information about financial or legal issues.

4.3.1.3 Connecting principles

Connecting principles link the antecedent, complete process transparency, to the consequent, sustainable project costs (Eq. 4.1). A vital connecting principle is that cost impacts are considered only when the information required to avoid the impact existed at the time of the impact and when this information could have been accessed with complete process transparency. For instance, during construction of the SALA building, a fire resulted in damage leading to \$420,274 in change order costs. While this is a significant cost for the sustainable project, at no point did any stakeholder possess information

indicating that the SALA building would catch on fire during construction. Because these fire damage costs are not connected to the antecedent by connecting principles, the costs are excluded from the counterfactual analysis. On the other hand, a construction change order was issued on the SALA project to relocate a fire hydrant (SALA record #45). In this instance, the local fire department knew the correct location of the fire hydrant at the point during design where avoiding the change order was possible. With better process transparency, which could have been provided by a project stakeholder who understood the need to consult with the fire department on the hydrant location, the location information could have been accessed. However, in this case, a lack of process transparency related to “recognition of interdependencies” between stakeholders meant the correct location was not identified until the construction phase, resulting in a cost premium. The cost premium associated with this change order is linked from the antecedent using connecting principles and is, therefore, included in the consequent.

$$C = I * V,$$

where

V = Value

I = Impact of Connecting Principles

C = Cost Impact

Eq. 4.1

Several other connecting principles help define the magnitude of the consequent, sustainable project costs. These connecting principles are conservative, contributing to the likelihood that cost impacts identified in this counterfactual analysis are understated. Connecting principles for the SALA and Forest Resources counterfactual scenarios include:

- *Rework full cost:* When rework resulting from a lack of process transparency is required, 100% of the cost of this rework is included in the consequent (Eq. 4.2). For example, Forest Resources record #9 is the “cost to cut and remove framing at the elevator penthouse.” Because this change is rework, or work that was possible to avoid completely, the entire change order amount is included in the cost impact. In practice, costs associated with rework frequently include more than just the rework items themselves, since other aspects of the project are typically affected. These costs, which are more difficult to quantify, are excluded from the consequent.
- *Liquidated damages for cost of delays:* In construction contracts, a clause for liquidated damages outlines the contractor’s cost obligations for each day the project is late past the agreed upon completion date. Liquidated damage clauses are typically determined based on the value of the beneficial use of the building by the owner and therefore are used in this research to estimate costs resulting from delays in any phase of the project. For the SALA building, liquidated damages were \$2,000 per day. Therefore, when a lack of process transparency results in project delays, each day of delay is multiplied by \$2,000 and 100% of this cost is included in the consequent (Eq. 4.2). For example, SALA counterfactual record #5 is a design contract amendment for “telecommunications revisions due to owner revisions.” Following completion of the bid documents, Penn State notified the engineer of changes required to originally designed locations of phone data outlets. Because bid documents were already complete, the engineer could not absorb the time for the design

change in the original schedule and required an additional week to modify the locations of phone data outlets on the bid documents, resulting in a 5-day time extension to the project. The liquidated damages amount of \$2,000 per day is multiplied by the 5-day time extension to calculate the \$10,000 cost impact reflected in SALA counterfactual record #227 “Delay costs – amendment for telecom revisions.”

$$I = 1.0$$

Eq. 4.2

When

I = Connecting Principle Influence for Rework, or Delay Costs

- *Change order premium cost:* For both buildings, work associated with construction change orders costs more than the same work would cost as part of the construction contract. General contractors included a 5% mark-up for overhead and profit on contract work and a 10% mark-up for overhead and profit on change order work. Therefore, 5% of the costs of non-rework change orders that could have been prevented with greater process transparency are included in the consequent. To illustrate, Forest Resources record #49 involves “mechanical changes per bulletin 5.” Adding these changes in full to the consequent is incorrect, because, if these changes were included in the original design, the contract price would have increased. However, the 5% premium for change orders is included in the consequent (Eq. 4.3). This 5% estimated influence for this connecting principle is most likely conservative as industry experts familiar with projects at Penn State anticipated change order premiums between 20% and 30% (Appendix B).

- *Value engineering premium cost:* A “value engineering” effort on the SALA building solicited input from construction professionals to generate suggestions for reducing the building’s construction costs. This value engineering effort resulted in a \$1,927,000 construction cost reduction provided by the contractor. However, cost reductions from value engineering are typically less than the reduction in contract price possible if these changes were incorporated in the original design of the project. Estimates of the value engineering credit amount by industry experts familiar with Penn State projects ranged between 70% and 75% of the value of the removed work. To remain conservative, only 5% of the total value engineering amount was included in the consequent (Eq. 4.3).

$$I = 0.05$$

$$\begin{array}{l} \text{When} \\ I = \text{Connecting Principle Influence for Change Orders or} \\ \text{Value Engineering} \end{array} \quad \text{Eq. 4.3}$$

4.4 Step 3: Define the Scope of the Counterfactual Analysis

Step 3 involves refining the antecedent, consequent, and connecting principles specified in Step 2 by defining the scope of the counterfactual analysis. General scope considerations to be defined may include types of impacts examined, perspective of the analysis and time of the analysis.

When specifying the types of impacts for inclusion in the consequent, understatement of impacts is likely if only those impacts directly related to the antecedent

are examined. However, determining impacts that are indirectly related to the antecedent is difficult and inclusion of these impacts can reduce the credibility of the counterfactual analysis. For instance, increased employee motivation leading to more productive workers and decreased labor costs is one possible consequent of increased process transparency. However, this type of indirect consequent is difficult to quantify and relies on less-certain connecting principles. One solution is to consider only impacts directly related to the antecedent with the understanding that the total impacts are probably understated.

For project delivery, examination of the counterfactual scenario from the perspective of the project owner is often appropriate as the owner ultimately experiences the majority of impacts in project delivery. Consequently, defining the scope of the counterfactual analysis from the owner's perspective ensures that cost impacts identified are a reflection of actual costs borne by the project as opposed to costs simply shifted from one group to another. To illustrate, a general contractor may save \$50,000 by successfully arguing that moving the occupants of the building is another stakeholder's responsibility. Despite the contractor's savings, the owner must now hire another contractor to perform this work, so there is no overall benefit for the project.

The period of time for analysis also requires consideration when defining the scope of the counterfactual analysis. Depending on the research objectives, impacts may be examined for an entire project or for another period, such as one year or one month.

4.4.1 Step 3 example

For the SALA and Forest Resources counterfactual analyses, direct costs are calculated from the owner's perspective starting with the planning phase and ending at the conclusion of the turnover phase (Figure 4-4). Examining cost reductions possible with improved process transparency from the owner's perspective is appropriate as owners typically are the ultimate decider on whether or not to build sustainably. Only costs directly resulting from a lack of process transparency are considered, because indirect costs are difficult to quantify (NIST 2002). For instance, excluded from this analysis are costs associated with the decreased productivity of an OPP employee who is frustrated with a lack of process transparency. This exclusion of indirect costs contributes to the likelihood that cost impact estimates for this counterfactual analysis are conservative.

4.5 Step 4: Set up the Quantitative Cost Study

In Step 4, researchers identify impact records, which are hypothesized steps or points in the delivery process where impacts on the consequent are apt to appear. In addition to identifying impact records, characteristics are selected to help filter, classify, and prioritize collected data. Step 4 and the following Step 5 are closely related, and several iterations may be necessary between these steps prior to moving to Step 6.

Selection of impact records depends on the counterfactual scenario specified in Step 2, and the process map(s) developed in Step 1 can help highlight expected impact records. One example of a direct impact record is a construction change order, where

impacts, in the form of costs, are explicit. However, impact records may also implicitly show impacts. For instance, if meeting minutes from the design phase reveal extensive discussion of an unclear process, these minutes can be translated from an indirect to a direct impact record by using an economic measure. Here, the appropriate economic measures are the meeting participants' hourly wages. Cost impacts are determined for this extensive conversation by multiplying the number of attendees at the meeting, the amount of time spent on the topic, and the economic measure (Eq. 4.4).

$$V = T * E,$$

Where

$$\begin{aligned} T &= \text{Technical Value} = \text{Number of Attendees} * \text{Time Spent on Topic (Hours)} \\ E &= \text{Economic Value} = \text{Weighted Average Hourly Wage (\$/Hr)} \\ V &= \text{Value} \end{aligned} \quad \text{Eq. 4.4}$$

Researchers' objectives for data analysis will guide their selection of characteristics to filter, classify, and prioritize their data. While not always possible, defining these characteristics prior to data collection reduces the probability of researchers having to re-process data. Filtering of data relies on clear definition of the antecedent. Filtering increases measurement reliability by helping researchers avoid measuring consequents outside the constructs of their project. Classification is intended to help support the analysis of collected data. Researchers studying project delivery may choose to classify impacts by delivery phase, stakeholder impacted, delivery phase when the impact could have been eliminated, and more detailed attributes of the antecedent (NIST 2002). Prioritization, or identifying when acting on the classifications is most beneficial, is integral to conclusions drawn from the data analysis.

4.5.1 Step 4 example

Level I and level II process maps were consulted to identify impact records for the SALA and Forest Resources buildings. Because the cost impacts being studied are those related to process transparency, process maps were especially valuable for revealing where communication and interaction were required between stakeholders. Accessible cost records were then identified by reviewing project files and by consulting with project stakeholders. Figure 4-5 shows impact records examined grouped by delivery phase.

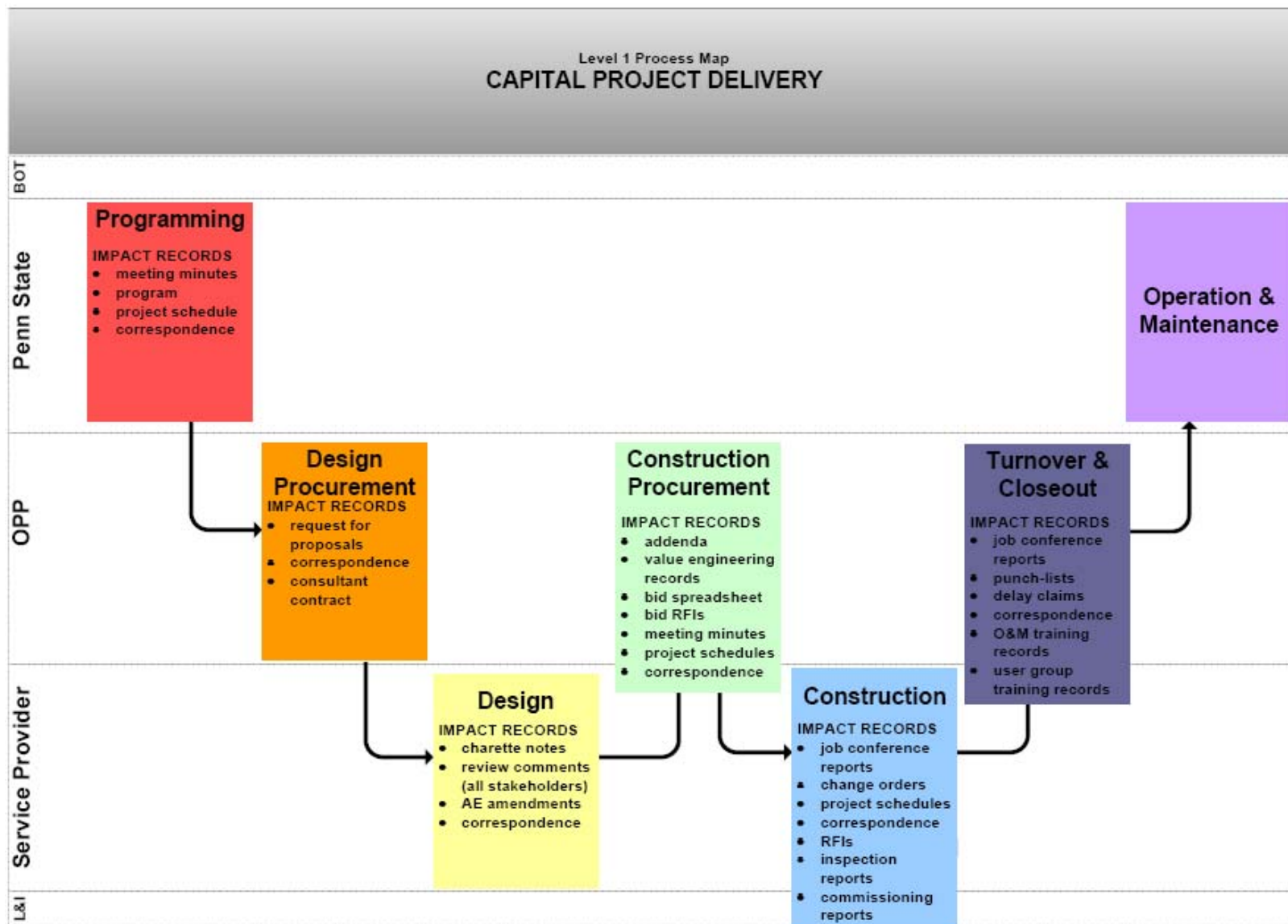


Figure 4-5: Potential Impact Records for the Counterfactual Analyses

A Microsoft Access database (Appendix B) was developed to assist with filtering, classifying and prioritizing the process transparency costs identified in the impact records for the SALA and Forest Resources projects. This filtering, classifying and prioritizing makes possible the analysis of results in Chapter 5 and the conclusions drawn in Chapter 7. The associated form used to populate the database is shown in Figure 4-6, and Table 4-3 provides descriptions for each of the form fields. Categories where classification warrants detailed descriptions are described in the following sections.

ID #			
227			
Event			
example			
Transp Attribute	Transp Type		Delivery Phase
When Avoidance?	Cost Category	Cost Record	Date
Tech Measure	Tech Value	Econ Measure	Value
	0		\$0.00
CPs	CP Impacts	Cost Impact	Assumptions
	0%	\$0.00	
Notes			

Figure 4-6: Form Used to Populate the Database of Process Transparency Cost Records

Table 4-3: Description of Process Transparency Cost Record Database Form Fields

Field	Description
Transparency Attribute	Select the attribute of process transparency that would have the greatest influence on preventing this event from occurring
Transparency Type	Classify the event as more related to organization or project transparency
Delivery Phase	Select the phase of the delivery process where the event occurred
When Avoidance?	Select the phase of the delivery process where added transparency could have prevented the event from occurring
Cost Category	Select the cost category most closely linked with the event's cost impact
Cost Record	Describe the cost record that allows determination of cost impacts
Date	Enter the date of the cost record
Tech. Measure	Enter the tech. measure (e.g., hours or units) that, along with an econ. measure, translates indirect cost records to direct cost impacts
Tech. Value (T)	Enter the numerical value of the tech. measure
Econ. Measure	Enter the econ. measure that, along with a tech. measure, translates indirect cost records to direct cost impacts
Value (V)	Multiply the tech. value and the econ. value
CPs	Define key connecting principles linking the event to a cost impact
Impact of CPs (I)	Define how the connecting principle changes the value to a cost impact
Cost Impact (C)	Use connecting principles to translate the value to cost impacts

4.5.1.1 Cost categories

Classification by cost categories based on an established measurement framework helps ensure that a more complete scope of the counterfactual analysis is measured, prevents situations where entire cost categories are overlooked and assists analysis of results. For the study of the SALA and Forest Resources buildings, costs were classified as avoidance, mitigation or delay costs (NIST 2002).

- Avoidance costs result from activities undertaken to minimize problems associated with lack of process transparency before they occur (e.g., meeting time, requests for information, approvals and design review comments).

- Mitigation costs are associated with activities required to respond to problems caused by a lack of process transparency (e.g., design or construction rework, administrative double handling, untimely stakeholder input and additional maintenance).
- Delay costs result when a lack of process transparency contributes to impeding use of the building by the owner (e.g., contract time extensions).

4.5.1.2 Transparency attribute

Cost impacts are also classified by attribute of the process transparency definition (Table 4-3). This classification increases measurement reliability by ensuring that only costs associated with process transparency are included in the consequent. The classification also allows prioritization of results based on cost impacts associated with different attributes of the process transparency definition.

- Cost impacts classified in the “recognition of status” category could have been avoided with better stakeholder understanding of the position of the process. Avoidance efforts aimed at satisfying the “recognition of status” attribute include descriptions of the process itself or demonstrations of the group’s location in the process (e.g., instructions and look-ahead schedules). SALA record #15, “Job conference project process status updates,” reflects avoidance costs associated with project process status updates during construction progress meetings. Many mitigation costs related to scope additions could have been avoided by recognition of status. For example,

SALA record #72, “Install additional tack-board surfaces throughout the building,” results from a change order during construction. Undoubtedly, some member(s) of the user group understood the need for tack boards at a point in SALA’s delivery process when avoiding the change order premium was still possible. However, an incomplete understanding of the project’s status contributed to a failure to communicate the need for tack boards prior to the construction phase.

- A subset of the recognition of status attribute is “recognition of problems,” where stakeholders not only understand the process, they can also identify areas where problems may arise. For example, stakeholders who recognize that building code approvals require multiple time-consuming steps can identify these approvals as a potential problem area for monitoring. Due to the minimal distinction between these attributes, impacts related to “recognition of problems” are classified in the more broad “recognition of status” category.
- Cost impacts classified in the “recognition of interdependencies” attribute could have been avoided had stakeholders understood how they interact with others for the process. Avoidance efforts addressing “recognition of responsibilities” include descriptions of who does what in the process, such as a responsibilities matrix. Many mitigation costs related to scope changes could have been avoided by “recognition of interdependencies.” For example, mitigation costs resulting from SALA record #97, “steel revisions per marked-up shop drawings,” could have been avoided with more effective interaction between the design team, contractor, steel detailer and steel fabricator.

- “Recognition of responsibilities” refers to stakeholders understanding their own role in the process and is a subset of the “recognition of interdependencies” attribute. Due to the minimal distinction between these attributes, impacts associated with “recognition of responsibilities” are classified in the more broad “recognition of interdependencies” category.

Cost classification is limited to the attributes contained in the “recognition” subheading of the process transparency definition. Classification is not performed by attributes contained in the “facilitation” and “enabling” subheadings. Attributes contained in these subheadings require complex connecting principles to link the antecedent (process transparency) to the consequent (cost impacts). For example, while significant cost impacts may result from more effective stakeholder communication, examining these impacts with a counterfactual analysis is impractical.

For the SALA and Forest Resources buildings, the cost impacts resulting from incomplete process transparency are typically related to multiple attributes of the process transparency definition. To address this issue, cost impacts were classified within their most closely associated attribute. The attributes of the process transparency definition are interrelated. Stakeholders must recognize the status of the process if they hope to recognize interdependencies, and vice versa. The primary reason for the classification described in this section is not necessarily to distinguish with perfect accuracy between the two attributes, but rather to filter out those costs unrelated to process transparency.

4.5.1.3 Transparency type

Imperfect process transparency may exist for a project in which there are multiple organizations involved, or it may also exist within a single organization. An owner-requested change during construction could be avoided with organizational transparency. For instance, the cost impacts reflected in SALA record #62, “upgrade elevators per PSU requirements,” could have been avoided if greater process transparency were present within OPP. Transparency is also vital on the project-level, where stakeholders work with unfamiliar groups on unfamiliar processes. Re-design costs associated with SALA record #3, “design for added faculty offices,” could have been avoided with complete process transparency between the designer, the architecture faculty, and Penn State’s administrative staff. Like the process transparency attributes, types of process transparency occur on a continuum, and costs are classified within the type of process transparency with which they are most closely associated.

4.6 Step 5: Perform the Quantitative Impact Study

In Step 5, the quantitative impact study is performed by calculating and then combining all of the impacts associated with the impact records obtained in Step 4. These combined impacts represent the difference between the counterfactual scenario and the actual scenario.

4.6.1 Step 5 example

Data collected for the quantitative cost study of the SALA and Forest Resources buildings are available in Appendix B and summarized in Chapter 5. A couple of detailed examples illustrate how the quantitative impact study was performed for this research project.

4.6.1.1 The Forest Resources locally-harvested wood example

The locally-harvested wood issue on the Forest Resources building is one example where improved process transparency could have reduced sustainable building costs. The Pennsylvania Forest Products Association was involved during the design phase and supplied wood for the Forest Resources building, including; 3,430 linear feet of base trim, 1,640 linear feet of chair rail, 4,395 linear feet of running trim, 600 linear feet of miscellaneous trim, 4,380 square feet of wood panels, 1,935 square feet of red oak ceiling, and 2,235 linear feet of door casing (Figure 4-7). This equates to over two linear miles of trim, rail, and casing, and over one-tenth of an acre of panels and ceiling. The locally-harvested wood is a relatively sustainable solution, since the wood came from local forests that have grown in size by 20% since 1995 (PFPA 2005). The locally-harvested wood example is a perfect illustration of integrated design. A stakeholder, not traditionally involved in the design process, is involved early, and the result is a sustainable solution.



Figure 4-7: Locally-harvested wood on the Forest Resources Building

Unfortunately, the locally-harvested wood example also provides a lesson-learned on the importance of process transparency for sustainable project delivery. During the construction phase, the timing of the wood products' availability on site was critical to enable completion of related work and maintain the project schedule. However, supply of the wood was based on the production schedules of the wood fabricators. Materials were delivered to the site based on convenience to the fabricator and not based on when materials were needed by the contractor. This unfortunate situation resulted in approximately \$175,000 worth of mitigation costs, which are outlined in Table 4-4.

Table 4-4: Summary of Cost Impacts Related to the Locally harvested wood Example

Record #	Description	Cost
51	Extend general conditions (general contractor) due to late millwork	\$75,000
54	Additional labor to install stringer wood	\$4,703
61	Additional labor to install wood base due to late delivery	\$5,958
116	Construction manager time extension related to late woodwork	\$89,143
Total		\$174,804

At first glance, the locally-harvested wood example appears to be a win-win situation for both the Forest Products Association and Penn State. The Forest Products Association develops their relationship with Penn State and Penn State receives a more

sustainable material for their building. Regrettably, a lack of process transparency exists, aligned with the “recognition of status” and “recognition of interdependencies” attributes of the transparency definition. The importance of material delivery and sequencing of the construction process is opaque to the Forest Products Association and the importance of the production schedule is opaque to Penn State’s project team. If either Penn State’s project team or the Forest Products Association had recognized the status of the other’s process, or if either group recognized the interdependencies between the two, \$175,000 of the costs associated with the locally-harvested wood could have been avoided.

4.6.1.2 The SALA diversified occupancy in the studios example

During delivery of the SALA building, avoidance efforts related to process transparency resulted in record #31, “diversified occupancy in the studios.” The applicable documents supporting this record are the 11/26/2001 notes from the design charrette. During the charrette, discussion occurred regarding the occupancy in the studios.

“ARUP (the designer) noted in the meeting that the PSU program generated significantly higher mechanical loads than for a facility of this type. Brian Orland (PSU representative) described how occupancy of the building responds to a teaching schedule and that the faculty did not expect the building to ever be 100% occupied. Typical occupancy predictions were predicted to be between 50% and 70%. ARUP explained how accurate, simultaneous occupancy predictions or “diversified occupancy” (rather than number of desks to be accommodated) are key to determining the capacity of the mechanical systems.”

Because the designer clarified the energy modeling process, specifically the diversified occupancy calculations, Penn State’s user group provided lower occupancy predictions that likely decreased the size and costs of the mechanical system and will lead to reduced

energy consumption for the life of the SALA building. This sustainable solution was made possible by the designer assisting the user group with their “recognition of status” of the process for energy modeling. The notes from the charette reflect an indirect record of costs in the form of time spent discussing the issue at the charette. These indirect measures were translated to direct measures using the hourly wages of the meeting participants. The resulting avoidance costs of \$500 associated with this record were a valuable investment for the SALA project team.

4.7 Step 6: Perform the Qualitative Impact Study

In this step, qualitative data is obtained from project stakeholders to supplement the quantitative data from the project records. By comparing the quantitative and qualitative data, triangulation is possible, adding rigor to the counterfactual analysis. When the quantitative and qualitative data support each other, showing similar impacts of the antecedent on the consequent, there is increased certainty in results of the counterfactual analysis. Generally, design of instruments for collecting qualitative data (e.g., surveys, questionnaires and interviews) should enable gathering of stakeholders’ opinions of the antecedent’s effect on the consequent. Obtaining data from multiple stakeholder groups contributes to a balanced view of these effects.

4.7.1 Step 6 example

To qualitatively evaluate the counterfactual delivery of the SALA and Forest Resources buildings, semi-structured interviews were used to gather stakeholders' perspectives of the impact of process transparency on sustainable building costs. This type of interview allowed the researcher to balance focus of interview questions with flexibility to probe into more detail on specific areas of interest (Fellows 1997, Sociology Central 2007). Project stakeholders were asked questions in the following categories:

- “Additional documentation” questions to ensure entire sets of available information were not overlooked;
- “Additional information” questions to supplement incomplete information in the project records;
- “Cost impact verification” questions to confirm major cost impacts identified in the review of the project records; and
- “Connecting principles verification” questions to confirm connecting principles used in the research.

Specific questions and responses from the semi-structured interviews are listed in Appendix B. In each category, initial questions were posed and related follow-up questions were asked prior to moving to the next category. This format allowed discussion and clarification of the answers provided by the respondent. In addition, the semi-structured format provided an opportunity for interview subjects to reveal costs related to process transparency that were not initially identified by the researcher (Sociology Central 2007).

4.8 Ensuring Validity

Each of the following forms of validity is addressed in the counterfactual analysis applied to project delivery. Addressing validity improves the likelihood that research conclusions represent the real-world facts (Trochim 2006).

- Conclusion validity requires a relationship between the antecedent and consequent. Threats to conclusion validity occur when there is insufficient evidence to relate the antecedent and consequent.
- Internal validity requires a causal relationship between the antecedent and consequent. Threats to internal validity occur when changes to a variable other than the antecedent is causing the changes in the consequent. Correct use of counterfactual analysis requires that the antecedent under investigation is the only variable changed (Section 3.3). This requirement eliminates confound variance, where outside variables cause changes to the consequent.
- Construct validity relies on how the antecedent and consequent are defined and operationalized to the counterfactual scenario. A primary threat to construct validity is failure to adequately define the antecedent and consequent in accordance with the research question under investigation. Completing Step 2 of the application of counterfactuals to project delivery increases construct validity.
- External validity depends on how the results from the counterfactual analysis are generalized to other projects, which may include different people, places, or times. The researcher may choose to perform additional studies that

account for these differences, demonstrate why these differences are not major threats to external validity or qualify their conclusions accordingly (Trochim 2006).

4.8.1 Ensuring validity example

Examples of how each type of validity was addressed for the study of process transparency and sustainable building costs on the SALA and Forest Resources buildings are outlined in Figure 4-8. Importantly, each validity type shown in the figure requires a “yes” answer to the preceding validity type. For instance, construct validity is inconsequential in the absence of conclusion validity.



Figure 4-8: Ensuring Validity Example (Adapted from Trochim, 2006)

4.9 Chapter Summary

Counterfactual analysis was adapted and applied to project delivery to determine whether reduced costs for sustainable buildings are possible by increasing delivery process transparency. Six general steps of this adapted method are provided along with

specific examples of their application to study the SALA and Forest Resources projects.

This application shows that counterfactual analysis is a useful strategy for developing theory regarding project delivery. The results of this application show that reduced costs for sustainable buildings are possible by increasing delivery process transparency.

Discussion and analysis of these results are provided in the following Chapter 5.

Chapter 5

Process Transparency and Sustainable Building Costs: Results and Analysis

Using counterfactual analysis to study the SALA and Forest Resources projects, it becomes apparent that reduced costs for sustainable buildings are possible by increasing delivery process transparency. For the SALA and Forest resources buildings, cost savings possible through improved process transparency exceed \$880,000 and \$460,000 respectively. Analysis of these potential cost savings leads to the following observations:

- While the majority of mitigation costs appeared during or after the construction phase of project delivery, in most cases avoidance efforts were needed during or prior to the design phase to prevent these costs;
- Costs invested in efforts to improve process transparency represent a small fraction of the costs of efforts to fix problems resulting from a lack of process transparency; and
- Lack of process transparency within an organization can result in costs in the same way as lack of process transparency within a project team.

These observations inform the efforts to enhance process transparency that are the subject of the following Chapter 6.

5.1 Cost Reductions Possible With Perfect Process Transparency

Project cost reductions possible with perfect process transparency for the SALA and Forest Resources buildings are over \$880,000 and \$460,000, respectively (Table 5-1). These cost reductions represent approximately 3% (SALA) and 1.5% (Forest Resources) of each building's design and construction costs. When estimates and assumptions were required to determine these cost reductions, the most conservative option was selected. Consequently, the cost reductions are likely understated. Further, as discussed in Chapter 7, improved process transparency may lead to desirable project outcomes in addition to decreased project costs (e.g., more sustainable buildings, better stakeholder relationships and better designs that yield greater cost reductions).

Table 5-1: Cost Reductions Possible With Complete Process Transparency

	# of Records	Cost Impact
SALA	164	\$883,444
Forest Resources	121	\$462,121

5.2 Cost Impacts by Project Phase

Costs related to a lack of process transparency for the SALA and Forest Resources buildings are displayed organized by date in Figures 5-1 and 5-2. Figure 5-3 shows project phases where costs related to a lack of process transparency were experienced and Figure 5-4 reveals the phases where avoidance efforts could have eliminated these costs. While the majority of mitigation costs appeared during the construction phase or later, in most cases, avoidance efforts were needed during the

design phase or earlier to prevent these costs. Consequently, efforts to improve process transparency seem to have greater potential when they target the earlier phases of project delivery.

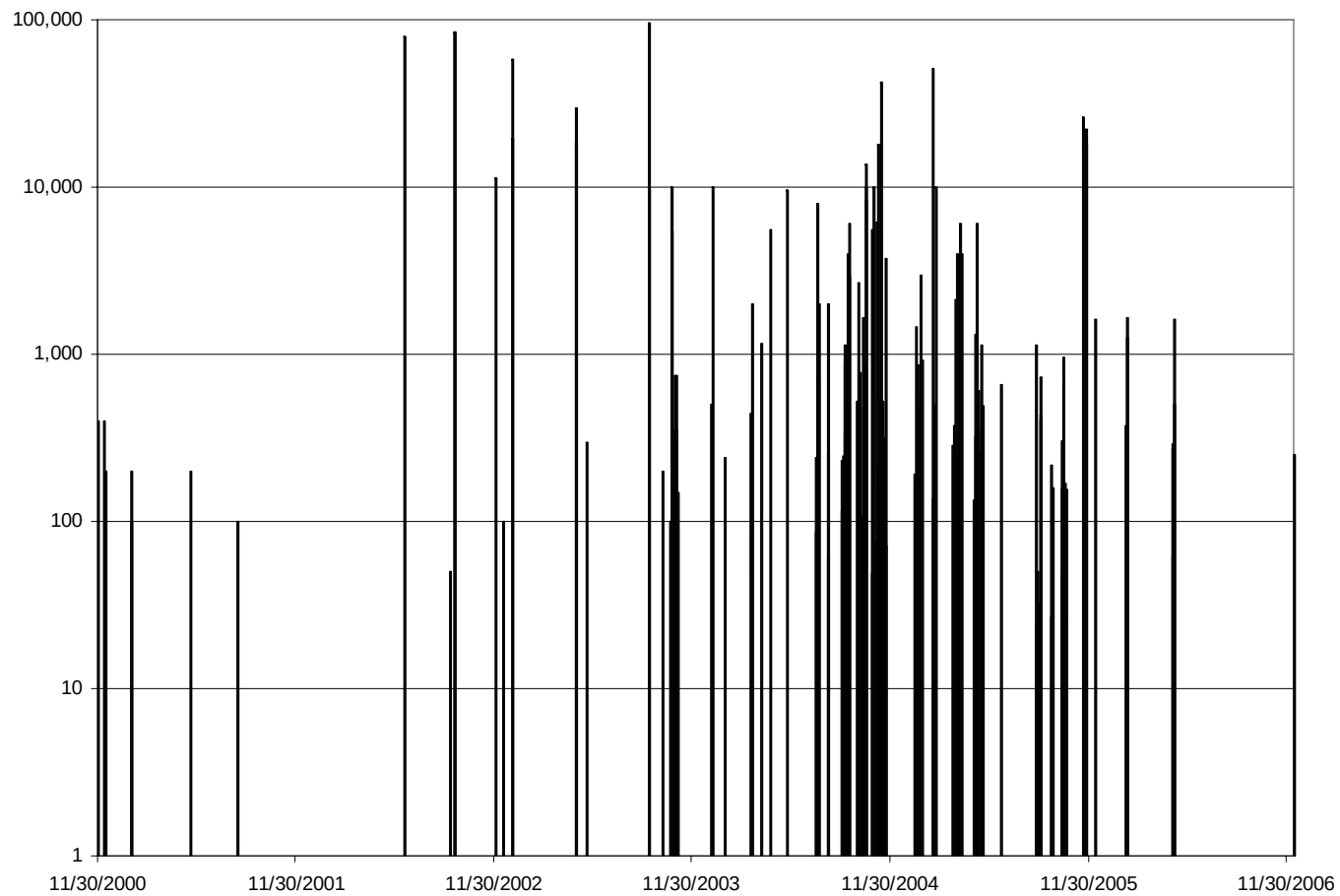


Figure 5-1: SALA Time-Series Cost Impact Data (Logarithmic scale to ensure visibility of all impacts)

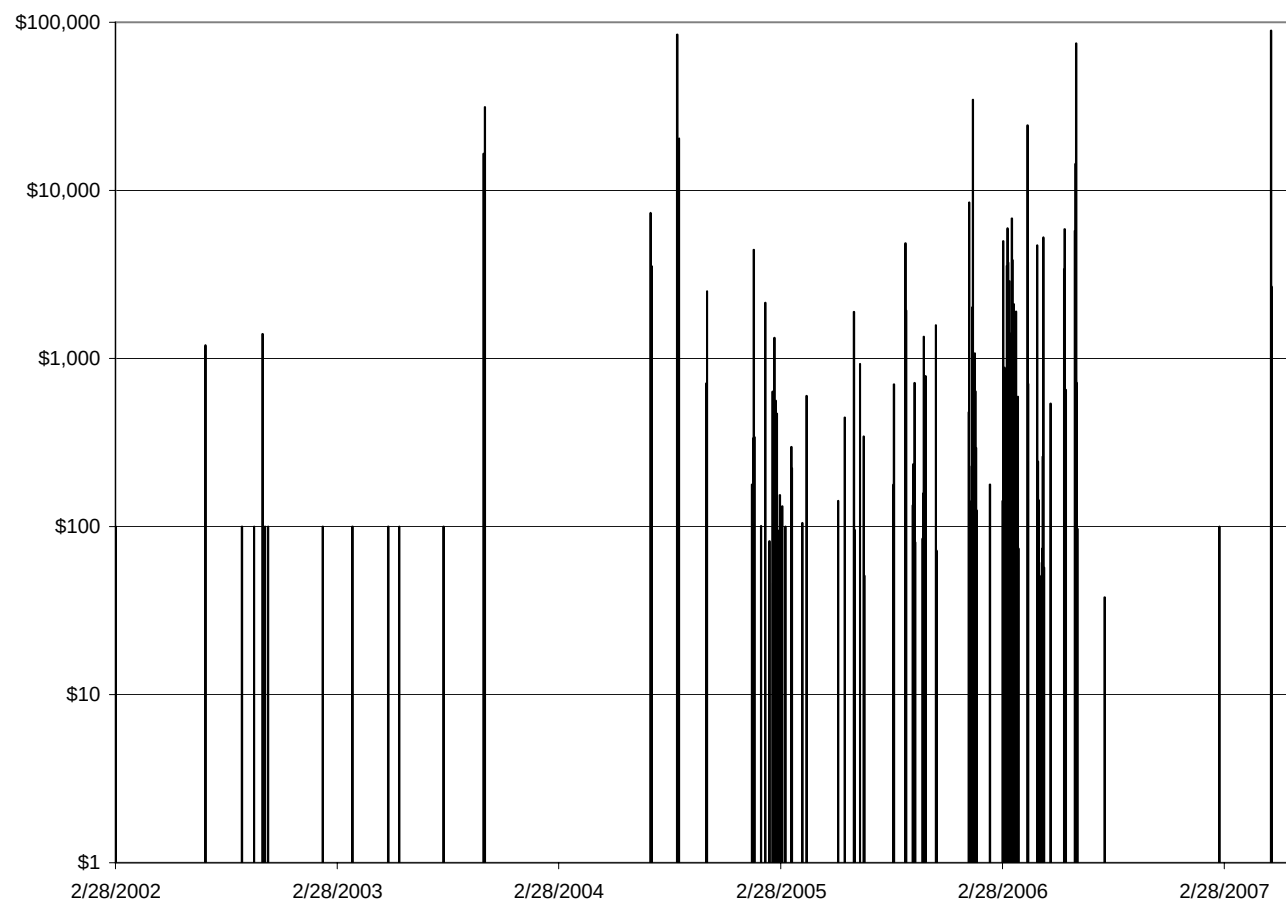


Figure 5-2: Forest Resources Time-Series Cost Impact Data (Logarithmic scale to ensure visibility of all impacts)

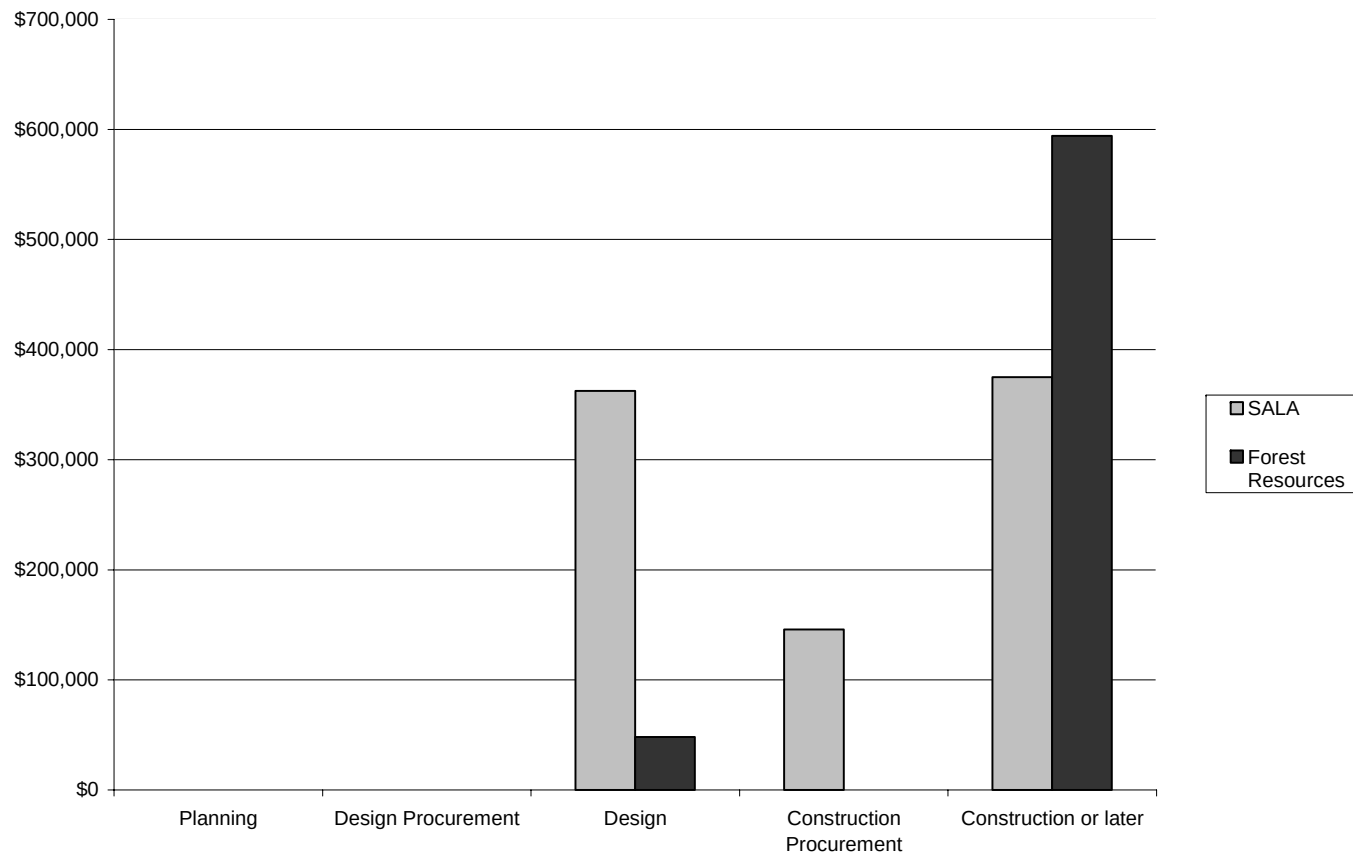


Figure 5-3: Cost Impacts by Project Phase

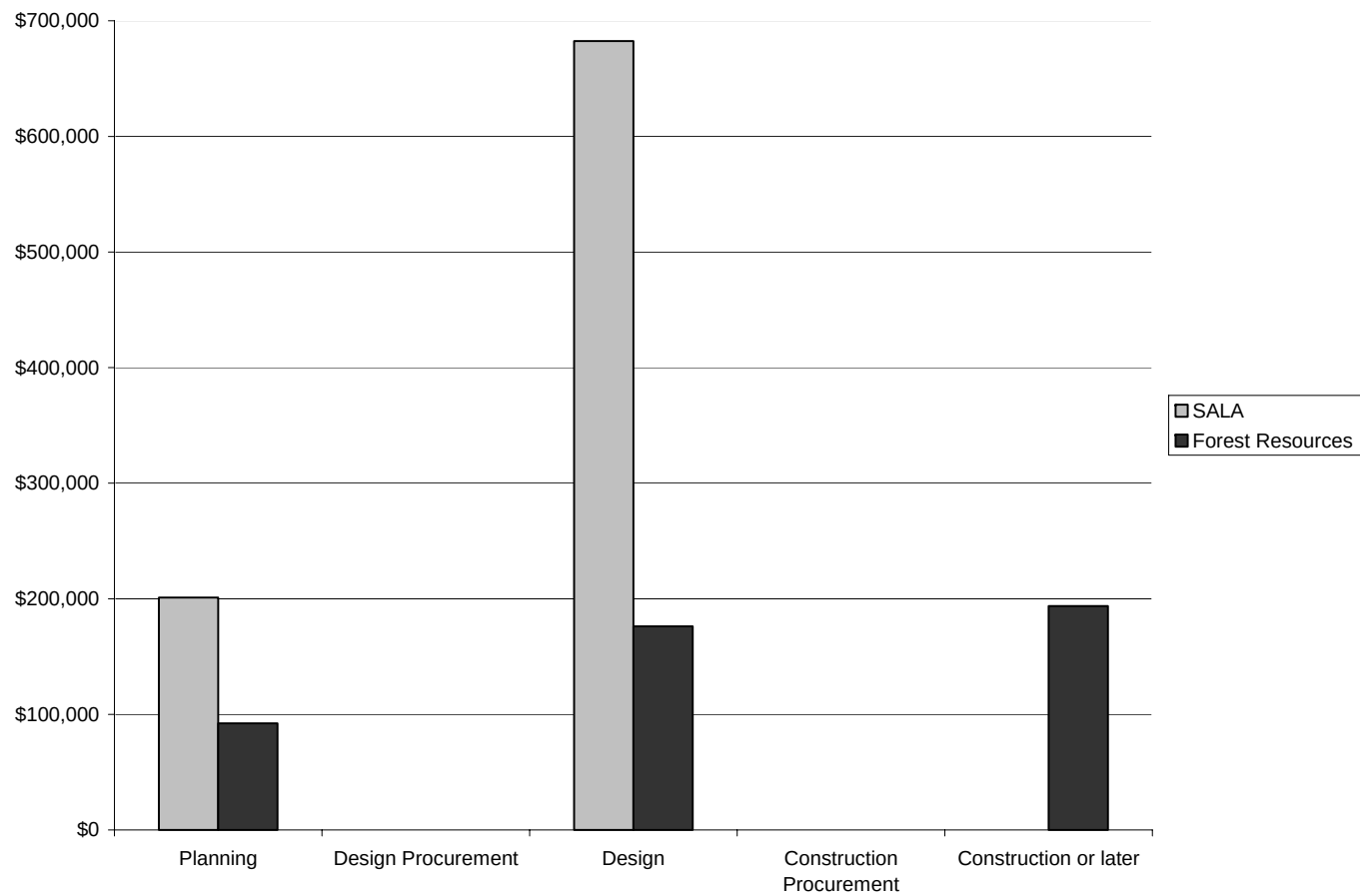


Figure 5-4: Phase Where Avoidance Efforts Could have Eliminated Costs

5.3 Cost Impacts by Cost Category: Avoidance, Mitigation and Delay

Costs related to a lack of process transparency are organized by cost category in Figures 5-5 and 5-6. Avoidance costs result from activities undertaken to minimize problems before they occur, mitigation costs are associated with activities required to respond to problems, and delay costs result when use of the building by the owner is impeded. Avoidance costs associated with activities enhancing process transparency for both the SALA (2%) and Forest Resources (17%) buildings were a small fraction of the mitigation and delay costs resulting from a lack of process transparency. Accordingly, there is vast potential to invest in avoidance efforts that can reduce mitigation and delay costs. One such effort, process mapping, is explored in Chapter 6.

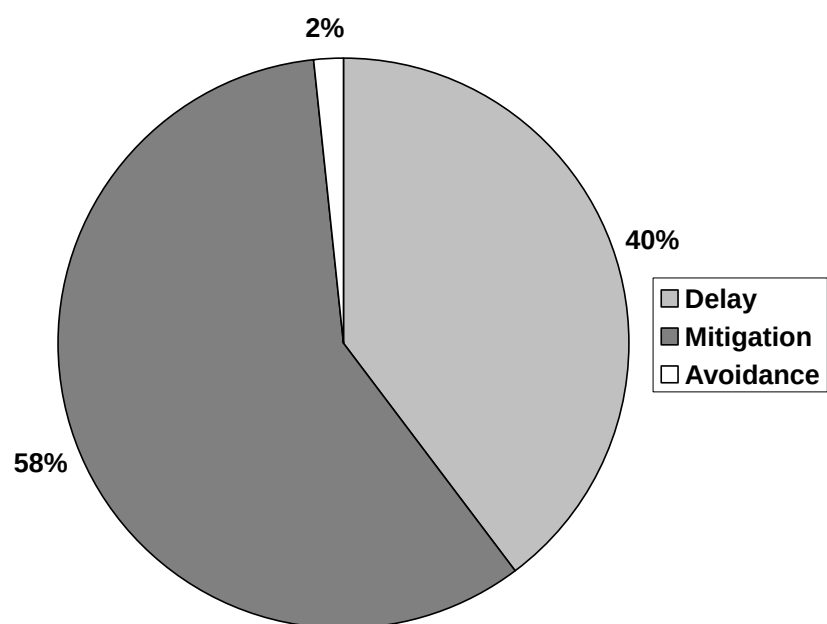


Figure 5-5: SALA Cost Impacts by Cost Category

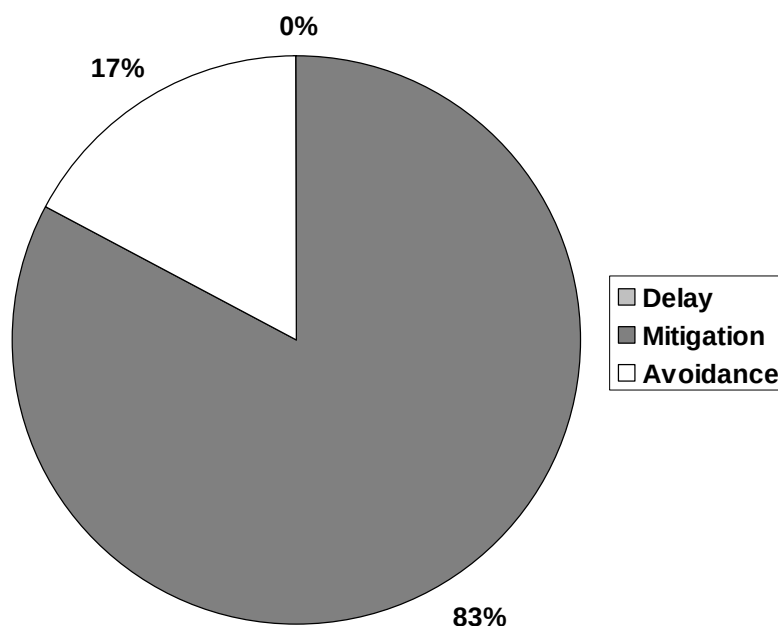


Figure 5-6: Forest Resources Cost Impacts by Cost Category

5.4 Cost Impacts by Transparency Type: Organization and Project

Imperfect process transparency may exist on a project, where multiple organizations are involved. It may also exist within a single organization. For both the SALA and Forest Resources projects, costs related to imperfect project transparency were more prevalent at 71% and 88% respectively (Table 5-2). However, each project also incurred significant costs (\$258,532 for SALA and \$54,076 for Forest Resources) related to lack of organizational transparency. So, while efforts to improve process transparency

at the project level have greater potential benefits, applying these efforts within organizations is also worthwhile.

Table 5-2: Cost Impacts by Transparency Type

Type	SALA		Forest Resources	
	Cost Impact	Percentage	Cost Impact	Percentage
Project	\$624,912	71%	\$408,045	88%
Organization	\$258,532	29%	\$54,076	12%

5.5 Cost Impact by Transparency Attribute

Cost impacts classified by attribute of the process transparency definition are shown in Table 5-3. Costs associated with the “recognition of status” attribute could have been avoided if stakeholders had understood the position of the process. To address these costs, tools such as schedules and process maps may be appropriate. Results showed 66% and 62% of costs were most related to lack of the “recognition of status” attribute for the SALA and Forest Resources projects respectively.

The remaining costs were most related to lack of the “recognition of interdependencies” attribute of the process transparency definition. Cost impacts associated with this attribute could have been avoided had stakeholders understood how they interact with others for the process. For the “recognition of interdependencies” attribute, tools such as responsibility matrices or process maps that include organizational perspective are more appropriate.

Table 5-3: Cost Impacts by Transparency Attribute

Attribute	SALA		Forest Resources	
	Cost Impact	Percentage	Cost Impact	Percentage
Recognition of Status	\$583,717	66%	\$286,988	62%
Recognition of Interdependencies	\$299,727	34%	\$175,133	38%

5.6 Chapter Summary

Cost impacts approaching \$900,000 for the SALA building and \$500,000 for the Forest Resources building confirm that reduced costs for sustainable buildings are possible by increasing delivery process transparency. Analysis of these cost impacts by project phase, cost category, transparency type and transparency attribute provides additional insight into the relationships between process transparency and sustainable building delivery. These insights inform efforts to enhance process transparency, which are the subject of the following Chapter 6, and further discussion of the practical implications of these insights are provided in Chapter 7.

Chapter 6

Enhancing Transparency with Process Mapping

The preceding chapters have described how increased delivery process transparency can lead to reduced costs for sustainable buildings. One question that logically follows this finding is, “How can process transparency be enhanced?” Responding to this question, process mapping was studied for its potential to enhance process transparency within an organization. Process maps are a tool showing the activities and procedures of organizations using pictorial images (Curtis 1992). A review of literature uncovered relationships between process mapping and the various attributes of the process transparency definition. Then, quizzes and surveys were used to study the use of developed process maps in an employee training session at OPP. For this application, process mapping enhanced transparency an average of 18%. The resources committed to this process mapping effort were valued at slightly less than \$50,000, which compares favorably to the over \$310,000 in savings possible through organizational transparency that was demonstrated in the previous chapter (Table 5-3).

6.1 Context

The study discussed in the preceding chapters shows that reduced costs for sustainable buildings are possible by increasing delivery process transparency. With this information comes a need to identify methods to enhance process transparency. In this

chapter, process mapping is examined for its potential to enhance the same process transparency that is valuable for sustainable building projects. Figure 6-1 shows this relationship.

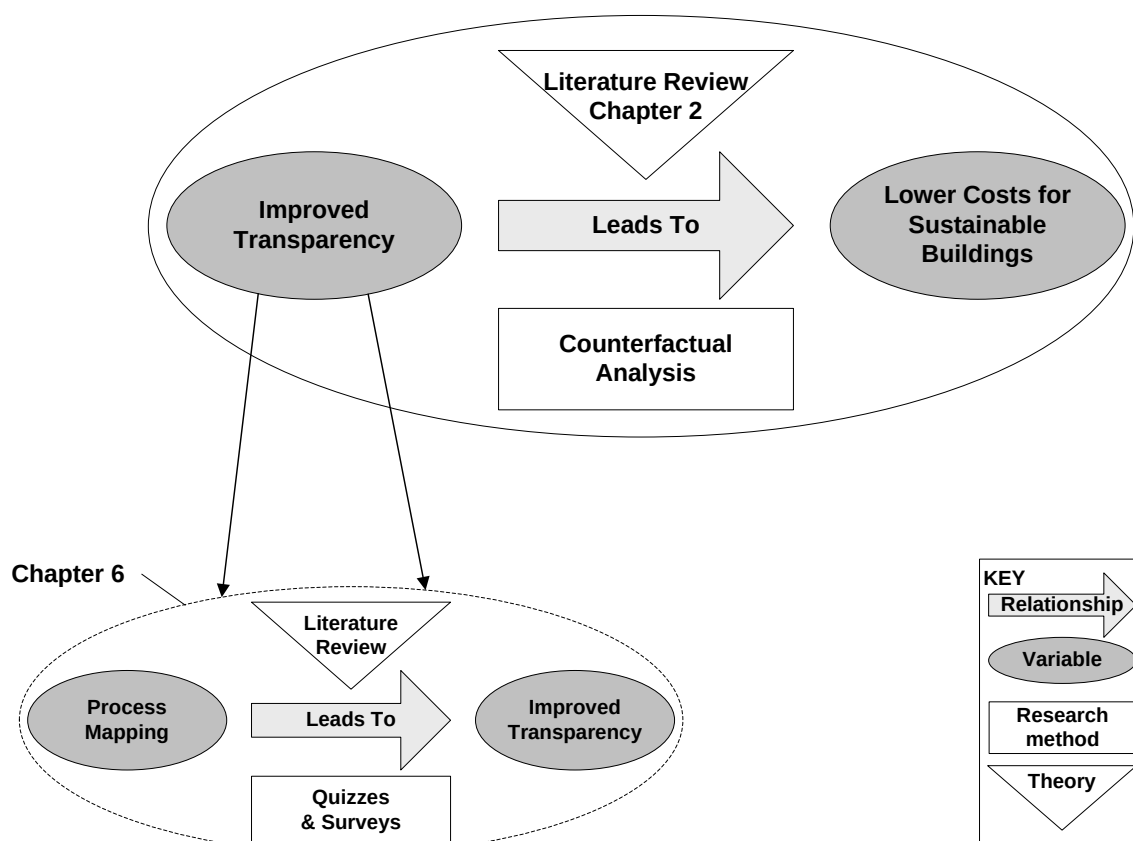


Figure 6-1: How Chapter 6 Material Contributes to this Research Project

6.2 Problem

Because reduced costs for sustainable buildings are possible by increasing delivery process transparency, there is an incentive to identify strategies that increase process transparency. One strategy is simply for project stakeholders to be aware of the

value and attributes of process transparency and therefore make a conscious effort to improve it both within their organization and on their project teams. For example, as a project nears conclusion of the design development phase, the designer could call the user group and inform them that scope changes requested after this phase will result in a cost premium.

Increasing awareness is just one strategy for improving process transparency. Specific tools with potential to add process transparency are also valuable. Schedules and responsibility matrices are example tools frequently used on building projects. However, these tools are typically used for the planning of work as opposed to the execution of work, to which process transparency is more closely related. In addition, these tools often fail to show the flow of information in a process, and seeing this flow is essential to enhancing process transparency. Finally, because their use is already widespread in current practice, these tools are unlikely to impact existing levels of process transparency.

Other industries offer helpful suggestions for enhancing process transparency. In a manufacturing environment, suggested approaches to improve process transparency include (Greif 1991, Koskela 1992):

- eliminating clutter,
- making the process directly observable through layout and signage,
- using measurements to make invisible attributes of the process visible,
- showing process information in work areas, and
- utilizing visual controls so people recognize standards and deviations from them.

When these approaches are adapted to project delivery, where work processes typically lack the physical visibility present in a manufacturing environment, a suggested first step

is to make work processes transparent by charting them (Koskela 1992). One tool frequently used for charting processes, process mapping, is examined in this chapter for its ability to enhance process transparency.

6.3 Process Mapping: A Potential Solution?

Process maps are one way to represent the activities of an organization, showing a series of events performed to complete an undertaking. Process maps provide both a “conversion view,” showing progress as a series of conversions of inputs to outputs, and a “flow view,” showing the flow of information, for the project delivery process. This flow view is essential to process transparency and is overlooked in most construction project schedules (Santos 1998, Ballard 2000). An example process map is provided in Figure 6-2.

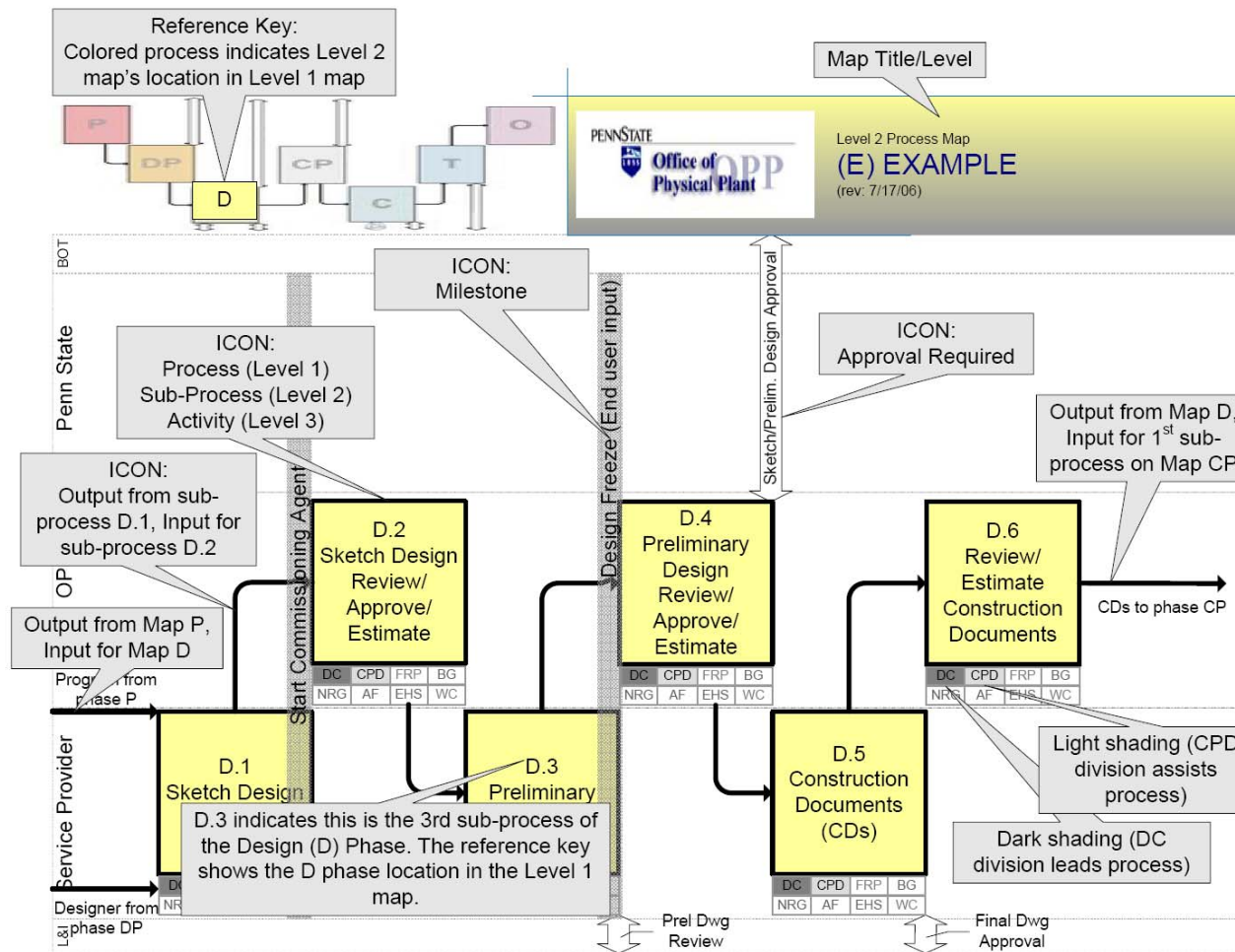


Figure 6-2: Example Process Map with Descriptions

Discussion of the benefits of process mapping frequently focuses on improvements resulting from revising processes based on improved, “future-state,” process maps (Rother 1998). In these scenarios, the original process is mapped, and the resulting map is used to identify opportunities for improving the original process. These improvements are reflected in the future-state map, which is applied to modify, and hopefully improve, the original process. These future-state benefits of process mapping are different from the value examined in this chapter, the transparency value related to development and use of the current-state maps prior to improving the processes themselves.

6.4 Research Approach

A review of literature was performed to identify relationships between process mapping and the various attributes of the process transparency definition. Then, quizzes and surveys were developed and used to study the use of the current-state process maps in an employee training session at OPP.

6.4.1 Literature review

A literature review was performed seeking evidence that process mapping may be considered as a method to enhance process transparency. While the review uncovered useful background information for the study described in this chapter, the literature shows a general need for further study of the impact of process mapping on transparency.

In fact, researchers studying process mapping recognize that empirical evidence of the benefits of process mapping is limited, regardless of whether these benefits are related to transparency (Sedera 2002, Bandara 2005).

As there is little evidence of the benefits of process mapping for general business processes, it is predictable that a similar issue exists for the construction industry where there is a significant gap in literature with respect to implementation, as opposed to design, of process models (Tzortzopoulos 2005). In response, determining actual improvements resulting from process mapping efforts is the subject of one of the three research questions resulting from the literature review of process mapping in construction (Tzortzopoulos 2005). The study at OPP helps address this research question.

6.4.1.1 Process mapping benefits related to transparency

While there is a need for further study of the impact of process mapping on transparency, existing literature does provide useful background information for this further study. References discuss, but do not demonstrate, benefits related to each attribute of the process transparency definition (Damelio 1996, Smith 1999). These references are listed in Table 6-1, categorized as refereed and non-refereed articles and by attribute(s) of the process transparency definition each reference discusses.

Table 6-1: References Showing that Process Mapping Can Enhance Transparency

	Non-Refereed	(Wreden 1998)	(Keller 1999)	(Pojasek 2006)	Refereed	(Austin 2001)	(Kagioglu 2002)	(Buchanan 1998)	(Vakola 2000)
Recognition									
of status			x	x			x	x	x
of problems			x					x	x
of responsibilities		x	x	x				x	
of interdependencies		x	x	x				x	
Facilitation									
of system performance understanding								x	x
of feedback on performed activities			x						
of effective communication						x	x		x
Enabling									
decision making				x					

6.4.1.2 Refereed articles

Refereed articles provide evidence of the impact of process mapping on transparency. Related benefits are identified in studies of organizational learning in construction organizations and in case-study research of a hospital environment.

Similar to construction projects, responsibilities in hospitals are fragmented, and workers frequently focus only on the activity within their particular occupational group (Buchanan 1998). In addition, hospital staff members typically function independently in their dealings with patients (Buchanan 1998). Process mapping helps mitigate these issues and observed benefits directly related to attributes of the process transparency definition include “recognition of status,” “recognition of problems,” “recognition of

responsibilities,” “recognition of interdependencies,” and “facilitation of system performance understanding.”

Reinforcing the hospital case study, literature from the construction industry discusses how process mapping impacts transparency. Several of the espoused construction industry benefits of process mapping listed in Table 6-2 are directly related to attributes of the process transparency definition, including better communications, better and more-timely information exchanges, and reduction of errors and rework. The first two are related to “facilitation of effective communication” and the third is related to “recognition of problems.”

Table 6-2: Espoused Benefits of Process Mapping (Adapted from Tzortzopoulos 2005)

Organization	Process	Client
Competitiveness	Less time and costs	Better product quality
Consistency through replication	Better planning	Fitness for purpose
Optimize predictability	Better and timely information exchanges	Delivered on time
Support partnering and contractual agreements	Better communications	Delivered to cost
Basis for IT systems	Reduce errors and rework	
Educate new employees	Benchmark for improvement	

In another construction industry study where process maps were used during design, the contribution of process mapping to transparency is explicitly recognized:

“Process mapping has also been used as a means of illustrating the various processes and information flows within the design and construction process and has proved to be beneficial in terms of transparency (Kagioglou 2002).”

However, the origins of this quotation, while valuable in shaping this research, do little to diminish the need to investigate the transparency-related benefits of process mapping.

The most relevant study forming the basis of this quotation is related to the “facilitation of communication” attribute of the process transparency definition. In this study, the

benefits of following process maps to guide a design process were evaluated for three groups in a design competition, with one group using maps rigidly, one using maps as a reference, and one not using maps at all. The primary benefit for the team using the maps rigidly was an improvement in team atmosphere (Austin 2001).

The influence of process mapping on organizational learning in construction organizations has also been studied (Vakola 2000). Case studies of three construction organizations found they were initially unclear of their existing processes, and all three organizations eventually realized benefits from mapping these processes. Process mapping provided an “overall overview of their processes and facilitated the identification of potential weaknesses” (Vakola 2000). This statement is related to the “recognition of status,” “recognition of problems” and “facilitation of system performance understanding” attributes of the process transparency definition. The three construction companies also realized benefits related to the “facilitation of communication” attribute of the process transparency definition as one effect of the process mapping was “improved process and information communication within these companies” (Vakola 2000).

6.4.1.3 Non-refereed articles

Evidence of the impact of process mapping on transparency is present in articles discussing companies, including Deloitte Consulting, Cambridge Management Consulting, Taro Pharmaceuticals, and Farmer’s Insurance. Even though the articles providing this evidence are not refereed, the information provided is still valuable. Both

Deloitte Consulting and Cambridge Management Consulting realized process mapping benefits similar to the “recognition of responsibilities” and “recognition of interdependencies” attributes of the process transparency definition (Wreden 1998). Taro Pharmaceuticals also realized immediate benefits from process mapping that included increased awareness of the impact of one operation on another and reduced instances where no one is performing a task because they think others are (Wreden 1998). Process mapping at Farmer’s Insurance also had transparency-related benefits. The benefits identified at Farmer’s are related to attributes of the process transparency definition including “recognition of status,” “recognition of problems,” “recognition of responsibilities,” “recognition of interdependencies,” and “facilitation of feedback on performed activities” (Keller 1999). A management consultant specializing in programs for sustainability also recognizes the impact of process mapping on transparency (Pojasek 2006). Process mapping is considered a valuable communication tool, aligned with the “facilitation of effective communication” attribute of the process transparency definition and other transparency-related benefits are similar to the “recognition of status,” “recognition of responsibilities,” and “recognition of interdependencies” attributes of the transparency definition. Evidence of benefits related to the “enabling decision-making” attribute is also provided:

“It (process mapping) is a vehicle for expressing and releasing the knowledge, creativity, and energy that reside within every group of employees, regardless of their position or level within the organization (Pojasek 2006).”

6.4.2 Research study

Based on the literature review, there is an opportunity for contribution by studying the impact of process mapping on transparency. The research method described in this section is designed to serve two purposes. First, an example for each step of the method demonstrates how the study of organizational process transparency at OPP was performed. Second, the underlying concept for each step of the method is explained so other organizations can utilize the method to study their own process mapping efforts.

6.4.2.1 Step 1: Develop process maps

A process mapping protocol was developed to add structure and consistency to OPP's ongoing mapping efforts. Existing literature, OPP input, and researchers' experiences contributed to the Lean and Green (L&G) modeling protocol (Klotz 2007). Using this protocol, overview (macro-level) maps and more-detailed (micro-level) maps were developed at OPP. An example map is provided in Figure 6-2, and additional maps are available to OPP employees and the public on OPP's website⁴.

Following a similar procedure to the map development in Step 1 of the application of counterfactual analyses to project delivery (Section 4.2), micro-level map development began with a review of applicable documents, including organizational procedure manuals, standard forms, project records, and schedule templates. Next, multi-

⁴ <http://www.opp.psu.edu/about/divisions/dc/manual/index.html>

disciplinary teams were formed consisting of participants familiar with the process being mapped. These groups helped create the micro-level maps for the associated process.

Step 1 General Concept: The organization selects an existing mapping method or develops its own and applies this method to create its process maps.

6.4.2.2 Step 2: Develop quizzes

After the maps were created, quizzes were developed with each question testing a unique attribute of the process transparency definition (Table 4-3). For example, the question, “Which of the following project phases is led by OPP’s Design and Construction division?” tests OPP employees’ “recognition of responsibilities.” For each of three different process maps, two quizzes (Quiz A and Quiz B) of approximately equal difficulty were developed. Appendix C shows these quizzes along with comments demonstrating the attribute of the process transparency definition each question tests. Quizzes were reviewed by upper-level managers at OPP and pilot tested by OPP employees not involved in the research study.

Step 2 General Concept: Development of an objective measure, quizzes, will enable testing of the impact of process mapping on the dependent variable under examination.

6.4.2.3 Step 3: Develop surveys

To supplement the quizzes, surveys were also developed, with each question soliciting perceptions on a different attribute of the process transparency definition. For instance, users' perceptions of their "recognition of responsibilities" were collected with the question: "How much did the review of process maps contribute to an understanding of your role in OPP processes?" The survey questions utilized a Likert scale ranging from 1 (none) to 5 (a lot). Appendix C shows these surveys marked-up with a description of the attribute of the process transparency definition each question tests. As with the quizzes, surveys were reviewed by upper-level managers at OPP and pilot tested by OPP employees not involved in the research study.

Step 3 General Concept: Developing a subjective survey enables gathering of opinions on the impact of process mapping on the dependent variable. Combining results from the subjective survey and the more objective quizzes provides greater certainty of the impact of process mapping on the dependent variable under investigation.

6.4.2.4 Step 4: Administer quizzes and surveys

The use of process maps in employee training at OPP was studied. Fourteen OPP employees attended the training session, and the impact of process mapping on transparency was examined for a macro-level process map, representing OPP's entire building delivery process, and for two different micro-level maps, representing OPP's contracting process and project close-out process. For each process map, half of the training participants completed Quiz A prior to reviewing the map and Quiz B after

reviewing the map, while the other half of the participants completed the quizzes in the opposite order. All participants also completed the subjective survey after reviewing each map.

Step 4 General Concept: To evaluate the impact of process mapping on transparency, the quizzes are administered to participants before and after a meeting where current-state process maps are developed or used. The quizzes should be close to equal in difficulty, so that differences in the before and after quiz scores represent the transparency difference and not a difference in quiz difficulty. To account for any remaining difference between the two quizzes, half of the meeting participants complete one quiz prior to the meeting and the other quiz after the meeting. The other half of the meeting participants complete the quizzes in the opposite order. At the conclusion of the meeting, all participants complete the subjective survey.

6.5 Results and Analysis

The study at OPP demonstrated that review of process maps in employee training enhanced overall process transparency. . Generally, for each attribute of the transparency definition, the total correct answers on the quiz taken prior to using process maps in the training session are compared to the total correct answers on the post-training quiz. For instance, if there are 5 correct answers to the question related to “recognition of status” on the pre-quiz, and 7 correct answers to the corresponding question on the post-quiz, the associated percentage increase would be $(7-5)/5$, or 40%. To show a comprehensive view of all attributes of the transparency definition, radar plots are utilized comparing pre-quiz

performance (dashed lines on Figures 6-3, 6-4 and 6-5) to post-quiz performance (solid lines on Figures 6-3, 6-4 and 6-5) for all attributes of the transparency definition.

Review of the macro-level capital project delivery (Figure C-1) process map resulted in a 5% increase in transparency. Review of the micro-level close-out (Figure C-2) and contracting (Figure C-3) process maps resulted in transparency increases of 27% and 20%, respectively. Further, the subjective data for all three process maps show that employees perceived the process mapping as positively impacting transparency.

Table 6-3 shows a summary of transparency enhancement by attribute and process. Notably, “recognition of status” and “recognition of interdependencies” were enhanced by 43% and 10%, respectively. This increase is potentially valuable as imperfect amounts of these attributes resulted in substantial cost impacts to the SALA and Forest Resources projects.

Table 6-3: Summary of Transparency Enhancement by Attribute and Process

	Capital	Close-out	Contracting	Avg.
<i>Recognition</i>				
of status	0%	80%	50%	43%
of problems	-33%	25%	0%	-3%
of responsibilities	0%	33%	43%	25%
of interdependencies	-29%	-40%	100%	10%
<i>Facilitation</i>				
of system performance understanding	-22%	57%	-57%	-7%
of feedback on performed activities	41%	16%	8%	21%
of effective communication	59%	26%	16%	34%
<i>Enabling</i>				
decision making	27%	16%	5%	16%
Avg. Enhancement	5%	27%	20%	18%

6.5.1 Objective quiz results

The first process map reviewed in the training session at OPP was a macro-level map representing the capital project delivery process (Figure C-1). As shown in Figure 6-3, the points on the radar plot related to the post-quiz are farther away from the center of the plot, on average, than the points related to the pre-quiz. Therefore, it appears that transparency has increased after the training using the process maps. Comparing the before and after points for each attribute shows increases in the scores for “facilitation of communication,” “facilitation of feedback” and “enabling decision making.” Notably, “recognition of problems,” “recognition of interdependencies” and “facilitation of system understanding” all decreased after using the process map. This inconsistent result is discussed further at the end of this section.

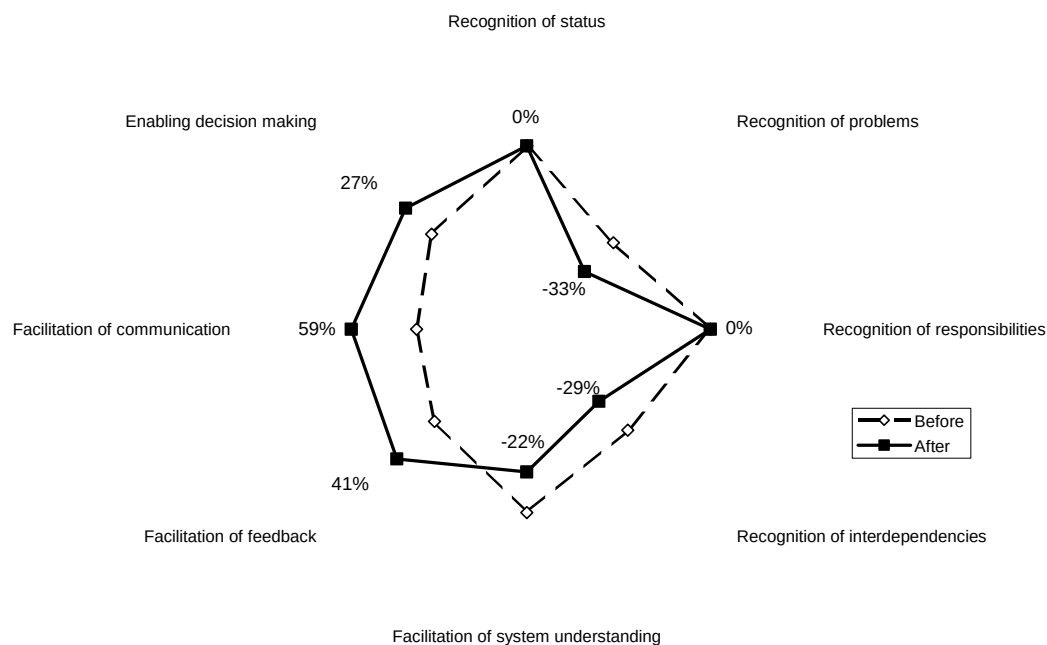


Figure 6-3: Percent Enhancement of Transparency by Attribute (Capital Project Process Map)

Next, the micro-level map showing the closeout process was reviewed (Figure C-2). As shown in Figure 6-4, all of the points on the radar plot related to the post-quiz (with the exception of “recognition of interdependencies”) are farther away from the center of the plot than the points related to the pre-quiz. Therefore, it appears that transparency has increased after the training using the process maps.

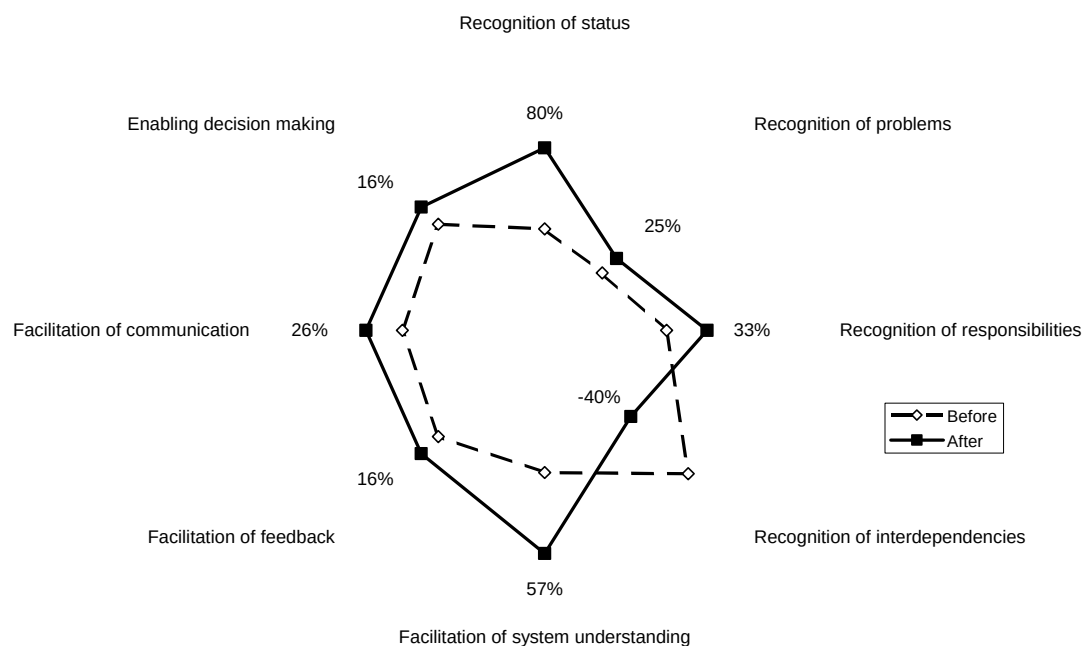


Figure 6-4: Percent Enhancement of Transparency by Attribute (Close-out Process Map)

Finally, the micro-level map showing the contracting process was reviewed (Figure C-3). As shown in Figure 6-5, all of the points on the radar plot related to the post-quiz (with the exception of “facilitation of system understanding”) are farther away from the center of the plot than the points related to the pre-quiz. Therefore, it appears that transparency has increased after the training using the process maps.

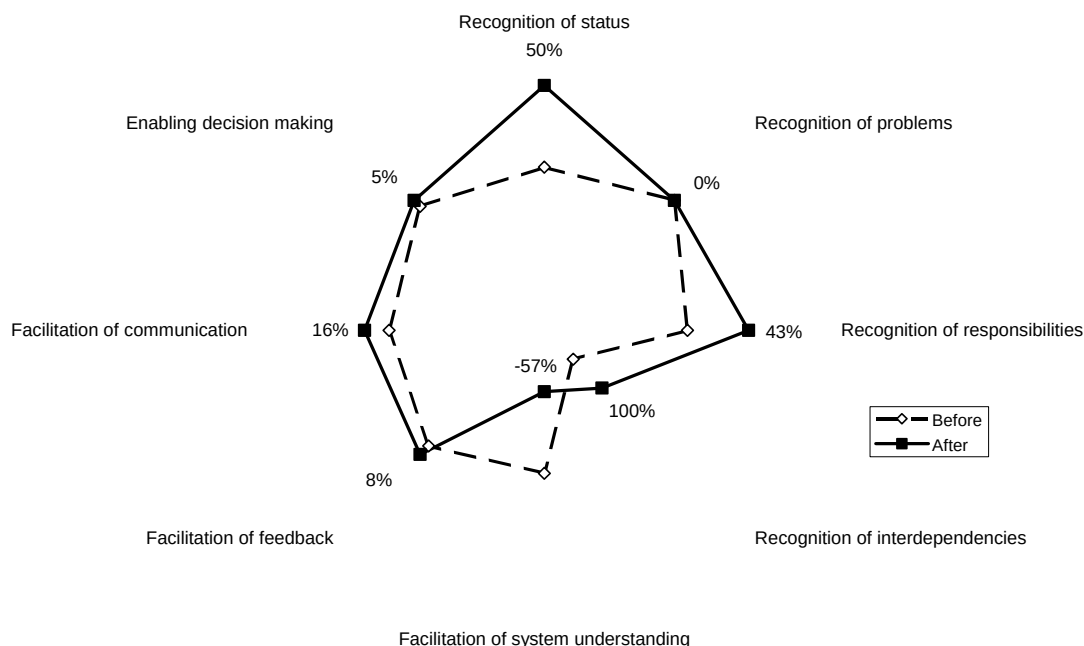


Figure 6-5: Percent Enhancement of Transparency by Attribute (Contracting Process Map)

As stated previously in this section, there were several instances where process transparency appeared to decrease after using the process maps. For the closeout and contracting process maps, where only one attribute of the definition decreased (Figures 2 and 3), the inconsistency is probably a result of random variability. This variability could be reduced by increasing the number of questions related to each attribute of the transparency definition and increasing the number of participants in the study. For the capital project delivery process map, three of the transparency definition attributes decreased after the training session (Figure 4), which may be due to differences in pre-quiz and post-quiz questions. One attempt to account for these differences was to require

half of the meeting participants to complete one quiz prior to the meeting and the other quiz after the meeting, while the other half of the meeting participants complete the quizzes in the opposite order. However, for the study at OPP, one of these groups of participants had a much different background than the other and was therefore better able to answer questions related to their background, regardless of whether they had seen the process maps yet or not. This variability could be reduced in future studies by ensuring the groups have similar backgrounds to each other.

6.5.2 Subjective survey results

The results from the subjective survey confirm the objective quiz results for each of the process maps used in the training session. For the capital project delivery process map, employees perceived an increase in transparency of 3.8 (between 3 – “somewhat” and 5 – “a lot”). For the contracting and close-out process maps, the subjective survey shows a perceived increase in transparency of 3.7. Data collected from the subjective survey adds certainty to the conclusions drawn from the objective quiz results. The average perceived transparency enhancement, organized by attribute of the process transparency definition is shown in Figure 6-6.

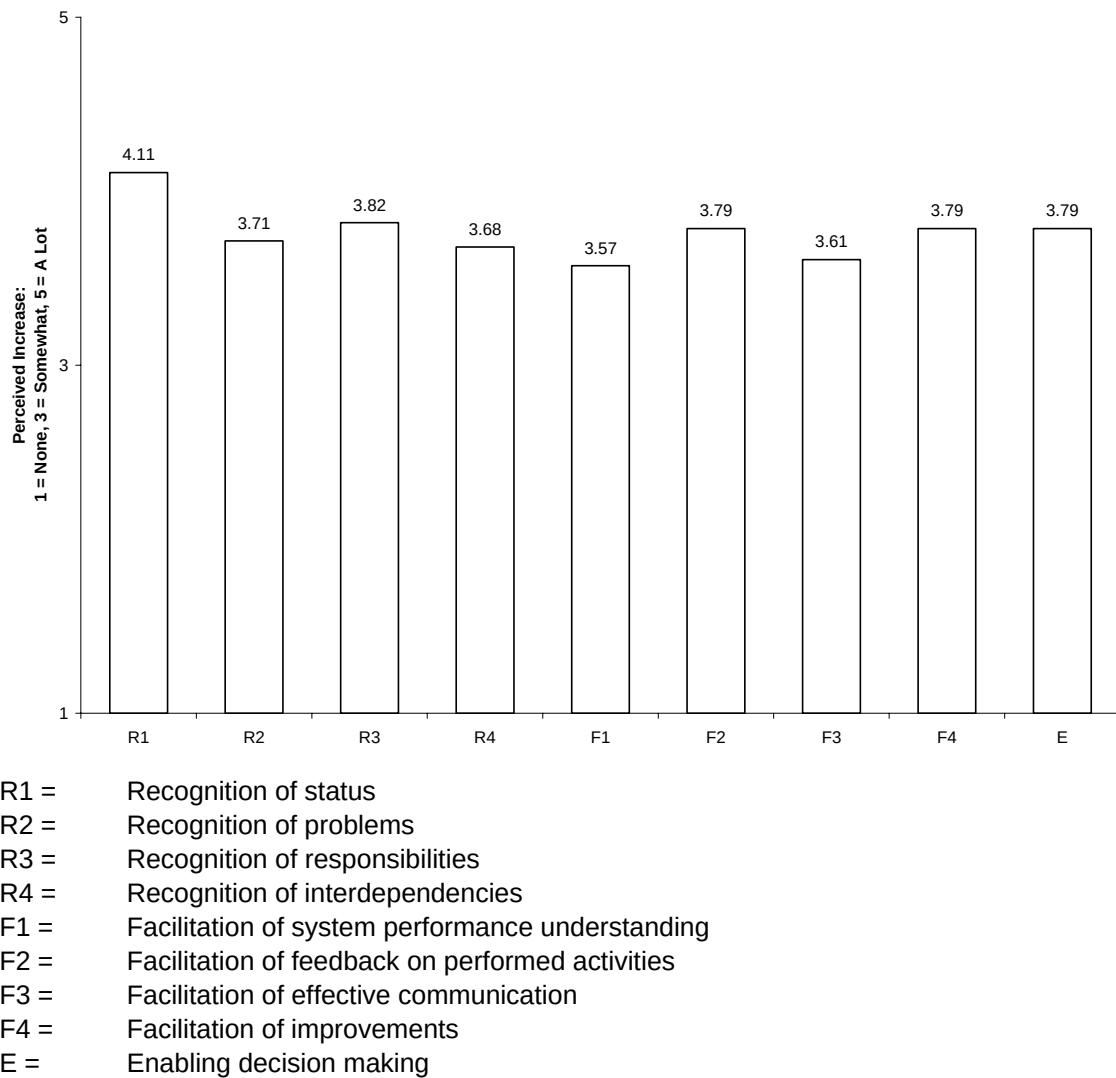


Figure 6-6: Perceived Enhancement of Transparency by Attribute

6.5.3 Process mapping feasibility analysis

Based on the study at OPP described in this chapter, process mapping may be considered as one method to enhance process transparency. However, additional questions remain. Does process mapping cost less than imperfect process transparency?

Could process mapping create a larger problem than imperfect process transparency? Is process mapping faster than alternative solutions to the process transparency problem? Is process mapping less expensive than alternative solutions to the process transparency problem (Booth 2003)? These following sections address these questions.

6.5.3.1 Does process mapping cost less than the problem it is meant to address (imperfect process transparency)?

The estimated cost of the process mapping effort to date at OPP is just under \$50,000 (Table 6-4). This cost estimate assumes the researcher and organization begin with a basic understanding of process mapping, otherwise slightly higher costs are expected.

Table 6-4: Cost Estimate for OPP's Process Mapping Effort

Map Type	Hours Invested by Employee Title								
	Qty	D	AD	PM	CQ	CA	A	M	R
L1 Draft	1	1							3
L1 Final	1	1		1					3
L2 Draft	7	7		7					21
L2 Final	7	2		7					14
Micro Draft	31	31	31	62	31	31	31	31	93
Micro Final	31	31	31	62	31	31	31	31	93
Total Hrs		73	62	139	62	62	62	62	227
Wage/Hr		\$100	\$75	\$75	\$75	\$50	\$35	\$50	\$50
Cost		\$7,300	\$4,650	\$10,425	\$4,650	\$3,100	\$2,170	\$3,100	\$11,350
Total Cost									\$46,745

Employee Titles

- D = Director
- AD = Assistant Director
- PM = Project Manager
- CQ = Construction Quality Representative
- CA = Contract Administration
- A = Administrative Staff
- M = Miscellaneous
- R = Researcher

It is difficult to determine whether enhancing process transparency between 5% and 27% is worth the \$50,000 investment for a single project such as the SALA or Forest Resources building. However, the results of the counterfactual analyses for the delivery of these projects, summarized in Table 5-3, demonstrate that OPP could have avoided over \$250,000 (SALA) and \$50,000 (Forest Resources) with perfect organizational process transparency. Further, the developed process maps are applicable to multiple projects. Extrapolating the results from SALA and Forest Resources to Penn State's current five-year Capital building plan reveals a \$5-million savings possible through increased organizational process transparency (OPP 2007). Finally, this research examines only the impact of reviewing maps in training on transparency. Other benefits potentially realized through process mapping are not considered.

6.5.3.2 Will process mapping create a bigger problem?

The process mapping effort at OPP was not observed to cause any problems. Organizations may be concerned that, by understanding their processes, competing organizations may gain an advantage. In fact, this concern is more likely to result in ancillary benefits by helping organizations work better with others and enabling efficiencies for both. Further, this concern has limited applicability for OPP which, as an administrative component of a public institution, has limited competition.

6.5.3.3 Is process mapping better than alternative solutions?

This question is difficult to answer definitively. Process mapping was selected as a solution to investigate based on suggestions in the literature and because mapping was already partially underway at OPP. Minimal effort went into evaluating whether this particular use of process mapping was the best possible way to enhance transparency. There are other ways to use process maps and there are tools in addition to process mapping that will enhance process transparency. In fact, OPP employees completed subjective surveys after more traditional training modules that did not incorporate process maps. The subjective results from these training modules show process transparency increases that were similar to the increases achieved by modules that incorporated process maps (Tables C-2 through C-5). Additional research could examine other ways to enhance transparency.

6.6 Conclusions and Implications

In this section, conclusions and implications related to process mapping as a method to enhance process transparency are discussed⁵. When evaluating conclusions based on the research described in this chapter, the following limitations should be considered.

1. In this research study, it was assumed that better understanding and recall of OPP's processes equate to higher transparency. This assumption is required when

⁵ Conclusions related to decreased sustainable building costs possible through increased delivery process transparency are included in the following chapter.

using quizzes and surveys to collect the information related to transparency. To eliminate the need for this assumption, researchers would have to devise another method to measure transparency.

2. The empirical portion of this research study was limited to one field test in one organization (OPP), three process maps (capital project delivery, contracting, and close-out), one mapping protocol (L&G mapping protocol), and one group of people (the 14 employees who attended the training). These scope limitations should be considered prior to extrapolating the results of this study to other organizations. This study was intended to show that process mapping may be considered as one method to enhance process transparency. It was not intended to show definitively the impact of process mapping on transparency for all applications in all organizations.
3. This research study only examined map use within an organization. Process mapping as a method to enhance process transparency was not tested in a project team⁶.

Two principal contributions result from the research described in this chapter. Each of these contributions is related to showing benefits of current-state process maps. In many organizations, development of process maps is an intermediate step in process improvements. For instance, in Lean production's Value Stream Mapping (VSM) method, development of a current state process map provides a basis for analyzing the

⁶ A study was attempted within a project team on an OPP project, but is not included here because it was administered by the project team leader and not the researcher, which may have introduced bias into the results. The results from this study are available in Appendix C.

existing process, developing an improved, future-state map, and realizing benefits when implementing the future-state map (Hines 2000). The value of process mapping as an intermediate step leading to process improvements is accepted broadly (Rother 1999, Womack 2003). However, understanding the value of process map development prior to implementing any improvements is also valuable as organizations currently have minimal evidence that their process mapping investment will have short-term benefits. The mapping of processes within an organization requires a significant investment of resources, and quickly demonstrating a return on this investment can justify further investment and motivate organizations to proceed to the later steps of their process improvement efforts. The two primary contributions of the research described in this chapter are as follows.

1. By showing that process mapping may be considered as a method to enhance process transparency, evidence is provided supporting one short-term benefit of process mapping. The results from the study at OPP add to the limited body of knowledge on the early-stage benefits of process mapping. This contribution has implications for OPP. Prior to this study, evidence showing the benefits of process mapping at OPP was limited to employee speculation. With the completed study, empirical evidence showing transparency benefits helps justify process mapping and provides incentive for OPP to proceed to the later steps of its mapping efforts.
2. The method outlined in this chapter provides a way to measure the impacts that mapping an organization's processes and then using these maps to communicate the organization's business processes have on individual employees' understanding and recall of those business processes. This method is designed to

be straightforward to assist other organizations evaluating the early stages of their process mapping efforts.

6.7 Chapter Summary

Because reduced costs for sustainable buildings are possible by increasing delivery process transparency, tools that enhance process transparency have value. Process maps were developed and their use was studied for its impact on process transparency. Based on quizzes and surveys administered in an employee training session at OPP, process mapping enhanced transparency on average. Consequently, process mapping may be considered as a method to enhance process transparency.

Chapter 7

Conclusions

The application of counterfactual analysis to building project delivery demonstrates that reduced costs for sustainable buildings are possible by increasing delivery process transparency. Further, use of process maps in training is a viable method for enhancing process transparency. These results show the value of stakeholders' being aware of and striving to enhance process transparency in the delivery of sustainable building projects. These results also generate additional research questions regarding the applicability of process transparency to other types of sustainable projects and other methods to enhance transparency. Conclusions resulting from this research study are organized here in the following categories:

- Limitations that reveal the types of conclusions readers can reasonably draw from this research;
- Theories developed based on the primary relationships identified between research variables;
- Intellectual merit related to aspects of this research that, while only tangentially related to the relationships between variables, are of academic interest;
- Practical implications of potential interest to industry and other researchers;
- Broad impacts that include widespread, longer-term, and indirect implications of the research project; and

- Possible future research that was uncovered by performing the current research project.

7.1 Limitations

The limitations of this study inform the types of conclusions that can reasonably be drawn from this research. In addition, by discussing limitations of the counterfactual analysis, the “cognitive consistency bias” criterion for rigorous counterfactual analyses is addressed. This research develops the theory that reduced costs for sustainable buildings are possible by increasing delivery process transparency, but the research is not intended to show definitively the magnitude of this relationship. The counterfactual method and narrow breadth of the study do not support detailed conclusions, such as “increasing process transparency by 75% can decrease the costs to deliver a sustainable building by 10%.” Recognizing that this research is aimed at developing theory is the overarching tactic for addressing the following research limitations.

1. Cost reductions possible for sustainable buildings related to process transparency are probably understated. Whenever assumptions were required to perform the counterfactual analysis, selection of the conservative option ensured that the resulting cost magnitude was also conservative. Several other factors also contribute to the understatement of cost impacts and therefore help validate generalization of the primary results of this study, that reduced costs for sustainable buildings are possible by increasing delivery process transparency, to

other capital projects. Primary factors contributing to the understatement of cost impacts are as follows:

- a. Operations costs resulting from a lack of process transparency are excluded from this study. Many hypothesized benefits related to enhancing process transparency occur in the operations phase of the project. For instance, process transparency can help ensure that user groups understand how to operate their new building. However, due to a lack of data availability, these operations costs are excluded, contributing to the understatement of cost impacts.
- b. The objective data collection was performed using existing project files, which provide an incomplete view of costs experienced on the project. For example, inefficiencies resulting from a sub-contractor's failure to report a completed system installation ready for commissioning agent review are not reflected in the project files. One attempt to mitigate involved supplementing data collected from the project files with data collected through interviews with project stakeholders (Section 4.27).
- c. Two sustainable building projects, both at Penn State's University Park campus, were examined to determine cost reductions possible with increased process transparency. This narrow scope may seem to limit the external validity of this study. However, both the evidence from the broad-scoped literature review, and the relative similarity with which projects are delivered, reinforce the findings from Penn State. Further, Penn State is an owner organization whose experienced project management group has a

proven record of successfully delivering major capital projects. Since the counterfactual analysis reveals significant cost impacts related to lack of process transparency on Penn State projects, these impacts are probably even larger for projects with less sophisticated owners.

2. Perfect process transparency was applied as the antecedent for the counterfactual analysis. Achieving perfect process transparency is unlikely. This research assumes that, since perfect process transparency leads to lower costs for sustainable buildings, then this is also the case, to a lesser degree, for incremental enhancements of transparency.
3. Lack of process transparency is one of the many factors contributing to various cost impacts, and determining the specific cost impacts associated with each factor is not feasible. This research relies on reasoning that, despite the multiple possible root causes of cost impacts, the costs included could have been eliminated with complete process transparency.
4. The research does not distinguish costs related to process transparency present on sustainable projects from costs present on any project. Separating these costs would be a delicate task, as optimal delivery of sustainable buildings likely promotes practices beneficial for all building types. Enhanced process transparency probably promotes a greater magnitude of cost decrease as well as increased sustainability for sustainable projects due to their complex, integrated process.

7.2 Theories Developed

Theories developed from this research result from observed relationships between research variables. These relationships are described below and shown in Figure 7-1.

1. **Reduced costs for sustainable buildings are possible by increasing delivery process transparency.** The empirical results from the application of counterfactuals to project delivery for this research build on a synthesis of Lean and sustainability theory. Both support the hypothesis that increased process transparency can decrease costs for sustainable buildings.
2. **Process mapping may be considered as a method to enhance process transparency.** Process mapping was examined as a method to add transparency and potentially improve delivery of sustainable building projects. This finding adds to existing knowledge about the benefits of process mapping.

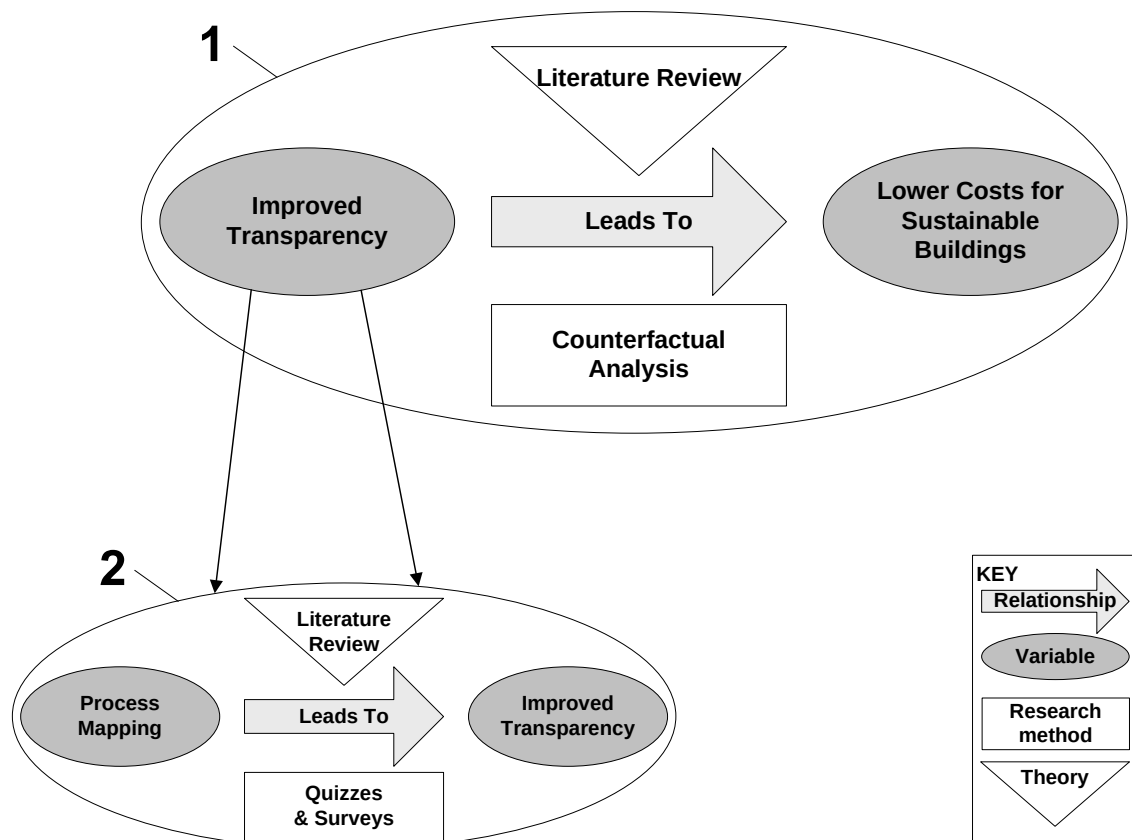


Figure 7-1: Theories Developed

7.3 Intellectual Merit

In addition to the theories developed, several parts of this research have advanced understanding both within and outside the building construction field. These intellectual merit contributions are as follows:

1. **A rigorous method for applying counterfactual analysis to project delivery was developed and applied.** This method, described in Chapters 3 and 4, is influenced by previous applications of counterfactual analysis to construction and to other, more mature, fields including economics and political science (Fogel

1964, Belkin 1996, NIST 2002). Drawing from these previous applications, the method developed for this research is explicit and comprehensive for straightforward application using commonly available resources and references within construction industry organizations. This adaptation and application of counterfactual analysis contributes to the reliability of the research results and can assist others studying project delivery.

2. **A comprehensive list of suggested attributes valuable for sustainable building delivery was developed.** This list, organized by suggested phase of implementation, was developed through a review and synthesis of literature and case studies as part of the background research for this project. The list can serve as a reference for organizations delivering, or researchers studying, sustainable buildings (Figure 2-6).
3. **A measurable definition of transparency based on Lean theory was developed and utilized.** Despite its recognized value, process transparency is a complicated concept to define in a way that allows measurement. The process transparency definition developed for this research (Table 4-3) was successfully used to provide a measure of process transparency. Other groups can adapt this definition and the research methods described in Chapter 6 to measure process transparency.

7.4 Practical Implications

Practical implications of this research project are a product of the results from the counterfactual analysis, which are outlined in Chapter 5. These practical implications, along with further descriptions of their significance, are as follows:

1. **Stakeholders delivering sustainable building projects should be aware of the value of process transparency.** Owners can facilitate transparency-enhancing interactions, and avoid some of the significant costs discussed in Chapter 5, by devoting more resources to stakeholders delivering building projects. As a result, these stakeholders (e.g., construction managers, designers and operations staff) will be able to contribute more of their expertise to the project. Ideally, these stakeholders will then make a conscious effort to enhance process transparency in their project teams and within their organizations. Consider the example of the designer who makes sure the user group understands that design changes made after a certain date will result in a cost premium. By clarifying this process and deadline, the designer is improving the delivery of the sustainable project by addressing the “recognition of status” and “recognition of interdependencies” attributes of the process transparency definition.
2. **The majority of mitigation costs appeared during the construction phase of project delivery and could have been avoided during design.** Consequently, investments in enhanced process transparency have the most potential when targeting the earlier phases of project delivery, including the design phase. This finding matches established theory that level of influence on cost is highest during

the early phases of project delivery (Paulson 1976). In addition to helping avoid costs during construction, transparency supports the value-generating nature of the design phase, where traditional management techniques, including detailed planning and “after-the-fact detection of variances” are less effective (Ballard 2002). Suggestions to enhance process transparency during the planning and design phases include:

- increased discussion and consideration of process in design meetings,
- use of process maps to communicate key planning and design processes, and
- process status correspondence made visible to stakeholders who are unaware of the day-to-day design process (e.g., operations and maintenance staff).

3. Avoidance efforts related to process transparency represent a fraction of the costs of mitigation efforts resulting from a lack of process transparency.

There are many opportunities for project stakeholders to invest in process transparency and realize a positive return on this investment. For example, it may cost \$100 in salary and benefits for a project engineer to spend an hour learning about the overall status of the project indirectly related to her responsibilities.

However, the project realizes a much greater cost savings if the project engineer’s resulting contribution leads to the elimination of a \$10,000 change order. In addition to investment by project stakeholders, other funding agencies may also consider supporting efforts that enhance process transparency.

4. **Delay costs represent a significant proportion of costs related to lack of process transparency.** Delays are a major source of cost impacts in all phases of project delivery. Project teams on university campuses often scramble to complete construction of a building in time for an upcoming semester, authorizing more expensive overtime hours and potentially compromising quality of the final product. On the other hand, lack of process transparency can contribute to month-long delays during planning and design that are seen as less consequential at the time but that inevitably contribute to the construction phase scramble. Ironically, lack of process transparency also prevents these early-phase stakeholders from recognizing the impacts their decisions have on the final building product.
5. **Cost impacts result from a lack of process transparency between stakeholder groups and also within these groups.** Efforts to enhance process transparency within an organization can be fruitful. Achieving organizational transparency seems easier than achieving project transparency because inter-organization processes are more repetitive and members of an organization are more familiar with their own processes. Still, the results from the study of the SALA and Forest Resources buildings show significant percentages of costs, 29% and 12% respectively, related to imperfect process transparency within an organization. This consideration is especially important for big, multi-division organizations like OPP, and the process mapping effort described in Chapter 6 is one strategy that may enhance process transparency within an organization.
6. **Research findings have implications for the introduction of project management software at OPP.** Evidence that reduced costs for sustainable

buildings are possible by increasing delivery process transparency helps validate the resources OPP is currently investing in project management software promising added transparency as one of its benefits. In addition, the software is adaptable to OPP's specific needs and therefore offers potential solutions to transparency issues. On the SALA project, user-group scope changes after the design development phase were an issue related to process transparency that contributed to increased project costs. In response, OPP can tailor the project management software to increase visibility of the required timing and deadlines for user-group scope changes.

7.5 Broad Impacts

This research may also contribute to more broad impacts in addition to the theories developed, intellectual merit, and practical implications discussed previously. These more-widespread, longer-term impacts are as follows:

1. **Process transparency may be included in sustainable building education.**

Education of professionals and students can introduce process transparency as an essential feature of the integrated process that is crucial to sustainable building delivery. For instance, generating sustainable solutions requires not only inclusion of building operations professionals in the design phase, but also that these professionals recognize the status of the process. Describing the importance of process transparency can draw out tacit knowledge from students who already have experience delivering sustainable projects. Or, when students lack this

firsthand experience, introducing the importance of process transparency will support their future effective contributions to delivery of sustainable projects.

2. **Increased process transparency is part of a broad shift in the construction**

industry. Increased transparency leads to greater separation of information from the hierarchy of “order giving” (Greif 1991). With a greater understanding of the big picture, stakeholders gain decision-making ability that can increase their happiness, productivity, and likelihood to positively influence the project. This contribution of process transparency is part of a broad shift in the construction industry’s plodding movement from a top-down to a more collaborative method of managing projects (Koskela 1992, Ballard (1) 2000, Howell 2004).

3. **Process transparency may be included as a consideration for Building**

Information Modeling (BIM) efforts. The findings of this research project support the product, organization, and process framework advocated in Virtual Design and Construction (Kunz 2003). The responsibilities of product, organization, and process designers are shown in Table 7-1. BIM efforts that focus only on building product information, and neglect process status and organization information, will not address the process transparency issues that led to significant cost impacts on the SALA and Forest Resources buildings.

Table 7-1: Responsibilities and Examples of Product, Organization, and Process Designers (Adapted from Garcia, 2003)

	Responsible for developing	Example
Product	artifact description	architects, structural engineers
Organization	organization structure for carrying out the plan	project manager and executive
Process	plan to build the artifact	design and construction managers

7.6 Future Research

Potential future research that was uncovered when performing the current research is discussed in this section, especially as it relates to the previously discussed limitations, theories developed, intellectual merit, practical implications and broad impacts.

1. **Can enhanced process transparency result in better, more sustainable, buildings in addition to reducing the costs of these projects?** This research project examines the impact of process transparency on costs for sustainable buildings. Another important question, indirectly addressed by this research, is whether enhanced process transparency may also lead to more sustainable buildings. Presumably, the integration between stakeholders that is enabled by increasing process transparency also results in solutions contributing to a more sustainable project. Evidence evaluating this presumption would provide important additional insight into the value of enhancing process transparency for sustainable building projects.
2. **Are some of the principles valuable for sustainable building delivery, including process transparency, also applicable to delivery of other types of sustainable projects?** Sustainable construction projects other than buildings (e.g., roads, bridges and utilities) and less-similar projects developing sustainable products (e.g., fuel-cell automobiles or solar panels) may also benefit from improved process transparency. Like buildings, these other project types are integral to global efforts towards sustainability.

3. **How else may application of counterfactual analysis assist study of project**

delivery? For sustainable building projects, counterfactual analyses could help satisfy the need to examine attributes, other than process transparency, with potential to improve these projects. Counterfactual analysis may also be appropriate for studying other projects with complex delivery processes, including product development. Continued application of counterfactual analysis can yield important insights while refining the method itself for future use.

4. **What are the best methods and tools for enhancing process transparency?**

With the greater understanding of its importance for sustainable building delivery comes a need to investigate the best methods to enhance process transparency. Continued study developing best practices for applying process mapping have value, but process mapping is just one of many ways to enhance process transparency. Other industries offer helpful suggestions for enhancing process transparency that could be examined. In a manufacturing environment, suggested approaches to improve process transparency include (Greif 1991, Koskela 1992):

- eliminating clutter,
- making the process directly observable through layout and signage,
- using measurements to make invisible attributes of the process visible,
- showing process information in work areas, and
- utilizing visual controls so people recognize standards and deviations from them.

5. Investigation is worthwhile of the best ways to ensure BIM efforts enhance process transparency. Other construction industry practices that could be

investigated for their potential to enhance process transparency include scheduling, project team meetings and use of detailed design intents (Maisey 2006).

6. **What are the next steps for this research at OPP?** Widespread use of the project management software being introduced at OPP will make available an extensive amount of data. Research could examine whether use of the software enhances process transparency. Further, data collected using the software regarding times and costs to complete tasks can provide insight into the relationships between variables, including process transparency, and desired project outcomes.

7.7 Concluding Remarks

Provided in this dissertation is evidence that improved process transparency may help contribute to more widespread application of sustainable building. Whether through process transparency or other means, increasing the market share of sustainable buildings is essential to reducing the negative impacts of the built environment, which will contribute to securing the future of the United States and improving the long-term prospects of humans on this planet.

1. **Reducing the impacts of buildings in the United States can help contribute to energy independence and national security.** In their 2006 strategic plan, the United States Department of Energy (DOE) affirms that “reliable and affordable energy is central to our economic and national security” (DOE 2006). As part of

their energy security strategic theme, a DOE goal is to improve the energy efficiency of our economy with strategies that include promoting “increased energy efficiency and sustainable practices in Federal facilities” and significantly increasing “the energy efficiency of residential and commercial buildings” (DOE 2006). Both of these goals would benefit from advances leading to a greater market share of sustainable buildings.

2. **Reducing the impact of buildings is essential to combating global climate change.** Global climate change is a complex problem requiring multiple solutions from a wide variety of fields. Researchers examining climate change have identified existing strategies and technologies whose combined implementation would reduce the United States’ global warming emissions in half by the year 2050 (Pacala 2004). Several of these general strategies, shown in Figure 7-2, would directly benefit from more widespread implementation of sustainable buildings including “reducing electricity use through efficiency,” “reducing non-electrical energy through efficiency” and “expanding renewable energy use.” Advances that contribute to a greater market share of sustainable buildings help promote these strategies.

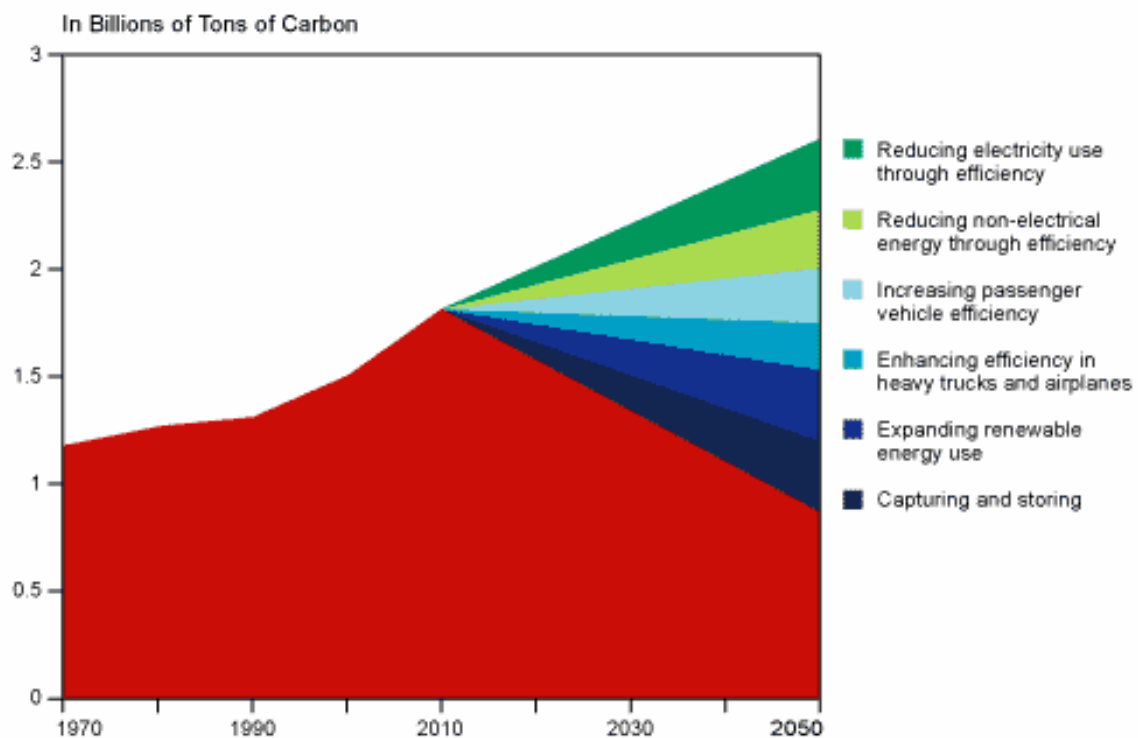


Figure 7-2: How to Cut U.S. Global Warming Emissions in Half (From Select Committee, 2008; adapted from Pacala, 2004)

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Appendix A

SALA and Forest Resources Building Information

A.1 Stuckeman Family Building for the School of Architecture & Landscape Architecture (SALA) (Adapted from Chesko, 2005)

The SALA building is located on the main campus of the Pennsylvania State University in University Park, PA (Figure A-1). The 111,000 square foot facility is four stories with a basement and consists primarily of classrooms, studios and offices. A design-bid-build delivery method with a general contractor was utilized with the contracting structure shown in Figure A-3. Design of the building began in January of 2001. Construction started in October of 2003, and the building was occupied in August of 2005, prior to the beginning of the fall semester. The building earned LEED-Gold certification, receiving 45 out of a possible 69 points (Figure A-4)

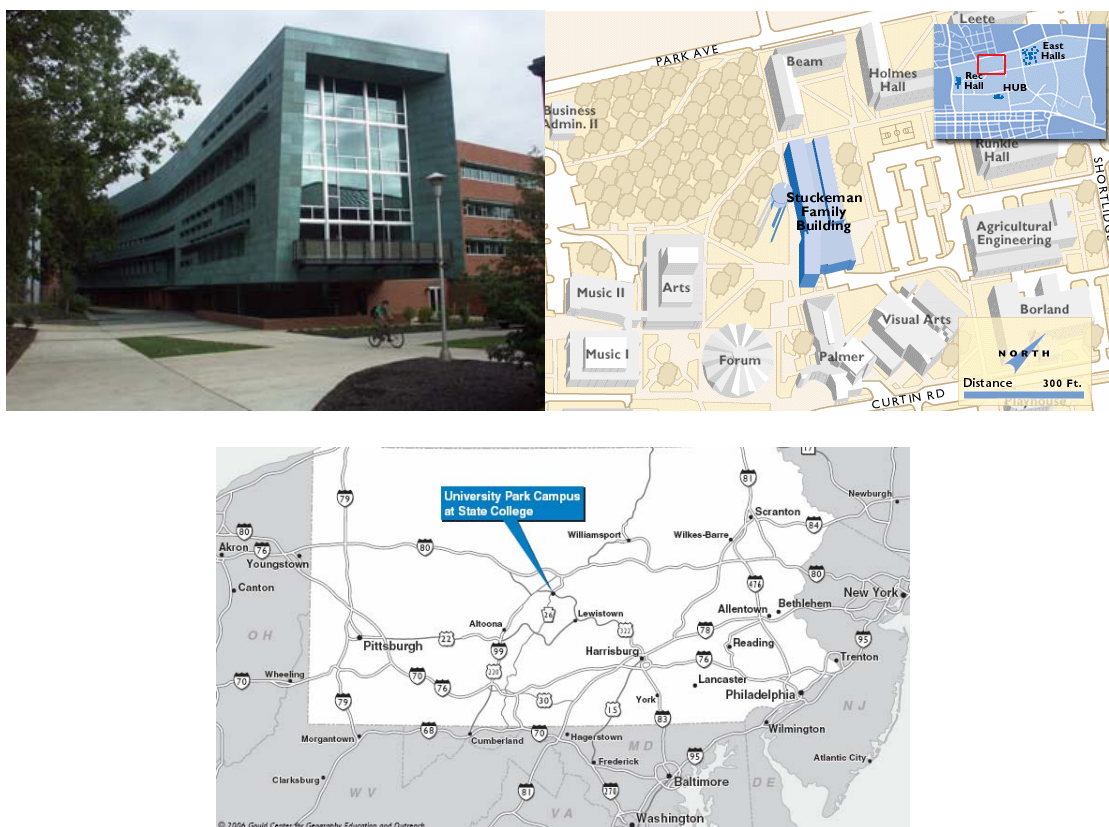


Figure A-2: SALA Building Image and Location

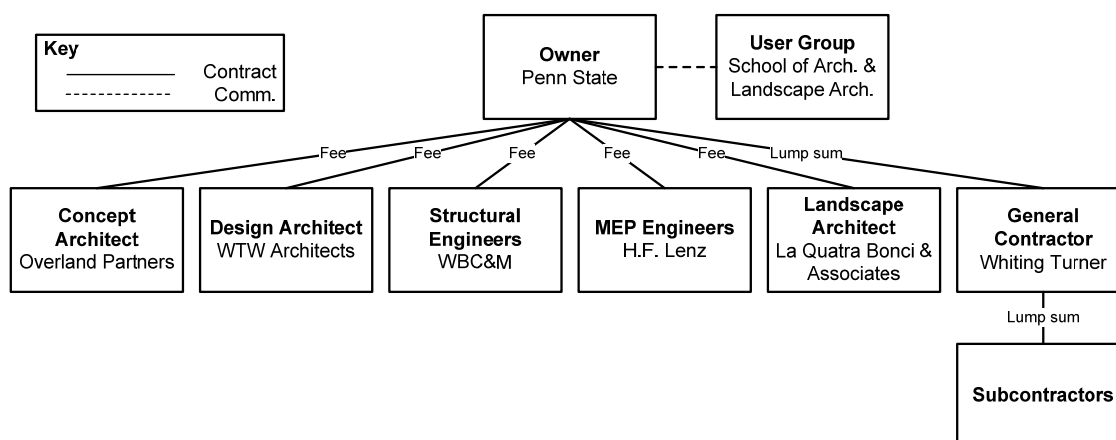


Figure A-3: SALA Organization Chart

		SALA, PSU Project # 1531 Certification Level: Gold 1/29/2007	
LEED for New Construction v2.0/2.1			
45 Points Achieved		Possible Points: 69	
Certified 26 to 32 points Silver 33 to 38 points Gold 39 to 51 points Platinum 52 or more points			
10 Sustainable Sites Possible Points: 14		6 Materials & Resources Possible Points: 13	
Y Prereq 1 Erosion & Sedimentation Control		Y Prereq 1 Storage & Collection of Recyclables	
1 Credit 1 Site Selection 1		1 Credit 1.1 Building Reuse, Maintain 75% of Existing Shell 1	
1 Credit 2 Development Density 1		1 Credit 1.2 Building Reuse, Maintain 100% of Shell 1	
1 Credit 3 Brownfield Redevelopment 1		1 Credit 1.3 Building Reuse, Maintain 100% Shell & 50% Non-Shell 1	
1 Credit 4.1 Alternative Transportation, Public Transportation Access 1		1 Credit 2.1 Construction Waste Management, Divert 50% 1	
1 Credit 4.2 Alternative Transportation, Bicycle Storage & Changing Rooms 1		1 Credit 2.2 Construction Waste Management, Divert 75% 1	
1 Credit 4.3 Alternative Transportation, Alternative Fuel Vehicles 1		1 Credit 3.1 Resource Reuse, Specify 5% 1	
1 Credit 4.4 Alternative Transportation, Parking Capacity & Carpooling 1		1 Credit 3.2 Resource Reuse, Specify 10% 1	
1 Credit 5.1 Reduced Site Disturbance, Protect or Restore Open Space 1		1 Credit 4.1 Recycled Content, Specify 5% 1	
1 Credit 5.2 Reduced Site Disturbance, Development Footprint 1		1 Credit 4.2 Recycled Content, Specify 10% 1	
1 Credit 6.1 Stormwater Management, Rate & Quantity 1		1 Credit 5.1 Local/Regional Materials, 20% Manufactured Locally 1	
1 Credit 6.2 Stormwater Management, Treatment 1		1 Credit 5.2 Local/Regional Materials, of 20% Above, 50% Harvested Locally 1	
1 Credit 7.1 Landscape & Exterior Design to Reduce Heat Islands, Non-Roof 1		1 Credit 6 Rapidly Renewable Materials 1	
1 Credit 7.2 Landscape & Exterior Design to Reduce Heat Islands, Roof 1		1 Credit 7 Certified Wood 1	
1 Credit 8 Light Pollution Reduction 1			
3 Water Efficiency Possible Points: 5		12 Indoor Environmental Quality Possible Points: 15	
Y Prereq 1 Minimum IAQ Performance		Y Prereq 1 Minimum IAQ Performance	
1 Credit 1.1 Water Efficient Landscaping, Reduce by 50% 1		Y Prereq 2 Environmental Tobacco Smoke (ETS) Control	
1 Credit 1.2 Water Efficient Landscaping, No Potable Use or No Irrigation 1		1 Credit 1 Carbon Dioxide Monitoring 1	
1 Credit 2 Innovative Wastewater Technologies 1		1 Credit 2 Ventilation Effectiveness 1	
1 Credit 3.1 Water Use Reduction, 20% Reduction 1		1 Credit 3.1 Construction IAQ Management Plan, During Construction 1	
1 Credit 3.2 Water Use Reduction, 30% Reduction 1		1 Credit 3.2 Construction IAQ Management Plan, Before Occupancy 1	
		1 Credit 4.1 Low-Emitting Materials, Adhesives & Sealants 1	
		1 Credit 4.2 Low-Emitting Materials, Paints 1	
		1 Credit 4.3 Low-Emitting Materials, Carpet 1	
		1 Credit 4.4 Low-Emitting Materials, Composite Wood & Agrifiber Products 1	
		1 Credit 5 Indoor Chemical & Pollutant Source Control 1	
		1 Credit 6.1 Controllability of Systems, Perimeter 1	
		1 Credit 6.2 Controllability of Systems, Non-Perimeter 1	
		1 Credit 7.1 Thermal Comfort, Comply with ASHRAE 55-1992 1	
		1 Credit 7.2 Thermal Comfort, Permanent Monitoring System 1	
		1 Credit 8.1 Daylight & Views, Daylight 75% of Spaces 1	
		1 Credit 8.2 Daylight & Views, Views for 90% of Spaces 1	
9 Energy & Atmosphere Possible Points: 17		5 Innovation & Design Process Possible Points: 5	
Y Prereq 1 Fundamental Building Systems Commissioning		Y Prereq 1 Innovation in Design: Green Building Education 1	
Y Prereq 2 Minimum Energy Performance		1 Credit 1.2 Innovation in Design: Exemplary Performance, EAc6 1	
Y Prereq 3 CFC Reduction in HVAC&R Equipment		1 Credit 1.3 Innovation in Design: Exemplary Performance, MRc5.1 1	
1 Credit 1.1 Optimize Energy Performance, 15% New / 5% Existing 1		1 Credit 1.4 Innovation in Design: Exemplary Performance, MRc4 1	
1 Credit 1.2 Optimize Energy Performance, 20% New / 10% Existing 1		1 Credit 2 LEED® Accredited Professional 1	
1 Credit 1.3 Optimize Energy Performance, 25% New / 15% Existing 1			
1 Credit 1.4 Optimize Energy Performance, 30% New / 20% Existing 1			
1 Credit 1.5 Optimize Energy Performance, 35% New / 25% Existing 1			
1 Credit 1.6 Optimize Energy Performance, 40% New / 30% Existing 1			
1 Credit 1.7 Optimize Energy Performance, 45% New / 35% Existing 1			
1 Credit 1.8 Optimize Energy Performance, 50% New / 40% Existing 1			
1 Credit 1.9 Optimize Energy Performance, 55% New / 45% Existing 1			
1 Credit 1.10 Optimize Energy Performance, 60% New / 50% Existing 1			
1 Credit 2.1 Renewable Energy, 5% 1			
1 Credit 2.2 Renewable Energy, 10% 1			
1 Credit 2.3 Renewable Energy, 15% 1			
1 Credit 3 Additional Commissioning 1			
1 Credit 4 Ozone Depletion 1			
1 Credit 5 Measurement & Verification 1			
1 Credit 6 Green Power 1			

Figure A-4: SALA LEED Points Achieved (USGBC (1) 2007)

A.2 School of Forest Resources Project Information (Adapted from Horn, 2005)

The Forest Resources building is located on the main campus of the Pennsylvania State University in University Park, PA (Figure A-6). The 92,000 square foot facility is four stories with a basement and houses classrooms, offices, laboratories and an auditorium. A design-bid-build delivery method with a construction management agency was utilized with the contracting structure shown in Figure A-7. Design of the building began in July of 2002. Construction started in August of 2004, and the building was occupied in January of 2006, prior to the beginning of the spring semester. The building earned LEED-Silver certification, receiving 36 out of a possible 69 points (Figure A-5).



Figure A-6: School of Forest Resources Building Image and Location

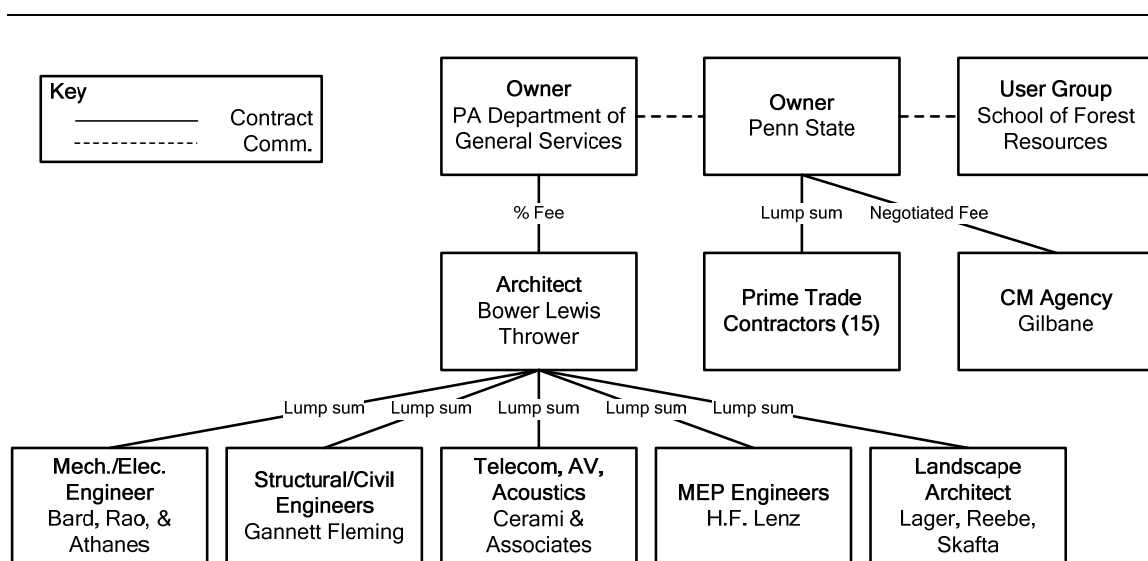


Figure A-7: School of Forest Resources Organization Chart

		PSU School of Forest Resources Bldg Project 10001700 Certification Level: Silver 2/19/2007	
LEED for New Construction v2.0/2.1			
36 Points Achieved		Possible Points: 69	
Certified 26 to 32 points Silver 33 to 38 points Gold 39 to 51 points Platinum 52 or more points			
8 Sustainable Sites Possible Points: 14		6 Materials & Resources Possible Points: 13	
Y Prereq 1 Erosion & Sedimentation Control 1 Credit 1 Site Selection 1 Credit 2 Development Density 1 Credit 3 Brownfield Redevelopment 1 Credit 4.1 Alternative Transportation, Public Transportation Access 1 Credit 4.2 Alternative Transportation, Bicycle Storage & Changing Rooms 1 Credit 4.3 Alternative Transportation, Alternative Fuel Vehicles 1 Credit 4.4 Alternative Transportation, Parking Capacity & Carpooling 1 Credit 5.1 Reduced Site Disturbance, Protect or Restore Open Space 1 Credit 5.2 Reduced Site Disturbance, Development Footprint 1 Credit 6.1 Stormwater Management, Rate & Quantity 1 Credit 6.2 Stormwater Management, Treatment 1 Credit 7.1 Landscape & Exterior Design to Reduce Heat Islands, Non-Roof 1 Credit 7.2 Landscape & Exterior Design to Reduce Heat Islands, Roof 1 Credit 8 Light Pollution Reduction		Y Prereq 1 Storage & Collection of Recyclables 1 Credit 1.1 Building Reuse, Maintain 75% of Existing Shell 1 Credit 1.2 Building Reuse, Maintain 100% of Shell 1 Credit 1.3 Building Reuse, Maintain 100% Shell & 50% Non-Shell 1 Credit 2.1 Construction Waste Management, Divert 50% 1 Credit 2.2 Construction Waste Management, Divert 75% 1 Credit 3.1 Resource Reuse, Specify 5% 1 Credit 3.2 Resource Reuse, Specify 10% 1 Credit 4.1 Recycled Content, Specify 5% 1 Credit 4.2 Recycled Content, Specify 10% 1 Credit 5.1 Local/Regional Materials, 20% Manufactured Locally 1 Credit 5.2 Local/Regional Materials, of 20% Above, 50% Harvested Locally 1 Credit 6 Rapidly Renewable Materials 1 Credit 7 Certified Wood	
4 Water Efficiency Possible Points: 5		9 Indoor Environmental Quality Possible Points: 15	
Y Credit 1.1 Water Efficient Landscaping, Reduce by 50% 1 Credit 1.2 Water Efficient Landscaping, No Potable Use or No Irrigation 1 Credit 2 Innovative Wastewater Technologies 1 Credit 3.1 Water Use Reduction, 20% Reduction 1 Credit 3.2 Water Use Reduction, 30% Reduction		Y Prereq 1 Minimum IAQ Performance Y Prereq 2 Environmental Tobacco Smoke (ETS) Control 1 Credit 1 Carbon Dioxide Monitoring 1 Credit 2 Ventilation Effectiveness 1 Credit 3.1 Construction IAQ Management Plan, During Construction 1 Credit 3.2 Construction IAQ Management Plan, Before Occupancy 1 Credit 4.1 Low-Emitting Materials, Adhesives & Sealants 1 Credit 4.2 Low-Emitting Materials, Paints 1 Credit 4.3 Low-Emitting Materials, Carpet 1 Credit 4.4 Low-Emitting Materials, Composite Wood & Agrifiber Products 1 Credit 5 Indoor Chemical & Pollutant Source Control 1 Credit 6.1 Controllability of Systems, Perimeter 1 Credit 6.2 Controllability of Systems, Non-Perimeter 1 Credit 7.1 Thermal Comfort, Comply with ASHRAE 55-1992 1 Credit 7.2 Thermal Comfort, Permanent Monitoring System 1 Credit 8.1 Daylight & Views, Daylight 75% of Spaces 1 Credit 8.2 Daylight & Views, Views for 90% of Spaces	
4 Energy & Atmosphere Possible Points: 17		5 Innovation & Design Process Possible Points: 5	
Y Prereq 1 Fundamental Building Systems Commissioning Y Prereq 2 Minimum Energy Performance Y Prereq 3 CFC Reduction in HVAC&R Equipment 1 Credit 1.1 Optimize Energy Performance, 15% New / 5% Existing 1 Credit 1.2 Optimize Energy Performance, 20% New / 10% Existing 1 Credit 1.3 Optimize Energy Performance, 25% New / 15% Existing 1 Credit 1.4 Optimize Energy Performance, 30% New / 20% Existing 1 Credit 1.5 Optimize Energy Performance, 35% New / 25% Existing 1 Credit 1.6 Optimize Energy Performance, 40% New / 30% Existing 1 Credit 1.7 Optimize Energy Performance, 45% New / 35% Existing 1 Credit 1.8 Optimize Energy Performance, 50% New / 40% Existing 1 Credit 1.9 Optimize Energy Performance, 55% New / 45% Existing 1 Credit 1.10 Optimize Energy Performance, 60% New / 50% Existing 1 Credit 2.1 Renewable Energy, 5% 1 Credit 2.2 Renewable Energy, 10% 1 Credit 2.3 Renewable Energy, 15% 1 Credit 3 Additional Commissioning 1 Credit 4 Ozone Depletion 1 Credit 5 Measurement & Verification 1 Credit 6 Green Power		Y Credit 1.1 Innovation in Design 1 Credit 1.2 Innovation in Design 1 Credit 1.3 Innovation in Design 1 Credit 1.4 Innovation in Design 1 Credit 2 LEED® Accredited Professional	

Figure A-8: School of Forest Resources LEED Points Achieved (USGBC (2) 2007)

A.3 Process Maps (Level I and II)

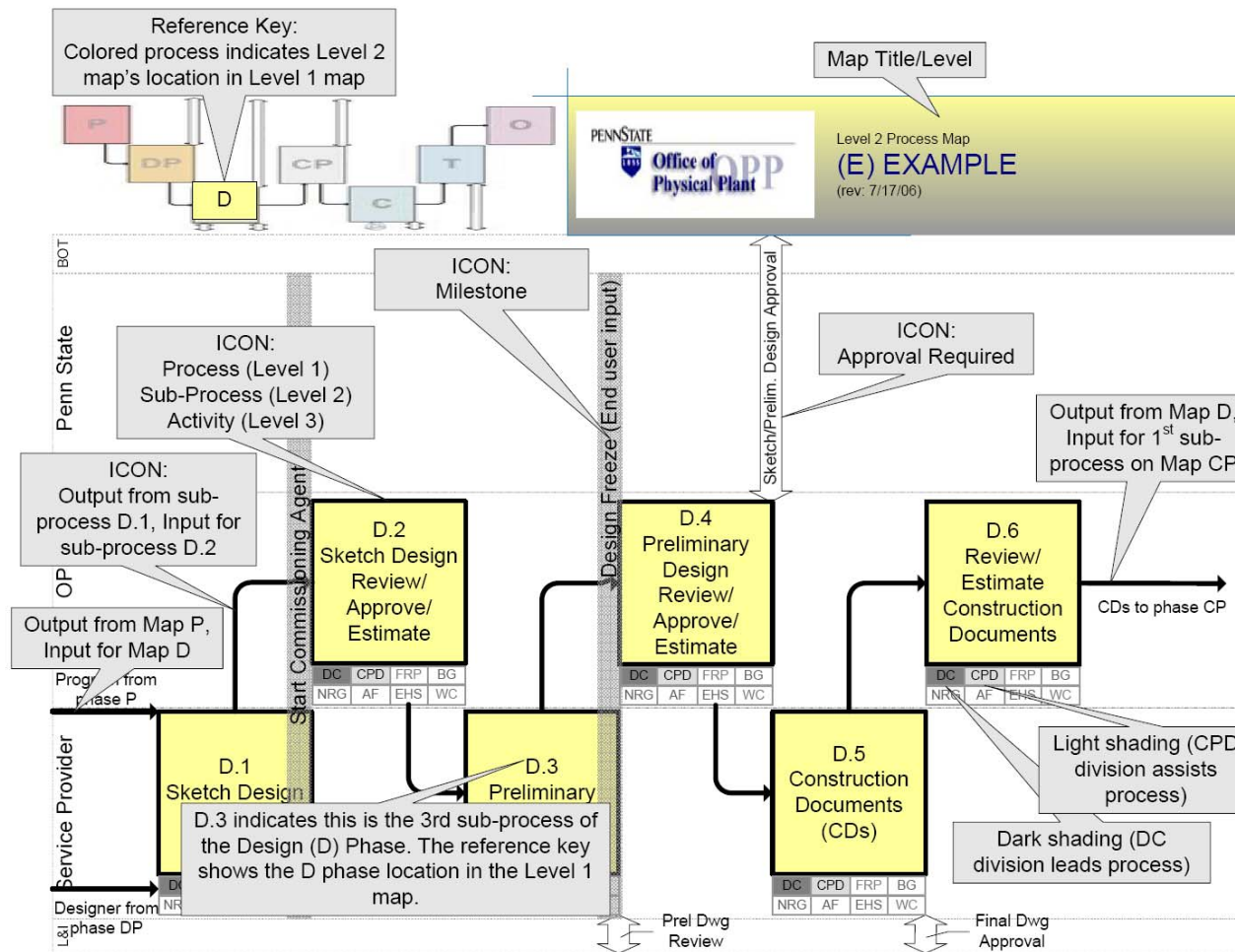


Figure A-9: Process Map Key

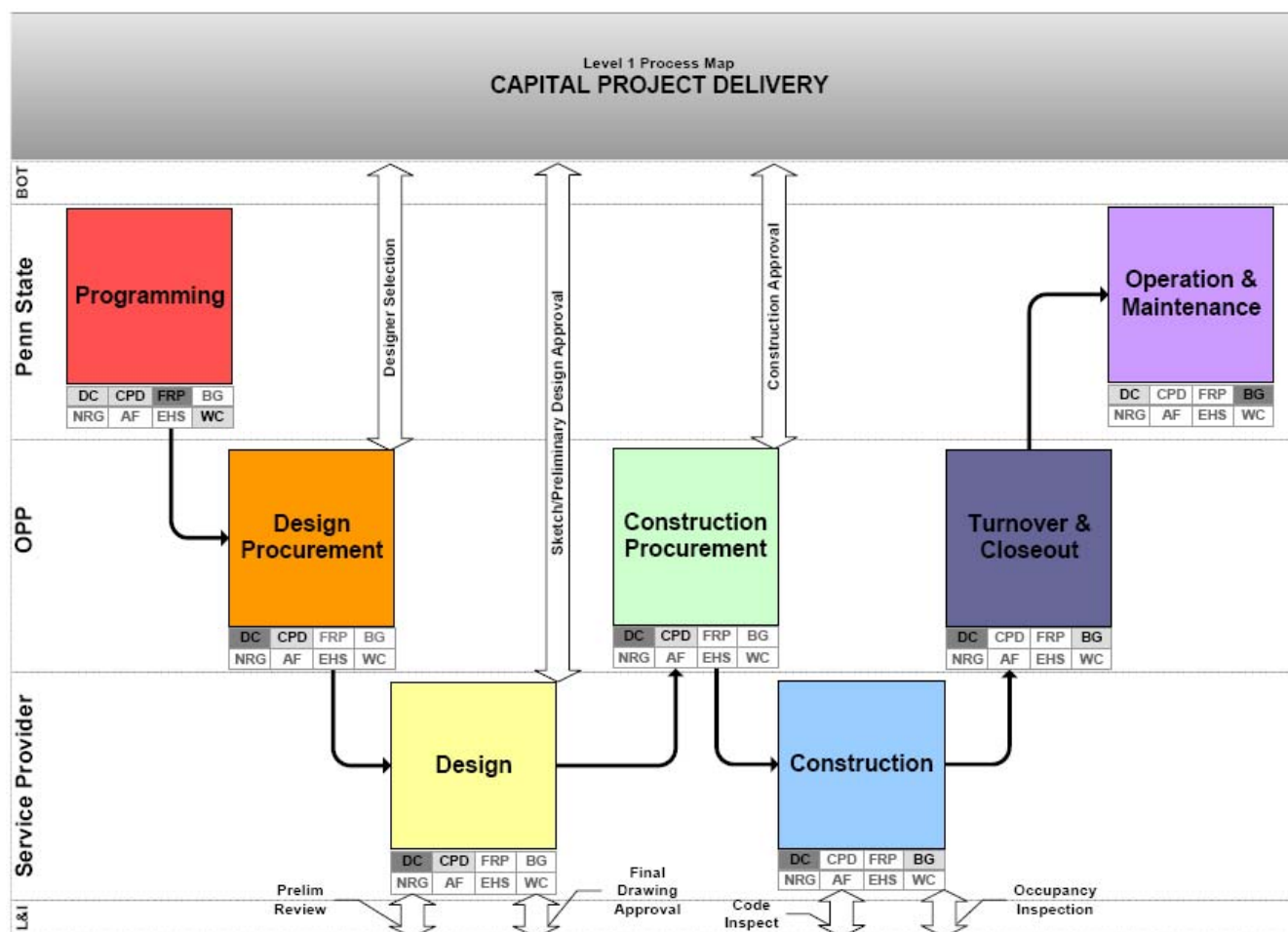


Figure A-10: Level 1 Process Map

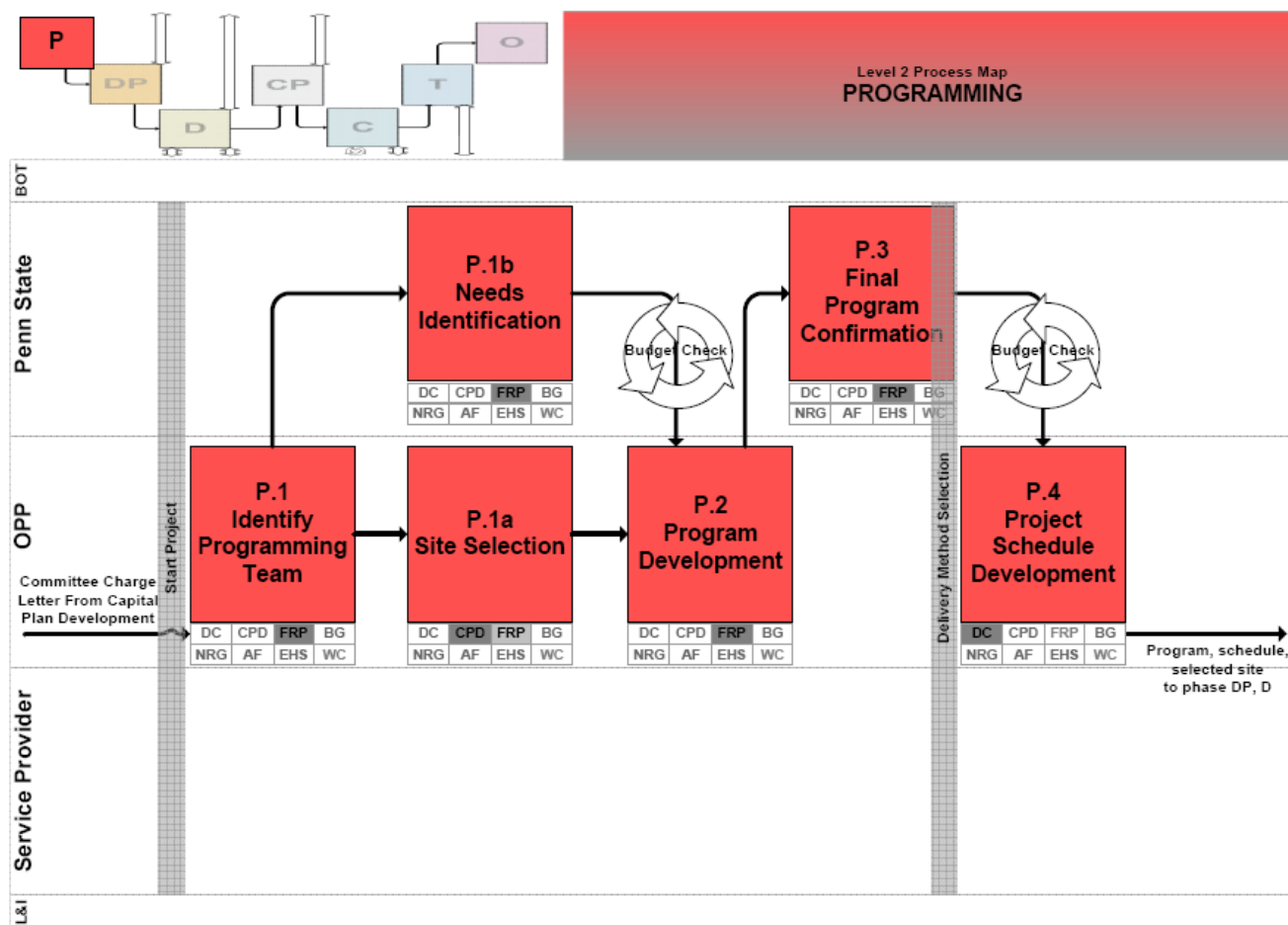


Figure A-11: Level 2 Process Map: Programming

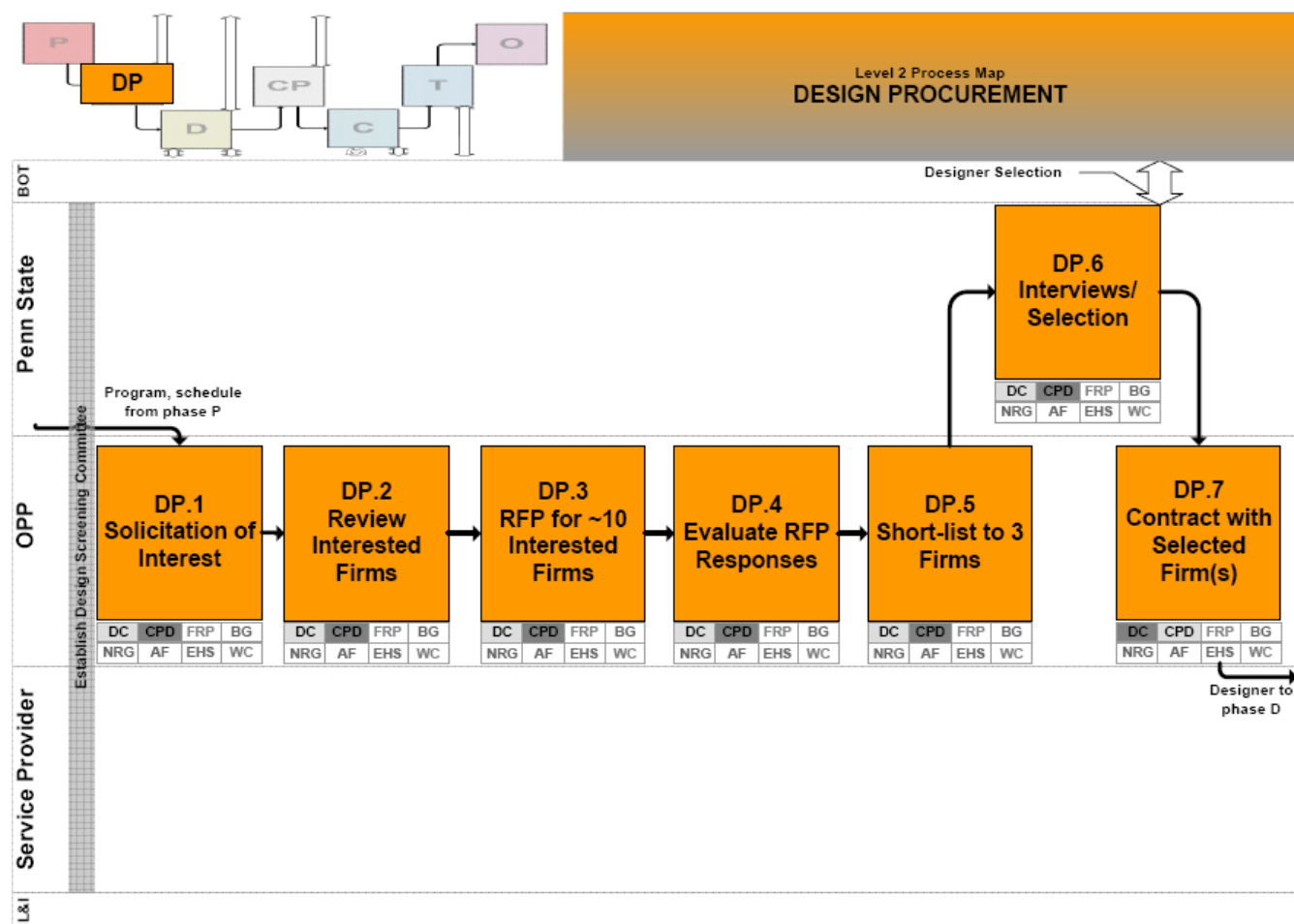


Figure A-12: Level 2 Process Map: Design Procurement

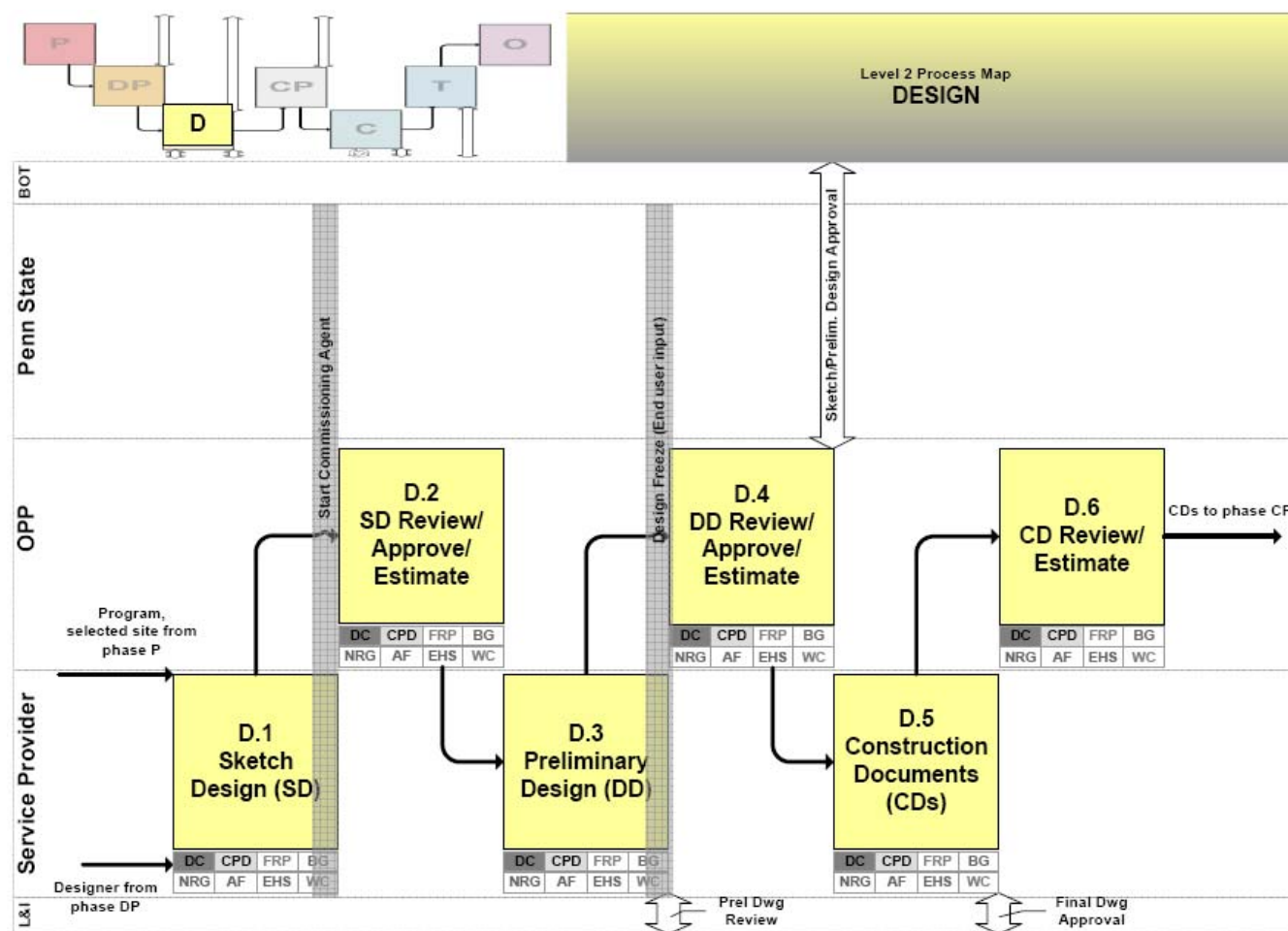


Figure A-13: Level 2 Process Map: Design

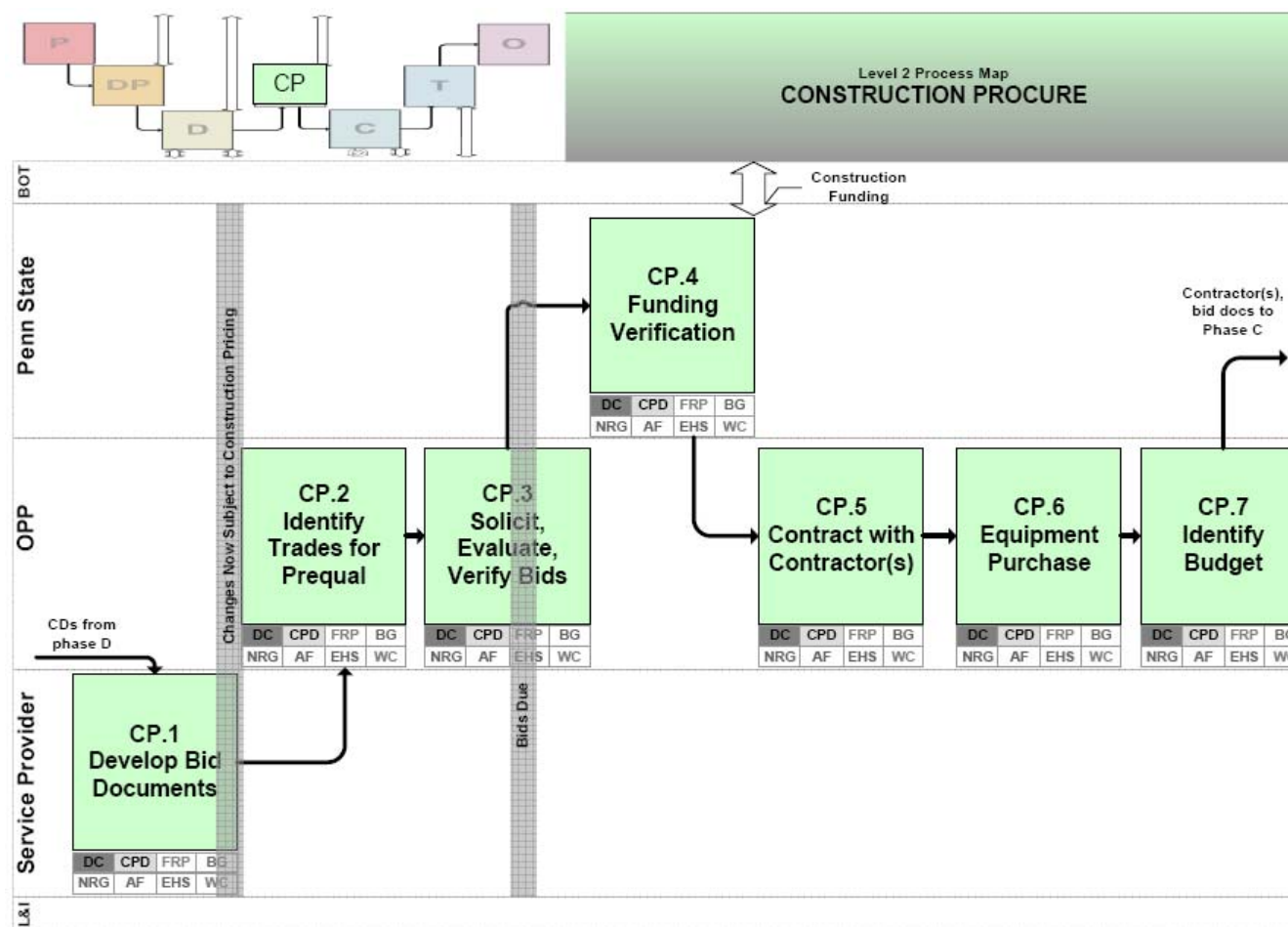


Figure A-14: Level 2 Process Map: Construction Procurement

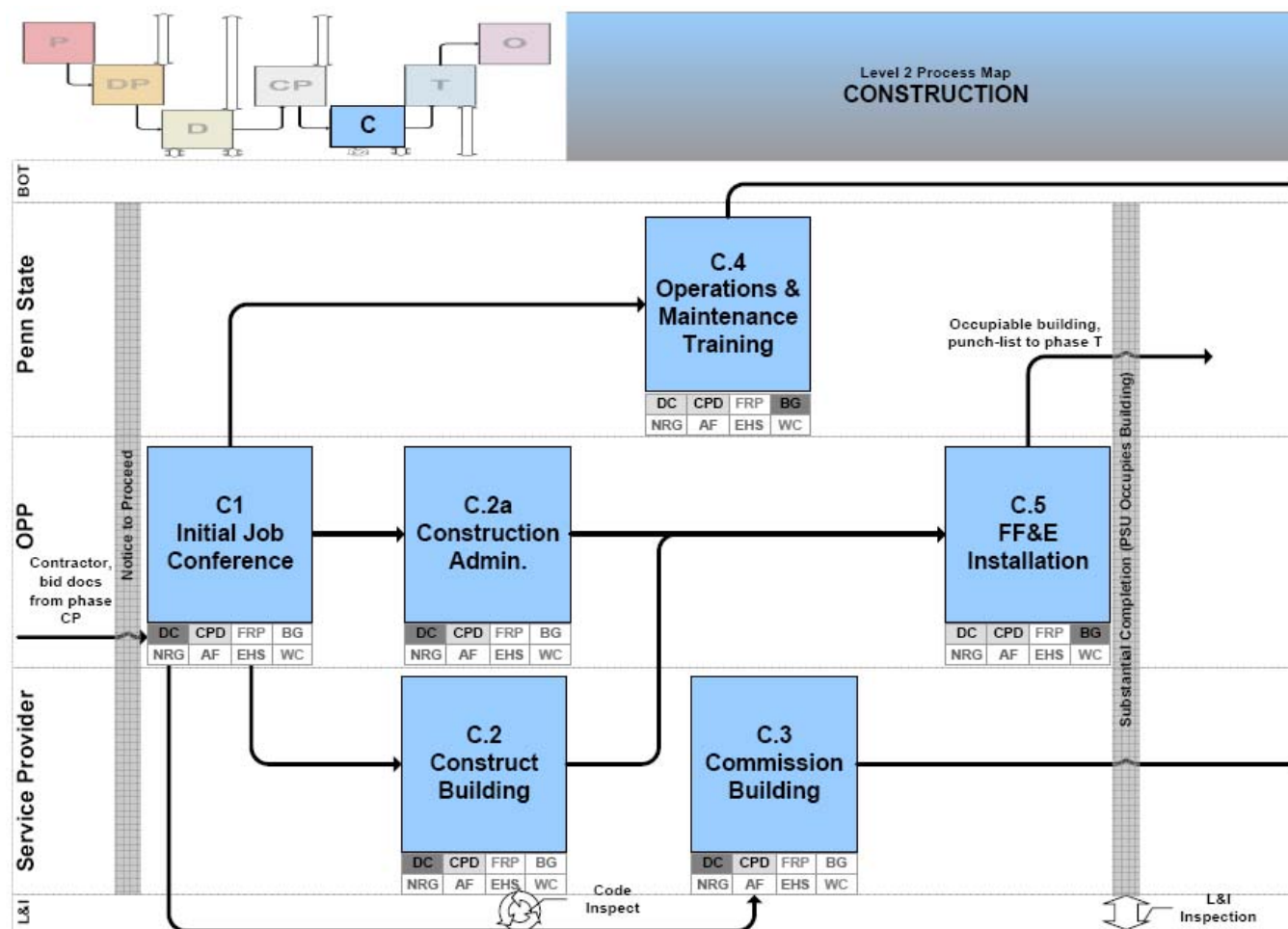


Figure A-15: Level 2 Process Map: Construction

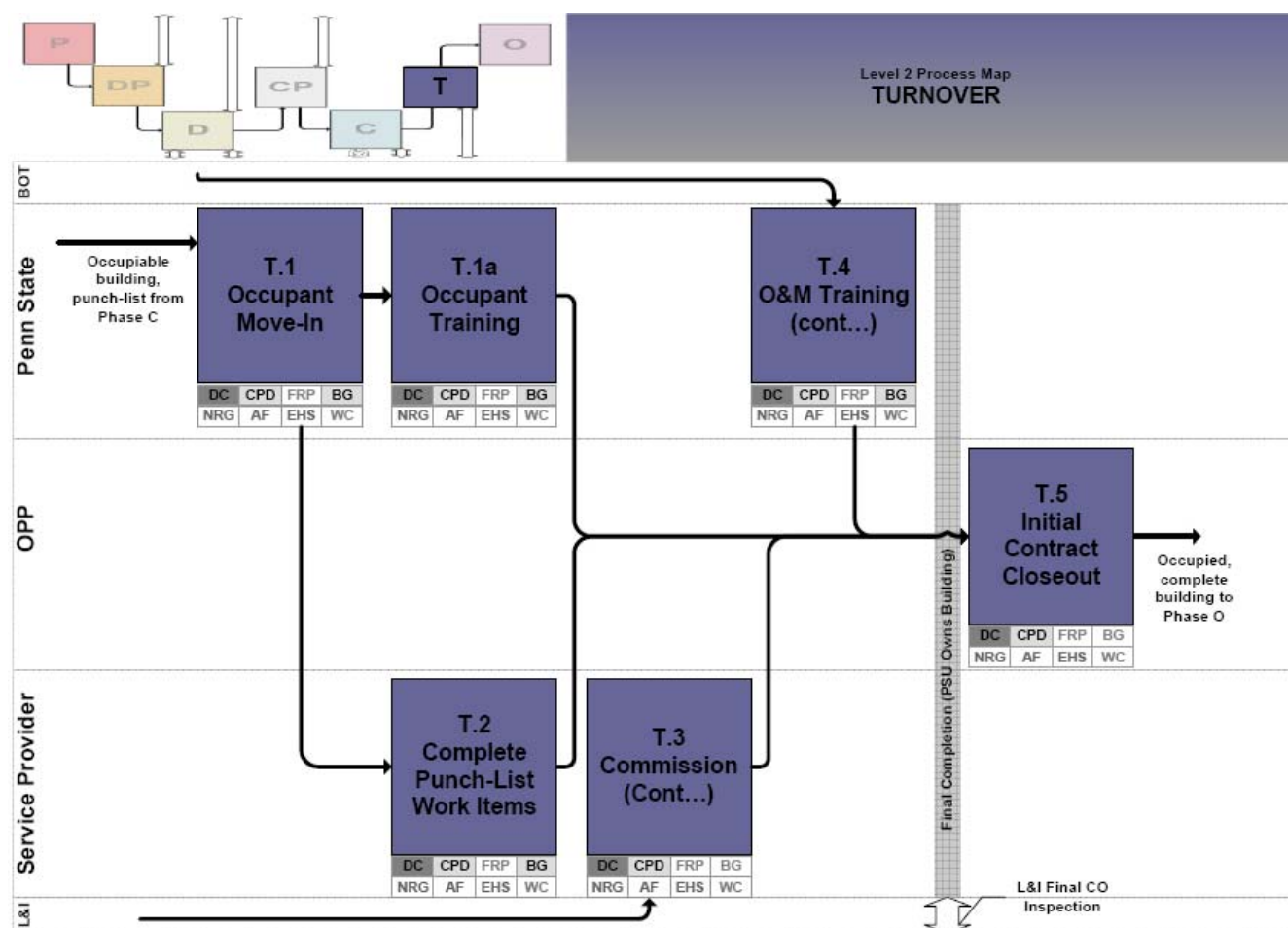


Figure A-16: Level 2 Process Map: Turnover

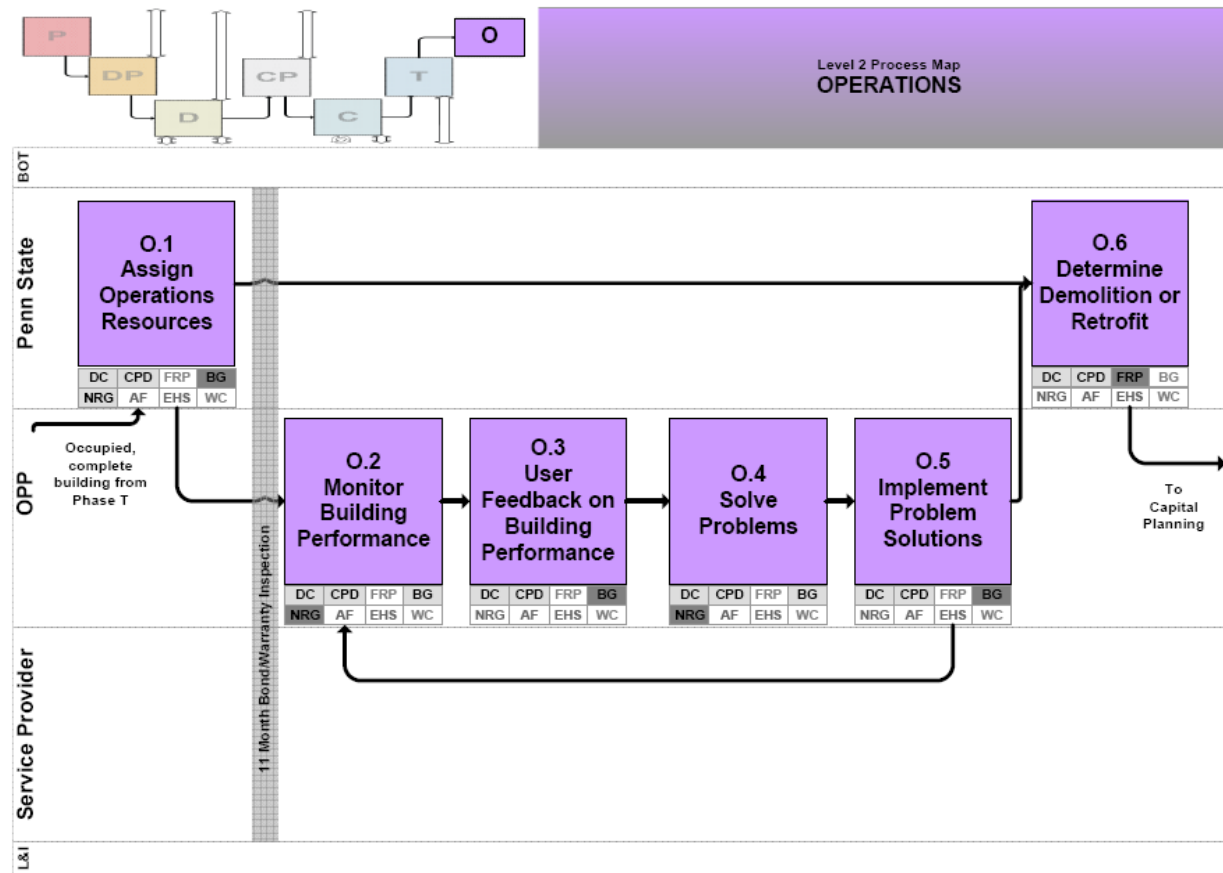


Figure A-17: Level 2 Process Map: Operations

Appendix B

Counterfactual Analysis Raw Data, Supporting Calculations, and Semi-Structured Interviews

B.1 SALA Raw Data and Supporting Calculations

ID #	Event					
1	Revised elevation studies (after original studies approved)					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
AE amendment	1/2/2003				\$57,734.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$57,734.00			Add LDs

ID #	Event					
2	Redesign administrative suite - result of added program during design					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		Planning	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
AE amendment	1/2/2003				\$19,656.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$19,656.00			Add LDs#http://

ID #	Event					
3	Design for added faculty offices - added program during design					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		Planning	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
AE amendment	12/4/2002				\$11,317.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$11,317.00			Add LDs#http://

ID #	Event					
4	Redesign administrative offices per PSU direction					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
AE amendment	4/30/2003				\$18,310.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$18,310.00			Add LDs#http://

ID #	Event					
5	Telecommunications revisions due to owner revisions					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
AE amendment	10/24/2003				\$5,479.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$5,479.00			Add LDs#http://

ID #	Event				
7	Initial Job Meeting - introduction of responsibilities				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$300.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$300.00			

ID #	Event				
8	Initial Job Meeting - introduction of responsibilities				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$750.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$750.00			

ID #	Event				
9	Initial Job Meeting - introduction of responsibilities				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$350.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$350.00			

ID #	Event				
10	Initial Job Meeting - introduction of responsibilities				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$150.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$150.00			

ID #	Event				
11	Initial Job Meeting - introduction of communication procedures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$300.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$300.00			

ID #	Event				
12	Initial Job Meeting - introduction of communication procedures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$750.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$750.00			

ID #	Event				
13	Initial Job Meeting - introduction of communication procedures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$350.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$350.00			

ID #	Event				
14	Initial Job Meeting - introduction of communication procedures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
JCR #1	10/27/2003				\$150.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$150.00			

ID #	Event				
15	Job conference project process status updates				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Job Conference Reports 2-4					\$12,069.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$11,625.00			See excel sheet for details

ID #	Event				
16	Value Engineering Cost Premium				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction Procurement	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
WT Revised Bid spreadsheet	9/12/2003				\$1,927,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$96,350.00			

ID #	Event				
17	VE cost of time				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction Procurement		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
WT Revised Bid Spreadsh	9/12/2003				\$9,500.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$9,500.00		3 weeks PM time (conserva	

ID #	Event				
19	Pre-Proposal Meeting				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction Procurement		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Pre-Proposal Meeting Minu	5/20/2003				\$100.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$300.00			In SALA contract

ID #	Event				
20	Selection process description letter to G. Schultz				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction Procurement		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
maruszewski letter to schult	10/7/2003				\$200.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$200.00			

ID #	Event				
22	Process Clarification to Stuckeman - BOT letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Planning		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	12/11/2000				\$400.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$400.00		1 hour per page of letter	

ID #	Event				
23	Process Clarification to Stuckeman - Schultz letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Planning		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	11/30/2000				\$400.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$400.00		1 hour per page of letter	

ID #	Event					
24	Process Clarification to Stuckeman - Stuckeman response					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Planning		N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
letter	12/15/2000				\$200.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$200.00	1 hour per page of letter		

ID #	Event					
25	Responsibilities discussion with Will (Zehngut, Riccardo time)					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Planning		N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
Discussion meeting minutes	1/30/2001				\$200.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$200.00	1 hour meeting		

ID #	Event					
26	Responsibilities discussion with Will (Will's time)					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Planning		N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
Discussion meeting minutes	1/30/2001				\$100.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$100.00	1 hour meeting		

ID #	Event					
27	Durst letter responding to George Hay					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design/Procurement		N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
Letter from Durst to Hay	5/21/2001				\$200.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$200.00	1 hour per page of letter		

ID #	Event					
28	Durst process update letter to Stuckeman					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
		Design		N/A	Avoidance	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
letter from durst to stuckem	8/15/2001				\$100.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
			\$100.00	1 hour per page of letter		lack of misplaced

ID #	Event				
29	Durst response to Stuckeman re: entrance				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	12/17/2002				\$100.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$100.00		1 hour per page of letter	

ID #	Event				
30	schematic redesign - direct cost (redesign after schematic already approved)				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Design		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
AE amendment	6/17/2002				\$80,086.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$80,086.00			add lds#http://ad

ID #	Event				
31	Diversified occupancy in studios				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Design		Design	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
ARUP notes from charrette	11/26/2001				\$500.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$0.00			Orland's time + ti

ID #	Event				
32	Conklin review comments				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Schematic review comment	9/11/2002				\$50.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$50.00		30 minutes per comment	

ID #	Event				
33	Clarification of testing and inspection requirements				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction Procurement		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	10/20/2003				\$100.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$100.00			

ID #	Event				
42	CO 1 - Revert to original pile design				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/5/2004				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$500.00			

ID #	Event				
44	CO 2 - Additional fencing around Hort woods				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/29/2004				\$4,851.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$242.55			

ID #	Event				
45	CO 3 - Revise location of fire hydrant				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/18/2004				\$8,891.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$444.55			

ID #	Event				
46	CO 3 - Install additional temporary lighting along the access road				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/18/2004				\$882.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$44.10			

ID #	Event				
47	CO 3 - Revise location of Fire Dept location				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/18/2004				\$1,778.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$88.90			

ID # Event					
48 CO 4 - Additional carpet tile					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/7/2004				\$22,965.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,148.25			

ID # Event					
49 CO 5 - Change brick size from utility to modular					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/22/2004				\$110,245.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$5,512.25			

ID # Event					
50 CO 6 - New chilled water line to Borland lab					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/24/2004				\$191,976.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$9,598.80			

ID # Event					
51 CO 7 - Pedestrian ramp at Palmer museum side entrance					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$4,844.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$242.20			

ID # Event					
52 CO 7 - Additional fiber optic splices as requested by PSU					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$1,735.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$86.75			

ID #	Event				
53	CO 7 - Flashing under site stone wall copings				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$879.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$43.95			

ID #	Event				
54	CO 7 - Admin area kitchen changes				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$14,241.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$712.05			

ID #	Event				
55	CO 7 - Extend CW lines to Runkle, Ag. Eng., Ceramics				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$160,452.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$8,022.60			

ID #	Event				
56	CO 8 - Add trees at revised service entrance				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/6/2004				\$1,199.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$59.95			

ID #	Event				
57	CO 8 - Window changes at gallery 152 and user services 150				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/6/2004				\$5,131.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$256.55			

ID #	Event				
58	CO 9 - Sheath & copper clad fin at clerestory window for structural support				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$2,299.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$114.95			

ID #	Event				
59	CO 9 - Modify door and hardware to match wood paneling veneer				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$4,617.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$230.85			

ID #	Event				
60	CO 9 - Relocate temp light pole to accommodate site utility work				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$1,327.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$66.35			

ID #	Event				
61	CO 9 - Revise book security system				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$2,100.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$105.00			

ID #	Event				
62	CO 9 - Upgrade elevators per PSU requirements				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$4,935.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$246.75			

ID #	Event				
63	CO 10 - Revise media stations				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$22,646.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,132.30			

ID #	Event				
64	CO 10 - Revise handrail support channel				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$6,695.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$334.75			

ID #	Event				
65	CO 10 - Add sloped sills				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$18,159.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$907.95			

ID #	Event				
66	CO 10 - Steam line premium time				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$6,895.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$344.75			

ID #	Event				
67	CO 10 - Temporary air line				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$8,585.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$429.25			

ID #	Event				
68	CO 11 - Add fire alarm interconnect to door				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/2/2004				\$1,669.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$83.45			

ID #	Event				
69	CO 11 - Revise window and canopy				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/2/2004				\$3,825.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$191.25			

ID #	Event				
70	CO 11 - Paint exposed accoustical deck				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/2/2004				\$58,360.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,918.00			

ID #	Event				
71	CO 12 - Modifications to library to accommodate mobile shelving systems				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$10,509.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$525.45			

ID #	Event				
72	CO 12 - Install additional tack board surfaces throughout the building				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$4,761.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$238.05			

ID #	Event				
73	CO 12 - Revise lighting control system for the building				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$53,054.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,652.70			

ID #	Event				
74	CO 12 - Change fabric-wrapped panels to Forbo surfaces				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$2,866.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$143.30			

ID #	Event				
75	CO 12 - Construct concrete bases at the truss connections				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$9,550.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$477.50			

ID #	Event				
76	CO 12 - Extend ductbank to revised high-voltage switch location				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/30/2004				\$15,599.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$779.95			

ID #	Event				
77	CO 13 - Power & data for room 118 projector				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$2,146.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$107.30			

ID #	Event				
78	CO 13 - Extend sunshade to align with adjacent windows				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$1,410.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$70.50			

ID #	Event				
79	CO 13 - Revise loading area door				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$2,071.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$103.55			

ID #	Event				
80	CO 13 - Modify library circulation desk				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$327.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$16.35			

ID #	Event				
81	CO 13 - Modify tiered studio for ICON lab				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$32,875.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,643.75			

ID #	Event				
82	CO 13 - Modify construction of classrooms 143 & 144				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$17,735.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$886.75			

ID #	Event				
83	CO 13 - Strip fixtures at light cove				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$11,947.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$597.35			

ID #	Event				
84	CO 13 - Change voltage of 2 electrical panels				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$3,247.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$162.35			

ID #	Event				
85	CO 13 - Reconstruct SALA access road				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$271,800.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$13,590.00			

ID #	Event				
86	CO 14 - Concrete storm line				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/8/2004				\$166,395.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$8,319.75			

ID #	Event				
87	CO 15 - Photocell at 5 exterior light fixtures				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/27/2004				\$991.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$49.55			

ID #	Event				
88	CO 15 - Construct immersive construction lab space				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/27/2004				\$111,888.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$5,594.40			

ID #	Event				
89	CO 15 - Change office partition type				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/27/2004				\$11,570.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$578.50			

ID #	Event				
90	CO 16 - Add security system installation to scope				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/4/2004				\$123,787.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$6,189.35			

ID #	Event				
91	CO 16 - Add hoist beam at elevator				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/4/2004				\$1,519.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$75.95			

ID #	Event				
92	CO 16 - Access panels for elevator governors				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/4/2004				\$4,131.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$206.55			

ID #	Event				
93	CO 17 - Install steel plate infills around 4th floor columns				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$11,802.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$590.10			

ID #	Event				
94	CO 17 - Fire-rated enclosure at top of elevator shaft				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$4,256.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$212.80			

ID #	Event				
95	CO 17 - Install a wood bench in office 323				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$3,063.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$153.15			

ID #	Event				
96	CO 17 - Additional photocells for exterior light control				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$991.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$49.55			

ID #	Event				
97	CO 17 - Steel revisions as required by marked-up shop dwgs and IFC dwgs				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$107,951.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$5,397.55			

ID #	Event				
98	CO 18 - Add bookdrop to library				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/8/2004				\$3,252.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$162.60			

ID #	Event				
99	CO 18 - Install additional support for operable partition				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/8/2004				\$5,952.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$297.60			

ID #	Event				
100	CO 18 - Revise routing of EF-3 ductwork				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/8/2004				\$10,545.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$527.25			

ID #	Event				
101	CO 18 - Add top support beams for elevator car rails				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/8/2004				\$1,604.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$80.20			

ID #	Event				
102	CO 19 - Add sprinkler heads under soffit in faculty offices				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/11/2004				\$3,812.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$190.60			

ID #	Event				
103	CO 19 - Add door operator at vestibule F101				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/11/2004				\$6,353.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$317.65			

ID #	Event				
104	CO 19 - Relocate RW conductors				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/11/2004				\$3,731.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$3,731.00			

ID #	Event				
105	CO 19 - Add strip lighting fixtures to office clerestory light cove				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/11/2004				\$1,437.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$71.85			

ID #	Event				
106	CO 20 - Carpet in rooms 102 & 103				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/14/2005				\$3,865.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$193.25			

ID #	Event				
107	CO 20 - Light fixtures at entrance soffits				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/14/2005				\$814.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$40.70			

ID #	Event				
108	CO 20 - Increase mechanical scope work due to lack of coordination in design drawings				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/14/2005				\$29,279.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,463.95			

ID #	Event				
109	CO 21 - Install 5th set of electrical feeders from MDP service entrance				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$4,023.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$201.15			

ID #	Event				
110	CO 21 - Revise layout of spray booth AH systems				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$17,403.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$870.15			

ID #	Event				
111	CO 21 - Lower elevation of library ramp wall per owner req.				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$1,129.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$56.45			

ID #	Event				
112	CO 21 - Add dry sprinkler heads to spray booth ductwork				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$9,219.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$460.95			

ID #	Event				
113	CO 21 - Change light fixtures in rms 102 103 per owner req				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$3,478.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$173.90			

ID #	Event				
114	CO 21 - Install screens in operable windows				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/19/2005				\$59,062.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,953.10			

ID #	Event				
115	CO 22 - Construction yard lighting				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/26/2005				\$11,033.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$551.65			

ID #	Event				
116	CO 22 - Storage rooms at stair 1 and 2				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/26/2005				\$18,508.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$925.40			

ID #	Event				
117	CO 23 - Implement changes in structural steel resulting from improperly coordinated design documents				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$50,780.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$50,780.00			

ID #	Event				
118	CO 23 - Increase width of site wall				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$2,722.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$136.10			

ID #	Event				
119	CO 23 - Install water tower drain line				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$10,079.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$503.95			

ID #	Event				
120	CO 23 - Chilled water bypass line				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$4,895.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$244.75			

ID #	Event				
121	CO 23 - Tie-in drain lines				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$2,695.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$134.75			

ID #	Event				
122	CO 24 - Change cable to direct burial				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$5,731.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$286.55			

ID #	Event				
123	CO 24 - Install track lighting and control changes per owner req				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$2,077.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$103.85			

ID #	Event				
124	CO 24 - Revise site lighting				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$7,427.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$371.35			

ID #	Event				
125	CO 24 - Add power/data to 143 & 144				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$2,364.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$118.20			

ID #	Event				
126	CO 24 - Revise condensate meter location and upgrade				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$4,421.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$221.05			

ID #	Event				
127	CO 24 - Change breaker amperage in life-safety panel				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$662.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$33.10			

ID #	Event				
128	CO 24 - Construct material storage area in work yard				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$42,619.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,130.95			

ID #	Event				
129	CO 25 - Power and controls to additional window operators				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$5,055.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$252.75			

ID #	Event				
130	CO 25 - Add railing to 4th floor level				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$2,204.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$110.20			

ID #	Event				
131	CO 25 - Revise library ramp walls				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$1,086.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$54.30			

ID #	Event				
132	CO 25 - Install perimeter metal panel in the social spaces				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$4,862.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$243.10			

ID #	Event				
133	CO 25 - Relocate sprinkler piping				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$6,052.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$6,052.00		

ID #	Event				
134	CO 26 - Additional power & data in Library				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$2,683.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$134.15		

ID #	Event				
135	CO 26 - Install 30 Amp circuits to tele-data rooms				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$6,400.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$320.00		

ID #	Event				
136	CO 26 - Horn strobe at FD connection				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$541.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$27.05		

ID #	Event				
137	CO 26 - Revise handrail height per L&I				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$1,309.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$1,309.00		

ID #	Event				
138	CO 26 - Access panels at spray booth ductwork				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$2,687.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$134.35			

ID #	Event				
139	CO 27 - Add DF-7 fixtures				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/4/2005				\$9,647.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$482.35			

ID #	Event				
140	CO 27 - Install in-wall blocking per FFE drawings				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/4/2005				\$2,147.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$107.35			

ID #	Event				
141	CO 27 - Revise ductwork layout in model shop				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/4/2005				\$12,091.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$604.55			

ID #	Event				
142	CO 27 - Revise edge details at stepped areas				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/4/2005				\$5,222.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$261.10			

ID #	Event				
143	CO 29 - Copper soffit above service area				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/16/2005				\$6,996.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$349.80			

ID #	Event				
144	CO 29 - Modify railing and gates at construction yard				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/16/2005				\$22,684.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,134.20			

ID #	Event				
145	CO 29 - Reinforce perimeter mezzanine beam slab				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/16/2005				\$9,821.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$491.05			

ID #	Event				
146	CO 31 - Corridor soffit change				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	6/21/2005				\$13,195.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$659.75			

ID #	Event				
147	CO 33 - Revise hardware at balcony door				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/25/2005				\$1,139.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,139.00			

ID #	Event				
148	CO 33 - Additional push button at interior vestibule				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/25/2005				\$484.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$24.20			

ID #	Event				
149	CO 33 - Relocate dust collection drop locations				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/25/2005				\$1,003.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$50.15			

ID #	Event				
150	CO 34 - PVC jacketing on rainwater covers				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2005				\$646.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$32.30			

ID #	Event				
151	CO 34 - Partition wall in Rm P006				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2005				\$7,891.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$394.55			

ID #	Event				
152	CO 34 - Revise construction yard railing				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2005				\$14,491.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$724.55			

ID #	Event				
153	CO 34 - Permanent filter bags				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2005				\$8,700.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$435.00			

ID #	Event				
154	CO 37 - Toilet paper dispensers				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/22/2005				\$531.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$26.55			

ID #	Event				
155	CO 37 - Install RAKKS shelving standards				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/22/2005				\$4,374.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$218.70			

ID #	Event				
156	CO 37 - Projection screens in classrooms 144 and 143				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/22/2005				\$3,202.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$160.10			

ID #	Event				
157	CO 39 - Modifications to meet L&I requirements				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$6,107.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$305.35			

ID #	Event				
158	CO 39 - Complete miscellaneous electrical revisions				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$983.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$49.15			

ID #	Event				
159	CO 39 - Additonal landscaping at construction yard hillside				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$3,191.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$159.55			

ID #	Event				
160	CO 39 - Piping changes in studios and IEL				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$3,383.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$169.15			

ID #	Event				
161	CO 39 - Hardwire desks				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$13,305.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$665.25			

ID #	Event				
162	CO 39 - Water tower fence materials				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$19,254.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$962.70			

ID #	Event				
163	CO 39 - Pavers at front entrance				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$3,350.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$167.50		

ID #	Event				
164	CO 39 - Relocate toilet paper dispensers				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$531.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$26.55		

ID #	Event				
165	CO 39 - Steel plates at grad studio railing				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/11/2005				\$3,106.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$155.30		

ID #	Event				
166	CO 43 - Temporary winter protection (necessary because of steel delays)				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$26,080.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$26,080.00		

ID #	Event				
167	CO 43 - Exterior handrails along walkway to trash compactor				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$1,583.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
			\$79.15		

ID #	Event				
168	CO 43 - Relocate existing lighting contactors				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$2,242.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$112.10			

ID #	Event				
169	CO 43 - Revise dust collector piping				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$856.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$42.80			

ID #	Event				
170	CO 43 - Modify rubber liner detail for parking lot bioswales				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$22,332.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$22,332.00			

ID #	Event				
171	CO 44 - Provide trash compactor & associated equipment				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	12/12/2005				\$32,532.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,626.60			

ID #	Event				
172	CO 46 - Extend trash compactor walls an additional 16"				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/7/2006				\$7,428.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$371.40			

ID #	Event				
173	CO 46 - Accoustical work in model shop etc...				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/7/2006				\$25,095.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,254.75			

ID #	Event				
174	CO 46 - Water tower fence installation				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/7/2006				\$33,147.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,657.35			

ID #	Event				
175	CO 47 - Weather station				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2006				\$5,842.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$292.10			

ID #	Event				
176	CO 47 - Vertical rod guards				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2006				\$5,445.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$272.25			

ID #	Event				
177	CO 47 - Sawcut chamfer in concrete bench				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2006				\$1,236.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$61.80			

ID #	Event				
178	CO 47 - Additional control valves for office radiant heat				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2006				\$10,057.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$502.85			

ID #	Event				
179	CO 47 - Architectural work associated with additional control valves				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2006				\$1,629.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$1,629.00			

ID #	Event				
180	CO 49 - Access point cables for wireless network				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	12/13/2006				\$5,007.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$250.35			

ID #	Event				
212	Delay Costs CO 1 - Revert to original pile design				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/5/2004				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$10,000.00			

ID #	Event				
213	Delay Costs CO 3 - Revise location of fire hydrant				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/18/2004				\$2,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,000.00			

ID # Event					
214 Delay Costs CO 7 - Pedestrian ramp at Palmer museum side entrance					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/15/2004				\$2,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,000.00			

ID # Event					
215 Delay Costs CO 8 - Add trees at revised service entrance					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	8/6/2004				\$2,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$2,000.00			

ID # Event					
216 Delay Costs CO 10 - Revise media stations					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/1/2004				\$4,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$4,000.00			

ID # Event					
217 Delay Costs CO 11 - Add fire alarm interconnect to door					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	9/2/2004				\$6,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$6,000.00			

ID # Event					
218 Delay Costs CO 13 - Power & data for room 118 projector					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/7/2004				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$10,000.00			

ID #	Event				
219	Delay Costs CO 15 - Photocell at 5 exterior light fixtures				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/27/2004				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$10,000.00			

ID #	Event				
220	Delay Costs CO 16 - Add security system installation to scope				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/4/2004				\$18,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$18,000.00			

ID #	Event				
221	Delay Costs CO 17 - Install steel plate infills around 4th floor columns				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/5/2004				\$42,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$42,000.00			

ID #	Event				
222	Delay Costs CO 23 - Implement changes in structural steel				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$10,000.00			

ID #	Event				
223	Delay Costs CO 24 - Change cable to direct burial				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
		Construction		Design	Delay
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/25/2005				\$4,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$4,000.00			

ID #	Event				
224	Delay Costs CO 25 - Power and controls to additional window operators				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005				\$4,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$4,000.00			

ID #	Event				
225	Delay Costs CO 26 - Additional power & data in Library				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	5/3/2005				\$6,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$6,000.00			

ID #	Event				
226	Delay Costs CO 43 - Temporary winter protection (necessary because of steel delays)				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Turnover	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	11/21/2005				\$18,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$18,000.00			

ID #	Event				
227	Delay Costs - Amendment for Telecom Revisions				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction Procurement	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Amendment	10/24/2003				\$10,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$10,000.00		1 week delay based on ame	

ID #	Event				
228	Delay Costs - Amendment for Admin Office Redesign				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Construction Procurement	Design	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Amendment	4/30/2003				\$30,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$30,000.00		3 week delay based on ame	

ID #	Event				
229	Delay Costs - Revised Elevation Studies & Schematic Design				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
		Design	Planning	Delay	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
WTW Correspondence	9/18/2002				\$170,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
		\$170,000.00		17 week delay based on 9/1 2002 WTW	

Table B-1: Calculation for SALA Job Conference Project Process Status Updates (ID# 15)

JCR	PSU		OPP		Contractor				Consultant			
	PM	DH	VP/D	PM	CQR	SPM	PM	Super	PE	A/E	Cx	O
2	1	1		1	1		1	1	1	3		2
3	1	2	1	1	1		2	1	2	2		
4	1	2		1	1		1	1	1	4	1	
5	1	2		1		1	1			3		1
6	1	1	1	1	1		1	1	2	3		
7	1	2		1	1	1	1	1	2	4		1
8	1	2		1	1			1	2	3		1
9	1	2		1	1		1	1	2	3		1
10		1		1	1		1	1	1	2		
11	1			1	1		1	1	2	3		2
12	1			1	1		1	1	2	2	1	1
13	1	2		1	1		1	1	2	3		1
14	1	2		1	1		1	1	2	3		2
15	1	2		1	1		1	1	2	3		1
16	1	2		1	1		1	1	2	3		
17	1			1	1		1	1	2	3		1
18	1			1	1		1	1	1	2		1
19	1	1		1	1		1	1	2	3		
20	1	2		1	1		1	1	2	2		1
21	1	2		1	1		1	1	2	2		1
22	1	2			1		1	1	2	2		
23	1	1		1	1		1	1	2	2	1	1
24	1	1		1	1		1	1	2	3		
25	1	2		1	1		1	1	2	2		
26	1	2		1	1		1	1	2	2		
27	1	1		1	1		1	1	2	3	1	
28	1	2		1	1		1	1	2	2	1	
29	1	1		1	1		1	1	2	3	1	
30	1	1		1	1		1	1	2	2	1	1
31	1	2		1	1		1	1	2	2	1	
32	1	1		1	1		1		2	3	1	1
33	1	2		1	1		1	1	2	2	1	
34	1	2		1	1		1	1	2	2		
35		2		1	1		1		2	3		
36	1	2		1	1		1	1	1	3	1	
37	1	2		1	1	1	1		2	2	1	1
38	1	2		1	1	1	1		2	2	1	1
39	1	2		1	1		1		2	2	1	1
40	1	2		1	1		1		2	3		1
People	37	60	2	38	38	4	39	32	71	101	14	24
Hrs/mtg	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Hrs	9.25	15	0.5	9.5	9.5	1	9.75	8	17.75	25.25	3.5	6
Wage/hr	50	100	100	75	75	150	125	125	100	125	125	75
Sub (\$)	463	1,500	50	713	713	150	1,219	1,000	1,775	3,156	438	450
Total Cost Impact											\$11,625	

B.2 Forest Resources Raw Data and Supporting Calculations

ID #	Event				
1	Sitework CO 10 - grading revisions				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	3/3/2006	N/A	0	Change Order Amount	\$1,300.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$65.00		

ID #	Event				
2	Sitework CO 6 - Membrane waterproofing				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/16/2005	N/A	0	Change Order Amount	\$9,400.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$470.00		

ID #	Event				
3	Sitework CO 5 - Services for groundbreaking ceremony				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Organizational	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/14/2005	N/A	0	Change Order Amount	\$12,690.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$635.00		

ID #	Event				
4	Sitework CO 3 - Increase steam tunnel base to 12"				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/13/2005	N/A	0	Change Order Amount	\$6,715.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$336.00		

ID #	Event				
5	Concrete CO 8 - Winter protection final				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	7/14/2005	N/A	0	Change Order Amount	\$6,874.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$344.00		

ID #	Event				
6	Concrete CO 6 - groundbreaking ceremony				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	4/4/2005	N/A	0	Change Order Amount	\$2,093.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$105.00			

ID #	Event				
7	Concrete CO 4 - groundbreaking ceremony				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/25/2005	N/A	0	Change Order Amount	\$1,903.94
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$95.00			

ID #	Event				
8	Concrete CO 4 - J line grade beam				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/25/2005	N/A	0	Change Order Amount	\$3,084.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$154.00			

ID #	Event				
9	Concrete CO 3 - Basement column per Asi 15				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	2/25/2005	N/A	0	Change Order Amount	\$2,537.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$127.00			

ID #	Event				
10	Concrete CO 3 - Rigid insulation on meadow wing detail				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	1/11/2005	N/A	0	Change Order Amount	\$3,556.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$178.00			

ID #	Event				
11	Masonry CO 1 - Temporary winter protection due to late project start				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	7/28/2004	N/A	0	Change Order Amount	\$147,363.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$7,368.00			

ID #	Event				
12	Masonry CO 2 - Temporary winter protection				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change order	2/2/2005	N/A	0	Change Order Amount	\$42,905.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$2,145.00			

ID #	Event				
13	Masonry CO 4 - Additional services per bulletin 3				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/6/2006	N/A	0	Change Order Amount	\$11,694.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$585.00			

ID #	Event				
14	Masonry CO 4 - exterior grade blocking & plywood				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/6/2006	N/A	0	Change Order Amount	\$1,324.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$66.00			

ID #	Event				
15	Masonry CO 4 - Revise jamb details at window				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/6/2006	N/A	0	Change Order Amount	\$21,500.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$1,075.00			

ID #	Event					
16	Masonry CO 4 - Rebar/grout at elevator shaft					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	1/6/2006	N/A	0	Change Order Amount	\$12,819.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes	
Change Order Premium	5%		\$641.00			

ID #	Event					
17	Masonry CO 4 - Add vapor barrier per rfi 502					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	1/6/2006	N/A	0	Change Order Amount	\$5,878.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes	
Change Order Premium	5%		\$294.00			

ID #	Event					
18	Masonry CO 4 - Add CMU to MW penthouse					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	1/6/2006	N/A	0	Change Order Amount	\$2,492.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes	
Change Order Premium	5%		\$125.00			

ID #	Event					
19	Steel CO 10 - Additional penthouse stair handrails					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	2/28/2006	N/A	0	Change Order Amount	\$2,849.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes	
Change Order Premium	5%		\$142.00			

ID #	Event					
20	Steel CO 10 - Elevator penthouse door and frame changes					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	2/28/2006	N/A	0	Change Order Amount	\$4,988.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes	
Rework Full Cost	100%		\$4,988.00			

ID #	Event				
21	Steel CO 9 - toilet room revisions per ASI 20				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change Order	10/5/2005	N/A	0	Change Order Amount	\$584.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$29.00			

ID #	Event				
22	Steel CO 9 - Cost to cut and remove framing at elevator penthouse				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/5/2005	N/A	0	Change Order Amount	\$716.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Rework Full Cost	100%	\$716.00			

ID #	Event				
23	Steel CO 9 - Additional steel to support additional AV projector				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/5/2005	N/A	0	Change Order Amount	\$1,626.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$81.00			

ID #	Event				
24	Steel CO 8 - Add support at wood decking				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	7/14/2005	N/A	0	Change Order Amount	\$1,019.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$51.00			

ID #	Event				
25	Steel CO 7 - Revised girt connection				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/28/2005	N/A	0	Change Order Amount	\$1,894.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Rework Full Cost	100%	\$1,894.00			

ID #	Event				
26	Steel CO 6 - Change elevator steel				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/17/2005	N/A	0	Change Order Amount	\$5,951.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$298.00			

ID #	Event				
27	Steel CO 6 - Revise steel per ASI 9				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/17/2005	N/A	0	Change Order Amount	\$4,437.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$222.00			

ID #	Event				
28	Steel CO 5 - ASI 7 steel changes				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/14/2005	N/A	0	Change Order Amount	\$916.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$46.00			

ID #	Event				
29	Steel CO 5 - Add basement column per ASI 15				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/14/2005	N/A	0	Change Order Amount	\$4,549.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$227.00			

ID #	Event				
30	Steel CO 5 - Modify shaft openings				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/14/2005	N/A	0	Change Order Amount	\$1,328.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost	100%	\$1,328.00			

ID #	Event				
31	Steel CO 4 - Add swing gate at basement stairs				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/9/2005	N/A	0	Change Order Amount	\$1,642.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$82.00		

ID #	Event				
32	Steel CO 1 - Engineered SDs for glue laminated beams				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/28/2004	N/A	0	Change Order Amount	\$14,273.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$714.00		

ID #	Event				
33	Roofing CO 7 - Skylight curb blocking				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Change order	3/7/2006	N/A	0	Change Order Amount	\$1,206.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$60.00		

ID #	Event				
34	Curtain wall CO 8 - Add plastic tubing below open feature				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$859.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$43.00		

ID #	Event				
35	Curtain wall CO 7 - Aluminum fascia				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	9/22/2005	N/A	0	Change Order Amount	\$38,708.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$1,935.00		

ID #	Event				
36	Curtain wall CO 5 - Provide door hardware				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	7/8/2005	N/A	0	Change Order Amount	\$18,582.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$929.00			

ID #	Event				
37	HVAC CO 12 - modify ductwork at 4th bridge				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	7/28/2004	N/A	0	Change Order Amount	\$428.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$21.00			

ID #	Event				
38	HAVC CO 12 - Add pressure gauges				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	8/15/2006	N/A	0	Change Order Amount	\$768.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$38.00			

ID #	Event				
39	HVAC CO 11 - Change VAV connections				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/27/2006	N/A	0	Change Order Amount	\$5,736.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Rework Full Cost	100%	\$5,736.00			

ID #	Event				
40	HVAC CO 11 - Modify fume hood exhaust ductwork				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/27/2006	N/A	0	Change Order Amount	\$14,444.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Rework Full Cost	100%	\$14,444.00			

ID #	Event				
41	HVAC CO 10 - Fin tube changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/9/2006	N/A	0	Change Order Amount	\$3,414.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost		100%		\$3,414.00	

ID #	Event				
42	HVAC CO 9 - Change steam PRVs for heat exchangers				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	5/18/2006	N/A	0	Change Order Amount	\$539.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost		100%		\$539.00	

ID #	Event				
43	HVAC CO 8 - Upgrade automatic dampers to stainless steel				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/21/2006	N/A	0	Change Order Amount	\$11,851.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium		5%		\$593.00	

ID #	Event				
44	HVAC CO 7 - schedule recovery/overtime				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$17,684.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium		5%		\$884.00	

ID #	Event				
45	HVAC CO 7 - atrium smoke damper changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$1,654.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium		5%		\$83.00	

ID #	Event				
46	HVAC CO 7 - new ductwork per rfi 484				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$2,007.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$100.00		

ID #	Event				
47	HVAC CO 7 - add duct to penthouse roof				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$1,309.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$65.00		

ID #	Event				
48	HVAC CO 6 - return air duct per ASI 18				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	11/10/2005	N/A	0	Change Order Amount	\$31,577.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$1,579.00		

ID #	Event				
49	HVAC CO 6 - Mechanical changes per bulletin 5				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	7/28/2004	N/A	0	Change Order Amount	\$70,698.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$3,535.00		

ID #	Event				
50	HVAC CO 1 - HVAC work in multiple rooms				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/28/2004	N/A	0	Change Order Amount	\$50,226.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$2,511.00		

ID #	Event					
51	GC CO 16 - Extend general conditions due to late Millwork					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of status	Project	Turnover		Construction	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	6/28/2006	N/A		0 Change Order Amount	\$75,000.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
Rework Full Cost	100%		\$75,000.00			

ID #	Event					
52	GC CO 15 - Additional signage					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of status	Organizational	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	5/3/2006	N/A		0 Change Order Amount	\$370.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
Change Order Premium	5%		\$19.00			

ID #	Event					
53	GC CO 15 - tube steel under growth chamber					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	5/3/2006	N/A		0 Change Order Amount	\$1,475.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
Change Order Premium	5%		\$74.00			

ID #	Event					
54	GC CO 14 - Additional labor to install stringer wood					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of status	Project	Turnover		Construction	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	4/26/2006	N/A		0 Change Order Amount	\$4,703.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
Rework Full Cost	100%		\$4,703.00			

ID #	Event					
55	GC CO 14 - Round columns per RFI 388					
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category	
recognition of interdependence	Project	Turnover		Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value	
change order	4/26/2006	N/A		0 Change Order Amount	\$4,885.00	
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions		Notes
Change Order Premium	5%		\$244.00			

ID #	Event				
56	GC CO 14 - Terrazzo strip around entrance mats				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Organizational	Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/26/2006	N/A	0	Change Order Amount	\$2,875.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$144.00			

ID #	Event				
57	GC CO 13 - Fin tube enclosure grilles				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/7/2006	N/A	0	Change Order Amount	\$18,675.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$934.00			

ID #	Event				
58	GC CO 13 - Add fin tube enclosures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/7/2006	N/A	0	Change Order Amount	\$38,000.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$1,900.00			

ID #	Event				
59	GC CO 13 - Electric room ceilings as drywall				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/7/2006	N/A	0	Change Order Amount	\$2,193.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$110.00			

ID #	Event				
60	GC CO 12 - Rework hollow metal frames & wood doors				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$3,549.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost	100%	\$3,549.00			

ID #	Event				
61	GC CO 12 - Additional labor to install wood base due to late delivery				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$5,958.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost	100%	\$5,958.00			

ID #	Event				
62	GC CO 12 - Temporary doors and enclosures				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$3,724.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost	100%	\$3,724.00			

ID #	Event				
63	GC CO 12 - Provide opening between rooms 201 & 202				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$768.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$38.00			

ID #	Event				
64	GC CO 11 - Pocket detail @ fin tube				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$2,516.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$126.00			

ID #	Event				
65	GC CO 11 - Revise GWB bulkheads				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$2,608.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$130.00			

ID #	Event				
66	GC CO 11 - Add fire extinguishers & cabinets				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$2,814.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$141.00			

ID #	Event				
67	GC CO 11 - insulation @ fin tube				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$4,583.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$229.00			

ID #	Event				
68	GC CO 10 - toilet room revisions				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/19/2005	N/A	0	Change Order Amount	\$1,699.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$85.00			

ID #	Event				
69	GC CO 10 - Drywallers overtime (schedule recovery)				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Organizational	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/19/2005	N/A	0	Change Order Amount	\$3,154.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$158.00			

ID #	Event				
70	GC CO 9 - Temporary heat				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	9/21/2005	N/A	0	Change Order Amount	\$96,854.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$4,843.00			

ID #	Event				
71	GC CO 8 - Add doors per ASI 17				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	9/1/2005	N/A	0	Change Order Amount	\$3,554.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$178.00			

ID #	Event				
72	GC CO 8 - Metal panel revisions				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	9/1/2005	N/A	0	Change Order Amount	\$13,992.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$700.00			

ID #	Event				
73	GC CO 7 - Additional setup for 2nd metal panel color				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/28/2005	N/A	0	Change Order Amount	\$1,914.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$96.00			

ID #	Event				
74	GC CO 5 - Hardware revisions per bulletin 4				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Organizational	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/11/2005	N/A	0	Change Order Amount	\$11,959.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$598.00			

ID #	Event				
75	GC CO 4 - Change partition/door/hollow in electric rooms				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/14/2005	N/A	0	Change Order Amount	\$1,410.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions	Notes	
Change Order Premium	5%	\$71.00			

ID #	Event				
76	Elevator CO 6 - 2 way communication system				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		Construction	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/13/2005	N/A	0	Change Order Amount	\$8,891.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$445.00		

ID #	Event				
77	Casework CO 5 - Additional electrical pedestals				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/26/2006	N/A	0	Change Order Amount	\$1,221.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$61.00		

ID #	Event				
78	Casework CO 3 - Change wood shelving to stainless steel				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/19/2005	N/A	0	Change Order Amount	\$26,993.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$1,350.00		

ID #	Event				
79	Casework CO 1 - Fume hoods				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/13/2005	N/A	0	Change Order Amount	\$88,720.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$4,436.00		

ID #	Event				
80	ATC CO 11 - Additional steam meter plate				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/29/2006	N/A	0	Change Order Amount	\$1,941.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$97.00		

ID #	Event				
81	ATC CO 10 - Damper changes & remote switch				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/22/2006	N/A	0	Change Order Amount	\$1,480.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$74.00		

ID #	Event				
82	ATC CO 8 - Humidity sensor for fishery area				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Organizational	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	11/10/2005	N/A	0	Change Order Amount	\$1,435.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$72.00		

ID #	Event				
83	ATC CO 5 - Design & supply of phoenix valves				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/14/2005	N/A	0	Change Order Amount	\$11,225.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$561.00		

ID #	Event				
84	ATC CO 4 - MEP changes per bulletin 2				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/26/2005	N/A	0	Change Order Amount	\$2,023.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$101.00		

ID #	Event				
85	Plumbing CO 14 - eye wash add				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Organizational	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	5/3/2006	N/A	0	Change Order Amount	\$5,203.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$260.00		

ID #	Event				
86	Plumbing CO 13 - compressed air for vacuum pump				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/26/2006	N/A	0	Change Order Amount	\$1,013.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$51.00		

ID #	Event				
87	Plumbing CO 12 - Plumbing piping at basement projection screen				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$2,880.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$2,880.00		

ID #	Event				
88	Plumbing CO 12 - Hose bib installation at column line F				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$2,734.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$137.00		

ID #	Event				
89	Plumbing CO 11 - Sump pit cover				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/7/2006	N/A	0	Change Order Amount	\$3,562.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$178.00		

ID #	Event				
90	Plumbing CO 10 - RWL at entrance canopies				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/3/2006	N/A	0	Change Order Amount	\$9,607.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$480.00		

ID #	Event				
91	Plumbing CO 10 - Rework casework plumbing				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/3/2006	N/A	0	Change Order Amount	\$8,469.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$8,469.00			

ID #	Event				
92	Plumbing CO 9 - Water closet at men's room				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Organizational	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/3/2005	N/A	0	Change Order Amount	\$2,672.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$134.00			

ID #	Event				
93	Plumbing CO 9 - piping for fume hood				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/3/2005	N/A	0	Change Order Amount	\$4,700.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$235.00			

ID #	Event				
94	Plumbing CO 8 - Water meter bypass				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/2/2005	N/A	0	Change Order Amount	\$2,837.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$142.00			

ID #	Event				
95	Plumbing CO 5 - Revised shower enclosure				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Construction	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/15/2005	N/A	0	Change Order Amount	\$1,259.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Change Order Premium	5%	\$63.00			

ID #	Event				
96	FP CO 7 - Electric room changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$1,302.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$1,302.00		

ID #	Event				
97	FP CO 7 - Cable tray changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$1,420.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$1,420.00		

ID #	Event				
98	FP CO 7 - atrium sprinkler revisions				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$6,800.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$6,800.00		

ID #	Event				
99	FP CO 7 - Relocate sprinklers				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$3,858.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$3,858.00		

ID #	Event				
100	Electrical CO 14 - Circuit breaker revisions				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/28/2006	N/A	0	Change Order Amount	\$718.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$718.00		

ID #	Event				
101	Electrical CO 13 - relocate MCC				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/9/2006	N/A	0	Change Order Amount	\$5,880.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$5,880.00		

ID #	Event				
102	Electrical CO 13 - Miscellaneous owner additions				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Organizational	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/9/2006	N/A	0	Change Order Amount	\$4,144.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$207.00		

ID #	Event				
103	Electrical CO 13 - miscellaneous changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	6/9/2006	N/A	0	Change Order Amount	\$13,049.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$652.00		

ID #	Event				
104	Electric CO 12 - Remove 3 lamp ballasts				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	5/3/2006	N/A	0	Change Order Amount	\$5,258.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$5,258.00		

ID #	Event				
105	Electric CO 12 - Change electric check meters				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	5/3/2006	N/A	0	Change Order Amount	\$1,134.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$57.00		

ID #	Event				
106	Electric CO 11 - Miscellaneous rework				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Construction	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/10/2006	N/A	0	Change Order Amount	\$24,417.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$24,417.00		

ID #	Event				
107	Electrical CO 11 - Miscellaneous additions				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	4/10/2006	N/A	0	Change Order Amount	\$14,151.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$708.00		

ID #	Event				
108	Electrical CO 10 - display case lighting				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$3,837.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$192.00		

ID #	Event				
109	Electrical CO 10 - Miscellaneous rework				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	2/28/2006	N/A	0	Change Order Amount	\$2,108.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$2,108.00		

ID #	Event				
110	Electrical CO 9 - Add power and controls for coiling fire door				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/9/2006	N/A	0	Change Order Amount	\$8,548.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Change Order Premium	5%		\$427.00		

ID #	Event				
111	Electrical CO 8 - Miscellaneous adds				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$40,442.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$2,022.00			

ID #	Event				
112	Electrical CO 8 - Access control panel/card access changes				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Organizational	Turnover		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/4/2006	N/A	0	Change Order Amount	\$34,649.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Rework Full Cost	100%	\$34,649.00			

ID #	Event				
113	Electrical CO 7 - Add spare site electrical conduits				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	10/24/2005	N/A	0	Change Order Amount	\$15,742.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$787.00			

ID #	Event				
114	Electrical CO 5 - Add smoke dampers & elevator backup				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	3/2/2005	N/A	0	Change Order Amount	\$2,641.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$132.00			

ID #	Event				
115	Electrical CO 4 - MEP changes to add split cooling system				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Construction		Design	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
change order	1/13/2005	N/A	0	Change Order Amount	\$6,836.00
Connecting Principles	Connecting Principle Impacts	Cost Impact		Assumptions	Notes
Change Order Premium	5%	\$342.00			

ID #	Event				
116	CM Amendment - Time extension related to late woodwork				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Turnover	Construction	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	5/16/2007	N/A	0	Amendment Amount	\$89,143.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$89,143.00			

ID #	Event				
117	CM amendment - change order fee increase				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of interdependence	Project	Turnover	Design	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	5/16/2007	N/A	0	Amendment Amount	\$2,679.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$2,679.00			

ID #	Event				
118	CM amendment - Escalation of base staff related to delays				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Construction	Planning	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	9/13/2004	N/A	0	Amendment Amount	\$20,330.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$20,330.00			Pg 3 of 5, 45178

ID #	Event				
119	A/E amendment - VE/bid negotiation services fee				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Project	Turnover	Planning	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	7/11/2007	N/A	0	Amendment Amount	\$24,125.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$24,125.00			

ID #	Event				
120	A/E Amendment - Re-design of mechanical penthouse				
Transparency Aspect	Transparency Type	Delivery Phase	When Avoidance?	Cost Category	
recognition of status	Organizational	Design	Planning	Mitigation	
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Work Order #8	10/27/2003	N/A	0	Amendment Amount	\$16,500.00
Connecting Principles	Connecting Principle Impacts	Cost Impact	Assumptions		Notes
Rework Full Cost	100%	\$16,500.00			

ID #	Event				
121	A/E Amendment - Rework related to revised project phasing				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		Planning	Mitigation
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Work Order #9	10/29/2003	N/A	0	Amendment Amount	\$31,295.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Rework Full Cost	100%		\$31,295.00		

ID #	Event				
122	Scheduling consultant contract				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	9/10/2004	N/A	0	contract amount	\$84,634.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$84,634.00		

ID #	Event				
123	Planning committee invitation - write letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Organizational	Planning		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	11/4/1997	Hours	1	Hourly wage	\$200.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$200.00		1 hour to write letter

ID #	Event				
124	Planning committee letter - read invitation				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Organizational	Planning		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	11/4/1997	Hours	5	Hourly wage	\$500.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$500.00		10 people x 1/2 hr

ID #	Event				
125	A/E letter clarifying regulatory approvals status				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Planning		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	2/28/2002	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hr x \$100/hr

ID #	Event				
126	A/E Orientation conference (DGS mandated)				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Orientation Summary Sheet	7/26/2002	Hours	10	Hourly wage	\$975.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$1,200.00		On excel sheet

ID #	Event				
127	Submission schedule letter by DGS				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Letter	9/24/2002	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour for DGS P

ID #	Event				
128	Engineer letter clarifying utility responsibilities				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of interdependence	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	10/14/2002	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour to write let

ID #	Event				
129	Drawing review comments re: code approvals				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Review comments	11/1/2002	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		15 minutes per co

ID #	Event				
130	Sketch design review meeting				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Meeting minutes	10/28/2002	Hours	13	Hourly wage	\$1,225.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$1,400.00		see excel sheet

ID #	Event				
131	DGS sketch approval letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	11/6/2002	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour to write let \$100.00

ID #	Event				
132	Borough review procedure clarification letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	2/4/2003	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x \$100 ho \$100.00

ID #	Event				
135	DGS preliminary approval letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	3/25/2003	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x \$100/hr \$100.00

ID #	Event				
136	DGS final approval letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	6/10/2003	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x 100/hr \$100.00

ID #	Event				
137	Wood flooring guild status letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	5/23/2003	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour for letter x \$100.00

ID #	Event				
138	A/E letter clarifying regulatory approvals status				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Design		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	8/22/2003	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x 100/hr

ID #	Event				
139	Final inspection letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Turnover		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	3/7/2005	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x 100/hr

ID #	Event				
140	Bond inspection letter				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Turnover		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
letter	2/20/2007	Hours	1	Hourly wage	\$100.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$100.00		1 hour x 100/hr

ID #	Event				
141	Job conference project process status updates				
Transparency Aspect	Transparency Type	Delivery Phase		When Avoidance?	Cost Category
recognition of status	Project	Construction		N/A	Avoidance
Cost Record	Date	Technical Measure	Technical Value	Economic Measure	Value
Job Conference Reports		Hours	0	Hourly Wage	\$6,750.00
Connecting Principles	Connecting Principle Impacts		Cost Impact	Assumptions	Notes
Avoidance Full Cost	100%		\$7,363.00		See Excel Sheet f

Table B-2: Calculations for Forest Resources Job Conference Project Process Status Updates (ID# 141)

JCR #	PSU Prof	OPP PM	CQR	Contractor		Super	A/E Arch	Eng	DGS PM
1	2	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	1	1	
3	2	2	1	1	1	1	1	1	1
4	2	1		1	1	1	1	1	1
5	2	1		1	1	1	1	1	1
6	2	2		1	1	1	1	1	1
7	2	1		1	1	1	1		
8	2	2	2	1	1	1	1	1	1
9	2	1	1	1	1	1	1		
10	1	1	1	1	1	1	1		
11	2	1	1	1	1	1	1		
12	1	1	1	1	1	1	1		
13	2	1	1	1	1	1	1		
14	1	1	1	1	1	1	1		
15	2	1	1	1	1	1	1		
16	1	1	1	1	1	1	1		
17	2	1	1	1	1	1	1		
18	1	1	2	1	1	1	1		1
19	2	1	2	1	1	1	3	1	1
20	2	2	2	1	1	1	3	1	1
21	1	1	1	1	1	1	1		
22	2	1	1	1	1	1	1		
23	1	1	1	1	1	1	1		
24	2	1	1	1	1	1	1		
25	1	1	1	1	1	1	1		
26	2	1	1	1	1	1	1		
27	1	1	1	1	1	1	1		
28	2	1	1	1	1	1	1		
29	1	1	1	1	1	1	1		
30	2	1	1	1	1	1	1		
31	1	1	1	1	1	1	1		
32	2	1	1	1	1	1	1		
33	1	1	1	1	1	1	1		
People	53	37	33	33	33	33	37	7	4
Hours/mtg	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total hrs	13.25	9.25	8.25	8.25	8.25	8.25	9.25	1.75	1
Wage	100	75	75	150	125	125	125	125	50
SubTotal \$	\$1,325	\$694	\$619	\$1,238	\$1,031	\$1,031	\$1,156	\$219	\$50
Total \$									\$7,363

CQR = Construction Quality Representative

DGS = Pennsylvania Department of General Services

Table B-3: Calculations for Forest Resources A/E Orientation Conference (ID# 126)

	PSU		A/E		CM	DGS	Cx
	SPM	PM	Principal	PM			
Number	1	1	1	1	1	5	1
Hours	1	1	1	1	1	1	1
Hourly Wage	\$100	\$75	\$175	\$125	\$125	\$50	\$125
Subtotal	\$100	\$75	\$175	\$125	\$125	\$250	\$125
Total							\$975

Table B-4: Calculations for Forest Resources Sketch Review Conference (ID# 130)

	PSU		A/E		CM		DGS	Cx
	SPM	PM	Principal	PM	Arch	Eng		
Number	1	1	1	1	1	1	1	5
Hours	1	1	1	1	1	1	1	1
Hourly Wage	\$100	\$75	\$175	\$125	\$125	\$125	\$125	\$50
Subtotal	\$100	\$75	\$175	\$125	\$125	\$125	\$125	\$250
Total								\$1,225

B.3 Semi-Structured Interviews

Semi-structured interviews were performed as part of the qualitative portion of the application of counterfactuals to project delivery (Section 4.27). For the SALA project, the OPP project manager and construction quality representative were interviewed. For the Forest Resources project, the OPP project manager was interviewed.

The following introduction was used prior to asking the interview questions:

“I was hoping you would be able to volunteer to answer some questions about the delivery of the SALA and Forest Resources buildings for me. The questions are related to

my graduate research being performed in Penn State's Architectural Engineering department."

The interviewees were then read the Implied Consent form (Figure **D-2**).

"Please let me know if you have any questions."

B.3.1 Question categories

Questions for the semi-structured interviews with project stakeholders depend primarily on the findings of the initial review of the project files. Following are representative examples of these questions organized by four general categories. Other project-specific questions along these same lines depend on the interview subjects' responses.

B.3.1.1 Additional documentation

Additional documentation questions seek input from project stakeholders to ensure available information is not overlooked. For example:

- Are there any other fruitful documents to look at other than the project files I have already reviewed? (e.g., files I have missed, electronic files and on-line schedules)
 - No additional files or major sources of information were available for the SALA or Forest Resources project.
- Were there design meetings? If so, where could I find these records? How many meetings were there and what was a typical agenda?

B.3.1.2 Additional information

Additional information questions seek answers from project stakeholders to incomplete information in the project records. For example:

- How much time was spent on Value Engineering?
 - For one SALA project manager, value engineering was a three-week, “all-consuming” process. The other project manager was only involved briefly at the very end of the effort.
- How long was the average “general discussion of progress” at job conference meetings?
 - 15 minutes
- How much time was spent in sketch review, A/E orientation, and other Department of General Services meetings?

B.3.1.3 Cost impact verification

Cost impact verification questions solicit the judgment of project stakeholders regarding major cost impacts identified in the review of the project records. For example:

- Could you tell me about (Insert major issue here, e.g., Forest Resources locally harvested wood) and how it impacted the project?
- Did the knowledge to avoid this situation exist with any stakeholder at any point in the project?
- How could this knowledge have been accessed?

- o The Forest Resources project manager's independent account verified the background regarding the Forest Resources locally harvested wood issue described in Section 4.26.1.1.
- o The SALA steel delays and related winter protection were also verified through the independent accounts of the project manager and construction quality representative. Both sides could have given a little to fix this issue.

B.3.1.4 Connecting principles verification

Connecting Principles Verification questions solicit the judgment of project stakeholders regarding connecting principles used in the research. For example:

- What is your best estimate for the change order price difference?
 - o Estimates ranged from 20% to 30% plus out-of-sequence work
- What is your best estimate for the value engineering credit difference?
 - o Estimates ranged from 70-75%.

Appendix C

Process Maps, Quizzes, and Surveys

C.1 Process Map (Capital Project Delivery)

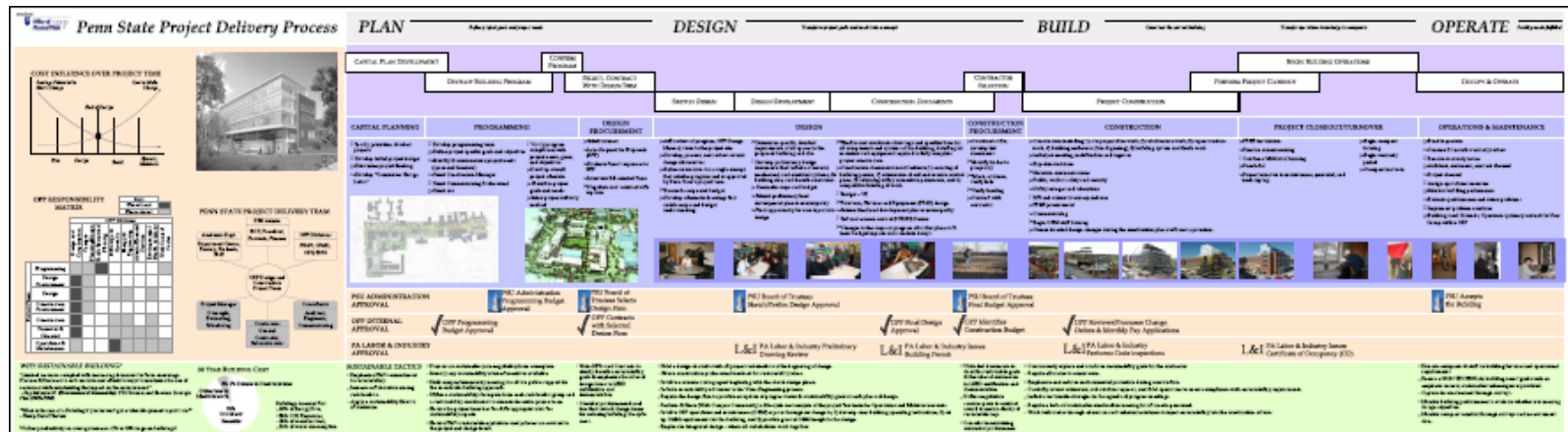


Figure C-1: Capital Project Delivery Process Map⁷

⁷ Process maps shown in this appendix are meant to illustrate basic formatting and not to provide detailed information. Full-size process maps are available at: <http://www.opp.psu.edu/about/divisions/dc/manual/index.html>

C.2 Quiz and Survey (Capital Project Delivery)

Design and Construction Staff Development



Pre-Module 1 Questionnaire

Please complete the following questions. All questions refer to OPP's capital project delivery process. *Your responses are anonymous.*

1. What is the correct sequence for the design process?
 - a) design development - sketch design - construction documents
 - b) design development - construction documents - sketch design
 - c) sketch design - construction documents - design development
 - d) sketch design - design development - construction documents

Comment [I1]: Objective learning evaluation (for comparison w/ post-test answers)

Comment [I2]: Recognition of status (stakeholders understand the position of the process)

Comment [I3]: Correct Answer
2. Which of the following has the potential to cause the biggest problem for an OPP project?
 - a) contractor input during design
 - b) design input during construction documents
 - c) commissioning input during design
 - d) operations input during sketch design

Comment [I4]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I5]: Correct Answer
3. Which of the following project phases is led by OPP's Design and Construction division?
 - a) programming
 - b) design
 - c) operations
 - d) all of the above

Comment [I6]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I7]: Correct Answer
4. Which OPP division leads the maintenance phase of a capital project?
 - a) design and construction
 - b) facilities resources and planning
 - c) campus planning and design
 - d) buildings and grounds

Comment [I8]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I9]: Correct Answer
5. Which capital project is likely farthest along?
 - a) a project finishing programming
 - b) a project just added to the capital plan
 - c) a project beginning construction procurement
 - d) a project beginning design procurement

Comment [I10]: Facilitation of system performance understanding (stakeholders can evaluate process efficiency)

Comment [I11]: Correct Answer
6. On a scale of 1-9, rate your ability to communicate with others about OPP's capital project delivery process. (1=no ability. 9 = perfect ability)
1 2 3 4 5 6 7 8 9

Comment [I12]: Facilitation of communication (stakeholders are given tools allowing effective communication)
7. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's capital project delivery process. (1=not comfortable at all. 9 = complete comfort)
1 2 3 4 5 6 7 8 9

Comment [I13]: Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process)



8. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's capital project delivery process? (1= not certain at all, 9 = completely certain)

1 2 3 4 5 6 7 8 9

Comment [I14]: Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)

9. Based on your experience to date at OPP, please provide any suggestions you have for improving OPP's delivery process for capital projects. Briefly explain how each suggestion would improve the capital project delivery process. It is OK to leave this question blank if you have no suggestions for improvement.

Comment [I15]: Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

Post-Module 1 Questionnaire

Please complete the following questions. Your responses are anonymous.

1. In your opinion, how much did training Module I contribute to the following?	None		Some what		A Lot
Describing OPP processes	1	2	3	4	5
Identifying areas of concern in OPP processes	1	2	3	4	5
Understanding your role in OPP processes	1	2	3	4	5
Understanding how you interact with other divisions and groups	1	2	3	4	5
Evaluating the efficiency of OPP processes	1	2	3	4	5
Determining whether your actions fit with OPP processes	1	2	3	4	5
Enabling effective communication	1	2	3	4	5
Identifying potential areas for improvement in OPP processes	1	2	3	4	5
Enabling your ability for decision making (based on an understanding of the total process)	1	2	3	4	5

Comment [I16]: Subjective Learning evaluation: This is the process of collecting, analyzing and reporting information to assess how much the participants learned and applied in the learning environment.
What Attitudes changed?
What Knowledge was learned?
What Skill improved or developed?

Questions 2-9 refer to OPP's **Capital Project Delivery Process**.

2. When does programming occur?

- a) prior to capital planning
- b) between capital planning and design procurement
- c) between design and construction
- d) after project closeout

Comment [I17]: Objective Learning Evaluation

Comment [I18]: Recognition of status (stakeholders understand the position of the process)

Comment [I19]: Correct Answer

3. Failure to complete which task as scheduled will likely create the longest delay?

- a) preliminary design approval by the board of trustees
- b) final design approval by OPP
- c) complete the punch-list
- d) install furniture

Comment [I20]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I21]: Correct Answer

4. Which of the following project phases is led by OPP's Design and Construction division?

- a) construction procurement
- b) construction
- c) closeout
- d) all of the above

Comment [I22]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I23]: Correct Answer

5. Which OPP division leads the programming phase?

- a) design and construction
- b) facilities resources and planning
- c) campus planning and design
- d) buildings and grounds

Comment [I24]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I25]: Correct Answer

6. Which capital project is likely farthest along?
- a project that just received programming budget approval
 - a project that just received final design approval
 - a project that just contracted with a design firm
 - a project that just identified a construction budget**
- Comment [I26]:** Facilitation of system performance understanding (stakeholders can evaluate process efficiency)
- Comment [I27]:** Correct Answer
7. On a scale of 1-9, rate your ability to communicate with others about OPP's capital project delivery process. (1=no ability, 9 = perfect ability)
- 1 2 3 4 5 6 7 8 9
- Comment [I28]:** Facilitation of communication (stakeholders are given tools allowing effective communication)
8. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's capital project delivery process. (1=not comfortable at all, 9 = complete comfort)
- 1 2 3 4 5 6 7 8 9
- Comment [I29]:** Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process) This concept of decentralization is central to lean theory, as it gives decision making authority to ground-level decision-makers.
9. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's capital project delivery process? (1 = not certain at all, 9 = completely certain)
- 1 2 3 4 5 6 7 8 9
- Comment [I30]:** Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)
10. Based on training module 1 and your experience to date at OPP, provide any suggestions you have to improve OPP's delivery process for capital projects. Briefly explain how each suggestion would improve the capital project delivery process. It is OK to leave this question blank if you have no suggestions for improvement.
- Comment [I31]:** Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

C.3 Process Map (Close-out)

See Figure C-2.

C.4 Quiz and Survey (Close-out)

Design and Construction Staff Development



Pre-Module IV Questionnaire (Closeout)

Please complete the following questions. All questions refer to OPP's closeout process.

Your responses are anonymous.

1. Which activity represents the end of the closeout process?

- a) establishing the date of substantial completion
- b) passing the bond inspection
- c) performing the contractor evaluation
- d) sending project folders to cold storage

Comment [I1]: Objective learning evaluation (for comparison w/ post-test answers)

Comment [I2]: Recognition of status (stakeholders understand the position of the process)

Comment [I3]: Correct Answer

2. Which problem will most likely prevent substantial completion for a project?

- a) an elevator permit is not in place
- b) the punch-list not complete
- c) final payment to the contractor has not been made
- d) the project is not closed in the VM system

Comment [I4]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I5]: Correct Answer

3. Which of the following activities is led by OPP?

- a) shop drawing distribution to the engineer and print room
- b) creation of the substantial completion punch-list
- c) written request for substantial completion inspection
- d) all of the above

Comment [I6]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I7]: Correct Answer

4. Which department (within OPP's Division of Design and Construction) sends the letter releasing the bond?

- a) project management
- b) contract administration
- c) construction services
- d) design services

Comment [I8]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I9]: Correct Answer

5. Which project is likely farthest along?

- a) a project that just reached substantial completion
- b) a project that just obtained occupancy permits
- c) a project that just completed punch-list work
- d) a project that just obtained zoning permits

Comment [I10]: Facilitation of system performance understanding (stakeholders can evaluate process efficiency)

Comment [I11]: Correct Answer

6. On a scale of 1-9, rate your ability to communicate with others about OPP's closeout process. (1=no ability, 9=perfect ability)

1 2 3 4 5 6 7 8 9

Comment [I12]: Facilitation of communication (stakeholders are given tools allowing effective communication)

7. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's closeout process. (1=not comfortable at all, 9=complete comfort)

1 2 3 4 5 6 7 8 9

Comment [I13]: Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process) This concept of decentralization is central to lean theory, as it gives decision making authority to ground-level decision-makers.

8. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's closeout process? (1= not certain at all, 9 = completely certain)

1 2 3 4 5 6 7 8 9

Comment [I14]: Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)

9. Based on your experience to date at OPP, please provide any suggestions you have for improving OPP's closeout process. Briefly explain how each suggestion would improve the closeout process. It is OK to leave this question blank if you have no suggestions for improvement.

Comment [I15]: Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

Post-Module IV Questionnaire (Closeout)

Please complete the following questions. All questions refer to OPP's closeout process. Your responses are anonymous.

1. Which activity should occur first?
 - a) complete the bond punch-list
 - b) perform the bond inspection
 - c) perform the contractor evaluation
 - d) make final payment to the contractor

Comment [I16]: Recognition of status (stakeholders understand the position of the process)

Comment [I17]: Correct Answer
2. Which of the following will likely cause a problem during the closeout process?
 - a) releasing final contractor payment prior to final inspection
 - b) releasing final contractor payment prior to bond inspection
 - c) releasing the bond prior to completing the job closing checklist
 - d) All of the above

Comment [I18]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I19]: Correct Answer
3. Which of the following activities is led by OPP?
 - a) bond inspection
 - b) contractor evaluation
 - c) final inspection
 - d) all of the above

Comment [I20]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I21]: Correct Answer
4. Which department (within OPP's Division of Design and Construction) leads the contractor evaluation?
 - a) project management
 - b) contract administration
 - c) construction services
 - d) design services

Comment [I22]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I23]: Correct Answer
5. Which project is likely farthest along?
 - a) a project that just submitted a request for final inspection
 - b) a project that just completed the bond punch-list
 - c) a project that just distributed warranties and O&M manuals
 - d) a project that just passed final inspection

Comment [I24]: Facilitation of system performance understanding (stakeholders can evaluate process efficiency)

Comment [I25]: Correct Answer
6. On a scale of 1-9, rate your ability to communicate with others about OPP's closeout process. (1=no ability, 9 = perfect ability)
1 2 3 4 5 6 7 8 9

Comment [I26]: Facilitation of communication (stakeholders are given tools allowing effective communication)
7. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's closeout process? (1=not comfortable at all, 9 = complete comfort)
1 2 3 4 5 6 7 8 9

Comment [I27]: Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process). This concept of decentralization is central to lean theory, as it gives decision making authority to ground-level decision-makers.
8. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's closeout process? (1= not certain at all, 9 = completely certain)

Comment [I28]: Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)

1 2 3 4 5 6 7 8 9

9. Based on training module IV and your experience to date at OPP, provide any suggestions you have to improve OPP's closeout process. Briefly explain how each suggestion would improve the closeout process. It is OK to leave this question blank if you have no suggestions for improvement.

Comment [I29]: Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

C.5 Process Map (Construction Contracting)

See Figure C-3.

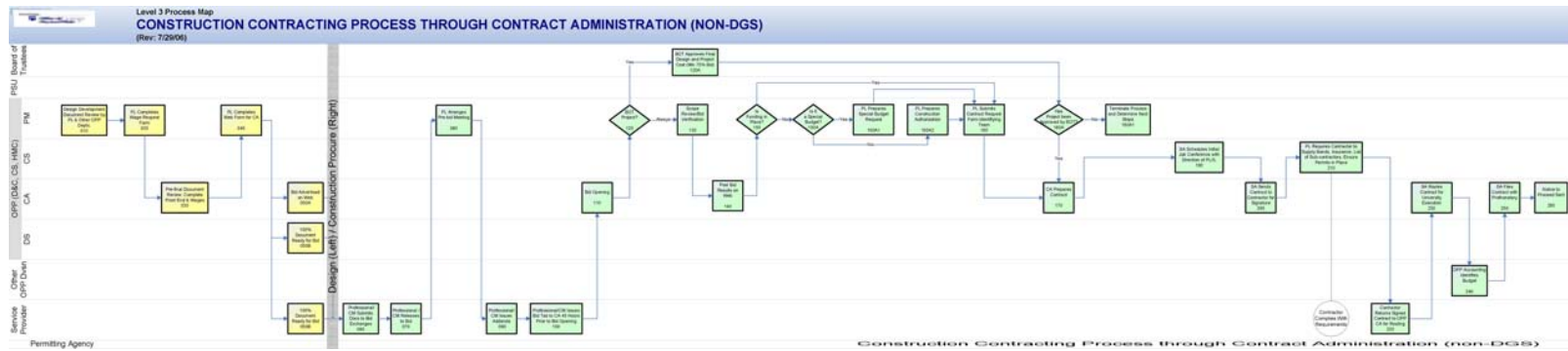


Figure C-3: Contracting Process Map

C.6 Quiz and Survey (Construction Contracting)

Design and Construction Staff Development



Pre-Module IV Questionnaire (Construction Contracting)

Please complete the following questions. All questions refer to OPP's construction contracting process. Your responses are anonymous.

1. Which activity represents the end of the construction contracting process?

- a) notice to proceed sent
- b) final budget approval
- c) final cost approval
- d) contractor returns signed contract

Comment [I1]: Objective learning evaluation (for comparison w/ post-test answers)

Comment [I2]: Recognition of status (stakeholders understand the position of the process)

Comment [I3]: Correct Answer

2. Which of the following will most likely terminate the construction contracting process for a Board of Trustee project?

- a) project funding is not in place
- b) lack of board of trustees approval
- c) project is special budget
- d) all of the above

Comment [I4]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I5]: Correct Answer

3. Which of the following activities is led by OPP?

- a) Submit documents to bid exchanges
- b) Release documents to bid
- c) Arrange the pre-bid meeting
- d) Issue addenda

Comment [I6]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I7]: Correct Answer

4. Which department (within OPP's Division of Design and Construction) schedules the initial job conference?

- a) project management
- b) contract administration
- c) construction services
- d) design services

Comment [I8]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I9]: Correct Answer

5. Which project is likely farthest along?

- a) a project that just scheduled the pre-bid meeting
- b) a project that just completed the wage request form
- c) a project that just advertised on the web
- d) a project that just completed design development review

Comment [I10]: Facilitation of system performance understanding (stakeholders can evaluate process efficiency)

Comment [I11]: Correct Answer

6. On a scale of 1-9, rate your ability to communicate with others about OPP's construction contracting process. (1=no ability, 9 = perfect ability)
1 2 3 4 5 6 7 8 9

Comment [I12]: Facilitation of communication (stakeholders are given tools allowing effective communication)

7. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's construction contracting process. (1=not comfortable at all, 9 = complete comfort)
1 2 3 4 5 6 7 8 9

Comment [I13]: Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process) This concept of decentralization is central to lean theory, as it gives decision making authority to ground-level decision-makers.

8. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's construction contracting process? (1= not certain at all, 9 = completely certain)
 1 2 3 4 5 6 7 8 9

Comment [I14]: Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)

9. Based on your experience to date at OPP, please provide any suggestions you have for improving OPP's construction contracting process. Briefly explain how each suggestion would improve the construction contracting process. It is OK to leave this question blank if you have no suggestions for improvement.

Comment [I15]: Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

Post-Module IV Questionnaire (Construction Contracting)

Please complete the following questions. All questions refer to OPP's construction contracting process. Your responses are anonymous.

1. Which activity should occur first?
 - a) send notice to proceed
 - b) route contract for PSU execution
 - c) send contract to contractor for signature
 - d) file contract with prothonotary

Comment [I16]: Recognition of status (stakeholders understand the position of the process)

Comment [I17]: Correct Answer
2. Which of the following is most likely a problem?
 - a) opening bids prior to having funding in place
 - b) completing construction documents prior to advertising bids
 - c) preparing the contract prior to the initial job conference
 - d) opening bids prior to issuing addenda

Comment [I18]: Recognition of problems (stakeholders can identify areas of concern in the process)

Comment [I19]: Correct Answer
3. For a Board of Trustees project, which of the following activities is led by OPP?
 - a) issue bid tab
 - b) open bids
 - c) final cost approval
 - d) all of the above

Comment [I20]: Recognition of responsibilities (stakeholders understand their role in the process)

Comment [I21]: Correct Answer
4. Which department (within OPP's Division of Design and Construction) completes the wage request form?
 - a) project management
 - b) contract administration
 - c) construction services
 - d) design services

Comment [I22]: Recognition of interdependencies (stakeholders understand how they will impact and be impacted by others for the process)

Comment [I23]: Correct Answer
5. Which project is likely farthest along?
 - a) a project that has just scheduled the initial job conference
 - b) a project where OPP accounting has just identified a budget
 - c) a project that has just received the signed contract from the contractor
 - d) a project that has just posted bid results on the web

Comment [I24]: Facilitation of system performance understanding (stakeholders can evaluate process efficiency)

Comment [I25]: Correct Answer
6. On a scale of 1-9, rate your ability to communicate with others about OPP's construction contracting process. (1=no ability, 9 = perfect ability)
1 2 3 4 5 6 7 8 9

Comment [I26]: Facilitation of communication (stakeholders are given tools allowing effective communication)
7. On a scale of 1-9, rate your comfort making decisions in your daily activities based on your understanding of OPP's construction contracting process. (1=not comfortable at all, 9 = complete comfort)
1 2 3 4 5 6 7 8 9

Comment [I27]: Enabling decision-making (Stakeholders are given the necessary tools so that they are comfortable making decisions based on their understanding of the total process) This concept of decentralization is central to lean theory, as it gives decision making authority to ground-level decision-makers.

8. On a scale of 1-9, how certain are you of the correct way to perform your activities related to OPP's construction contracting process? (1= not certain at all, 9 = completely certain)
1 2 3 4 5 6 7 8 9

Comment [128]: Facilitation of feedback on performed activities (stakeholders can determine whether their actions are correct)

9. Based on training module IV and your experience to date at OPP, provide any suggestions you have to improve OPP's construction contracting process. Briefly explain how each suggestion would improve the construction contracting process. It is OK to leave this question blank if you have no suggestions for improvement.

Comment [129]: Facilitation of improvements (stakeholders can identify methods to eliminate waste and create value, enabling continuous improvement)

Post-Module IV Questionnaire

1. In your opinion, how much did training Module IV contribute to the following?	None		Some what		A Lot
Describing OPP processes	1	2	3	4	5
Identifying areas of concern in OPP processes	1	2	3	4	5
Understanding your role in OPP processes	1	2	3	4	5
Understanding how you interact with other divisions and groups	1	2	3	4	5
Evaluating the efficiency of OPP processes	1	2	3	4	5
Determining whether your actions fit with OPP processes	1	2	3	4	5
Enabling effective communication	1	2	3	4	5
Identifying potential areas for improvement in OPP processes	1	2	3	4	5
Enabling your ability for decision making (based on an understanding of the total process)	1	2	3	4	5

Comment [130]: Subjective Learning evaluation: This is the process of collecting, analyzing and reporting information to assess how much the participants learned and applied in the learning environment.
What Attitudes changed?
What Knowledge was learned?
What Skill improved or developed?

Use a control group if practical
Evaluate knowledge, skills, &/or attitudes before and after program
Use paper and pencil test to measure knowledge or attitudes
Use performance test to measure skills
Get 100% response (require completion prior to leaving)

C.7 Raw Data

Table C-1: Abbreviations Used in this Section for Attributes of the Transparency Definition

Abbreviation	Attribute
R1	Recognition of status
R2	Recognition of problems
R3	Recognition of responsibilities
R4	Recognition of interdependencies
F1	Facilitation of system performance understanding
F2	Facilitation of feedback on performed activities
F3	Facilitation of effective communication
F4	Facilitation of improvements
E	Enabling decision making

Table C-2: Capital Project Process Map Raw Data from Surveys

Attribute	Participant (Random Order)														Avg.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
R1	5	5	5	4	3	4	4	3	4	3	4	5	4	5	4.14
R2	5	4	5	3	4	4	4	4	4	3	4	4	4	4	4.00
R3	5	3	5	4	3	4	***	5	3	3	5	4	3	4	3.92
R4	5	3	4	3	3	4	3	3	4	3	5	5	3	3	3.64
F1	5	3	5	3	3	4	3	2	4	2	4	4	4	4	3.57
F2	5	3	4	5	4	4	3	4	4	4	3	4	3	4	3.86
F3	5	3	4	3	3	4	4	3	4	4	3	5	3	4	3.71
F4	5	4	5	4	4	4	3	3	4	3	4	4	4	3	3.86
E	5	3	5	4	4	4	3	3	4	3	3	4	4	4	3.79
Avg.	5.1	3.7	5.0	4.1	4.0	4.7	4.3	4.2	4.9	4.2	5.1	5.7	5.0	5.4	4.67

Table C-3: Close-out and Contracting Process Map Raw Data from Surveys

Attribute	Participant (Random Order)														Avg.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
R1	5	4	5	4	5	4	4	4	4	3	4	4	4	3	4.07
R2	4	2	5	4	2	3	4	4	4	4	4	4	3	4	3.64
R3	4	4	5	3	4	3	4	4	3	4	4	4	5	5	4.00
R4	3	3	5	5	4	4	5	4	4	3	4	5	4	4	4.07
F1	3	2	5	4	5	3	4	4	4	3	4	3	2	4	3.57
F2	3	4	5	4	5	3	5	4	3	3	4	4	5	4	4.00
F3	3	3	5	4	5	4	4	4	3	2	4	4	3	4	3.71
F4	3	2	5	3	3	3	4	4	4	4	4	2	3	4	3.43
E	3	3	5	4	3	3	4	4	4	2	4	3	4	4	3.57
Avg.	3.4	3.0	5.0	3.9	4.0	3.3	4.2	4.0	3.7	3.1	4.0	3.7	3.7	4.0	3.79

Table C-4: Raw Data from Surveys for Module 2 (No Maps Used)

Attribute	Participant (Random Order)														Avg.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
R1	5	4	5	4	5	4	4	4	4	3	4	4	4	3	4.07
R2	4	2	5	4	2	3	4	4	4	4	4	4	3	4	3.64
R3	4	4	5	3	4	3	4	4	3	4	4	4	5	5	4.00
R4	3	3	5	5	4	4	5	4	4	3	4	5	4	4	4.07
F1	3	2	5	4	5	3	4	4	4	3	4	3	2	4	3.57
F2	3	4	5	4	5	3	5	4	3	3	4	4	5	4	4.00
F3	3	3	5	4	5	4	4	4	3	2	4	4	3	4	3.71
F4	3	2	5	3	3	3	4	4	4	4	4	2	3	4	3.43
E	3	3	5	4	3	3	4	4	4	2	4	3	4	4	3.57
Avg.	3.4	3.0	5.0	3.9	4.0	3.3	4.2	4.0	3.7	3.1	4.0	3.7	3.7	4.0	3.79

Table C-5: Raw Data from Surveys for Module 3 (No Maps Used)

Attribute	Participant (Random Order)														Avg.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
R1	3	4	4	5	5	4	5	4	4	4	5	5	5	4	4.36
R2	***	4	4	4	2	5	5	4	5	2	4	4	4	4	3.92
R3	4	4	4	5	5	5	5	5	5	4	5	5	5	4	4.64
R4	4	4	3	5	4	4	5	4	4	3	4	5	4	4	4.07
F1	4	4	3	3	2	4	5	5	3	2	3	4	5	4	3.64
F2	4	4	4	5	4	5	5	5	5	3	5	4	4	4	4.36
F3	4	4	3	4	5	4	5	4	4	2	3	4	5	4	3.93
F4	3	4	3	3	2	4	5	5	4	2	4	4	5	4	3.71
E	4	4	3	4	3	5	4	4	5	3	3	4	5	4	3.93
Avg.	3.8	4.0	3.4	4.2	3.6	4.4	4.9	4.4	4.3	2.8	4.0	4.3	4.7	4.0	4.06

Table C-6: Capital Project Process Map Raw Data from Quizzes Prior to Map Use

Attribute	Participant (Random Order)														Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)
R1	1	*	0	1	1	0	0	1	1	1	1	1	1	0	9	1	4
R2	1	*	1	1	1	1	1	0	0	0	*	*	*	0	6	4	4
R3	1	*	1	1	1	1	1	0	1	0	0	1	1	0	9	1	4
R4	1	*	1	0	1	1	0	1	1	1	0	0	*	*	7	3	4
F1	1	1	0	0	1	1	1	0	1	1	1	*	1	*	9	2	3
F2	2	1	3	1	3	1	4	2	3	3	3	3	2	1	2.29	Avg	
F3	2	1	1	1	2	1	4	3	3	2	2	2	2	1	1.93	Avg	
F4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1.00	Total	
E	3	1	4	1	3	1	4	4	3	1	2	3	2	1	2.36	Avg	

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-7: Capital Project Process Map Raw Data from Quizzes After Map Use

Attribute	Participant (Random Order)															Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)	
R1	1	1	0	1	1	1	1	0	1	1	0	0	0	1	9	0	5	
R2	1	1	0	0	1	0	0	0	*	0	0	0	0	1	4	1	9	
R3	1	0	0	1	0	0	0	1	1	1	1	1	1	1	9	0	5	
R4	0	1	0	1	0	1	1	0	*	0	0	0	1	0	5	1	8	
F1	1	1	0	1	1	1	1	0	*	1	0	0	0	0	7	1	6	
F2	5	3	4	4	4	2	2	4	1	4	2	3	3	4	3.21	Avg		
F3	3	4	4	3	4	2	2	4	1	4	2	3	4	3	3.07	Avg		
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	Total		
E	3	4	4	4	4	2	2	4	1	3	2	3	3	3	3.00	Avg		

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-8: Close-out Process Map Raw Data from Quizzes Prior to Map Use

Attribute	Participant (Random Order)															Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)	
R1	0	0	0	0	0	0	*	0	1	1	1	0	1	1	5	1	8	
R2	0	1	0	0	0	1	*	0	0	0	0	1	1	0	4	1	9	
R3	1	1	0	1	1	1	*	*	0	0	0	1	0	*	6	3	5	
R4	1	0	1	1	0	1	*	1	1	1	0	1	1	1	10	1	3	
F1	0	1	1	0	0	0	*	0	0	1	1	1	1	1	7	1	6	
F2	4	4	3	1	2	2	1	1	4	3	3	3	3	3	2.64	Avg		
F3	3	3	3	1	1	2	1	1	4	3	4	3	3	3	2.50	Avg		
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	Total		
E	3	4	3	1	2	3	1	1	4	3	3	3	3	3	2.64	Avg		

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-9: Close-out Process Map Raw Data from Quizzes After Map Use

Attribute	Participant (Random Order)															Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)	
R1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	9	0	5	
R2	0	0	0	1	0	0	1	0	0	0	1	0	1	1	5	0	9	
R3	0	*	0	0	0	0	1	1	1	1	1	1	1	1	8	1	5	
R4	0	1	0	1	1	0	1	1	0	0	0	1	0	0	6	0	8	
F1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	11	0	3	
F2	2	2	3	3	4	4	4	4	3	3	3	1	4	3	3.07	Avg		
F3	2	2	2	4	4	4	4	4	3	4	3	1	4	3	3.14	Avg		
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	Total		
E	2	2	3	4	4	4	4	4	3	2	3	1	4	3	3.07	Avg		

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-10: Contracting Process Map Raw Data from Quizzes Prior to Map Use

Attribute	Participant (Random Order)															Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)	
R1	0	1	1	1	0	0	1	1	1	1	1	0	0	*	8	1	5	
R2	1	0	1	1	0	1	*	1	1	0	1	1	0	1	9	1	4	
R3	0	1	1	1	1	0	*	0	1	0	0	1	1	*	7	2	5	
R4	0	0	0	0	1	0	*	0	1	0	0	0	0	0	2	1	11	
F1	0	1	0	0	0	0	0	1	1	1	1	1	1	0	7	0	7	
F2	4	3	4	1	4	2	2	4	1	3	4	2	3	3	2.86	Avg		
F3	4	3	4	1	3	2	2	4	1	3	3	2	3	3	2.71	Avg		
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	Total		
E	4	4	4	1	3	3	2	4	1	3	4	3	4	3	3.07	Avg		

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-11: Contracting Process Map Raw Data from Quizzes After Map Use

Attribute	Participant (Random Order)															Summary		
	1	2	3	4	5	6	7	1-	2-	3-	4-	5-	6-	7-	(1)	(*)	(0)	
R1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	12		2	
R2	1	1	1	1	1	0	0	1	0	1	0	1	0	1	9		5	
R3	1	1	0	1	1	0	1	1	*	1	0	1	1	1	10	1	3	
R4	0	0	0	0	0	0	0	1	1	0	0	1	1	0	4		10	
F1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	3		11	
F2	3	3	3	2	4	4	4	4	3	1	4	3	2	3	3.07	Avg		
F3	3	3	4	2	4	4	4	4	3	1	3	3	3	3	3.14	Avg		
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	Total		
E	3	3	4	2	4	4	4	4	3	1	3	3	4	3	3.21	Avg		

For R1-R4, F1:

(1) = Correct

(*) = Don't Know

(0) = Wrong

Table C-12: Contracting Process Map Data From Map Use at Hershey Medical Center⁸

	Before	After	% Increase
R1	2.75	3.64	32%
R2	2.69	3.82	42%
R3	2.88	4.00	39%
R4	2.69	3.82	42%
F1	2.63	3.64	39%
F2	2.69	3.73	39%
F3	2.25	3.45	54%
F4	2.56	3.55	38%
E	2.63	3.55	35%
	Avg.		40%

⁸ Data in this table likely includes bias as a member of the project team presented the quizzes. This data is therefore not included in Chapter 6.

Appendix D

Implied Consent Forms

Implied Informed Consent Form for Social Science Research The Pennsylvania State University

Title of Project: Evaluating Process Mapping at Penn State's Office of the Physical Plant

Principal Investigator: Leidy Klotz, Graduate Student
104 Engineering Unit A
University Park, PA 16802
(610) 247-9067; lek161@psu.edu

Advisor: Dr. Michael Horman
104 Engineering Unit A
University Park, PA 16802
(814) 863-2080; mjhorman@engr.psu.edu

1. **Purpose of the Study:** The purpose of this research study is to explore the use of process maps in training programs at OPP. Process maps are visual representations of work flows showing how activities are linked.
2. **Procedures to be followed:** You will be asked to answer questionnaires at 6 times during the training session (before and after 3 different sections of the training.) Because they are anonymous, participant responses will not be linked to each other. Only the group averages will be compared.
3. **Duration:** It will take about 15 minutes to complete the questions.
4. **Statement of Confidentiality:** Your participation in this research is confidential. The survey does not ask for any information that would identify who the responses belong to. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared because your name is in no way linked to your responses. Your confidentiality will be kept to the degree permitted by the technology used. No guarantees can be made regarding the interception of data via the internet by any third parties.
5. **Right to Ask Questions:** Please contact Leidy Klotz at (610) 247-9067 with questions or concerns about this study.
6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to take part in this research study.

Completion and return of the survey implies that you have read the information in this form and consent to take part in the research. Please keep this form for your records or future reference.

Figure D-1: Implied Consent – Process Mapping Quizzes and Surveys

Implied Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Evaluating Process Mapping at Penn State's Office of the Physical Plant

Principal Investigator: Leidy Klotz, Graduate Student
104 Engineering Unit A
University Park, PA 16802
(610) 247-9067; lek161@psu.edu

Advisor: Dr. Michael Horman
104 Engineering Unit A
University Park, PA 16802
(814) 863-2080; mjhorman@enr.psu.edu

1. **Purpose of the Study:** The purpose of this research study is to explore the use of process maps in training programs at OPP. Process maps are visual representations of work flows showing how activities are linked.
2. **Procedures to be followed:** You will be asked a series of interview questions about projects you have worked on. Your responses to these questions will be anonymous in my reporting of the research results.
3. **Duration:** It will take between 15-30 minutes to complete the interview.
4. **Statement of Confidentiality:** Your participation in this research is confidential. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. Your confidentiality will be kept to the degree permitted by the technology used. No guarantees can be made regarding the interception of data via the internet by any third parties.
5. **Right to Ask Questions:** Please contact Leidy Klotz at (610) 247-9067 with questions or concerns about this study.
6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to take part in this research study.

Answering the interview questions implies that you have read the information in this form and consent to take part in the research. Please keep this form for your records or future reference.

Figure D-2: Implied Consent – Interviews for Counterfactual Analysis

VITA Leidy Klotz

Leidy Klotz completed this dissertation as part of the requirements in pursuit of his Ph.D. degree in the Construction Management option of Architectural Engineering at the Pennsylvania State University. His primary teaching and research interests are in sustainability and the built environment. Prior to enrolling at Penn State, Leidy worked in a project management role for four years with Bovis Lend-Lease in New Jersey. While at Bovis, he earned his M.S. degree, via distance learning, in Construction Engineering from the University of Washington. Leidy holds a B.S. degree in Civil Engineering from Lafayette College in Easton, PA, and he is an Engineer in Training and a LEED Accredited Professional.