BREAKING THROUGH THE FIRST COST BARRIERS OF SUSTAINABLE PLANNING, DESIGN, AND CONSTRUCTION

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This work is dedicated to my wife Cathy for her patience, and my two sons John Mogge III, 1LT USMC, and David Mogge, Cadet 1st Class, USAF, my sons, who have delayed their professional engineering careers to protect and serve our country.

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Many people deserve acknowledgement for their contributions to this work. Dr. Annie Pearce, reader and cheerleader, challenged me on the first day of my first class at Georgia Tech. She said that this topic was one that needed to be addressed and her counsel could not have been more accurate. Dr. Anne Steinemann provided the missing link by agreeing to help me better understand what she sensed was a missing link—the planning. Dr. Roozbeh Kangari, in his most professional manner, taught me the proper way to use Fuzzy Logic and work with the available linguistic data. Dr. Jorge Vanegas provided yet another missing link in his counsel about how best to approach the research process, and through his parallel research on the sustainability and the built environment as a process. Ms. Patricia Johnson, as research librarian, took a personal interest in my work and success as a life-long learning student with countless hours of assistance. Ms. Jennifer McManus, CH2M HILL for her editorial and production help. Dr. Rita Oberle, my chairperson, and mentor for her enduring commitment to quality, academic rigor, and endless encouragement to complete the program and make a difference. There are many others, especially all of the interviewees. I could not have accomplished this work without the assistance of these true professionals. Finally, I acknowledge CH2M HILL for its financial support and the Vice Chairman of its Board, Major General (Ret) Bud Ahearn for his personal encouragement and life-long mentoring.

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SUMMARY

This work integrates elements of the bodies of knowledge for sustainability, planning, design, and construction to create an understanding of green project first cost drivers. Further, it extends conceptual models for sustainable infrastructure and the built environment process by creating a framework based linkage to analyze first cost impacts of project planning, design, and construction decisions. The framework functions as an analytical bridge between the built environment process and sustainability and is the principal contribution of this research.

Through a preliminary analysis of fourteen projects, the work draws out relevant planning, materials and methods, and estimating and scheduling best practices and guiding principles. The work then proposes a first cost impact framework derived from the preliminary analysis as a decision support tool and tests the framework using an expert system derived linguistic database. The test results support the functionality of the framework. The test linguistic database was developed through an interdisciplinary professional practitioner interview process using common green project planning, design, and construction strategies. The analysis of the data used Fuzzy Logic and presents findings helpful in understanding green project first cost drivers.

The work concludes with an assessment and a discussion of parallel research, and ten recommended areas for further research.

CHAPTER 1

INTRODUCTION

1.1 Introduction to the Study

Entering the 21st century, the foundations of sustainable development and specifically sustainable planning, design, and construction were emerging in a way that western societies saw sustainability as an extension of the recent age of environmentalism with the added components of social responsibility and economic fairness or equity (World Commission on Environment and Development [WCED], 1987). While theoretically a popular and correct view, sustainability did not immediately win the hearts and minds of those on the front lines of the U.S. construction industry (Federal Facilities Council [FFC], 2001). The concept of sustainability (Figure 1-1) was perceived by some practitioners as counterintuitive to the notions of free enterprise and a pragmatic business sense that predominates the construction industry in our country (Neumayer, 1999). As a concept, sustainability (Figure 1-1) is perceived to have multiple competing, yet complementary outcomes, and has sprouted a variety of interpretations (Neumayer,

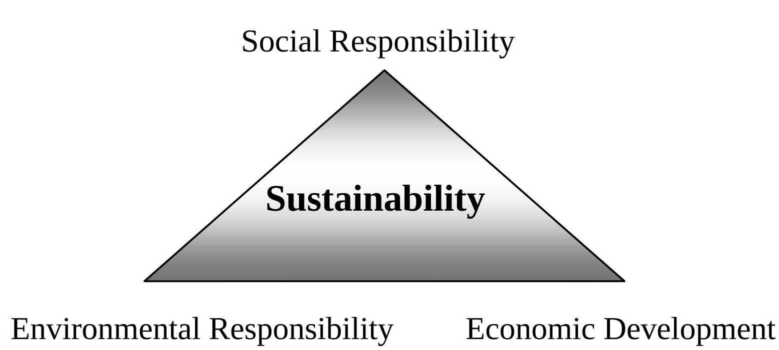

Figure 1-1 World Commission on Environment and Development (WCED) Sustainability Conceptual Model

1999). In the past several years however, and with respect to its truest sense, a broader acceptance of sustainability did emerge in the U.S. as a valid conceptual framework for private and public planning, design, and construction. Within the federal sector and specifically the Department of Defense, the conceptual models (Figure 1-2 and Figure 1-3) have become recognized and are common interpretations of sustainability with respect to the built environment (Pearce, 1999; Vanegas, 2003).

This research work builds on Dr. Pearce's and Dr. Vanegas' interpretations and continuing work in this area. Further, it integrates with respect to first cost impacts, the three traditional built environment factors of time, cost, and quality, with the principal tenets of sustainable development shown in Figure 1-2. The sustainable outcomes in the Pearce model neatly frame the larger and more specific context of sustainability with respect to planning, designing, and constructing the built environment.

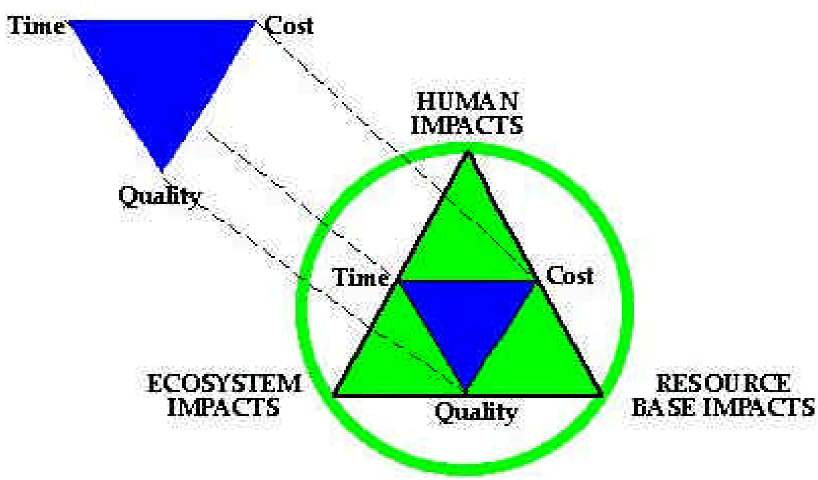

Figure 1-2 The Pearce Conceptual Model of Infrastructure Sustainability

During the period from the WCED (1987) until recently, the U.S. construction sector and other developed industrial and service sectors economies, viewed the application of the Pearce conceptual framework for sustainable design and construction as a value added requirement that rightfully justified additional costs to project planning and delivery (Hawken, 1993). The general thinking within the U.S. construction market was that the bearer of a construction requirement desiring it to be accomplished as a green project should be prepared to pay a premium for the delivery of the work in that manner. Thus, the first cost barrier phenomenon emerged (Hawken, Lovins & Lovins, 1999). Traditional design and construction processes were and continue to be accepted within the U.S. construction market as the normative cost basis, and are generally recognized to be working just fine perpetuating the general understanding that any additional requirements must necessarily be value added or premium services. Additionally, there is not a general sense of urgency to address the competing values that sustainability presents within the U.S. (Hawken et al., 1999). Further, the U.S. construction sector does not reflect a broad sense of accountability within its typical project delivery processes for the larger impacts these sustainability models depict. In a limited manner, the four desired outcomes on the outside of the Vanegas conceptual model shown in Figure 1-3 have been presented as a new paradigm within the U.S. construction sector (Pearce, 1999 April; Vanegas, 2003). To a large extent the normative approach to the built environment continues to represent the state of the art or status quo in the U.S. (American Institute of Architects [AIA], 2004). Advances in environmental science, the globalization of nation state economies, and competition for the earth's construction resources are beginning to change this thinking (CH2M HILL, 2000; Fussler & James, 1996). In its infancy, green design and construction was more of a statement of the values held by the owner of the project and little more, however a radical change is needed and is on the way. The Vanegas conceptual model (Figure 1-3) depicts this emerging new paradigm.

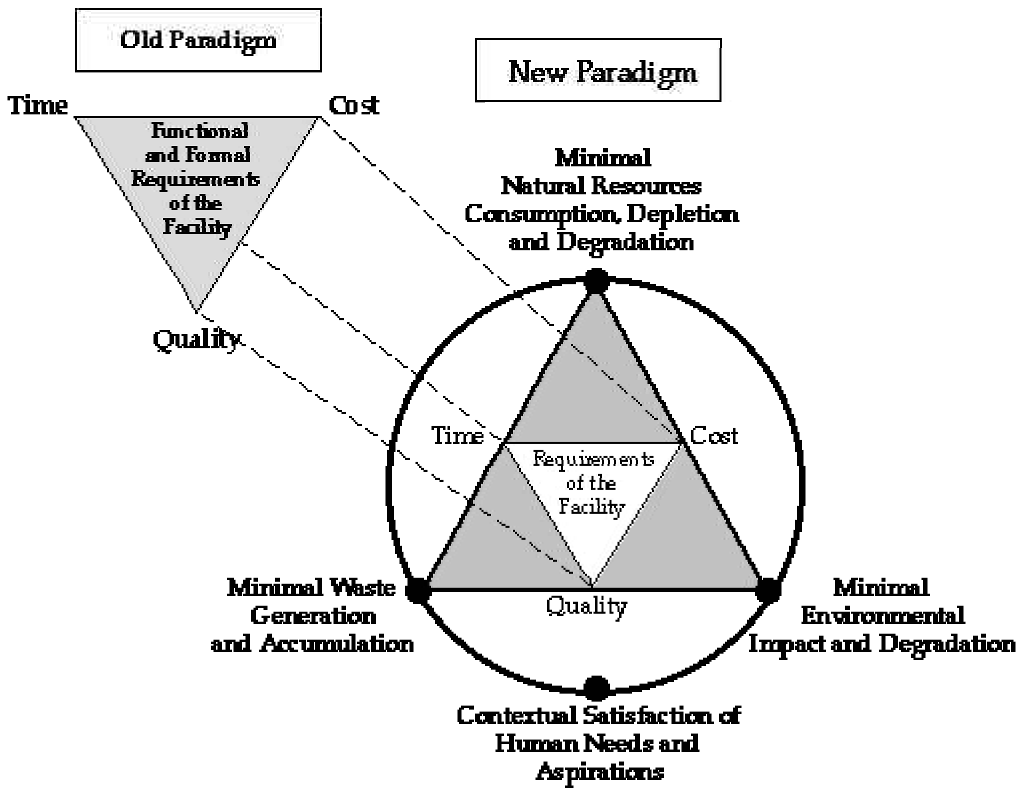

Figure 1-3 The Vanegas Conceptual Model of Infrastructure Sustainability as adapted from Pearce

This research advances the emerging paradigm shown in Figure 1-3 by addressing the challenge of first cost impacts for green construction and providing a cost impact framework for analyzing the drivers of sustainable planning, design, and construction first costs.

In the literature, visionary thinking and writing throughout the past decade such as, Ray Anderson's *Mid-course Correction* (1998) has led to the creation of a vast body of knowledge on sustainability. Within that knowledge domain the literature on sustainable design and construction now presents the rationale, logic, and a greater sense of urgency for industrialized western societies to be more accountable to the larger world population for their use of the earth's limited construction resources in their development and construction processes (Hawken et al., 1999). Competition for, and use of the earth's construction resources is beginning to be understood more precisely as a science, combining engineering, ecology, and economics in new and more beneficial ways (Hawken, 1993; Mendler & Odell, 2000; Neumayer, 1999; USGBC, 2003). Additionally, in the past few years, sustainable design and construction fundamentals have emerged as a key part of the required education foundation for most who choose to pursue professional roles in the design and construction sector of the U.S. economy (developed from Steinemann, 2003).

Yet, despite these advances, the first cost barrier, as presented by Hawken and others, in practice remains as either a myth or a reality in transition because its drivers remain unanalyzed due a lack of research (USGBC, 2003).

Hawken, Lovins and Lovins in *Natural Capitalism* (1999) suggest that an approach to the first cost barrier requires a revolutionary type change and articulated a philosophical approach of tunneling through the barrier. In this concept, they argue that the law of diminishing returns suggests that there is a limit to achieving (normative design and construction) cost effectiveness and that three engineering, economics and process oriented precepts should guide the thinking of future designers. According to Hawken they are:

- "The whole system should be optimized, [engineering]
- All measurable benefits should be counted, [economics]
- The right steps should be taken at the right time and in the right sequence" [process] (Hawken et al., 1999, p. 115).

Analyzing both qualitatively and quantitatively, these precepts helped form a key aspect of this investigation's research objectives and will be discussed more thoroughly in Chapter 5.

1.2 Motivation for this Study

As a practicing principal-in-charge, program manager, and former military engineering officer, two principal motivations have driven this researcher. The first driver is based on the researcher's current role and professional discipline. Over the past decade, as a life long learning advocate and construction professional, the notion of sustainability and sustainable development constantly engaged his curiosity, as it has countless others including the advisory committee for this work. More importantly, however, as an issue of professional practice, the conceptual model (Figure 1-3) and the vast body of knowledge represented in the literature of sustainability presented a challenge about the efficacy of normative and traditional design and construction practice and called to mind whether it was indeed reflective of the right thing to do. For some, as discovered in collecting the data for this research, the initial sense of it causes one to think that sustainable design is nothing more than just good design, design taught as an integrated science prior to the age of environmental awareness in the U.S. and the emergence of highly specialized facility engineering disciplines. The sustainable design and construction literature however, suggests that it is more than just good design. Through the synthesis of the literature a view emerged, that suggests that sustainable design and construction is more about new ways to design and construct—an opportunity for a true paradigm shift for this industry. Sustainable design and construction may indeed be good design in and of itself, but it is vastly different in real terms from that of the industry's practice norms of the last four to five decades, and definitely not just an evolutionary based change (CH2M HILL, 2000; USGBC, 2003; U.S. Department of Energy [DOE] Federal Energy Management Program [FEMP], 2003 August).

Unclear in the literature because of gaps in the knowledge base, but accepted in academia environs (Steinemann, 2003) was the dichotomy of why something so apparently and inherently sound in concept, was facing such resistance in practice. Like some paradigm shifts, one might suspect the resistance was just the normal at rest equilibrium of such a large economic sector at play, and in time, it would follow a normal evolutionary track. This might be exactly what is happening, but in the mean time, the U.S. as a nation, continues to operate inefficient and consumptive design and construction processes that over time are viewed as unsustainable (Price Waterhouse Coopers [PWC], 2002; Anderson, 1998; Barnett & Browning, 1995; Federal Facilities Council [FFC], 2001; Kozlowski, 2003; Ward & Dubos, 1972). Thus, a more full and definitive understanding of the differences between traditional (normative) design and construction, and sustainable design and construction became the author's professional development and research goals. The literature suggests the traditional measures of merit of quality and time do present issues, or perhaps even small barriers to the adoption of green design and construction, but not of the magnitude of cost as a barrier. Additionally at play in the professional service sector is the need to differentiate oneself from the competition (Berry, 1999; Cassidy, 2003b; Goldratt, 1997). The notion of defining a true competitive advantage through first cost breakthroughs is also intriguing.

As summarized in Chapter 2, there is ample evidence that the life cycle cost benefits derived through the normative project delivery process shown in Figure 1-4 for sustainable design and construction presents very favorable economic outcomes for building owners (Hawken et al., 1999; Katz, Alevantis, Berman, Mills & Perlman., 2003; Mendler & Odell, 2000). Thus, the focus of cost as barrier to adoption centers on the narrower topic of first costs. The literature supports that a practical first cost barrier exists (Landman, 1999), with respect to the widely held view of sustainable design and construction as it occurs in the normative project delivery process shown in Figure 1-4.

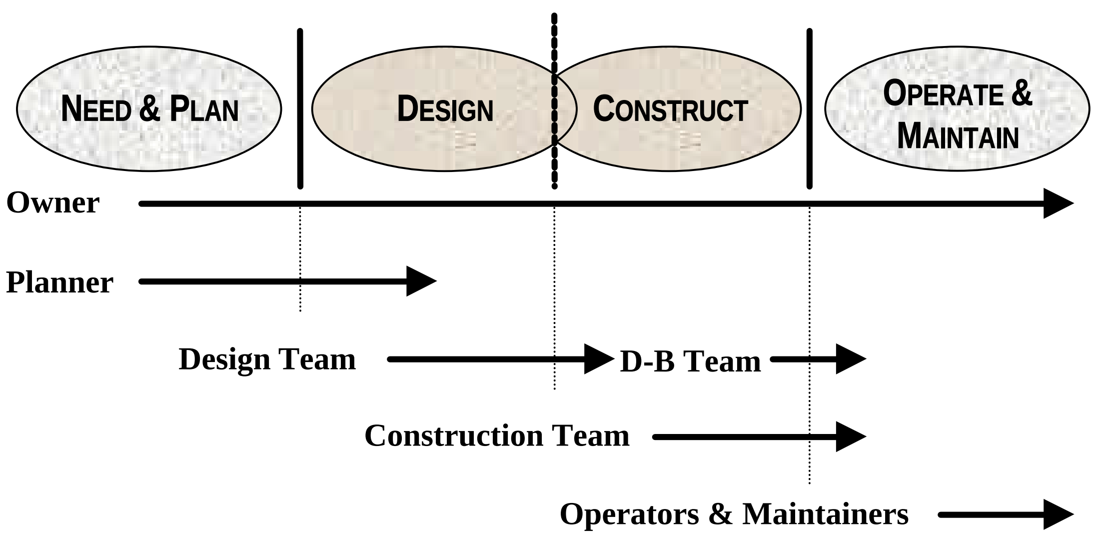

Figure 1-4 Diagram of the Normative Project Delivery Process

Well beyond the generally accepted basic project delivery process shown in Figure 1-4 is the Built Environment Process Model (Vanegas, 2001). This model presented and discussed in Chapter 2, Figure 2-1 presents a far more sophisticated and comprehensive understanding of how projects are delivered. It portrays multiple stakeholders who enter the process at different times and often may not be in alignment on even the most basic project objectives. Exploring this delivery process model with respect to normative first cost barriers also became a motivating part of the research because it might also be a path to uncover ways past the sustainable first cost barriers through process re-engineering or optimization.

While concise, Figure 1-4 depicts that current practice has, from a process perspective, multiple actors across four principal phases. Thus, a project will necessarily have to progress across multiple barriers created by function and discipline, which could also be drivers of higher first costs for sustainable projects. These barriers might be caused by the inefficiencies of the process, lost or dropped communications, professional disagreement, or a multitude of other issues as decisions regarding the project and its first costs are taken at different times by different actors within the normative approach and with little whole process integration.

This first cost barrier is amplified for sustainable projects meeting or seeking to meet the LEED™ Version 2.0 and other similar criteria schemes (FFC, 2001; Katz et al., 2003). The sustainability first cost barrier is reflected in the literature as a barrier and has been discussed as such in professional seminars, conferences, classes at the Georgia Institute of Technology and elsewhere. The broadly based and active practitioner dialog regarding the topic of first cost barriers for sustainable projects reinforced the need to undertake this investigation (AIA National Conference, 2000; Greening of Federal Facilities Workshop, 2000; Greenprints, 2000; Pearce, 1999 Fall). It is in understanding why the first cost barrier exists and in the issues and reasons surrounding it that pathways through it, or solutions for it, perhaps even competitive advantages from it might be developed. While perhaps challenging, the investigation also required an even more challenging approach to find and access highly competitive and business confidential data arena of project design and construction pricing in order to uncover the perceived and actual first costs. Acquiring data in this area was a challenge because of the common practice of maintaining cost data as business confidential and/or proprietary information. Recently however, other researchers have been able to gather and analyze some limited actual cost data (Katz et al., 2003; Matthiessen & Morris, 2004). Both Katz and Matthiessen conclude from their analysis of their actual cost data that there continues to be a first cost premium for sustainable projects, but that it is difficult to arrive at a cause and effect relationship for the first costs thereby further reinforcing the need for this work. Chapter 4 details the research methodology selected for this investigation and unveils how this challenge was addressed by bridging the built environment process model and the facility and infrastructure sustainability model with an expert based framework of cost impact analysis. Thus making it possible to uncover how the embedded decisions creating first cost impacts can be understood. The proposed cost impact framework was then tested as described in Chapter 5 by employing fuzzy logic and mathematics to treat the linguistic data collected. This approach to the investigation allows the use of the cost impact perceptions by experienced practitioners simulating the actual decision making activity. The development of the framework is discussed in detail in Chapter 4.

Secondary motivation comes from over thirty years of military and private sector engineering experience, many years of which were overseas. This experience and background created a sense of urgency and provided the research with a broadly based perspective beyond the common U.S. based approaches to sustainability. The research also benefited from direct access to early Department of Defense sustainable design and construction projects used to correlate the linguistic cost impact database with a limited but actual sets of comparative cost data. This part of the investigation is also discussed in Chapter 5.

Combining this military background and a developing knowledge of sustainability, the deduction[1] was made that there is also a larger and perhaps a more significant reason to understand the first cost barrier to green design, which if removed or broken, could lead to a more resource and energy efficient U.S. construction industry. The connection for this second motivation underpinning the research is based on the Clausewitzian theory that wars are politics by other means, and from extensive study and research into the causes of war at the United States Air Force, Air War College at Maxwell AFB, Alabama.[2] Throughout history, most wars have been fought for one or a combination of three fundamental reasons—ideological differing beliefs, geography, and/or natural resources (David, 1996). Focused on the latter reason for war, this research connected the need for first cost breakthroughs that will encourage all sectors of the U.S. economy to be more efficient but especially the construction industry with its resource intensive (inefficient) and extremely high material consumptive design and construction practices (Anderson, 1998; Hawken et al., 1999).

It is plausible to deduce that probability of conflict among nations for resources, whether regional or global, might be lessened or even avoided if the U.S. construction industry provided the leadership and pathway to more renewable and resource efficient means for our infrastructure and facility planning, design, construction, and operations processes. Some currently argue that the recent Iraqi conflict was in part based on the oil resources needed to provide the energy to sustain normative western life styles (www.stratfor.com/Premium Global Intelligence Report). The U.S. Department of Energy estimates that as much as 30% of the U.S. energy demand goes to its infrastructure and facility design, construction, and operations processes (www.eren.doe.gov/buildings/commercial_roadmap). Through the course of this investigation, it was found that other practitioners share this view. Continuing in the literature and recently through electronic media, are accounts by Defense Department and other federal agencies supporting the need to lessen the country's dependence on imported energy through its built environment and further tying the federal sector's interest in built environment sustainability, to this need for resource efficiency in our country (Air Force Center for Environmental Excellence [AFCEE], 2001; United States Air Force Reserve Command Headquarters [HQ AFRC, 2001]; United States Air Force Headquarters [HQ USAF], 2000; FFC, 2001). In addition to reinforcing the need, these governmental advocates often sponsor financial support through demonstration projects and special funding. In some of the case studies found on the Department of Energy's Renewable Energy/Buildings web site, their projects are presented as prototypical breakthrough projects and referred to as important in helping solve the U.S. energy demand issues.

If first cost barriers are an obstacle to a shift in western design and construction methodologies, then breaking down those barriers and finding alternative methods might help create a better future for the U.S. generations that follow us, through a more sustainable built environment.

1.3 Narrowing the Research

The research area and research question comprised a logical subordinate relationship. The research area is: The economics of sustainable planning, design, and construction. The broad research question is: What are the costs of sustainability? The literature review for this research through its supporting bodies of knowledge produced, through an assimilation process of topically relevant material, an extensive new body of knowledge. This more refined literature base is the body of knowledge for this research on the economics of sustainable design and construction. It revealed through categorization inspection and synthesis, knowledge gaps including the first cost impact gap. These gaps were then further refined by using an inclusive approach to group-like topics into a more definitive set of statements relative the research question into What are the costs of sustainability and more precisely, what are the first cost barriers?

The statements in Table 1-1 reflect the relevant gaps in the literature synthesized from the literature review of the three supporting bodies of knowledge for the research area. The bodies of knowledge are: sustainability, design, and construction. The planning body of knowledge was added later. The four bodies of knowledge will be addressed in more detail in Chapter 2.

Table 1-1 Gaps by Major Topics in Practice and the Literature on Green Design and Construction

• Initial costs as they relate to competitive advantage.
• Fundamental connection that efficiencies achieved through sustainable design and construction can be good initial investments.
• Acceptable economic models for first costs in project proformas.
• Comprehensive green design and construction automated manual costing/pricing tools.
• Development of analytical methodologies for least-cost/end-use design problems and solutions.
• Outcome (performance) based professional design compensation.
• Significant and compelling dialog on why sustainable design and construction is good (economically) for all infrastructure and facility stakeholder.
• Agreement on universal sustainability standards. (Multiple standards exist however the LEED Criteria is considered by most professionals as a de-facto standard.)
• Dialog on relationship of sustainable design and sustainable planning. (The American Institute of Community Planners has recently begun a significant focus in this area.)
• Professional dialog on project planning and definition as it relates to planning.
• Relationship to the design-build and solutions project delivery methods.
• Procurement, contracting, and acquisition strategies for building stakeholders and specifically owners as they relate to sustainable design and construction.

This set of statements individually defines numerous gaps in the existing body of knowledge for sustainable design and construction. Within this set of statements and taken collectively, is the research need for this investigation into the first cost barriers. Thus, the missing common denominator to many of the gaps is the first cost barrier. Additionally, the literature review identified an absence of literature with respect to sustainable planning in the context of the sustainable built environment model. This and a more extensive list of what is present in the literature are synthesized and discussed in more detail in the next chapter. Taken together they comprise a macro level summary of sustainable design and construction practice in the U.S. as reflected in the written bodies of knowledge for this work. The relevant gaps with respect to first cost and related topics are summarized in Table 1-1 because they relate to and form the basis for this research.

1.4 Navigating the Research

The broad design of this research is shown in Figure 1-5. This design reflects an approach adapted from an unpublished conceptual framework for research developed by Dr. Jorge Vanegas.[3] The diagram also shows the conceptual relationship of the principal bodies of knowledge, multiple data sources, and the partial expert systems approach of professional experience and practitioner interviews (Step 1). The point of departure or baseline for the investigation is derived through association and refinement of the literature for the bodies of knowledge to create the more focused body of knowledge describing the cost of sustainability (Step 2). From this point of departure the knowledge base of what is known, what is fuzzy, and what is unknown was created. This leads to an understanding of the drivers for the research. From this point of departure, the problem statement was developed and scoped leading to the hypothesis, the research question and research objectives (Step 3).

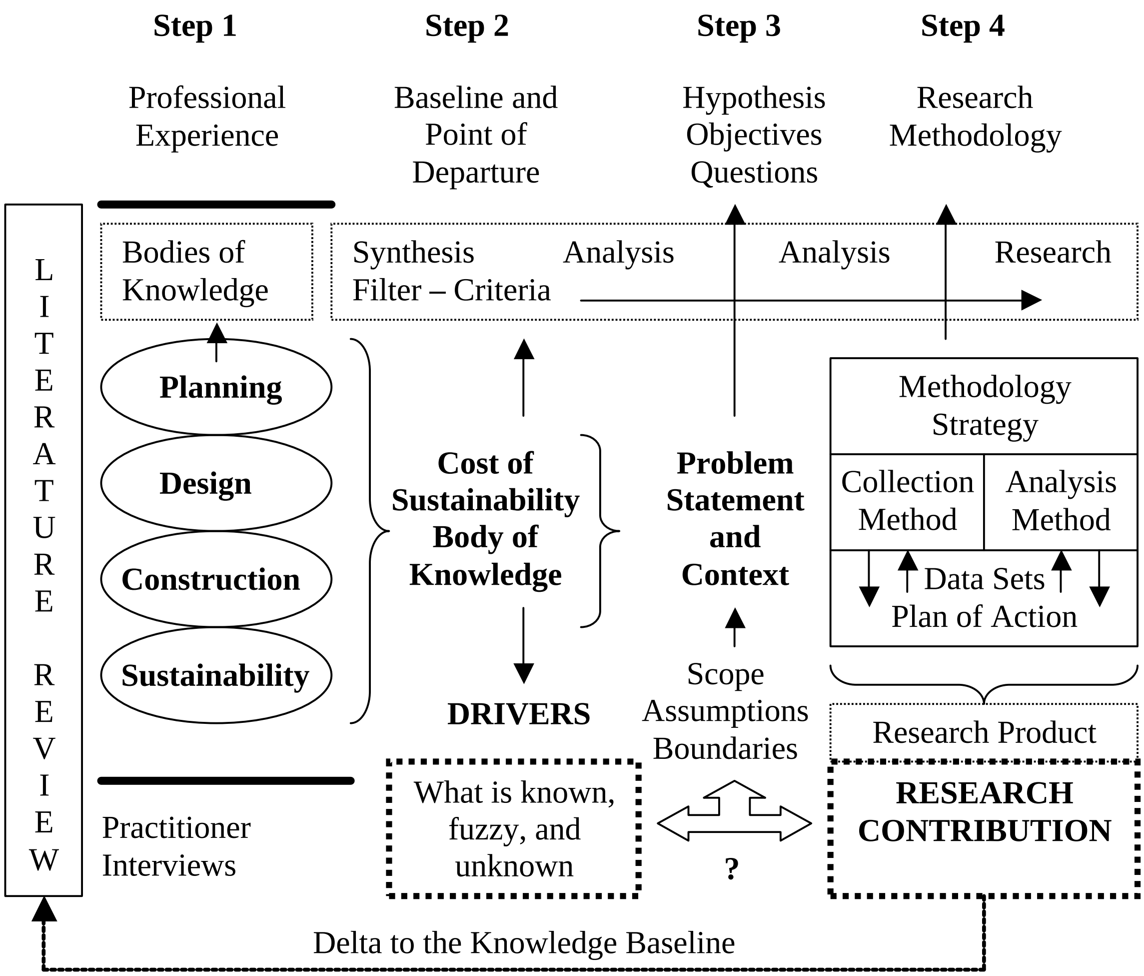

Figure 1-5 Design Concept of this Research [4]

To complete the research design, Step 4 depicts the relationships of the research methodology used, the methods of data collection, the methods of data analysis (see the Data Table, Table 1-2, at the end of this chapter for more details), and the plan of action followed. The resulting research product was then assessed to determine if it addressed the problem and contributed new knowledge. This is the approach used for this research, which addresses the fundamental research question, What is the cost of sustainability? This investigation is based on the thesis that through a more complete understanding of the costs of sustainability, ways to overcome the first cost barriers can be developed. Figure 1-6 graphically depicts this thesis and the logic of the resulting contribution.

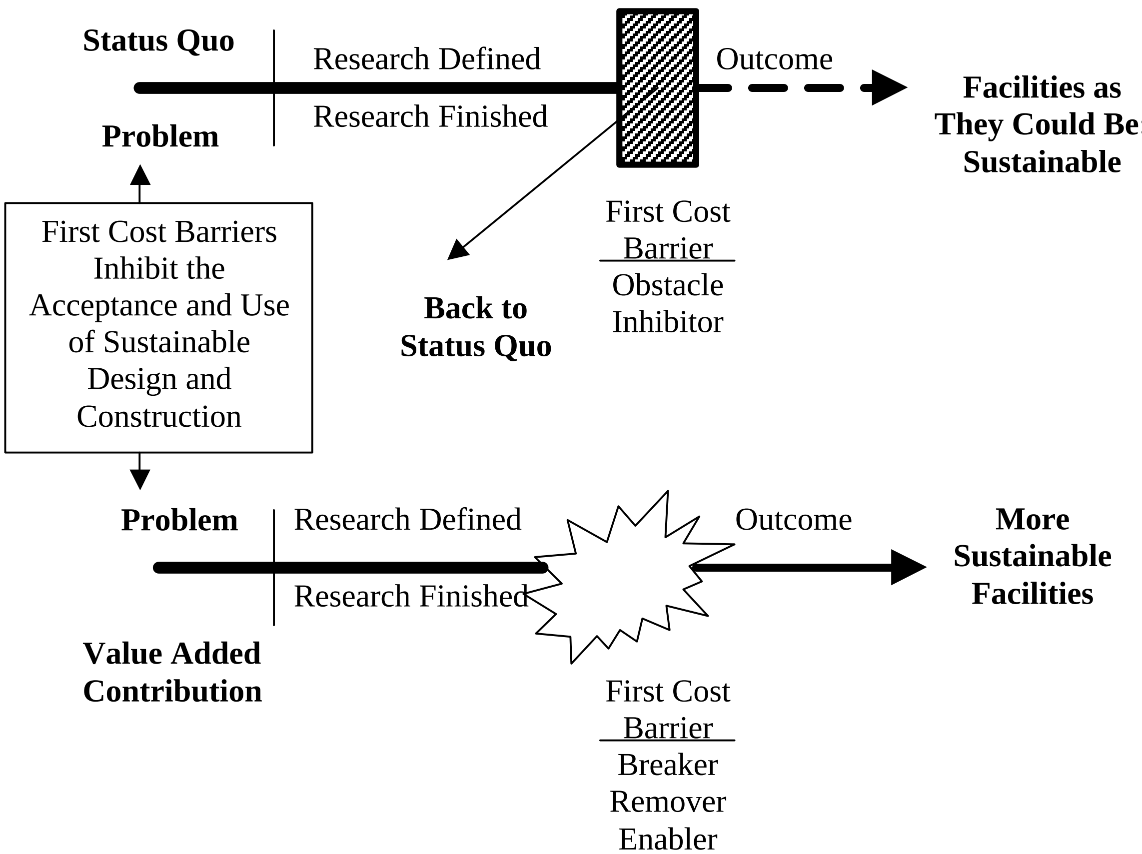

Figure 1-6 Pre and Post Research Hypothesis

Recapping the prior discussion, the research problem to be addressed is stated as: First cost barriers exist and are obstacles or inhibitors to sustainable facility projects in the U.S.

Restating the thesis of this investigation as a hypothesis; if the first costs of sustainability can be understood, then strategies to overcome the first cost barriers can be developed. The development of strategies to overcome the first cost barrier will enable more sustainable projects to be built in the U.S.

1.5 Research Objectives, Scope, Assumptions, Data Table, and Terminology

To understand how to address the broad research question, the investigation is further framed through a question based work break down approach using a theoretical and logical cause and effect relationship.

The specific research objectives reflecting this work break down approach and stated in the context of the research question are:

1. To understand the costs of sustainability, specifically the first costs, then it follows that drivers of the higher first costs are likely to exist. Therefore, the first research objective is to identify the principal drivers of first costs for green design and construction (Step 2, Figure 1-5).
2. To further understand the costs of sustainability, specifically the first costs, then it follows that the first costs likely differ from normative design and construction. Therefore, the second research objective is to compare the drivers that significantly differentiate green design and construction from normative design and construction (Step 4, Figure 1-5).
3. Since both normative and sustainable design and construction follow similar linear delivery processes, then it is likely to follow that exploration of the differences in the sub-processes (later to be called factors) might further help

understand higher first costs for sustainable projects. Therefore, the third objective is to explore the potential to alter the delivery process and sub-processes to find ways that may lead to the removal or lessening of first cost barriers for sustainable projects (Step 4, Figure 1-5).

4. Since both normative and sustainable projects use similar sets of process actors to carry out the delivery processes and sub-processes then it may follow that investigating the levels of interaction among actors within the processes may uncover ways to reduce costs and risks. Therefore, the fourth objective is to investigate the practice activity and process communications among actors to uncover opportunities to create a higher level of delivery process integration for sustainable projects (Step 4, Figure 1-5).

These four objectives, while fundamental outcomes of the design of the research, are also in part drawn from the principal topics of the practice and literature review synthesis discussed in the next chapter, and by adapting in part the work of Dr. Vanegas,' *The Project Definition Package; A Cornerstone for Enhanced Capital Project Performance* (2001).

1.5.1 The Research Scope

The broad nature of the research required a deliberately developed scope of work, which followed the design of the research previously described (Figure 1-5). The research used two existing models, Figure 2-1, the built environment process model and Figure 1-2, the commonly accepted conceptual model of infrastructure sustainability as the foundation for the analysis. The work departed from a body of knowledge created from the review of the literature and synthesis of the existing bodies of knowledge of sustainability, planning, design, and construction with respect to the cost and economics of sustainability (Chapter 2). From this point of departure a preliminary analysis of fourteen prototypical projects was performed which drew out relevant information to help create a proposed cost impact framework for the analysis of first cost impacts. The areas of sustainable planning, sustainable materials and methods, and construction estimating and scheduling were explored as potential areas where the drivers of first costs might be found (Chapter 3). The two models adopted for the investigation and the outcomes of Chapters 2 and 3 formed the basis of the design and use of the proposed cost impact framework (Chapter 4). The methods used to collect the needed data and test the proposed cost impact framework are also described in Chapter 4. The data collection criteria and the test of the framework using linguistic data are described in Chapter 5. The results of the framework test and assessment of its value are found in Chapter 6. Chapter 7 concludes the investigation with a high level summary and several recommended areas for related future research.

1.5.2 Principal Assumptions for this Research

The principal assumptions[5] for this work include the two models adopted for its basis. As described earlier, the infrastructure built environment model (Figure 1-2) is a commonly accepted conceptual model that aligns the measures of merit in a way that are logical. The built environment process model is a close approximation of the overall process used to create the built environment in the U. S. and other countries today. It was helpful for this research because it also broke the process down into meaningful functional steps associated with actors who typically make cost impact decisions regarding projects. As such, these two models are assumed to be valid models for this work and are not part of the research but rather are incorporated into it.

Other fundamental assumptions of this work are:

The analysis of a narrower set of U.S. building typologies (commercial and industrial) can form an adequate base for the extension to other building typologies with the exception of residential design and construction.

Linguistic data can be generalized and averaged using fuzzy set theory across groups of actors and provide acceptable results. This assumption will be discussed in more detail in Chapters 4 and 5.

LEED V2.0 is generally accepted as a consensus standard for sustainable design and construction in the U.S. but is not the only sustainable design and construction criteria set available to practitioners.

Project delivery methods largely use the same design and construction strategies but are differentiated largely by their contractual parties and their relationships to the delivery process.

1.5.3 Data Table

As an aid to fully understanding this work, a data table, navigation template, and glossary of terms as they are used in this research, have been included.

The organizational principle for the data to be collected followed the approach offered by Fellows and Liu for collecting data from respondents (1997, p. 90). The breadth of the study was guided by the data described in item 1 in Table 1-2. The depth of the study data was guided by items 3, 7, 8, and 9. The interviews described in item 6 balanced and rounded out the investigation in both breadth and depth.

Table 1-2 Data Used in this Investigation

Data	Source of Data	Application and Rationale
1. Initial survey information linguistic values (see Appendix A)	Initial DOE workshop on Greening Federal Facilities	Initial survey of the potential need for the investigation Broad practitioner identification
2. Design guides	Organizational policy documents	Development of proposed cost impact framework
3. Case study projects and metrics • Building type • Planning approach • Project strategies • Square footage	Project files and follow up calls with the design teams	To develop the underlying hypothesis To identify specific areas to focus the investigation To identify possible best practices To explore the extent of sustainability practiced To explore the extent to which the projects followed the built environment model
4. Project delivery methods	Literature review	To understand how the project delivery methods might affect first costs and project risk
5. Common project cost drivers from case studies	Literature review and project files	To understand how the planning context of a project might impact its first costs To understand how scheduling and estimating impact first costs To explore sustainable materials and methods costs To relate normative cost risk to sustainable design and construction risk
6. Linguistic interview data	Interview (see Appendix D)	To gain practitioner perceptions of first cost drivers as they occur through the built environment process model
7. Homestead ARB, FL Fire Station • Adaptive reuse strategies • Design documents • Construction cost data	Headquarters Air Force Reserve Command. Directorate of Civil Engineering (Used with permission)	To test the cost impact framework To correlate the interviewee first cost impact perceptions with actual first cost impacts To test the completeness of the cost impact framework To identify potential broader applications
8. March ARB, CA Squadron Operations Facility • Adaptive reuse strategies • Design documents • Construction cost data	Headquarters Air Force Reserve Command. Directorate of Civil Engineering (Used with permission)	Same as 7 above
9. March ARB, CA • Life Support Facility • Adaptive reuse strategies • Design documents • Construction cost data	Headquarters Air Force Reserve Command. Directorate of Civil Engineering (Used with permission)	Same as 7 above

Items 5, 7, 8, and 9 included specific design related and project definitional types of data. These items were drawn from case study projects and actual projects and used to correlate the linguistic data included:

- Project objectives
- Project financing
- Planning parameters—environmental, comprehensive and economic
- Design concepts
- Alternative solutions
- Project cost estimates and actual cost data
- Project LEED score sheets
- Construction methods and materials and technical innovations

1.5.4 Navigating the Research

The logic and flow of the work can be better appreciated with the aid of a navigation template. Figure 1-7 depicts the broad relationship of the research project with respect to how it was developed and has been presented. The template follows the conceptual model for proposing and executing research developed by Dr. Jorge Vanegas (1999).

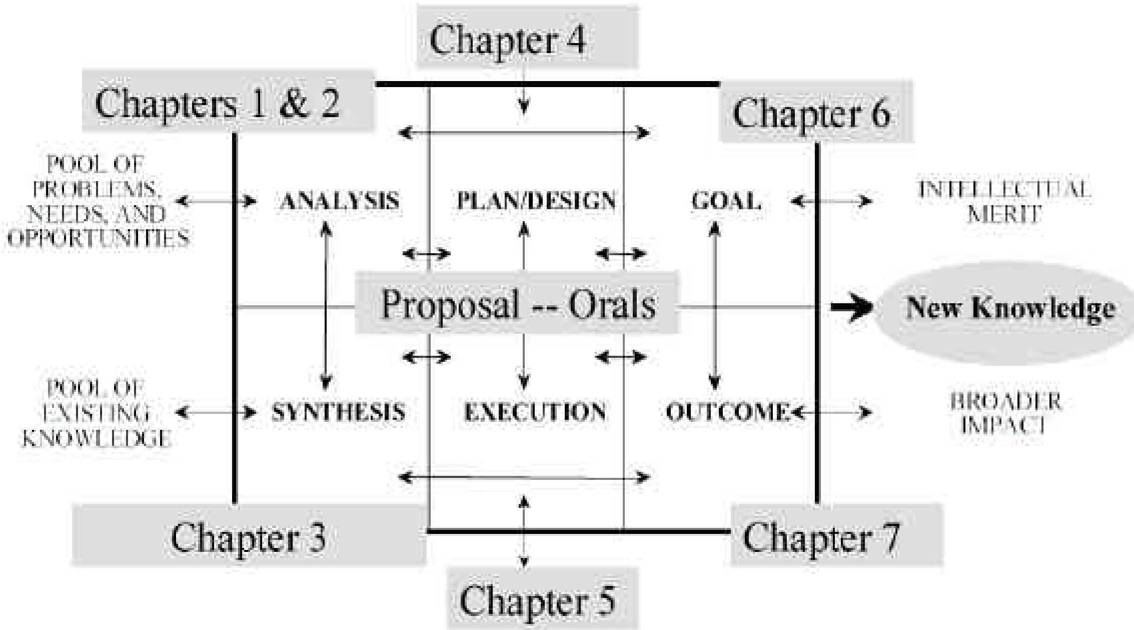

Figure 1-7 The Roadmap for the Integration of the Elements of the Research Approach, Proposal, and Research

1.5.5 Terminology Used in this Research

This investigation makes use of many terms in ways specific to this work. The following list is intended to aid the reader in capturing a full understanding of this research.

1. Initial Survey Information. The original expert practitioner questionnaire used in this research. The results provided confirmation of the need, urgency, and utility to undertake this investigation. This survey was offered to all 24 people in attendance at the conclusion of The Greening of Federal Facilities Workshop, April 2000, in Dallas, Texas.

2. Case Study Projects. A set of 14 case study projects from a possible pool of 53 completed or nearing completion in the U.S. as selected to provide the initial understanding of what data was available for the research. The project selection criteria included building typology, size, delivery method, design criteria used, and extent of project design and construction cost data available.
3. Design Guides. Sets of common and widely available criteria used by public and private organizations to provide designers and constructors guidance on the provision of sustainable facilities.
4. Practice Principle. An existing, emerging, and likely guiding truth associated with a specific professional approach to planning, design, and construction.
5. Framework. A method of organizing complex interrelated data designed to achieve a comprehensive and integral understanding of a problem.
6. Phase. A major component of the built environment project delivery process.
7. Factor. A sub-component of a phase.
8. Strategy. A sub-component of a factor.

Chapter 2 more fully discusses the overall practice and literature review (state of the art status) and establishes the point of departure for data collection, from which the research methodology was selected and developed.

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1 This deduction is based on personal military experience in the developing world where the access to resources many times determined the ultimate survival of the population.

[2] The researcher was a student at the Air War College from 1988-1989.

[3] Dr. Vanegas' conceptual approach to research was especially helpful is this investigation due to the complexity of the topic, the broad base to the literature underpinning the work and the need to operate with multiple data sets beginning with a preliminary analysis and ending with a testing structure for the validation of the principal contribution.

[4] This research used experienced and technical experts as part of its structure. As such, the reader will encounter data and statements derived from the experts and used as part of the overall research design. A full curriculum vitae and additional background information on the author and the experts consulted in the work can be obtained by contacting the author via email at jmogge@ch2m.com.

[5] Additional assumptions specific to the discussions in each chapter are included in the appropriate chapter.

CHAPTER 2

BASELINE AND POINT OF DEPARTURE

2.1 Introduction

This chapter establishes the knowledge baseline and point of departure for the research. With respect to the baseline, it presents sets of summary findings and a synthesis of the initial practitioner screenings, readings, and personal experience to form the foundation for the contribution. It reflects the researcher's review of the literature with respect to the topic. Further, it establishes a reasonable point of departure for bounding the existing bodies of knowledge so that the hypothesis for this investigation could be narrowed and focused. It is also representative of a continuing literature review by the researcher in the area of sustainable planning, design, and construction. Additionally, and more specifically, the findings come from a search for any literature uncovering useful information with respect to understanding first cost barriers, which when addressed might create competitive advantages for those who practice sustainable design and construction, those seeking to engage in the business, and those who teach in this area. The framework and process follows the Conceptual Framework for Research (Vanegas, 1999, p. 20-22[1]). The first part of this chapter is organized in the following manner:

- Discussion of Existing Baseline Information on the Research Area and Topic
- Literature Search Methods
- Quantitative Search Results
- Qualitative Search Results

- Analysis of the Results
- Synthesis of the Sustainable Design and Construction Knowledge Base
- Synthesis of the Sustainable Planning Knowledge Base

2.2 Baseline Knowledge on the Research Area and Topic

The research area of sustainable design and construction has amassed a significant baseline of literature in the past decade and continuing through 2004. The literature has grown from initial concepts by developed and developing countries in preparation for the Rio Earth Summit of 1992, to its present global state. The literature has also been leveraged, perhaps more than any other topic area, by intense international interest and the ease of access and sharing of information by means of the World Wide Web (web references are listed in the References). Beginning with the design of the research described in Chapter 1, it was found that the topic area needed to be narrowed substantially through an iterative process (Step 1 Figure 1-5). Therefore, the literature search was continued through multiple phases and updated throughout the course of this work. The principal reason, in addition to the quantity of information, was the lack of a concise use and consistent relative definition for the words sustainability, design, and construction. Additionally, there appeared to be a fundamental bias embedded in the literature of the research area toward environmentalism, hence the terms green design, green buildings, and green construction. This point is not made as a pejorative statement, but simply to introduce the need to strive for objectivity by further investigating the purpose of references and facts found in the literature.

The initial literature review was focused on the three principal bodies of knowledge as developed in the design for the research. These were sustainability, design, and construction. These three areas established the principal structure for the literature search by further placing them in the context of the research assumptions. Restated within the context of this work, they are: sustainability, as defined by the United Nations WCED (1987) shown in Figure 1-1, [facility] design and [facility] construction as defined by the built environment model (Vanegas, 2001, developed from Molenaar, Vanegas & Martinez, 2000) shown in Figure 2-1, and indirectly related to business economics (Malizia & Feser, 1999). By placing the topic words in their research context, a more precise search was possible and thereby enabled the relevant aspects of each body of knowledge to be drawn out.

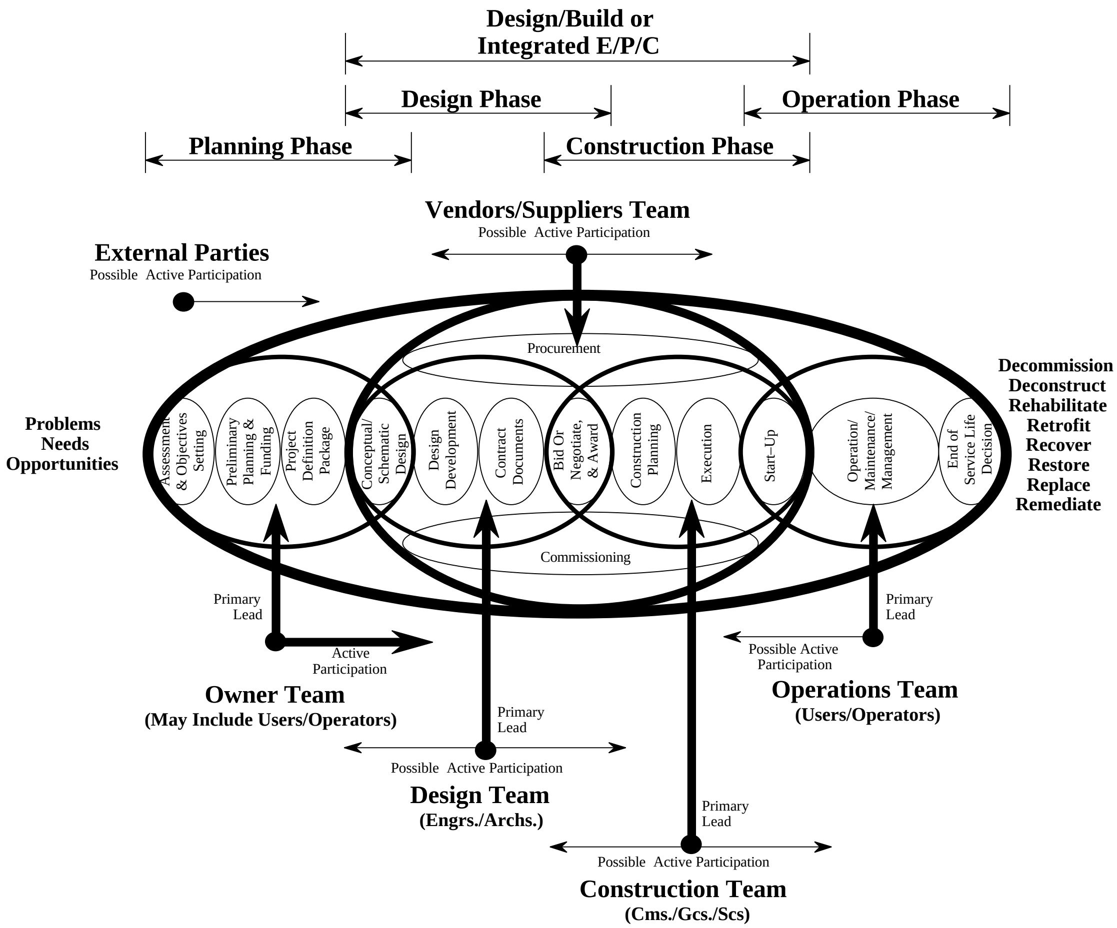

Figure 2-1 Built Environment Model (For Sustainability)
(Vanegas, 2001, developed from Molenaar and Martinez, 2000)

Experience and the literature suggests that as a process, the life cycle of a facility can be better understood if it is viewed in the context of a model. The Built Environment Model shown in Figure 2-1 was selected for this research because it represented many of the needed components to understand how the process can be broken down and better analyzed to understand its costs. The business economics literature introduces the notion of competitive advantage as a fundamental principle of sustainable businesses. One reference even makes the bold assertion that sustainability is in fact, a business term and not an environmental term (Fussler & James, 1996). By adopting this model as the basis for reviewing the design and construction literature, it was possible to categorize and frame the literature in ways that reflect how projects generally progress. This organizing structure later proved useful in creating the cost impact framework. Early in the literature review, two questions helped frame the research and focus the literature search. The first was:

What are the best professional practices to employ for building owners to achieve first cost savings through sustainable planning, design, and construction?

The second was:

To what extent can a competitive advantage for building owners be achieved through sustainable design and construction?

The principal dissertation topics, and the practice and literature review were then targeted towards practitioner screenings and the most recent technical journals, conferences, proceedings of related conferences, dissertations, case studies, and research currently under way. With the exception of *Natural Capitalism* (Hawken et al., 1999), *Mid-Course Correction* (Anderson, 1998), and *The Ecology of Commerce* (Hawken, 1993), only a few distantly related items were found in the business literature. Several areas of the literature discussed cost savings as functions of life cycle cost analysis, with the savings achieved as lower operational and maintenance costs. Only a few references in the literature were found that discussed or indicated cost savings as a function of initial costs. Several of the practitioners in the screenings agreed that at least conceptually, initial cost savings should be theoretically possible as a result of process alterations in the planning, design and construction phases of the normative project delivery process (Figure 1-4).

2.3 Search Methods

In addition to the practitioner screening, the literature search approach included the following general sources; books, technical journals, technical conference proceedings, magazine articles, technical reports and theses, and web sites. A systematic search of these sources was established through the Georgia Institute of Technology library with the assistance of Patricia Johnston. The literature databases were electronically and/or manually searched for related publications. An initial list of 178 publications for the research area was established not including the web sites. The key word logic that was used in an iterative fashion is shown below.

((sustainable with design) or (sustainable with construction)) and (competitive or prefer$4 or advantage or edge or budget$4 or benefit or financ$4 or cost)

In addition to the initial list, the web site search yielded valuable new material as well as duplications of what was initially found. The World Wide Web sites are rapidly becoming a frequently used mechanism for communication of the literature in this research area with new items appearing almost daily. Additionally, professional seminars and meetings provided useful sources of information. The following meetings were especially useful because they reaffirmed the need for this research and captured practitioner's views about this research topic:

- *The National Town Hall Meeting for a Sustainable America* (May 1999) sponsored by the President's Council on Sustainable Development.

- *Re-imaging the Suburbs: Smart Growth and Choices for Change* (January 2000) sponsored by the National Building Museum.
- *Greenprints 2000, 2001, 2002* (February 2000, 2001, 2002) sponsored each year by Southface Energy Institute and Georgia Environmental Facilities Authority (GEFA) and others.
- *The Greening of Federal Facilities Workshop* (April 2000) sponsored by the Department of Energy and the National Renewable Energy Laboratory.
- *The American Institute of Architects, Committee on the Environment Committee Meetings* (COTE) (May 2001, May 2002) held in conjunction with the Annual National Convention.

In addition to these meetings, informal surveys with practicing COTE and other professionals have yielded useful information and insight into the potential first cost barriers and benefits of sustainable solutions for their clients (Appendix A Initial Survey Information).

The researcher conducted an exhaustive search of relevant literature. Excellent bibliographies, annotated bibliographies, source lists, toolboxes, and web site lists in the areas of sustainability have led to many items not found in the more traditional ways. The literature review used an iterative-tiered approach and was comprehensive with respect to the principal aspects of the research area. Sustainability in and of itself has an enormous body of knowledge in publication. Narrowing this body of knowledge in expert and concise manners was challenging. The areas of design and construction taken with sustainability have a much smaller body of knowledge comparatively.

As an outcome of the literature review, other research actors were identified and are listed here.

- The Rocky Mountain Institute
- The U.S. Department of Energy
- The University of Florida
- Georgia Tech Research Institute and Georgia Institute of Technology
- Massachusetts Institute of Technology
- The University of South Carolina
- The U.S. Environmental Protection Agency
- US Green Building Council (USGBC)
- The University of Minnesota
- The American Institute of Architects, COTE
- Hellmuth, Obata, Kassabaum (HOK) Inc.
- Steven Winter Associates, Architects (SWA)
- CH2M HILL Ltd.
- KEEN Engineering Inc.
- The U.S. Department of Defense (all three services)

These actors were all very helpful to this work and several were exploring similar issues with respect to the economics of sustainability. Three (COTE, HOK, and SWA) indicated that they had recently completed similar work confirming the first cost barrier was an issue.

The area of business and economics with respect to design, construction, and sustainability was found to have a small comparative body of knowledge. There is however, related but not directly relevant literature in the manufacturing, automotive, and chemical industry areas with life cycle costing and life cycle assessment being the focus. Additionally, there are numerous books and courseware on ecological and environmental economics.

2.4 Quantitative Search Results

The phasing approach for the baseline literature review was established principally by the completion of the initial search, the formulation of the research methodology, and then again with the initiation of this document. The search was informally begun in September of 1999 with the understanding that the literature review was a necessary step in the formulation and appropriate narrowing of the research topic resulting in a solid and meaningful contribution to this body of knowledge. Beginning in 1999 and over the intervening period, the quantity of reviewed and cataloged material was extensive. To give the reader an understanding of the vast literature base comprising the topic area the following summary of the literature by type has been provided.

Books	13
Technical Journal Articles and Reports	54
Technical Conference and Symposia Proceedings	19
Magazine and Newspaper Articles	47
Theses	11
Web Sites (searchable and relevant)	73
Other (case studies, workshops, interviews, etc.)	22

Considering the design of the literature search, and the knowledge base from which it was drawn, the quantity of the relevant literature (239 items),[2] indicated that some theoretical and a significant amount of applied and practical research was under way. Most of the items discussed the economics of sustainability from a life cycle perspective. Several recent journal articles presented discussions on the cost and benefits of sustainable design. However, the literature search only uncovered a few articles that did more than continue to cite a need to address the first cost issue. Two studies (Katz et al., 2003; Matthiessen & Morris, 2004) however did focus on the topic of the first costs as a barrier to wider acceptance of sustainability. Both of these studies confirmed the need to continue this research effort.

2.5 Qualitative Search Results

The quality of the results from the literature review is presented as a function of the search method, the relevance of the documents found, and the researcher's experience. For this research area and this topic, and considering the interaction with other practitioners through the conferences and seminars, the overall qualitative results are comprehensive but focused. For example, in dialog with the managing principals of other member firms for the Committee on the Environment (COTE), it was determined that few were aware of the Defense Department's recent policies on incorporating sustainable design and construction in 10% of the 2004 Military Construction Program. This particular item of the literature base was important because it describes an artificial driver created by the Department of Defense beyond the pure economics of the industry. Similar documents from the Department of Energy also presented possible implications for first costs with respect to energy conservation and the associated technologies of renewable energy. In contrast however, especially in the areas of journal articles and publications, it was found that most practitioners were aware of the recent actual first cost work by Katz and by Matthiessen quantifying the first costs for certain types of buildings.

The qualitative assessment of the literature was based on the following set of criteria; quality of references, detail of information in the items, repeated themes, and the prestige of the referenced articles. The researcher also relied on his expectations of the anticipated quality by basing the quality assessment on 30 years and $3.5 billion of relevant environmental, planning, design, and construction practice. Relying on his experience and years of practical applications background, allowed critical analysis of each author's work, comments, or contribution with respect to theory and practical application of their information thereby dismissing some documents that did not add to fulfilling the research objectives.[3]

This quantitative and qualitative assessment approach supported an en-route synthesis of the literature and the basis for a more objective analysis of the literature creating sets of what is present, and more importantly not present in the literature and thus a useful and reasonable base to help form the point of departure. As mentioned earlier however, there remained in some of the literature an underlying environmental motivation that reflected broader social and political agendas, which accompany the topic of sustainability. For this reason, careful application of the data in creating the sustainability cost body of knowledge base was required.

2.6 Analysis and Assessment of the Literature Search

The practice and literature review was characterized by listing from each document its relevant main points including its essence, important highlights, the contribution, its reference base, what was learned, and possible citations. Each document was then further characterized from a practical perspective by noting what was well developed, or less developed, anticipated information that was missing and likely to be relevant with respect to this research.[4] These summary sheets (see Appendix A for an example) were then grouped to form smaller summaries to broadly outline the existing state-of-the-art and further refining the research objectives. These summaries were then further analyzed by grouping like-items through association, highlighting points that were likely to be useful later, key areas to explore further, and by identifying developing patterns of information which in the end created a general understanding of these three bodies of knowledge in the literature. The resulting summaries are shown in Table 2-1 and Table 2-2.

Table 2-1 Relevant, Well Developed and Present in the Knowledge Baseline[5]

• Highly developed dialog on sustainable businesses (economic) (Berry, 1999)
• Consensus on the value of Life Cycle Assessments (LCA) (FFC, 2001)
• Consensus on the value of savings through Life Cycle Costing (LCC) (Hawken et al., 1999; von Paumgartten, 2003)
• Several sustainable design standards (Mendler & Odell, 2000; US AFRC, 2001: www.sustainabledesignguide.umn.edu/.hmtl)
• Several sustainable construction standards (www.agc.org/ [Search sustainable & standards])
• Many convincing case studies supporting life cycle savings (www.swinter,com/projects/index.html; www.hok.com/sustainabledesign/database/welcome.html; U.S.DOE-FEMP, 2003)
• Many Green Building case studies without cost data (Mendler & Odell, 2000; USGBC, Making the business for high performance green buildings)
• Dialog on constituent parts of the built environment model that describe valued added aspects and added costs (PWC, 2002; Katz, 2003)
• Some academic/professional agreement on the main barriers (Pearce, 1999 Fall; AIA COTE)[6]
• Some academic/professional agreement on the benefits (Pearce, 1999 Fall; AIA COTE)
• Agreement on the need to better integrate design disciplines for sustainability (http://www.wbdg.org)
• Agreement on the need for public policy support (Steinemann & Ortolano, 1996; Krizek & Power, 1996)
• Professional advocacy in the areas of architecture and engineering (AIA COTE)—numerous online and conference based sources)
• Cross-functional professional interest (www.wbdg.org)
• Emerging academic programs and courseware (Steinemann, 2003)
• Broad international interest from a social and ecological perspective (Fussler & James, 1996; WCED, 1987)
• Well-developed international business approaches (Fussler & James, 1996; Cole, 2000)
• Some U.S. business interest from cost and image perspectives (Anderson, 1998; Berry, 1999; PWC, 2002; U.S.DOE-FEMP, 2003)
• Widely held views that sustainable facilities cost more (Cassidy, 2003; www.bdcmag.com/magazine/articles/b0306edit.asp; USGBC, multiple sources)
• Professional dialog that sustainable features often conflict with quality (Greening of Federal Facilities Workshop, 2000 April)
• Professional dialog that productivity of occupants is connected with IEQ (Browning & Romm, 1998; Jackson, 2003)
• Professional dialog that indoor environmental quality affects productivity (Browning & Romm, 1998; USGBC, multiple sources; Jackson, 2003)

Table 2-2 Relevant But Not Well Developed or Not Present in the Knowledge Base

• Dialog on relationship of sustainable design and sustainable planning
• Initial costs as they relate to competitive advantage
• Solutions to the barrier of discipline integrated planning and design
• Fundamental connection that efficiencies achieved through sustainable design and construction can be good business
• Dialog on why sustainable design and construction is good for facility owners
• Acceptable economic models for project development proformas
• Acceptable sustainable design and construction automated cost estimating tools
• Agreement on universal sustainability standards
• Professional dialog on project definition as it relates to planning
• Development of least-cost/end-use design problems and solutions
• Performance based professional design compensation
• Relationship to the design-build shift
• Procurement, contracting, and acquisition strategies for building owners

Taken in aggregate, these lists form the foundation for understanding the initial three main bodies of knowledge related to the specific research area and topic (planning followed later). There are opportunities to develop other topics from this literature review and some of these are captured as areas for future research throughout this document. Two such topics are sustainable project proformas and building performance based professional design compensation. By deduction from Tables 2-1 and 2-2, there was an absence of literature with respect to understanding the first costs of sustainable design and construction and therefore the hypothesis presented in Chapter 1 remained an area for further exploration potentially resulting in additional contributions to the knowledge base. The next section provides a broader synthesis of the literature with respect to the research hypothesis.

2.7 Synthesis of the Sustainable Design and Construction Knowledge Base

The practice and literature review analysis presented in the previous section expressed as lists what existed and what did not exist in the literature. It was helpful to create an even more useful set of statements by combining the tables into a broader list of statements to express concisely the tenets of the emerging cost of sustainability body of knowledge. This synthesis was performed by further grouping like-topics (heuristic commonality association) and testing those topics against the research hypothesis in the form of investigative statements. Later, qualifying statements (integration) drawn by contrasting the statement with the research objectives were added thus increasing its value as a tenet of the cost of sustainability body knowledge. For example, one summary statement is: Interdisciplinary design integration is needed. This statement has a more complete meaning when presented in the context of the research problem by asking if design integration is a desired outcome then would the entire built environment process benefit in terms of cost if this concept were extended to the entire process? The statement might also infer academic and practice changes could be needed. This qualifying process, where it was possible to derive such statements, further assisted in refining the research questions, the types of data to be gathered, and eventually the analytical methodology. This narrowing step was also used to further develop the scope of the proposed research question and integrate through association the broader research objectives. As such, it represented a basic synthesis of the current practice and literature with respect to this investigation. Thus, the main elements of the cost of sustainability body of knowledge for this research were:

- Sustainability is both an environmental and a business term. This implies that both engineering and economic considerations are relevant.
- Business models can be applied to this area of research (such as business process re-engineering), an implication that in practical application, process optimization might be possible.
- Public policy for sustainable design and construction is largely absent. Establishes a relevant point with respect to codes and cost of compliance.
- Sustainable design and construction is an advocacy-based activity. Few regulatory drivers exist that mandate green design and construction, another factor in understanding its costs.
- Adequate technical design and planning tools are available.
- Research is centered in the environmental arena. Research in the other elements of the conceptual framework is needed. Presents implications for first costs.
- Appropriate tools and business support for sustainable Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) exist. Infers that current economic cost and benefit analysis theory can be applied.
- Cross-functional professional interaction is needed. Green design and construction may be part art and part science.
- Interdisciplinary design integration is needed. Infers academic and practical application changes might be needed.
- Public policy for sustainable planning is emerging. Infers it lags the design and construction bodies of knowledge.

- Building owner’s perspectives are relatively recent. Building owners are becoming well versed on the benefits of sustainability.
- Initial cost and pricing tools are inadequate. Multiple and inconsistent approaches to cost and pricing are likely being used. Value pricing might be more widely used at this stage of its development.

In broad terms, this list suggested there are multiple issues and potential topics across the three bodies of knowledge, sustainability, (facility) design, and construction. The list also introduced another body of knowledge that resulted from the synthesis as being relevant. Sustainable planning, as a key part of the facility requirements statement and as a key determinant of the potential facility solutions deserved a much closer look, and an assessment of its knowledge base and practice. Sustainable planning therefore became the primary focus area for the rest of the literature and practice review and is discussed next.

2.8 Relationship of the Sustainable Planning Knowledge Base to the Study

Sustainable planning is now a rapidly emerging discipline within the community of professional planners and educators (Godschalk, 2004). For the purposes of this discussion sustainable planning is much like sustainable design in that it is planning which integrates and balances the desired outcomes built environment sustainability as shown in Figure 1-3. The shift to sustainable planning now appears in the literature to have resulted from the extensive intra-professional dialog on the topic of sustainability in the early 90’s, where both physical and social planners struggled with how to better integrate physical planning and public/social planning policy within the broad context of sustainability (Beatley, 1995). It was possible to see from the literature that this concept of competing values within the planning community was the initial reason for the slow start. If one thinks about the planning sub-disciplines with respect to the conceptual framework for sustainability illustrated in Figure 2-2, it becomes even easier to appreciate why the elements of the planning profession were at odds. As represented in the literature, economic development planning, environmental stewardship planning, and social equity planning were not necessarily areas to share common visions and objectives. In many cases, they were treated as fairly independent activities and in practice and the literature hampered with conflicting sets of values (Berke & Conroy, 2000; Maclaren, 1996). Yet, it stands to reason and thus became important to explore that as a fundamental phase of the sustainable built environment model, contextual planning could be a principal determinant for green project's costs.

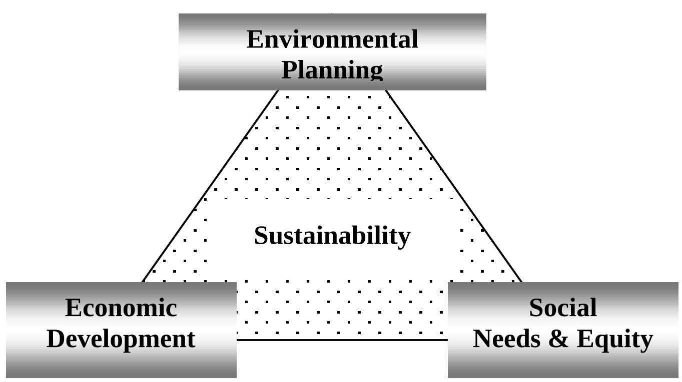

Figure 2-2 Conceptual Planning Framework for Sustainability

The body of knowledge in the area of sustainable development (as defined by the WCED in 1987), and sustainable planning as a more limited aspect of development and as previously defined was extensive. The relevant writings on sustainable planning for cities and communities that set the context for the costs were less extensive and began, for the most part, in the mid-nineties. As a component of, and perhaps the most essential part of sustainable development, the early sustainable planning literature immediately and consistently presented the inherent environmental concerns versus desirable economic growth as competing values. The technical aspects of how environmental assessments as required by the National Environmental Policy Act of 1969, and similar state laws requiring analysis and development of regional impact statements, many times resulted in growth limitations and or no-growth decisions. Their purpose was to cause an analysis of all reasonable options to the development as a planning activity and encourage the selection of the option with the least environmental impact. The other aspects of planning economic development and social equity could not compete well with the heavy environmental focus (Berke & Conroy, 2000). Thus, preventing environmental impact rather than a balance of all three planning responsibilities is believed to be the foundational basis for legitimate debate in the literature. Additionally, because of its strong association to the environmental focus, the literature sometimes related environmental assessments as equivalent to sustainable planning (Berke & Conroy, 2000). This is thought to have further confused and delayed the advent of sustainable planning initiatives in the United States. Less than precise and sometimes synonymous use of the terms sustainable planning, sustainable development, and environmental planning are likely to have contributed to the lack of early and broad acceptance across the profession to the practice of sustainable planning.

Toward the end of the last decade, the literature began to address the aspect of social equity (Krizek & Power, 1997). As environmental problems began to be differentiated by jurisdictional and economically related solutions, the stratification of social concerns about environmental impacts began to develop in more noticeable ways (Wilson, 1998). In essence, and as reflected in the literature, one might infer that the planning followed the money, in as much as the more wealthy the sector was, the more access to the natural resources it had and therefore the more consumptive patterns of life emerged. Conversely, the less wealthy sectors tended to have less access and more restrictive consumptive patterns. This social equity paradox presented a difficult planning situation for planners responsible to all socioeconomic sectors. This third dimension of social equity was discussed extensively in the planning literature and in some cases, it was presented as a generational issue (Berke & Conroy, 2000; Neumayer, 1999). This further complicated the planning profession's attempts to strike sustainable planning initiatives, but supported the current academic interest prevalent in higher education. Despite these challenges, current practice and the literature have numerous examples of sustainable planning with differing levels of success (Godschalk, 2004).

Not withstanding the differing views and planning agendas, the broad framework of sustainability (Figure 2-2) was present in the sustainable planning body of knowledge and was fairly consistent in its representation of environmental stewardship, economic development, and social equity as the principal components of the fundamental conceptual framework.

The literature also reflected a shift in the sustainable planning body of knowledge after The National Town Meeting for a Sustainable America was held in May 1999. This broadly attended live and internet based meeting was considered by many practitioners as the landmark event that helped bring a consensual framework forward and affirmed the need for sustainable planning in the U.S. The arrival and acceptance of this consensus framework for sustainable planning and development marked a turning point in its evolution and acceptance in the United States. Numerous writings and presentations prepared for the meeting used this fundamental framework (Figure 2-2) as an organizing approach. Perhaps even more relevant was the extremely diverse and broad participation, with estimates in the range of 2,600 live and virtual attendees who represented all three components of the framework. Thus, it provided the needed support and to some extent, broad acceptance of the framework. In the following years, the literature reflected even more specific and operationalized definitions of sustainable planning (Neumayer, 1999; Godschalk, 2004).

One of the earlier writings in 2000 questions, through a principle based comparison, whether the direct objective to create a sustainable plan for a community actually results in a plan that is more sustainable than plans that do not have sustainability as a direct objective. The authors compared plans with respect to the following definition for sustainable development.

> Sustainable development is a dynamic process in which communities anticipate and accommodate the needs of current and future generations in ways that reproduce and balance local social, economic, and ecological systems, and link local actions to global concerns (Berke & Conroy, 2000).

The results of the comparison were mixed, but generally suggested that the explicit inclusion of sustainable concepts and objectives have no affect on how well the plans actually promote sustainable principles. There is however, a significant additional cost (Berke & Conroy, 2000). Berke and Conroy concluded that a better, more complete understanding of how to operationalize sustainable planning was needed. In short, they suggest that most of the sustainable plans are no better than the good planning practiced today.

Their view of the state-of-the-art for sustainable planning is not shared across the U.S. planning community. The American Planning Association (APA), in conjunction with the U.S. Department of Energy's Center for Sustainable Development, has recognized the need to mainstream the principles and practices of sustainable development across all sectors and regions of the U.S. (APA Planning Research, http://www.planning.org/resources-yc/doe.htm). It is fair to say and the literature supports, that sustainability whether it relates to planning, development, or design and construction of facilities, has not yet been fully operationalized. The literature also suggests that a strong need continued to exist for all professionals promoting practice consistent with the tenets of sustainability to continue to transition all aspects of their professional practice from less sustainable methods (Mogge, 2000). Regardless of how one views sustainable planning, this assessment presented yet another underlying hypothesis with respect to the cost of sustainability, that is: if sustainable planning has direct relationship to the built environment model, then as a context setting activity it is likely to present cost implications to the process. Given this assessment of sustainable planning as an important and related body of knowledge, it appeared that sustainable planning might have an important place in understanding the overall cost of sustainability and more specifically the first costs of a project.

2.9 Basis for the Knowledge Contribution

Beyond understanding the knowledge base and its principal elements, the design of the research (Step 3 Figure 1-5) also required a more precise understanding of the need. While it is broadly stated in Chapter 1, this section focuses the need for this research with respect to the scope of the research and sets the context for the work, leading to the point of departure for the research.

The basis for the knowledge contribution of this research [The Cost Impact Framework and its Use] was developed in part by analyzing the timing of the need. The absence of knowledge regarding the costs of sustainability can be better understood when placed in the context of the evolution of sustainable planning, design, and construction. From a practical perspective, one might suspect that in time, the knowledge gaps would close themselves and therefore a more complete and useful contribution should be coupled to the timing of the need. This section also briefly presents the market need with respect to the development of the related bodies of knowledge.

The state-of-the-art and underlying knowledge base for sustainable planning, design and construction has, in the past two years shifted in many aspects from a technology focused research and development phase to a practical application or early innovation and use phase that has also been characterized in the literature as the initial practice phase (Cassidy, 2003a). This phase followed approximately five years of prototypical sustainable design and construction projects reported in the literature by many of the practitioners as case studies to help define the emerging technologies, materials, and methods. Comparative use evidence supports this characterization (von Paumgartten, 2003). The AIA COTE reported the number of green designs commissioned in 2002 were estimated to be double that of 2001. Additionally, the green designs commissioned in 2003 were estimated to be double that of 2002. While this reflected a significant year over year increase in interest and use, the 2003 sustainable design commissions were only estimated to be between two and three percent of the total construction value of all facility design work commissioned in the United States (AIA COTE, 2002; USGBC, December 2003). With a modest extrapolation of this type of continued interest and growth,[7] and with the assumption that green design interest is likely to continue to grow at least two percent faster per year than the normative industry rate of growth, then the compounded growth period to reflect 15-20% of the new commissions is approximately 12 years from the end of 2003. It is also reasonable to assume that a 10-15% use factor can be considered reflective of a mature technology[8] as a projection of growth through innovation (developed from Cassidy, 2003b).[9] Based on these assumptions, the likely evolution curve was created and portrayed using a research development, innovation, and maturation breakdown structure and is shown in Figure 2-3. The curve suggests that sometime around the year 2015 green design and construction is likely to enter its own normative phase. If these growth and development assumptions are reasonably correct, then the time to truly understand the first costs of sustainable planning, design, and construction is now.

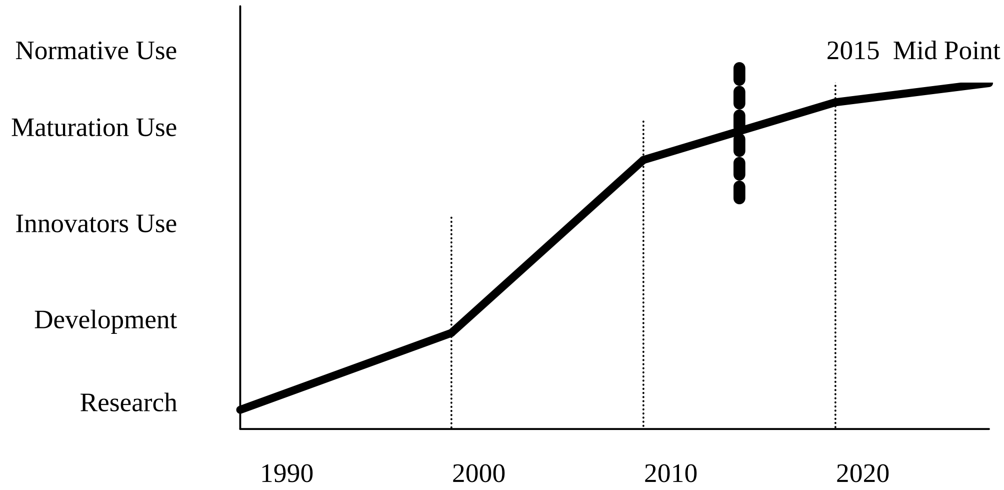

Figure 2-3 Likely Maturation Curve for Sustainable Buildings

This general understanding of the likely timing for the maturation of sustainable design allowed development of a better understanding of the likely market demand. Additionally, with the design and construction knowledge gaps identified, the next step in the design of the research (Step 3 Figure 1-5) was to drive these two aspects together in a way that makes sense and create the point of departure for this work. The next section provides this discussion on the point of departure for the work.

2.10 Point of Departure and Discussion of the Future Research

The need, the practice gaps from the literature review process and the author's hypothesis established the fundamental elements of the needed baseline and consequently a point of departure for this research. Additionally, the scope of this effort and the assumptions underlying it has uncovered additional areas for future research.

The first was an apparent need to introduce some type of larger scale sustainable planning to establish an appropriate context for sustainable facility projects. The second area concerned how facility solutions are developed for building owners, and if they are unnecessarily constrained by today's architectural and engineering paradigms. By this, it is meant that the magnitude of this industry is such that it could have formed its own expectations, norms, and behaviors. These might be acting as internal governing mechanisms that warrant far more understanding than this work could address. One might consequently ask, are these mechanisms management and/or leadership issues?[10] One might also ask if the current paradigm is what causes us to consider sustainability as added features vice inherent aspects of the design. The third area related to the second and was voiced and presented many times in the literature, interviews, and workshops. It is an apparent need for all professionals associated within the larger context of the sustainable built environment model to integrate their efforts early and frequently in the provision of their services to building owners. One might further question if this is a business and/or academic concern.[11]

The area of sustainable planning was briefly explored in parallel with the main research focus of this work to better understand its likely relationship to first cost impacts. It appeared there is a need to more extensively investigate the use and limitations of sustainable planning criteria to understand how sustainable planning might influence the provision of facilities, the viability of alternate facility solutions, and technical integration of professional services in the project development, concept design, or design development phases and perhaps throughout the entire facility delivery process. There are also many more obvious aspects of common sustainable planning strategies like adaptive re-use of existing facilities, the aspects of code compliance, and numerous other potential drivers of costs that could relate to future competitive advantages for building owners.

Referring back to Figure 1-5, the intent of this chapter was to establish the basis for the research. To summarize, the literature is non-conclusive with respect to the causes of additional first costs for sustainable design and construction. The literature does support that a first cost barrier exists. Framed with underlying assumptions about how engineering and design technologies mature the researcher has suggested that a need to more rapidly advance the evolution is likely. Lastly, there are other areas of future research beyond the scope of this work that are likely to increase understanding of the broader topic of the costs of sustainability. Based on these points, the research turned to a preliminary analysis of sustainable planning, materials and methods, and scheduling and estimating as initial areas to investigate.

Taken collectively the synthesis presented is the point of departure for this investigation into the first cost barriers to sustainable design and construction. Additionally, the synthesis of the bodies of knowledge outlined in the design of the research (Figure 1-5) have helped form a new body of knowledge, that of the cost of sustainable design and construction. This point of departure creates the needed foundation for a full understanding of the research topic and subsequent investigation of the research question.

Chapter 3 provides the transition from this point of departure to a preliminary analysis of fourteen case study projects used to help create the cost impact analysis framework developed from the investigation.[12] This transition chapter extends this foundation by looking closely at the current sustainable planning practices, the materials and methods of sustainable design, and the scheduling and cost estimating practices used for sustainable design and construction. In each of the areas, the available data and the strategies (or factors) used are explored with respect to understanding the first costs of sustainable design and construction. Further, the preliminary analysis identified key variances in the way the strategies differ from normative planning, design, and construction strategies to help demonstrate the logic of the of the analytical framework and how it can be used.

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[1] The referenced framework is an unpublished document developed by Dr. Vanegas as an aid to graduate students doing research at both the Masters and Doctoral level. It was particularly helpful given the complexity of this topic and the multiple type of data used in the preliminary and main analysis.

[2] Most but not all of the references for this work were drawn from this literature review. Not all of the 239 items were used. For a complete list of all documents, contact the author at jmogge@ch2m.com.

[3] This research is in part based on an expert system that by design uses the experience of the researcher and those practitioners who provided the initial screening information and the practitioners who were later interviewed with respect to sustainability strategies.

[4] This approach to the literature review resulted in highlighting an additional body of knowledge (Sustainable Planning), which was not originally identified as a key area to explore. It will be discussed in more detail in Chapter 3.

[5] This table was developed through a synthesis of the literature, however in some cases there were sources that presented such compelling or insightful evidence that they have been identified specifically.

[6] The Georgia Tech course and the AIA COTE references are cited as indicative of multiple events where dialogue on the topic occurred.

[7] The basis for this extrapolation was in part derived from a continuing dialog with practitioners during the 2003 AIA COTE annual meeting.

[8] The literature does not present data quantifying the extent of usage required in the building industry to consider a technology mature. However, the DOE renewable energy web site does discuss incubation periods for related energy technologies in their technology roadmaps. The so-called incubation periods range from 4 to 8 years.

[9] The researcher, in consultation with other building practitioners regarding market demand and acceptance developed this projection using the USAF's aircraft research and development program model as a guide.

[10] The notion of leadership or management in large complex organizations or process driven industries is an important issue to understand if one believes that management is about things and leadership is about people.

[11] Again, the notion here is to discern the bodies of knowledge needed to address the potential research area. There is evidence in the literature that both of these bodies of knowledge may have an important connection to the question.

[12] The case study projects were identified from the pool of 53 potential case studies available in the green literature. The selected projects were all of the projects from this pool with sufficient data to support the preliminary investigation.

CHAPTER 3

PRELIMINARY ANALYSIS, SUSTAINABLE PLANNING, SUSTAINABLE MATERIALS, METHODS, CONSTRUCTION ESTIMATING, AND SCHEDULING

3.1 Introduction

This chapter provides in three parts (Sustainable Planning, Materials and Methods, and Estimating and Scheduling), a preliminary analysis that focuses on the manner a green project is framed from the inception of the need, to context of the project planning, to the concept definition, to the design development and the contract documents. The first sections of the chapter present a new understanding of the relationship of sustainable planning as a likely critical phase to the other built environment phases and develops an initial understanding of how this part of the process influences the first costs of a green project. A pilot database of fourteen case study projects shown in Table 3-1 are identified for analysis based on their typology, intended use, owner characteristics, basis of design, and the availability of their underlying design decision development data. Examining the foundation of how a project is developed leads to an understanding of the myriad of ways to address the fundamental problem the project is intended to resolve and to some of the cost drivers associated with it.

Table 3-1 Case Study Projects Used in the Preliminary Analysis

Project	Planning Approach	Size in Gross SF	Completion Date
Nortel Headquarters	Adaptive Re-use	970,000	1997
Missouri Historical Society	Expand Existing Site	129,000	1997
Federal Reserve Bank	Change Use	618,000	1998
SC Johnson Headquarters	Greenfield New	250,000	1997
Turner Feature Animation	Given New	64,000	1998
US EPA Environmental Research Center	Greenfield New	1,170,000	2000
Homestead Fire Station	Adaptive Re-use	26,000	2001
CARB Sun City House #2	Given Prototype	2,000	1999
Administration for Children's Services	Renovation	140,000	1999
Environmental Studies Center	Given New	16,000	2000
Bronx Criminal Court House	Given New	500,000	2000
Four Times Square	Given New	1,600,000	2003
Hennepin County Library	Given Expansion	125,000	2003
Phillips Eco Enterprise Center	Change Use	64.000	2000

The need for a project, the design concept, and the desired outcome of a project are perhaps the most important drivers behind choosing to use a sustainable or normative approach for a project because they define the end use of the project. The more common sustainable design and construction strategies found in most sustainable design guides like segregation of construction debris for recycling, re-use of construction wastes, lean procurement, local purchasing, and materials optimization schemes that deal specifically with how the construction contractors and the project managers carry out the work are important, but only in the tactical sense. They are well developed and present in nearly all projects carrying any sort of sustainable label. Perhaps the more strategically important drivers with respect to first costs are the motivational aspects and value sets of the designers and how they present the sustainable solutions and options to their clients (Mogge, 2001b). A simple question yields powerful insight.

Does one enter the design practice with the view that sustainable design is simply modification of the traditional design process with the exception of employment of green specifications?

If the answer is yes, than the fundamental planning factors are most likely absent and the inherent resource efficiencies are likely lost. Often heard in professional circles[1] today is an expressed interest in learning and practicing sustainable design, quickly qualified with statements like when the materials and methods are more common place. Other reservations included the cost (inferred premium) of sustainable construction, or the more common view that sustainability costs more. To truly understand the first cost of sustainable design, a fundamental understanding of the planning factors should be developed that drives the design goals and strategies to achieve them.

The needed approach focuses on the traditional planning and design functions as an integrated effort with a multi-dimensional solution as the outcome. Integrating the myriad of issues into the problem statement is the task of the project planner who should use non-traditional skills to develop the project alternatives. Setting the project goal and the strategies to attain the goal is the aim of sustainable project development and project planning.

3.2 Sustainable Project Planning and the Case Study Projects

The projects listed in Table 3-1 are comparatively assessed for their likely first cost impacts by studying their characteristics, the nature of their design guidance and their reliance on project planning strategies. In some cases where the needed project planning information was not published, the design team was contacted to provide additional insight. The results of this comparative assessment are shown in Table 3-2. The comparison looks at the guiding project planning strategies, the size of the project, the year completed, and the basis of the design that defines each project as a green project versus a normative one.

Like virtually every aspect of project planning and project development, there are many tools to guide the project planner initially. Design guides and criteria packages are the most commonly used tools. For the set of case study projects, the basis for each design was further examined by comparing the project definition strategies of the five more commonly used green design guides in the U.S. that were used for the projects.

The Design Guides were:

- The HOK Sustainable Design Guide[2]
- The Steven Winters Associates Design Guidance[3]
- The DOE-2.1E Guidance (National Renewable Energy Laboratory-NREL)
- LEED V2.0[4]
- The University of Minnesota (UMN) Design Guide

Common to all of the guides were three basic sub-functions; site work, energy, and water (except the DOE-2.1E). As previously suspected, the assessment revealed that the scale or the size of the project matters. The larger projects defined as over 100,000 GSF (nine of the fourteen) are new construction projects with complex space requirements. Eight of the nine are also characterized as having a high or medium reliance on project planning to achieve their respective sustainability strategies. While it is difficult to be certain, there appears to be a common strategy to provide a more detailed scrutiny of the site options for each project as a key part of the overall planning. What appears to be possible with the higher front-end requirements analysis is an opportunity to truly understand the environmental impacts prior to site selection and thus develop the appropriate criteria for the site selection decision. Additionally, it allows a broader opportunity to look beyond the boundary of the project to explore the project in the context of its economic and social environments (Steinemann & Leonard, 1996). The eight projects with high or medium reliance on planning all have varying degrees of analysis that focus on the linkages to the transportation and utility infrastructure, nature of the surrounding ecosystems, and community (see Table 3-2). Thus, the projects tend to yield a more comprehensive understanding of the overall impact of the planning options. Other considerations presented, but not universally used, included solar and wind orientation, local microclimates, and natural landscaping. Each of the design guides used in the development of these projects has significantly different criteria with respect to the site selection criteria as a sub-function of project planning.

Table 3-2 Sustainable Project Planning Project Case Study Comparison

Requirement	Size	Year	Reliance on Planning**	Planning Guide
Planning Approach*	**KSF**	**ECD**	**Low to High**	**LEED, UMN, HOK, SWA, DOE**
Adaptive Re-use	970	1997	High	HOK
Expand Existing Site	129	1997	High	HOK
Change Use	618	1998	High	HOK
Greenfield New	250	1997	High	HOK
Given New	64	1998	Low	HOK
Greenfield New	1,170	2000	Low	HOK
Adaptive Re-use	26	2001	High	LEED V1.0
Given Prototype	2	1999	Low	SWA, DOE-P1/NREL
Renovation	140	1999	Low	SWA, DOE-2.1E
Given New	16	2000	Low	SWA, DOE-2.1E
Given New	500	2000	High	SWA
Given New	1,600	2003	Low	SWA, DOE-2.1E
Given Expansion	125	2003	Medium	UMN
Change Use	64	2000	High	UMN

* For these case study projects, an adaptive re-use approach was characterized as re-using and altering a structure for a different from original purpose. Expanding an existing site is characterized as re-use of a current location thus inferring a need for interim occupancy. Change use was characterized as a re-use without structural alterations or adaptations.

** The linguistic value for the reliance on the planning strategies was derived by inspection of the project data when it was present, inspection of the site plan for the project with respect to the existing conditions, and in some instances by direct dialog with the design team.

The case study projects also reflect a cost impact issue concerning project scale. The six projects with a low reliance on planning to achieve the desired strategy vary from large to small. Some focus exclusively on energy, and when the site was a given, the project design development phase and the materials and methods used are the pathways to achieve the desired level of sustainability. Also relevant to the case study data is the relationship of energy and scale, and the theme that large facilities should focus on energy as a driver for their sustainability more than smaller ones. This might be because the multiplier of scale for unit cost calculated savings presents an impressive life cycle savings argument for larger buildings, but it may do little to influence the first costs of a project. The Natural Capitalism concept of tunneling through the cost barrier (Hawken et al., 1999) makes strong theoretical sense, but in practicality it was not used with respect to the initial costs of the projects in this case study set. The singular dimension of energy as presented by the DOE and the NREL criteria is important and certainly advanced the practice of sustainable design and construction, but also lacked the broader focus to drive comprehensive sustainable outcomes. Additionally, sustainability focused heavily on energy reduction tends to overshadow other relevant associated issues like natural and man-made resource efficiencies found in the more comprehensive guides that appear to have a stronger relationship to the purpose of understanding the first costs of sustainability.

As the case study data in Table 3-2 suggests, an early sustainable project planning orientation appears to be important with respect to how a project is approached and integrated into the site selection. Six of the fourteen projects reflect a given site and suggest that had the site selection decision been unconstrained, a higher level of sustainability might have been achieved for less cost. In the more detailed review of this issue for these six projects, with an underlying assumption that green fields would have been the likely alternative sites, it is determined to be likely that a higher level of sustainability would not have been realized and perhaps been problematic. This is because the remaining design strategies are not sufficient to have resulted in achieving the project's green goals. What does this suggest about project planning as a principle? Taking the case study data and back-casting, the site planning function suggests that both the building owner and the planner/designer need a high level of interaction with the public planning officials much earlier in the process of project formulation and planning. This is especially relevant if the desired outcomes of the project are to be focused on enhancing the environmental performance of the planning area for the project. Stated another way, the project must almost be without boundaries or viewed as part of a system, which is an underlying theme of sustainability (Hawken et al., 1999). Traditional design practice does not generally approach projects from this perspective with the exception of federally funded projects, which normally require National Environmental Policy Act (NEPA) analysis and documentation (FFC, 2001). With respect to current practice, what this suggested is that behaviors and planning practices need to change for the traditional actors in the planning and design phases of the built environment process, if first cost barriers are to be overcome.

The designers need to engage the planning agenda, and the planners need to engage the design agenda.

As suggested in the literature (Berke & Conroy, 2000; EDAW, 1999; Wilson, 1998), and again with this case study data, a higher degree of integration much earlier in the project planning is needed. Ideally, the project planning team should embrace the public planning function, the owner and/or fiduciary, and the designer. Typically, the designer is singularly focused on the owner's needs. A behavior change is perhaps desired and needed.

Sustainable design and construction as discussed earlier, is rapidly evolving as an emerging aspect of professional practice (Cassidy, 2003a). In looking further into the data from the pilot projects, it is apparent that while each project was guided by an excellent design guide, the guides vary significantly. Again, this is an especially relevant aspect of project planning and concept development.

Another area worthy of exploration is understanding if, and how, the design guides themselves influence first costs. Stated as a hypothesis, what guide should a practitioner use and why if the aim is to achieve lower first costs. To explore this question for project planners Table 3-3 was created to comparatively assess each of the major criteria from each of the five guides used for the case studies. It should be noted that other sustainable design guides exist than those used for these projects, such as the newer versions of the LEED from the USGBC. These include guides for commercial interiors, existing buildings and building shells. It was not the intent of this research to provide a comprehensive comparison of all guides, rather just the ones pertaining to the case study projects identified as reflecting the state-of-the-art practice. The criteria were organized along the major functions of the built environment process (Figure 2-1). This was an especially useful format in developing this understanding of the first costs of sustainable design and construction because the phases of the built environment process, when viewed as a model, allow a more seamless understanding of the entire delivery process. It stands to reason that as the responsibility for each phase transitions from actor to actor the intent and accountability associated with the project may take on new dimensions as well as lose critical aspects of the initial project planning concepts.

Table 3-3 Pilot Project Design Guide Comparison

Built Environment	HOK	USGBC LEED v 1.0	UMN	SWA	DOE 2.1E
Planning	Strategic Facility Planning	Site Planning	Site Planning	Site Strategy	-
	Programming	Urban Redevelopment	Ecological	-	-
	Site Work	Transportation	Alternative Transportation	Directed Development	-
	Strategic Environmental Mgt	Storm Water	-	-	-
Design	Energy	Energy	Energy	Energy	Energy Efficiency
	Materials	Materials	Materials	Materials	Whole Building Energy Performance Guide
	IAQ	IEQ	-	Healthy	-
	Water	Water	Water	Water	-
	-	-	-	Raw Materials	-
	-	-	-	Production	-
	-	-	-	Distribution	-
	-	-	-	Installation	-
Construction	Recycling	Recycling	Recycling	Conserve Resources	-
	Waste Mgt	Waste Mgt	Waste Mgt	Waste Mgt	-
Operations and Maintenance	Building Commissioning	System Commissioning	Maximize Mechanical Systems Performance	-	Whole Building Performance
Deconstruction	-	-	-	-	-
Demolition	-	-	-	-	-

To distill the relevant project planning principles from these design guides required understanding the specific aim of the project. To be green, or to be sustainable was insufficient and not specific enough. In some cases, as with the HOK guide, its reflection of practical experience—a what works, what doesn't approach appears to be the organizing framework for the guide, a sort of best practices approach. Additionally, it can also be viewed as an accumulation of those practices that eventually resulted in the guide being developed. The HOK web page guide (www.hok.com/sustainabledesign/database/welcome.html) shares over nine years of development and was later published as a textbook and is now in its second edition (Mendler and Odell, 2000). The Steven Winters Associates (SWA) operating principles (www.swinter.com/projects/index.html) have grown from sponsored research by the DOE and the NREL. The obvious focus of the SWA practice has been in the area of energy use and conservation for the built environment and their major criteria reflect this. In the case of the University of Minnesota (UMN) Sustainable Design Guide (www.sustainabledesignguide.umn.edu/SusDesGuideContent/casestudies.html), it is an outgrowth of the broader topic of sustainability for the built environment and is somewhat similar to the USGBC's LEED V 2.0 criteria. BRE's Environmental Assessment Method (BREEAM) criteria largely used in the United Kingdom and in Europe are coupled with sponsored research for the United Kingdom and European environment and needs. As an educational outcome, the UMN guide comes close to breaking down the traditional boundaries represented by the phases of the built environment process model. It features a broader understanding of materials and methods of construction (discussed later in this chapter), and explores the more fundamental resources that are used in the construction industry. Additionally, it is more outcome oriented with respect to project planning and goal setting. The UMN design guide may be the most useful for project planners, project developers, and owners to understand because it communicates its strategies less on an actor based orientation. To elaborate this point, the nature of the criteria in the guide is such that understanding the goal of the building owner is fundamental to choosing the appropriate design guide.

Table 3-3 indicates that the planning reliance of the case study projects is dependent on the criteria of the guide and the achievement of its supporting strategies. Accordingly, the projects will likely yield different outcomes and consequently different first costs impacts based on the design guide used for the project.

The case study projects and the outcomes represented by each project had a reasonable correlation to the strategies of its respective design guide. They also shared a common core of criteria shown below with the exception of the DOE-2.1E (www.sustainable.doe.gov/articles/ptipub.html).

Common Core Sustainability Criteria in Case Study Project Design Guides

- Site Planning
- Energy
- Water
- Materials
- Recycling
- Waste Management
- Commissioning

From a project planning perspective, an interesting issue arose from this core set of criteria. Stated directly, what if any is a potential unifying theory? A reasonable argument could be made that it was resource efficiency. While perhaps not apparent, the literature did not present sustainable planning as a resource efficiency theory. The theory held and presented in the literature for sustainable planning is more focused on environmental stewardship. This also holds for many of the organizing frameworks in secondary and higher educational programs on the topic. Testing this from a practitioner perspective[5] that most people approach sustainability from an environmental or social responsibility perspective placing in it the context of conflict with normative planning, design, and construction approaches, while also ignoring the economic value, and thus the first cost issue. Again, a behavioral and theoretical shift is needed within the entire community of sustainable practitioners to better understand the first costs challenge of sustainable design and construction. To effect such a paradigm shift and in so doing a possible shift in understanding and managing the first costs of sustainable planning, design, and construction, the drivers of change must be also identified.

What creates a sustainable planner/practitioner behavioral shift—perhaps a new set of planning principles? To state these common core criteria as a set of project planning principles we refer back to the manner in which they were used by the guides they were drawn from. Embedded in each of these planning criteria are elements of essential understanding and integration that follows.

Site Planning. The UMN guide captures this criteria extremely well and introduces five sub-criteria, shown in Table 3-4, which taken collectively yield noteworthy projects in the set of case study projects. The UMN sub criteria are:

Table 3-4 UMN Site Planning Criteria

•	Direct development to environmentally appropriate areas.
•	Maintain and enhance the biodiversity and ecology of the site.
•	Use microclimate and environmentally responsive site design strategies.
•	Use native trees, shrubs, and plants.
•	Use resource efficient modes of transportation.

As basic as these might seem, the broader issue of strategic project planning, such as whether to build new, sell existing facilities, renovate, lease, consolidate, decentralize or to change a business process is absent. The HOK Guide however, and the depth and experience of that firm with sustainable design allow such consultation and present non-traditional opportunities to add real value to a potential client's needs and therefore potentially significantly different cost outcomes (Mendler & Odell, 2000). Who is best suited to provide such consultation as a routine element of the built environment process model? The case studies suggest it is the project planner, but operating in a role independent of winning planning or design commissions—perhaps a new role that combines the contextual planning, the problem definition, and the physical project concept development. Practically speaking, all too often the business aspects of professional consulting, be it planning, project definition or development, or architectural and engineering design get in the way of providing the highest and best advice possible for building owners and operators.[6] Theoretically, this area closely paralleled Hawken's tunneling through the cost barrier approach (Hawken et al., 1999). There is good practical news that is beginning to set the stage for this expanded new role to take root. The current trend among Architect-Engineer-Construction (A-E-C) firms and some Engineer-Procure-Construct (E-P-C) firms is a migration to the concept of facility-oriented management consulting as an element of professional service to their clients (CH2M HILL, 2000). This shift to non-traditional work outside of the normative design and construction services opens the door to recommend non-building solutions previously viewed as not in the best interests of these firms. This shift could begin a change in the paradigm to more sustainable outcomes. Stated as a principle then:

Adding value to one's client through strategic project planning should be considered as a key project planning principle (Mogge, 2001a).

Energy. The most extensive research on this common core sustainability criteria exists in the DOE documentation (www.eren.doe.gov/buildings/commercial_roadmap/pdfs/roadmap_lowers.pdf). With respect to project planning, it is easy to be overwhelmed with the vast and comprehensive research underway by the DOE NREL. This is a sustainability field of specialty unto its own. The hundreds of criteria and standards brought forward by the DOE NREL are evidence of this. The challenge for the practitioners with respect to first costs is to organize these criteria in a way that makes sense and makes them useable. Steven Winter Associates has provided this organizing feature and has made enormous progress by specializing in this area of sustainability. Their overarching principle is reflective of all building types and scales largely because of the conditioning equipment and lighting requirements associated with each type. It is also directly reflective of the DOE-2.1E standard and is quoted.

SWA Energy Management Principle

> To the maximum extent economically feasible, a building should rely on conservation and renewable energy sources rather than fossil fuel for its operation. It should meet, and in most instances exceed current Whole Building Energy Performance Goals (www.swinter.com).

As a project planning principle, it embodies the necessary and fundamental elements of resource efficiency. Both the HOK and the UMN guides offer more practical and detailed criteria. Further, they introduce the rapidly emerging issue of indoor environmental quality initially absent from the DOE work. The HOK guiding principle for energy is as follows."

HOK Energy Management Principle

> Building orientation and massing, natural ventilation, daylighting, and other passive strategies, can all lower a building's energy demand and increase the quality of the interior environment and comfort of the occupants. The efficiency of required systems is maximized through use of advanced computer modeling and life cycle cost analysis (Hellmuth, Obata & Kassabaum).

The relevance of this approach with respect to first costs was significant, and in the case study projects the more attention paid to the overall planning of the facilities the less the cost of the mechanical systems.

As a guiding principle, the project planner should carefully evaluate the goals of the project and the desired outcomes to choose the correct energy approach. The UMN guide provides a more practical and traditional set of sub-criteria shown in Table 3-5.

Table 3-5 UMN Energy Criteria

•	Optimize building placement and configuration for energy performance.
•	Optimize building envelope thermal performance.
•	Provide daylighting integrated with efficient electric lighting systems.
•	Provide efficient electric lighting systems and controls.
•	Maximize mechanical system performance.
•	Use efficient equipment and appliances.
•	Use renewable or other alternative energy sources.
•	Integrate all systems and reduce total energy use.

Regardless of the set of energy principles or criteria used, the broadly stated DOE-2.1E criteria, the more concise and focused HOK and SWA principles, or the specific UMN criteria, the project planner should investigate closely the critical aspect of energy planning as a fundamental, if not the most crucial aspect of successful sustainable project planning and a key ingredient in resource efficiency as an approach to possibly reducing first costs.

Water. All of the design guides treat water in much the same way promoting the central feature of conservation and re-use as the fundamental approaches. The UMN design guide, which reflects the LEED V1.0 rating criteria very closely, has three sub-criteria that the project planner should embrace. Each was relevant to life cycle costs and some appeared to be cost neutral with respect to first costs. They are shown in Table 3-6.

Table 3-6 UMN Water Management Criteria

• Manage site water.
• Use gray water systems.
• Use biological waste treatment systems.
• Conserve building water consumption.
• Conserve cooling tower water consumption.

A more concise statement that embodies these actions and offers a more useful principle is found in the SWA criteria and is quoted.

SWA Water Management Principle

> In many parts of the country, fresh water is an increasing scarce resource. A sustainable building should reduce, control, or treat runoff, use water efficiently through appliance specification, and recover gray water for on-site use when feasible (SWA Web Site).

Hindsight suggests these energy and water planning principles, had they been understood and practiced in Florida and California on a wider scale over the past two decades, could have contributed enormously to substantially different outcomes than what is currently being experienced in those states. This retro-perspective assessment for energy and water suggests that these principles were and continue to be, the most urgent and most important of the seven common core sustainability criteria for the project planner to embrace with respect to understanding both life cycle costs and first costs.

Materials. Like energy, the more traditional A-E-C firms have focused on the materials approach to characterize sustainable projects.[7] This is an important long-term aspect of sustainable design in the view of most practitioners. However, the case study projects relied on materials for approximately 30% of the contribution to their sustainable outcomes. There are some practical approaches, like the USGBC's Green Building Resource Center, (Online Resource) and the National Institute of Standards and Technology (NIST) BEES V2.0 that are starting to become the referees of genuine value and quality in the commodity race to produce green building materials. Significant impacts with respect to the first cost of green design and construction by product claims should be carefully evaluated by the project planners. A comprehensive comparison of the many design guides with respect to materials is beyond the scope of this research, but the five associated with the case study projects are addressed in more detail in the next section. Suffice it to say, the operative project planning principle with respect to the common core sustainability criteria is:

> The materials are an important aspect of sustainable outcomes and to the extent feasible should be selected based on the specific needs of the design (Mogge, 2001a).

Recycling and Waste Management. These criterion are fundamental to the broad concept of resource efficiency and as used in the case study projects were important to a better understanding of the costs of sustainability. The traditional and current understandings reach into the ecological and land use aspects of our lifestyles in the U.S. The guiding project planning principle derived by inspection from the case study projects is to embrace these criteria in a consistent manner with the current local practice and level of community support. All of the design guides adopted approaches that are widely used today. With this as the basis, the guiding project planning principle should be targeted at affecting one's philosophical approach to consumption patterns and the environmental impact. Generally however, from the case study projects this aspect of project planning adds to the first cost challenge. Restated, the project planning principle for recycling and waste management is:

> Conscientious should be the principle with respect to waste (Mogge, 2001a).

Commissioning. Optimization and maintenance are the fundamental aspects of most commissioning criteria (CH2M HILL, 2000). In short, like any high performance system, efficiency of operation is a function of getting it right, and keeping it right. Bridging the design, construction, and maintenance gaps of the built environment process model is the aim of these criteria. The guiding thought is integrated simplicity.

Presented as a principle for commissioning:

> The perspective of the project planner should always be broad enough to recognize the practicality of the built environment process and plan ways to focus on the needs of the owner and or operator to eliminate the traditional boundaries that separate the designer from the constructor from the maintainer (Mogge, 2001a).

3.3 Summary, Case Study Projects, and Sustainable Planning

The case study projects are selected and assessed to better understand how sustainable project planning and development impacts overcoming first cost barriers (see Table 3-7). The assessment suggests that project planning and development should be a solution oriented activity that looks across and beyond the traditional planning, design, construction, operations, and maintenance functions of the built environment process.

Further, the assessment suggests sustainable planning should embrace a focus on the problem to be addressed, and the right management philosophy to solve the problem, looking beyond traditional planning, design and engineering approaches. This assessment suggests sustainable planning should have as its hallmark a service ethic to a client that transcends the traditional business of consulting planning and engineering and be thought of as a resource management function focused on facility and infrastructure problems. As Hawken states, it should be a least-cost-end-use (Hawken et al., 1999) approach where costs are defined as holistic costs to society for the resources of water and energy and the non-renewable resources of the earth. The project planning end use should be understood to be the most efficient possible. This type of approach forms the basis for future research into the relative weighting of this phase of the built environment process. It also serves as the basis for the development of the cost impact framework with respect to the organizational structure of the planning part of the framework further discussed in Chapter 4.

Table 3-7 Assessment of Case Study Planning Principle Impacts on First Costs

Sustainable Planning Principle	Resource Efficiency Role in Project Costs	Impact on First Costs **
Site Planning	Yes	High
Energy	Yes	Medium
Water	Yes	Low
Materials	Yes	Medium
Recycling	Yes	Low
Waste Management	Yes	Low
Commissioning	Yes	Medium
** Linguistic value derived by association of related resource efficiency strategies to the planning of the core study projects.		

3.4 Future Area of Sustainable Project Planning Research

While important to understanding first costs, further research into this set of project planning principles is beyond the scope of this investigation. The areas discussed above are restated so that others interested in this topic might consider investigating them as an important area of future research in sustainability.

1. "Adding value for one's client through strategic project planning, should be considered as a key project planning principle" (Mogge, 2001b).

2. "To the maximum extent economically feasible, a building should rely on conservation and renewable energy sources rather than fossil fuel for its operation. It should meet, and in most instances exceed current Whole Building Energy Performance Goals" (SWA).

3. "In many parts of the country, fresh water is an increasing scarce resource. A sustainable building should reduce, control, or treat runoff, use water efficiently through appliance specification, and recover gray water for on-site use when feasible" (SWA).

4. "The materials are an important aspect of sustainable outcomes and to the extent feasible should be selected based on the specific needs of the design" (Mogge, 2001b).

5. "Conscientious should be the principle with respect to waste" (Mogge, 2001b).

6. "The perspective of the project planner should always be broad enough to recognize the practicality of the built environment process and plan ways to eliminate the traditional boundaries that separate the designer, from the constructor, from the maintainer" (Mogge, 2001b).

As a preliminary premise, these are the prototypical six essential building blocks for successful sustainable project planning and development.

3.5 Sustainable Materials and Methods

This second part of the preliminary analysis extended prior research in this area and investigated the materials and methods of the case study projects in order to more fully analyze and understand the "first cost context" of the design development, contract documents, and construction phases of the built environment process model. As discussed earlier, the growing popularity of green design and construction would suggest that this emerging and specialized practice would yield a distinct set of materials and methods associated with it. As discussed in the literature review and drawn from current practice, there is evidence to support this expectation. One such item is the Green Building Resource Center, online (www.usgbc.org). Another is the Center for Resourceful Building Technology (www.crbt.org). The current literature and the data from the case study projects suggests that on average approximately 30% of the materials used in green facilities are unique to sustainable practice. The uniqueness of the materials can best be described as those types of materials that are not common to normative design and construction or resource efficient materials used in uncommon ways. For example, two such material applications identified in the case studies are unpainted Homosote™ used as a sound absorbing ceiling material and a final color impregnated Harde™ Board (cement fiber board) used for exterior finishes.

In the area of sustainable construction practice and methods, the pace of change appears to be higher with a focus on the three strategies of high performance systems (www.crbt.org), reducing energy use, and reducing construction waste and debris. In addition to the waste reduction/minimization strategies, there is evidence that within the waste streams, what cannot be eliminated is looked more closely for its recyclable value more than in past practice.

There is also evidence that the construction methods associated with green design are driven by a more comprehensive set of design decisions. The decisions focus on getting the building envelope right, which in some cases may lead to restructuring the manner and order in which construction and construction management activities take place. The web site Whole Building Design (www.wbdg.org) offers extensive discussions on this topic. Establishing the right order of the design activities and reflecting that order in the actual construction is of paramount interest in several of the case study projects because it is fundamental to resource efficient design and construction. In a few of the cases, the traditional boundaries of the design process and the construction award process are merged to allow a higher level of communication among the owner, the designer, and the construction contractor. This supports the premise that a higher level of integration within and across the built environment process model is critical to achieving lower first cost sustainable design and construction outcomes. More evidence is needed to confirm this premise.

The collective impact of these evolving approaches to the use of sustainable materials and methods for green construction has important implications for the planning and estimating of sustainable construction projects as well as all construction projects. When resource efficient materials and construction methods are developed and used, many times these efficiencies are translated directly and indirectly into lower overall initial project costs and lower life cycle costs (Mogge, 2001a).

3.6 Materials and Methods Assessment of the Case Study Projects

The way forward in sustainable design and construction, and specifically the progress to date in creating, marketing, and thus specifying environmentally friendly materials and their associated construction methods to use them properly is impressive. Similar to the sections on sustainable planning, the case study projects are reviewed with respect to the sustainable materials and methods used in each of the projects. For this part of the preliminary analysis, the case study project set is studied to uncover its likely impacts on project costs.

The case study projects (Table 3-1) selected, based on the criteria discussed earlier are designed by firms recognized as leaders by the AIA COTE or emerging leaders in the practice of sustainable design. These case study projects are leading examples of sustainable design and construction with respect to materials usage and some are professionally recognized as such. Equally impressive is the designer's and owner's willingness to share extensive information about the case studies making it possible for the profession at large to learn from the projects.

These projects are largely early adopter projects, in terms of the maturity of sustainable design. The projects range from small federally funded work (less than 26,000 SF) to large privately funded work well over 1,000,000 SF. The nature of the materials used in these projects varies greatly, and are principally functions of the project's overall sustainability goals and implementing strategies.

Concurrent with the case study projects, several extensive materials and material systems research activities are underway which are currently providing continued advancements in the technologies of sustainable design and construction. The U.S. Department of Energy, Office of Building Technology is one of the leading governmental institutions and has a series of technology roadmaps designed to help industry focus on the needed changes. These practical research activities include items like the *High Performance, Commercial Buildings Technology*, and the *2020 Building Envelope Technology* roadmaps (www.eren.doe.gov/buildings/commercial_roadmap). In the private arena, the National Center for Appropriate Technology (NCAT), Center for

Resourceful Building Technology (CRBT) operates an online Guide to Resource Efficient Building Elements (www.crbt.org/index.html). This guide, funded by the Brown Foundation, presents sixteen sections that parallel the Construction Specifications Institute format. This ongoing research is presented to underscore the relative fluidity of the materials and methods probable cost impacts.

As part of the overall selection criteria mentioned earlier, several case study projects were selected because they are the most detailed and current with respect to their use of unique materials and methods.

Eleven of the fourteen projects are designed by the firms Hellmuth, Obata, and Kassabaum (HOK) (www.hok.com/sustaianbledesign/database), or Steven Winter Associates (SWA) (www.swinter.com/projects/index). This is partially because both firms are recognized as leaders in the materials and methods of sustainable design and construction, consequently much is learned from their pioneering work.

The case study project materials selection criteria focuses on three items; cost, aesthetics, and availability of materials. HOK has a competitive advantage over other firms based on the amount of federal work they do because they are leveraged as early adopters by the Executive Orders 13123 and 13148 requiring most government agencies to proactively establish internal policies to promote environmental accountability, greening and sustainable design. The HOK projects meeting the needed selection and data criteria described earlier are:

- Nortel Brampton Centre, Ontario, Canada
- Missouri Historical Society Museum Expansion and Renovation, St Louis, Missouri

- Federal Reserve Bank of Minneapolis, Headquarters and Operations Center, Minneapolis, Minnesota
- SC Johnson Headquarters, Racine, Wisconsin
- Turner Feature Animation, Glendale, California
- US Environmental Protection Agency, Environmental Research Center, Research Triangle Park, North Carolina
- Homestead ARB Fire Station, Homestead, Florida

Other HOK private sector projects were reviewed but not included as case studies due to a shortfall in needed data. These projects included:

- Bell-Northern Research Carling Lab 5 and Headquarters
- Cummins Engine Company Fuel Systems Plant
- Hobart House, Grosvenor Place
- Maryland Stadium Authority, Camden Yards
- Nature Conservancy Headquarters Building

In a similar fashion but on a smaller scale, the pioneering work of SWA in collaboration with the DOE NREL produced and tested a prototype house for Del Webb Corporation in Surprise, Arizona. The Consortium for Advanced Residential Buildings (CARB) project features innovative ways to re-apply existing materials through design innovation to radically reduce energy costs (www.swinter.com/projects/sun_city_carb). The significance of this project is that it serves as a model to demonstrate the importance of good design focused on the methods of construction without relying on unique or green materials.

Much of the current thinking and practice is that green design must necessarily assume a heavy reliance on green materials as a prerequisite to achieving sustainability. The SWA CARB #2 project challenges this assumption and consequently challenges some of the more commonly used sustainability rating programs which have as their basis a materials reliance theme or component.

LHB Engineers and Architects, a lesser known, but none-the-less pioneering design firm's project is selected as a case study based on the University of Minnesota's Minnesota Sustainable Design Guide, from the UMN's case studies section.[8] This project was developed with precisely the opposite approach of the SWA Carb #2 project. The Green Institute's Phillips Eco-Enterprise Center (PEEC) a 64,000 SF facility in Minneapolis features a heavy reliance on materials to achieve their sustainability strategies. The LHB Engineers and Architects design for this project employs a four-part materials strategy. The project integrates salvaged and remanufactured materials, recycled materials, design for de-construction principles facilitated by material selections and design-for-less materials concepts. Perhaps one of the most advanced materials and methods strategies in the U.S., it is a 2002 benchmark project for understanding how to incorporate and integrate materials to achieve sustainable outcomes. Some of the more interesting features include:

- 22,000 Bricks salvaged from a century old Chicago warehouse.
- Steel joists salvaged from a 1960 warehouse in Washington County, Minnesota, eliminating the need for 50 tons of new steel.
- Stair treads re-milled from 75 year old Douglas fir beams salvaged by the U.S. Army eliminating the need for 804 board feet of virgin timber.

Other re-use items include sinks, doors, fire extinguisher cabinets, windows, and remanufactured workstations. For the strategy of design-for-less material use, the features include polished exposed concrete block walls eliminating the need for drywall, high exposed ceilings painted white to eliminate 26,000 SF of drop ceilings, and pre-cast panels with embedded pigment saving about 80 gallons of paint. For the strategy of high recycled content products and materials, the project incorporates bathroom tiles made from 100% recycled glass, refurbished carpet from re-modeled buildings in the area, Solenium as a 100% recyclable floor covering, and parking lot surfaces batched with over 50% recycled materials. For the PEEC design strategy of using materials manufactured from renewable sources, the design includes windowsills made of Environ bi-composite, a composite material that comes from soybeans and recycled newspaper, concrete panels constructed with 10% fly ash saving approximately 53 cubic yards of traditional concrete aggregate. Other more common sustainable products such as linoleum, no volatile organic compounds (VOC) emissions and low VOC emission paints and Low-E glazing are also used.

The contrasting applications of material reliance for sustainability between the CARB #2 house and the PEEC facility with respect to materials usage suggests that regardless of the overall approach to the project, the application of the design guide and the project's goals are key determinants in both its life cycle and first costs more than its reliance on material strategies.

Additionally, across the case study set of projects, the nature and scale of the design requirements appear to be determinant factors with respect to the design's materials and methods. In general, for projects less than 500,000 gross square feet (GSF), the opportunity to approach the design solution from a materials perspective is present. For larger projects, the sustainability focus appears to be on creating the most efficient building envelope through design, and creating the largest possible offset in energy requirements when compared to traditional energy demands on a unit basis. Table 3-8 reverses the reliance comparison previously discussed and presents a summary of the case study projects and their strategies with respect to achieving sustainable outcomes. The reliance values are determined by inspection of the project data and for some projects, through direct feedback from the project manager or design team leader.

Table 3-8 Sustainable Project Case Study Data
Reliance on Materials and Design for Sustainability

Project	Gross Square Feet	Reliance on Materials	Reliance on Design
Nortel Headquarters	970,000	Low	High
Missouri Historical Society	129,000	Very Low	High
Federal Reserve Bank	618,000	Medium	High
SC Johnson HQ	250,000	Very Low	High
Turner Feature Animation	64,000	High	Medium
US EPA Research Center	1,170,000	Medium	Medium
Homestead Fire Station	26,000	Medium	Medium
CARB #2	2,000	High	Low
Administration for Children's Services	140,000	High	Low
Environmental Studies Center	16,000	Low	High
Bronx Criminal Court	500,000	Low	High
Four Times Square	1,600,000	Very Low	High
Hennepin County Library	125,000	High	High
Phillips Eco Enterprise Center	64,000	Very High	High

As this case study project data indicates, there appears to be a propensity to rely on sustainability strategies focused on materials and methods to achieve sustainable outcomes in projects less than 250,000 GSF. As reflected in Table 3-8, there are exceptions to this general statement, but it appears that scale does matter. It also appears that the larger the project, the greater the need to have the design address the energy metrics as the most fundamental aspect of its sustainability. In almost every large project, there are strategies focused on improving the performance of the building envelope. The materials involved in these strategies are targeted at the DOE-2.1E performance criteria. In the case of curtain wall systems, special features are added to create better daylighting while keeping out the ultraviolet heat. Additionally, the designs call for highly integrated mechanical systems that focus on reducing the overall energy demand for the project. The most common performance metric is a 30% reduction over comparable systems for normative (pre DOE –2.1E) performance criteria.

The green design development materials related strategies are reviewed in more detail for each of the projects in the case study set and found to vary with respect to the nature of the strategies employed. Table 3-9 summarizes the principal types of strategies in use. The relationship of the design strategies and the green materials and methods also vary, as shown in the table. The range of strategies include basic product substitution to completely new building systems with the most complex being a computational fluid dynamics net energy export scheme for the Environmental Studies Center Project at Oberlin College, designed by SWA in association with William McDonough and Partners.

Table 3-9 Summary of Sustainability Strategies and Relevant Material Concepts

Strategy	Relevant Material Concept
Materials Minimization	Elimination of conventional finishes
Dramatic Day lighting	Light shelf integration into curtain walls
Super Tight Envelope	High tech insulation
Heat Reflectance	Low E and smart glazing
Material Durability	Locally produced and natural finishes
Maintenance Free	Limited to no sealant or paint
Indoor Air Quality	No-VOC emission products
Life Cycle Costing	Conservation features, waterless
Energy DOE 2.0	Integrated envelop and HVAC systems

Two projects clearly stand out with respect to the rest of the case studies and deserve specific mention. Interestingly, both of the projects are new construction requirements and less than 100,000 GSF. The case study data suggests that the scale of the project matters in the development and planning of sustainable projects. This might become an important consideration for any future research with respect to the weighting given the phases. Both of these projects are very highly discipline integrated designs with non-traditional solutions for their programs. Additionally, they have a strong central focus to their sustainable features, suggesting that a high quality, yet simple approach might yield the best outcome and might have a corresponding relationship to first costs. This is an important, albeit an early preliminary notion, when looking at the relationship of the design concept to the materials and methods chosen to support the strategies developed to achieve the design goal and at the same time address first cost issues.

The first project is the Green Institute Phillips Eco-Enterprise Center (PEEC) in Minneapolis, Minnesota, designed by LHB Engineers and Architects and mentioned earlier. It is an award winning 64,000 SF office/light industrial building [National Award for Sustainability, President's Council on Sustainable Development, May 1999]. Featured in 2002 as a case study on the UMN's) sustainable design guide web page, its central sustainability focus is energy minimization and highly innovative materials strategies. The UMN Sustainable Design Guide is in and of itself a highly integrated six-part guide that is much easier to use than LEED V2.0 or any of the other more common rating schemes. Its parts presented as strategies for the PEEC project are listed in Table 3-10.

Table 3-10 PEEC Strategies Based on the UMN Design Guide

Guide Section	Design Strategy
1.1	Direct Development to Environmentally Appropriate Areas
1.4	Use Native Trees Plants and Shrubs
1.5	Use Resource Efficient Modes of Transportation
2.1	Manage Site Water
3.1	Optimize Placement and Configuration for Energy Performance
3.2	Optimize Building Envelope Thermal Performance
3.3	Provide Day-lighting Integrated with Electric Lighting Controls
3.4	Provide Efficient Electric Lighting Systems and Controls
3.5	Maximize Mechanical Systems Performance
3.8	Integrate All Systems and Reduce Total Energy Use
4.3	Provide Ample Ventilation for Pollutant Control and Thermal Comfort
4.4	Provide Appropriate Thermal Conditions
4.7	Provide Views, View-space and Connection to the Natural Environment
5.2	Use Salvaged and Remanufactured Materials
5.3	Use Recycled Content Products and Materials
5.4	Use Materials from Renewable Sources
5.5	Use Locally Manufactured Materials
5.6	Use Low VOC-emitting Materials
6.2	Design-for-less Material Use
6.4	Design Building for Disassembly
6.5	Salvage and Recycle Demolition Waste

The central focus of the project is reflected in these 21 energy use and materials selection strategies. The greatest challenges to overcome include scheduling the installation of the salvaged materials and receiving code official approval for the more innovative systems and products. With respect to the rest of the case study projects, this project presents the most comprehensive and innovative materials-based approach to sustainability. There are more strategies in the guide than used on this project, and it is important to note that the quality and level of its sustainability is not a function of the number of strategies used, but rather the outcome generated by the application of the integrated set of strategies.

The second project is the Center for Environmental Studies, Oberlin College, designed by William McDonough and Partners in conjunction with SWA. This project focuses on a holistic approach to the entire building as a volumetric study of how natural and conditioned air can and should move through the spaces. The team collaborated to arrive at solutions using state-of-the art design concepts employing commercial off the shelf materials. The HVAC designer, Lev Zetlin Associates performed a DOE level 2.1E energy analysis and used a Computational Fluid Dynamics (CFD) based design to minimize the building's energy use. This is a significant additional cost to the design, but a huge trade off in actual construction costs (Zetlin Associates, personal communication, December 2001). The idea behind the design and the follow-on materials and methods, is to use the sun and the ambient air when advantageous, and when not, to engage the HVAC systems through optimization of the building's envelope. The notion that the materials and methods may or may not be considered sustainable and the design normative, but still yield a green outcome is an important trend in green design, which has a heavy focus on energy efficiency. The features of the design included:

- A CFD designed atrium (actual space configured to enhance the flow of air based on the analysis of the thermal data and a simulation of the air movement).
- An active solarium that functions to collect heated or cooled air and/or to pre-heat or pre-cool air as needed. The idea behind this space is similar to a variable air ventilation mixing box within a conventional system, except that the ductwork

box is actually a useable space. Additionally, the airflow regulators are the wall openings located at precisely the correct place to enhance the thermal lift of the air.

- The optimization of ultra high performance glazing further enhanced by site orientation but positioned to enhance daylighting throughout the facility.
- A highly insulated opaque wall system.
- A Geothermal heat pump and displacement ventilation system.
- A Photovoltaic panel array for connected load.

The sharp contrast between these two state-of-the-art sustainable facilities, one focused on a set of largely materials-based strategies that try to re-use embodied energy, and the other focused on the nature of the design to radically reduced the future consumed energy, provide support for an early integration of the project planning, conceptual design and design development phases.

These two case study projects also help in understanding how to develop a new mental model for integrating the early parts of the built environment process with new a new tool for the advanced planning and estimating of sustainable projects and provide important indicators in further understanding the first costs associated with the design development phase. As key case study projects, they also provide the needed limits to help frame the relationship between the design goals and the construction methods.

The materials and methods of sustainable design and construction outcomes appear to exhibit strong relationships to their rating systems and their design guides and thus their first costs (Mogge, 2001a). In the case of the UMN Sustainable Design Guide, its focus is clearly oriented to a materials and methods selection process coupled with a strong focus on energy. In the case of the LEED V2.0 rating system, essentially a score card for sustainability and a design driver, the focus appears to be broader with more criteria associated with site selection and environmental conservation. Regardless of the design guide or the rating system used, the case study projects suggest that design professionals must approach the project and its requirements with a clear understanding of what the desired sustainable outcome is. This orientation based outcome is also presented in many areas of the sustainability literature (Cassidy, 2003b) and reinforces the previous discussion about the importance of higher levels of integration among the actors in the project planning, development and definition phases of the built environment process model.

There are also many factors still emerging. The Department of Energy with its Office of Building Technology and their various technology roadmaps present one vision, and within the same department through another office, the Renewable Energy Laboratory presents yet another focus, that of solar power. In the absence of a nationally recognized facility energy consensus standard, today's project planner and designers are left to their professional working knowledge of technology and practice. This ad hoc situation tends to further exacerbate the way forward for sustainable design and construction, especially that which is not goal focused. It also tends to muddy the waters with respect to the resource efficiencies possible with respect to first costs.

To further understand if the materials and methods as reflected in the construction specifications are first cost drivers or impediments to more wide spread use of sustainable design, it is helpful to go back to Center for Resourceful Building Technology's *Guide to Resource Efficient Building Elements* previously mentioned. The online edition presented in a format similar to the Construction Specification Institute (CSI) suggests that the number of suppliers from individual products to building components and systems is growing rapidly. Their current database (with similar data from BEES V2.0, eBuild, HOK Sustainable Materials Database, and the EBN Greenspec materials database) shows over 2,000 national level suppliers. In addition to its subscriber suppliers, the CBRT estimates that the available but unregistered number of suppliers might be as much as five times the current CRBT number and growing monthly. Regardless, the case study projects suggest that to create sustainable outcomes one must not necessarily depend on or use unique sustainable materials. In fact, many of the case study projects simply use normal construction materials in new ways to achieve comparable results. For example, the pilot CARB case study house #2 by SWA uses steel and aluminum framing in a thermal break fashion to achieve a 100% increase in the R-value of the wall. When examined from an energy and durability perspective, the energy saved from this application compared to the embodied energy used to create it could easily be less when one considers the increased durability over other alternatives. Their discussion of the project's LCA supports this outcome (www.swinter.com/projects/sun_city_carb). In another application, HOK specifies Homosote as a tackable wall surface for their Turner Feature Animation Facility. The Homosote, made from 100%-recycled paperboard, was left unpainted eliminating the need for fabric wall covering.

3.7 Summary, Case Study Projects, and Sustainable Materials and Methods

The data from the case study projects specifically focuses on their materials and methods of construction. This suggests that the design concept and the desired outcome for a project are more important prerequisites to achieving sustainability than its materials and methods. There are more common sustainability strategies like, segregation of construction debris for recycling, re-use of construction wastes, lean procurement, local purchasing, and materials optimization schemes that deal specifically with how the construction contractors and the project managers carry out the work. These however are now well developed methods and present in nearly all projects carrying any level of recognition as a sustainable project. While not to be taken lightly, these are not likely avenues for further exploration and research into understanding the costs of sustainability and the first cost question because they are occasionally present in normative construction already. By establishing this point, the investigation can be better bounded and focused on the areas more likely to yield stronger understandings of the cost drivers. Consistent with the section on sustainable planning, this section on sustainable materials and methods suggests that the more important cost drivers are the motivational aspects and value sets of the designers, and how they present sustainable options to their clients, their design teams, and the constructors who build their designs.

The sustainable design literature discusses continuing education and interest by practicing professionals in learning and practicing sustainable design. Many of the continuing education courses on the topic focus on green materials and methods as being the principal differences between normal practice and sustainable practice and indirectly reinforcing the existence of the first cost barrier as a function of unique and limited materials and expertise. This section suggests that when the actors of the built environment process truly understand the costs of sustainability, they develop a fundamentally more accurate perspective that the materials and methods associated with its practice are most likely not the principal cost drivers.

The case studies also indicate that financial benefits and professional recognition are likely for the building owners and their designers who chose sustainable outcomes. Four of the case study projects have attained special recognition. The building owners report not only satisfaction with the financial performance of their investments but also high satisfaction with some unanticipated intrinsic outcomes like reduced employee absenteeism and increased productivity, and recognition within their work force for providing world class work environments.

While sustainable materials and methods are important to sustainability, integrated planning and design is what gives sustainability meaning and value within its contextual setting. The facility planning and design business is not fundamentally changed with any of the case study projects but the nature of the project's design did change. What is also clearly changing from the case studies, and is still changing, is the designer's understanding of the materials needed to achieve the outcome and a stronger and more active leadership in developing the specifications that reflect the materials and methods needed to achieve their intended design outcomes. In a more limited sense, it is also clear within this limited set of projects is that as the specifications changed the project outcome changed. There is some indirect evidence of this based on the scale of the projects. The more successful ones, in terms of actually achieving their intended performance, have been facilities with less than 65,000 GSF. As an area for future research, it would be interesting to investigate why this occurred. One possible explanation might be that the designers, unlike practice today, did not hand off the design to specification writers to finish the job but took the provision of the specifications on as an integral part of the overall design development. Residential scale work in the green arena tends to further support this notion. A similar outcome but with a more complex, replicable, and adaptable framework based approach was developed for use by the Maryland Department of Natural Resources for the green renovation of rowhouses (Terralogos, 2001). Be it the Earthcraft™ homes, the CARB projects, green products by Rylan Homes, or many of the other recognized and published residential work, it appears that scale of the project does matter with respect to sustainability.

3.8 Sustainable Cost Estimating, Scheduling, and Procurement

The previous sections of this case study preliminary analysis established some of the needed support for a framework which could be based on the initial conclusion that well planned sustainable design concepts, guided by the proper criteria, and the desired outcomes for a project, which are developed and shaped by interactive planning and design are the most important drivers in achieving sustainability and understanding its first costs. This section will continue to examine the case study projects with respect to their cost estimation, their scheduling, and their procurement approaches. Strategies like lean procurement, local purchasing, and materials optimization schemes that deal specifically with how the construction contractors and the project managers carry out the work are some of the types of the related issues associated with this focus. This discussion also establishes the relative basis for considering the multiple project delivery methods possible to deliver sustainable projects and some of the advantages and disadvantages of each with respect to the costs of sustainability.

The previous sections also helped establish as a fundamental, yet practical frame of work, some guiding project planning principles and tenets for the practice of sustainable design and construction in a manner that help define the first cost issues and also help form the basis for the proposed cost impact analytical framework. This professional practice frame of work is grounded in the preceding summary on materials and methods and restated. A sustainable design practice should be:

- More about design than specifications.
- More about using what we have more efficiently than it is new technology.
- More about simplicity and functionality than complexity.
- More about motivation than it is technical and material knowledge.
- More about doing what is right for the long term than business as usual.

Likewise, the planning factors that provide the frame of work for planning a project and ultimately result in the achievement of the project goal and shape the overall costs, specifically the first costs, are very important. Thus, the planning factors are more vital to understand in sustainable cost estimating processes when compared to their importance in traditional design and construction practices. The set of project planning principles distilled from the assessment of the same set of case study projects also represents the state-of-the-art for practitioners to follow because they incorporated new materials and methods based on the project's goals. It is important to keep these points in mind as one considers the scheduling and cost estimating aspects of sustainable design, because they present the practice framework needed to flow and cost the work properly, especially when considering different methods or approaches for project delivery, including using the design-build method.

In the built environment process, the more integrated the phases, the more relevant the cost estimating and scheduling functions become because the traditional process is highly discipline and functional centric. Accordingly, the focus of cost estimating and project scheduling for sustainable practice should ideally emerge from a seamless integration of the planning, the design, and the construction phases. An important aspect of the research hypothesis for this part of the case study project analysis is that today's normative and highly sophisticated cost estimation and project scheduling approaches do not directly recognize that much of the cost inherent in green construction today results from uncertainty about how best to achieve the desired outcome as it passes from phase to phase. This was apparently the case with the PEEC project when the designers found it difficult to convince code officials that the sustainability strategies were sound. The concept of uncertainty and risk was investigated through interviews with the designers of the case study projects but there is little evidence that such a seamless cost estimation process was used except in a very limited extent for the PEEC, CARB #2, Environmental Studies Center and the Homestead Fire Station projects. Said another way, there appears to be much lost in the transition from phase to phase with respect to first costs. The resulting uncertainty from actor to actor that was generated translated to risk, which likely translated to additional cost. This hypothetical concept is shown in Figure 3-1.

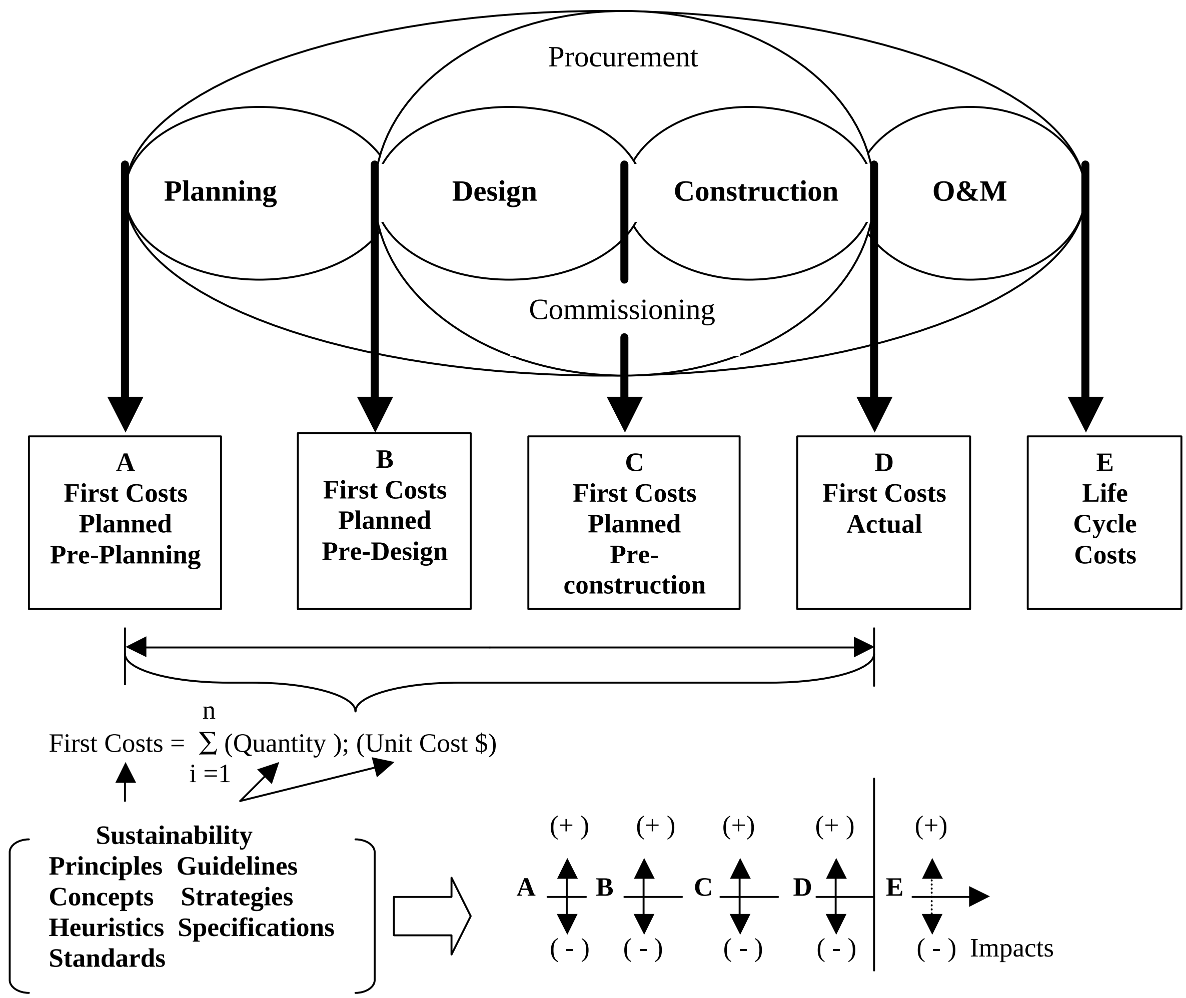

Figure 3-1 Concept Model of Cumulative Risk and First Costs for the Built Environment Process

In addition to a higher than normal level of integration for the planning and design development activities of the PEEC, CARB #2, Environmental Studies Center, and Homestead Fire Station case study projects, their higher overall first costs might have been reduced had the communication and integration concept shown in Figure 3-1 been used to better integrate their cost estimation and scheduling and avoid the impacts. To take this concept a step farther, had the same concept been used to explore the selection of the delivery methods for the projects, it might have been possible to achieve a cost breakthrough by essentially eliminating the conceptual impacts between the phases which represent the risk and uncertainty of the actor's decisions and with respect to the following actor. A concept similar to this is the subject of a recent investigation by the National Institute of Standards and Technology, Advanced Technology Program. The report, *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry* (Gallaher, O'Connor, Dettbarn & Gilday 2004), suggests that $15.8 billion in annual interoperability costs can be attributed to the industry's inefficiencies caused by its paper-based practices, a lack of standardization and inconsistent technology adoption among stakeholders. Many similar issues are also present in the built environment process model barriers as Figure 3-1 portrays.

For the construction phase, construction contracts between the owner and the construction contractor largely provide the transition from design to construction in the design-bid-build delivery methodology with ample opportunity for more risk and uncertainty to be introduced. The contract documents form the basis to communicate the requirements of the project with respect to its planning and design. This process requires essentially a duplication of effort with an opinion of cost and the project schedule provided by the design firm for the owner and the same activities undertaken by the construction company (usually a quantity take off and current market quotes for materials and services), each for their respective use and protection within the contract. This approach is inefficient and a major reason why the industry is shifting to alternative project delivery methods like design-build contracts. A more risk adverse and uncertainty tolerant approach (Figure 3-2) is one where that traditional boundary defined by a triangular relationship does not exist.

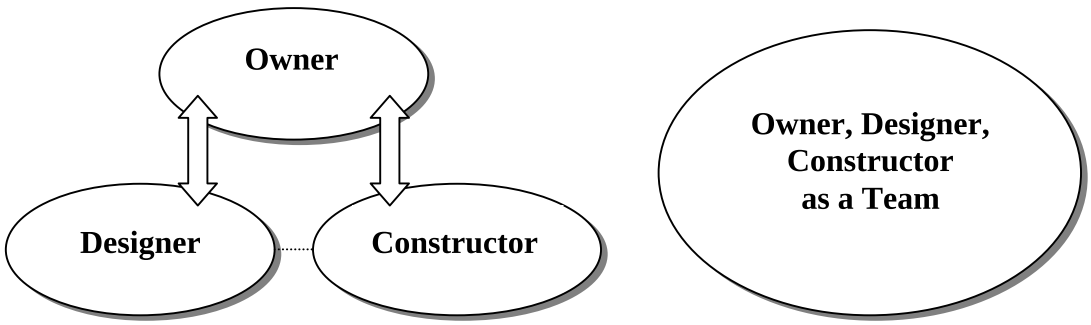

Figure 3-2 Delivery Relationship Among Actors

The right side of Figure 3-2 shows the actors as a team where the contractual relationship between the owner and the constructor is replaced not by a sub-contractual relationship between the traditional players subordinate to the interests of the owner (typical design–build), but a project solutions delivery team (CH2M HILL, 2001) with little to no distinction between the design and construction actors, their core responsibilities, and the phases of the project. The solutions team operates much like a turnkey approach. Meaning the outcome of the project is defined by a performance standard, and is focused on the project versus the process of delivering the project. While none of the case study projects use this exact approach, the Homestead Fire Station and the CARB #2 projects use procurement strategies that approximate a similar outcome. These will be discussed in more detail in the next section. The fundamental outcome can be overall lower costs through the removal of uncertainty and time, and an alignment around a commonality of purpose. These two case study projects also exhibit lower costs than expected with their partial solutions approach, conceptually mirroring the theory of least cost end use presented in *Natural Capitalism* (Hawken et al., 1999).

While keeping in mind the limitation of the non-statistical representation these projects have, they do present strong prototypical case study data needed for exploring the state-of-the art of sustainable practice for project cost estimating, scheduling and methods. These projects suggest that bridging the traditional phases and functions of construction projects with a common estimating and scheduling activity might be helpful in understanding the costs of sustainability. While not specifically stated or within the scope of this investigation, the same logic can be applied to the commissioning and operations/maintenance interface. The case study projects from the original 14 and discussed in the next section, provide some evidence that this commissioning-operations interface has even more significance for sustainable practice and its costs. The literature provides additional evidence that life cycle costing applications that cross this barrier can have significant impact on the financial performance of green projects (Coplen, 2004; Mendler & Odell, 2000; Rose, 2003; Terralogos, 2001).

3.9 Estimating and Scheduling Assessment of the Case Study Projects

Two of the case study projects reveal a much higher degree of integration in their delivery with respect estimating, and scheduling. In both cases the project definition is fundamental to their achieving more desirable financial performance and, in some measure, lower first costs. The first project, the 26,000 square foot adaptive re-use of the Homestead Air Reserve Base Fire Station (Figure 3-3), used a procurement approach which reflected its cost estimating and scheduling unlike most similar federal projects. With the understanding that the knowledge level and capability of the local, state, and regional construction firms to effectively carry out an any level of LEED design was limited; the USAF went forward with an invitation of interest to small and medium size firms in the state of Florida. The invitation asked the firms to identify their interest in learning and/or enhancing their green construction capabilities as well as to present their qualifications to carry out facility construction and renovation projects ranging from $3-7 million dollars. This solicitation focused on the firm's ability and willingness to work side by side with the owner and design team from the 25% stage through the operational commissioning of the facility. The construction fee would be negotiated using a cost plus incentive award format. The incentive was based on achieving a bronze or higher LEED V2.0 rating, as well as the overall financial performance of the project. Unlike the traditional low bid approach characteristic of a design-bid-build procurement method, this approach placed an equal burden on the owner, the design firm, and the construction contractor to work through the design and construction phases in a near seamless manner. It in effect, placed dis-incentives on communication failures, changes, risk, errors, and schedule slippage. These are some of the traditional risk related pitfalls of the industry with the exception of safety. From the 25% design stage, the construction contractor was actively involved in understanding not just how to get it built, but the rationale behind virtually every aspect of the design. This active involvement is similar to value engineering, but not after the fact, thus avoiding the inefficient design effort, introducing an interactive design-build perspective and eliminating the time to process the value engineering proposals. From a more practical perspective, it also provided the construction contractor an early opportunity to shop for the right materials or to propose substitute materials with similar performance characteristics based on market pricing during the design. With more than ample lead time, he was able to have his bills of materials completed for each stage of the construction early, thereby further eliminating any risk of delay caused by materials, expediting submittals, as well as eliminating all premium shipping costs. From the designer's perspective this facilitated a higher degree of design integration since in virtually every case, the construction contractor consulted the designers when material alternatives were present. Enhanced form, fit, and functionality followed.

Figure 3-3 Homestead ARB Fire Station

From the aspect of project scheduling, the team looked closely at each step of the project to drive a high degree of practical understanding from a trade and constructability perspective. Knowing the optimal or at least preferred sequence of placing the work, and the limitations of the craftsmen involved in the construction, the contractor made timely input virtually eliminating all situations of delay, facilitating early commitments from his preferred subcontractors and greatly reducing the uncertainty throughout the project construction schedule. This allowed far more than optimization of the critical path, but an optimization of all related sequences of the work. It also facilitated early starts of non-critical path work thus preserving time contingencies by rolling them forward in the schedule to the point where they were either used later or captured as earlier task completions.

Major project cost advantages were generated through high level and early integration of the designer and constructor. In several cases the input from the contractor actually drove significant changes to the design and provided financial and qualitative advantage. For example, rather than replace the aluminum, high bay roll-up doors, a re-manufacturing option was proposed by the contractor and selected. It proved feasible when the doors were removed and shipped to the original manufacturer at a time when the manufacturing line could be interrupted. As one of the initial construction tasks, the contractor arranged to have the doors taken down and delivered to the manufacturer's plant just in time to insert them in his production line. The cost to re-manufacture the doors as an interruption to the line would have been higher than new doors. The advanced scheduling and integration between the vendor and the contractor saved over 40% on the cost of the doors with no difference in quality or performance. Additionally, all of the aluminum was re-used in its highest and best primary use. The raw material needs were reduced to 10% of the materials normally used with new stock doors.

To better understand the cost and schedule impacts, the comparative matrix shown in Table 3-11 was developed from the Homestead Fire Station to show how a truly seamless approach, or integrated project delivery focus, differs given the most common project delivery methods. In looking across the table, one might ask, what is the best value proposition (relationship) for the respective actors in the process? Which method can provide significantly enhanced value for the process actors as well as owners by reducing uncertainty while driving up quality and driving down overall risk? What relationships do these present with respect to cost estimation and project scheduling? This discussion between actors is very important in analyzing the first costs because the construction process is essentially a series of decisions by the owner, planners, designers, and constructors which impact each actor and phase of the process differently.

Beginning with the assumption that time is money, and uncertainty drives costs up and extends schedule, then the converse logic suggests that the more time and uncertainty taken out of the transitional activity of moving a project from planning to design to construction the more added value is created. Capturing the added value through advanced cost estimating and scheduling methods becomes the challenge for sustainable design and construction practitioners seeking competitive advantages over traditional methods. In reality, it is not just about the cost estimating and scheduling but how those activities manifest themselves in the work planning and procurement approach.

Returning to the project previously discussed, Table 3-11 describes the relationships between the project delivery process (procurement method) and cost estimating and schedule issues, and establishes that they are of a significantly high order and are directly connected with respect to the design and the construction work breakdown structure. The design and construction planning team worked through a series of hypothetical and then real approaches to the project procurement method establishing relative linguistic values for each method with respect to the principal first cost drivers. This table reflects the documentation of the entire project delivery team's acquisition selection evaluation. The team was composed of members from the USAF, HOK Inc., the Homestead Fire Department, the Base Civil Engineer, and the HQ AFRC staff.

Table 3-11 Acquisition Methods to Cost Driver Analysis, Homestead ARB Fire Station

Cost Drivers (Read Down)	Project Delivery Methods (Read Across)					
	Design- Bid- Build (Low Bid, separate actors)	**Design Build** (Best Value, single entity)	**Design Build** (AE-Fee at Risk, Contractor Teamed)	**Design Build Joint Venture** (shared project value risk)	**Equity Position Finance, Design and Build** (shared venture capital and project value risk)	**Project Solutions Delivery Team** (Seamless design, construction and operations entity, no subordinate contracts) Sustainable
AE Business Risk	Low	Medium	High	High	Very High	Low
Communication Failures	Very High	High	Medium	Medium	Low	Very low
Project Cost Control	Low	Low	Medium	High	High	Very High
Design Errors	High	Medium	Medium	Low	Low	Very Low
Design Omissions	High	Medium	Medium	Low	Low	Very Low
Design Risk	High	High	Medium	Medium	Low	Low
Full Optimization	Low	Low	Low	Medium	High	Very High
Quality Factor	Medium	Medium	Low	Low	High	Very High
Schedule Control	Low	Low	Low	Medium	High	Very High
Uncertainty Factor	Very High	High	High	Medium	Low	Very Low
Value Engineering	High	High	Medium	Medium	Low	Very Low

To illustrate just one of the many such project decisions, the process for meeting the truck washing requirement will be described. The sustainability strategy has as an objective to recapture all process water (truck washing is the principal activity and largest water use). Integrating the operations requirement into the design initially was thought to require a special indoor wash stall with custom floor drains, grease and oil traps, a filter system, and a storage tank. Working side by side with the fire department operations staff, the designer and contractor recognized that this approach would require a continuous movement of the eight primary response vehicles in and out of the one stall and the construction of an additional stall. Adding another stall and moving the vehicles around to use it was viewed as a costly and inefficient solution. The contractor, familiar with the facility's existing storm drainage system looked for a more efficient way and suggested that using the parking ramp in front of each stall and the existing storm drainage system as the primary wash water collection method. All that was required was curbing to contain the water on the sides of the ramp and a diverter valve, pump and filter system, and tank, to contain and store the water when washing. After washing and removal of the water, the valve would be left open to allow storm water to flow normally. The contractor also suggested that re-using the stand-by generator fuel tank (system replaced with a PV system) as the storage vessel instead of buying a new tank. All that was required was to clean it and relocate it inside the facility to prevent the water from becoming too hot to use during the summer. The cost and schedule savings from this approach to providing this feature as opposed to the initial design concept of adding a new stall were significant. More importantly, the operational practicality for the fire fighters was one of immediate acceptance and endorsement. After all, they did not intend to wash their vehicles during a rain event. The notion of shifting the vehicles around every morning, and the additional risk of an accident while backing up these large trucks was avoided. The owner, designer, and the constructor thought through the requirement seamlessly as a team. One might argue the designer should have been able to think of this simple solution. In hind sight most would agree that the designer should have, but the fact of the matter was, the designer was in a mindset of building something new, and the contractor had the mind set of simplicity and keeping costs low. The operators had a mindset of less work and risky backing procedures. The integration of these mindsets is what created the value. This is a small example of the practical value of a seamless solutions approach. The cost estimation for this feature is detailed in Table 3-12.

Table 3-12 Cost Comparison Fire Station Wash Water Reclamation System

Original Concept (Build a New Stall)	Unit of Measure	Parametric Cost	Total
Construct Stall	Square Feet (1200)	$240,000	$240,800
Water filtration equipment	Lump Sum	16,000	16,000
Storage Tank (New)	Lump Sum	5,000	5,000
Pump and Piping	Lump Sum	8,000	8,000
Total			**$249,000**
Solutions Concept (Retrofit existing ramps) Flatwork and Curbing	Square Feet (1200) Linear Feet (800)	$40,000	$40,000
Water Filtration Equipment	Lump Sum	$16,000	$16,000
Retrofit Existing Fuel Tank	Lump Sum	$2,000	$2,000
Pump and Piping	Lump Sum	$10,000	$10,000
Total			**$68,000**
Cost Savings			**$181,000**
Schedule Savings			**4 Months**

Little hard actual cost data exists within the available and published case studies of sustainable design and construction projects to provide statistically defendable proof that a highly integrated owner-designer-constructor systems approach can yield a first cost break through like the one illustrated. However, other examples of this type of integrated planning and design outcome support the need for careful analysis of the nature of the delivery system for a project. The objective should be to select the delivery method that will most successfully allow a high degree of integration to arrive at a no or *low* first cost impact factor. Experience and the case studies support that the procurement or project delivery methodology decision within the built environment process model is an important determinant in a project's first costs. Most of the sustainable projects in the literature to date have focused on technology, materials, methods, and life cycle analysis to define their sustainability. This case study project shows that integration with respect to procurement and construction can be equally as definitional. In the previous section, the comparative matrix of design guides illustrates the current thinking that the traditional project delivery approach (design-bid-build) places extraordinary emphasis on the design, procurement, construction, and operations of facilities as the best approach to achieving the desired sustainability. Breakthrough thinking requires that we see beyond the status quo of the current processes and projects and extrapolate the integration concept forward. Immediately visible is that projects with the highest quality of the project definition and the highest degree of commonality of purpose, coupled with a seamless integration of the actors can result in lower risk and lower uncertainty for each actor and the project. Conceptually if we can take out project risk and uncertainty then lower costs and tighter schedules should follow. Understanding how to capture these efficiencies through process re-engineering becomes the work of the sustainable solutions project delivery team (CH2M HILL, 2001; Lowenthal, 1994).

Turing back to Gallaher's (2004) work on the costs of interoperability, he presents evidence that significant costs (inefficiencies) are incurred as technologies are adopted in fragmented ways by the different process actors at varying times. Extending this argument suggests that as project delivery processes rapidly assimilate the technologies of sustainable design and construction, the imperative to fundamentally change the traditional project management approaches becomes more of a necessity. The leveraging of the green building industry by practicing professionals through more sophisticated approaches to project delivery has the potential to draw out the wastes and drive integration and seamless process execution (concurrent technology adoption) into their practice. A quick assessment of Table 3-11 indicates how important it is to think through the entire built environment process for clients. This is a possible opportunity to tunnel through the cost barrier as discussed by Hawken in *Natural Capitalism* (Hawken et al., 1999).

The project case study data suggests the implications for project cost estimating and project scheduling as activities of the procurement approach are significant. In traditional project delivery processes, the project definition suffers each time the project moves to a new phase with a new principal actor. Two of the case studies (Homestead Fire Station and CARB #2) also suggest that quantifying the loss through a risk evaluation and/or uncertainty assessment lends support to the notion that breakthrough thinking is possible, but the traditional (design-bid-build) delivery process and the other twelve case study projects appear unable to transcend their contractual and actor defined phases to take advantage of the opportunity. The reasons for this are practical and routed in the time honored measures of merit defined for each phase of the process versus a single measure of merit for achieving the planned outcome (Holmes, 1994). It is classic process sub-optimization (Roberts, 1994). Roberts argues that in process re-engineering the focus is not actually the process but the purpose the process was created for that should be the goal. The case studies give reason to suspect that a new project delivery process could accompany a major shift in the technologies of sustainability and is needed to achieve genuine first cost breakthroughs.

How to characterize the cost and schedule issues and isolate them within a prototypical delivery process as the conceptual model of the process (Figure 3-1) shows is an important area to explore. In the case study of the Homestead Fire Station, the designer prepared a traditional opinion of costs, which the USAF used as the baseline of comparison with actual construction costs as the contractor presented them. The more significant areas of difference included unit costs, crew size, overhead, and task completion time. The cost data comparison also indicated variations in material quantities that were accounted for by line item, variation between actual material take-offs and pricing guide-based or more parametric estimations. Understanding the transitional aspects of a seamless delivery approach will require a more thorough analysis of how risk and uncertainty can be reduced and is an area for further research and beyond the scope of this investigation.

The second case study project with sufficient data to analyze the cost estimating and scheduling within a concept of seamless project delivery was the Sun City Grand CARB #2 project by Del Webb Corporation in conjunction with Steven Winter Associates and sponsored by the National Renewable Energy Laboratory, U.S. DOE. This project had a very practical and useful set of developmental technologies as its core focus and took a traditional speculative housing project to a sustainable outcome by applying utility conserving technologies to it. CARB #2 Sun City Pilot Project energy technologies included:

- Thermal-break steel studs as in-fill stud in exterior and interior walls.
- Sungate 1000 low-e double glazing.
- Thermal-break aluminum window frames.
- 3 Ton-SEER 12.5 AC unit.
- Furnace in garage replaced with air handle in center of the house.
- No return ductwork.
- Round sheet metal supply mains with flexible mounts under R-30.
- Heating by hydronic coil, fed by high output water heater.
- Transfer duct between master suite and main living space.
- Constant bathroom exhaust ventilation.
- Two high efficiency exhaust fans in the attic.
- 3/8" Hot water supply lines for quick hot water supply.
- Flexible gas piping with manifold in the garage and snap in fittings.

Typically, one would suspect that these conservation features would add anywhere from 10-25% to the base price in the speculative housing market. When taken as a traditional project this would likely be the case. When approached from a *solutions perspective* with all stakeholders' interests accounted for, significant cost advantages were achieved. The base price of the identical footprint model in 1996 was $112,900. Accounting for inflation and adjusting for downward market influences the 1999 cost was $125,000. The CARB Pilot Project house was completed for a total installed cost of $113,000 in 2000. Additionally, the near seamless approach to carrying out the project drove risk and uncertainty out of the cost. While still a small project (less than 1,700 SF), it also represents the scalability of the sustainable solutions concept of advanced project delivery. It has significant cost and schedule implications with respect to advanced methods.

Table 3-13 was developed from the web site project description of the CARB #2 project to better understand how cost estimating and scheduling might impact the procurement and delivery methods. It presents a comparative matrix of three procurement approaches (delivery methods). The first method is the model based non-speculative specific construction contract with optional features. In defining the owner's requirements, risk, uncertainty, and sub optimization can result. Communication failures and schedule extensions, all of which equate to cost, can also creep into the project. In the second method, a more refined design has a truer project definition and unless built by the designer sometimes fails or at least falls short of actually delivering the design as intended. The third method is similar to the Homestead Fire Station case study discussed previously, in that it has as a project delivery team with all of the actors–owner, designer, and contractor–all working together as a team to define and carry out the project from start to finish. There are in effect no hand-offs from phase to phase. The CARB #2 house reflects a seamless process with little distinction among the responsibilities of the actors or the timing of their contributions to the team. While this particular case study project was not an intentional seamless project, but rather evolved into one, it demonstrates an advanced delivery system and its results parallel what can be expected from one. The owner Del Webb, in conjunction with Steven Winter Associates and eight subcontractors, worked side by side to plan, select, and integrate each of the technologies to be tested. Indirectly, and unknowingly they functioned as a solutions team with the aim of driving both initial and life cycle costs down. Additionally, each technology application was compared to a baseline (standard house without advanced technology) construction task period to determine if actual construction time was saved. The results were more vague than hoped for in the area of schedule compression due to the experimental nature of the technologies. The SWA project team estimated that in future applications a ten percent efficiency in the construction schedule could be expected simply due to fewer tasks to be accomplished. When looked at from a production perspective, the high level of integration virtually eliminated all controllable project risk and drove uncertainty with respect to variations in scope and overall design changes lower. Much of the literature for sustainable design and construction presents the theory of getting the right steps in the right order as fundamental to achieving a high level of sustainability. This case study project demonstrates this theory.

Table 3-13 Cost Drivers to Project Delivery Methods, Sun City Grand CARB House

Cost Drivers (read down)	Project Delivery Methods (read across)		
	Traditional Model Based, Contract Specific Development Home	Custom Designed/Custom Built Home	Sustainable Solutions Partnership (Owner, Utilities, Designer and Builder)
Code Compliance	Low	Medium	High
Energy	High	Medium	Low
Growth Impact Permits	High	Medium	Low
Speculation Costs	High	Medium	Low
Water	High	Medium	Low
Options	Very High	High	Medium

Table 3-13 indicates code compliance as a high risk and corresponding cost driver, and design options as a medium risk cost driver. While both can be characterized as externally driven, they can also be managed to lower levels with thoughtful effort by the designer through integration. For example, should the prospective owner want the interior wall configuration modified, the designer can use the high performance thermal modeling software developed with the technology to determine any needed adjusts to the air conditioning supply outlets or if a particular configuration is ill-advised. Similarly, model code updates based on advanced technology and the test project data can be provided to the local code officials well in advance of the work and explained with respect to the benefits they deliver. Like the Homestead Fire Station however, the more significant impacts are found in removing unqualified risk and uncertainty, both of which influence the cost estimate and schedule. High levels of planning, design, and construction integration either consciously adopted or gained through the procurement and delivery methodology, will likely deliver first cost advantages. Taken a step further, a solutions delivery approach sets the stage for first cost breakthrough.

3.10 Breaking Through

There are numerous opportunities to carry this research further. For the purposes of this investigation however, these case study projects provided the needed support to create a conceptual project cost impact framework presented in Chapter 4.

Advanced cost estimating and scheduling, as independent sub-activities within the built environment process will certainly continue to evolve with integrated digital technologies and near real time continuous applications. Cost estimating models linked to computer based design information using emerging artificial intelligence and fully automatic estimations are possible with today's technology. They can be linked to parametric systems that have real time material pricing information based on direct market feedback loop (Dan Kohlhass, Avanco International, personal communication, February 2004). Together in an interactive format, they could form the basis for an advanced decision support model that allows sustainable design strategies to be compared with normative approaches from a cost and schedule impact perspective. Advanced project scheduling can be even more automated than it is already. Intelligent scheduling programs that link work breakdown structures to construction task performance standards and the computer-based designs can automatically determine crew size, task duration, and start-stop times. Advanced project scheduling tools available in systems like Primavera™, Timberline™, or the Bentley Microstation™ Business Practices Suite, can perform complicated estimating and scheduling tasks in a fraction of the time needed just five years ago.

With respect to the first costs of sustainable design and construction, the built environment process and the ability to move interactively (using technology) across its phase barriers presents a strong potential to drive lower first costs when coupled with advanced estimating and scheduling approaches and tools. This call for advanced integration of technology for capital project delivery and functional interoperability is discussed extensively by Gallaher (2004). Further investigation in this area is beyond the scope of this research but is vital.

Developing the most sustainable design option analysis through interactive design and construction process integration is the next area for breakthrough thinking in project estimation and scheduling. Just the nature of the integration discussed in the two examples in this section shows how rapidly today's methodology and tools might become obsolete. One must ask, what are the best practices for the project cost estimators and schedulers in sustainable practice? Extrapolating from these cases, clearly the material quantity and take off approach using unit cost data must still be at the core of any kind of advanced estimating process. How the work breakdown structure that represents each task to be performed is developed, and the materials to be used for each step, appear to be the parts of the traditional process that must change. Typically, these steps in the process are fed the necessary data by the design team. In a highly integrated solutions team approach, a cost modeling function that provides a decision support function is needed. In fact, an automated design and construction information system technology that is query based and that is linked to the proper cost and schedule models can speed the process and reduce the possibility of errors by virtually constructing the project through work process optimization technologies.

The principal focus for responding to a need for significantly advanced cost estimating and scheduling approaches could be derived from these questions (adapted and developed from Roberts, 1994):

1. What is the best value proposition for the respective actors in the process?
2. Which procurement or project delivery method can provide significantly enhanced value for the process actors as well as owners by reducing uncertainty and driving up quality and driving down overall risk?
3. What relationships do the answers to these questions present with respect to cost estimation and project scheduling?

Estimators, schedulers, and project managers should begin with the assumption that time is money and uncertainty drives costs up and extends schedule, and anything they can do to reduce the transitional activity of moving a project from planning, to design, to construction, to operations will result in the creation of added value through optimization. Capturing the added value through advanced cost estimating and scheduling methods becomes the challenge for sustainable design and construction practitioners seeking first cost breakthrough over traditional methods.

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1 Based on the author's involvement and participation in various professional conferences and meetings to include the AIA COTE, the ULI, and multiple Greenprints Conferences.

2 The HOK Design Guide second edition is one of the first and more extensive guides used in the U.S. It parallels the USGBC LEED Rating System.

3 The Steven Winters Associates Design Guidance tends to be more oriented toward energy efficiency and whole building optimization.

4 The USBC LEED rating system is rapidly becoming the informal consensus standard for green building in the U.S.

5 During the initial screening of expert practitioners at the Greening of Federal Facilities Workshop, the author posed this question; "Do you see sustainability as an efficiency theme or environmental theme?" Most experts replied "environmental" and some replied "neither but social."

[6] This concern reaches beyond the research at hand and introduces yet another concern that the professionalism of practitioners of the built environment could be at a point where the best interests of their clients competes with the emerging view of engineering services as a commodity based service.

[7] Drawn from professional practice dialog and present in the case studies.

[8] The UMN case studies and the UNM design guide can be found at: www.sustainabledesignguide.umn.edu/SustDesGuideContent/casestudies.html

CHAPTER 4

ANALYTICAL APPROACH, COST IMPACT FRAMEWORK, AND THE APPLICATION OF FUZZY SET THEORY

4.1 Introduction

Building on the extensive development of the built environment process model (Figure 2-1), this chapter discusses the overarching analytical approach as a process, the multi-criteria sets of data used to create the prototype cost impact framework, the data collection processes, and the method of analysis developed to derive and test the proposed cost impact framework as the new knowledge contribution. The remainder of the work is outlined to further aid the reader. Chapter 5 will present an analysis of the interview and actual project data. Chapter 6 presents the assessment of the analysis and the corresponding contributions of this work and what they mean with respect to the research questions. Finally, Chapter 7 presents a self-assessment of this work, discusses parallel research and presents a recap of possible future research identified throughout this work as suggestions for ways to continue extending and advancing this work.

As discussed in Chapter 1 and depicted in Figure 1-5, the bodies of knowledge that comprised this research area and this specific investigation into the cost of sustainability are sustainability, planning, design, and construction. The preliminary analysis discussed in the last chapter was based on fourteen case study projects and a synthesis of relevant data from these projects in a way that presented new understandings derived from the data so that a useful assessment could be made.

Part of this assessment yielded the need to bridge the traditional built environment process and sustainability strategies to gain an understanding of their costs remained a valid goal. The preliminary analysis confirmed the need to work through a deliberate approach that adopted both the built environment process model (Figure 2-1) and the sustainable infrastructure model (Figure 1-3) as principal assumptions underlying the approach for the research. Underlying the use of both of these models is the assumption that the built environment process model and the conceptual model of infrastructure sustainability are valid models. These conceptual models represent processes which closely approximated the way the projects proceed in the U.S.[1] There may be other valid models, and as an area of future research it would be good to comprehensively assess other models for their applicability for cost breakthrough. This research therefore, was based on the adoption of these models, which became the foundations for the cost impact framework. The built environment process continues to evolve as the delivery methods change in the U.S. and the model was further extended by Dr. Vanegas in *Roadmap and Principles for Built Environment Sustainability* (2003). This research also advanced and extended the utility of the built environment process model by adapting it as the starting point for the development of the cost impact framework, which assimilates both the crisp and fuzzy data from multiple data sources (see Table 1-1).

The complete research approach and the more detailed analytical approach presented in this chapter, build on the formulation of the body of knowledge for the first costs of sustainability and the establishment of the point of departure. As a process, this chapter will discuss all of the activities that further detailed the actions depicted in Figures 4-2 through 4-5. This overall approach was developed over an extended time frame with the special knowledge provided by Dr. Kangari and Dr. Oberle on the application of fuzzy logic and expert systems respectively. As with any research effort, this first step began early in the definitional stage of the research by investigating the availability and types of first cost data and the processes by which such data could be accessed (Fellows & Liu, 1997). Beginning with the case study projects and working outward through contacts made at conferences and workshops it was determined that many project managers and architects as well as parallel engineering design managers of sustainable design were willing to share linguistic data that compared their sustainable design solutions with normative (non or less sustainable) designs. This linguistic feedback was presented with respect to the broadly based understanding that sustainability costs more as discussed in Chapter 1. Consequently, many practitioners frequently provided cost impact qualifiers (low, medium, or high impacts) with respect to their early sustainable projects as compared to their normal practice. Thus, the data was linguistic and generally was discussed as impacting normal costs. Few practitioners however, were willing or able to share actual cost data. Until recently (Katz et al., 2003; Matthiessen & Morris, 2004), there has not been access to actual cost data for multiple reasons. One of the more prevalent reasons was the proprietary nature of their working estimates or the construction bids. Another and perhaps more relevant, was that they had accepted the underlying supposition that higher first costs were unavoidable and therefore some had not really focused on the first costs, a self fulfilling prophecy of sorts. Others acknowledged that their clients would not grant permission. Some acknowledged that they simply did not know the costs. After gaining an understanding of what data existed, the quality was determined by comparing the literature review and point of departure information, the data gathered through the initial survey information, and the case study data from the preliminary analysis. The results pointed to a need to formally interview practitioners with respect to their design decisions and how they impact others sharing the delivery process with them (see Appendix C for final interviewee list and expert group professional biographical sketches). The types of data needed were derived by identifying the most common planning, design, and construction strategies used in a wide area review of previous and current case studies discussed in Chapter 3.

4.2 Overarching Analytical Approach

The research design and the analytical approach which forms the foundation of this investigation was based on establishing a logical framework that compared data across multiple types of green design and construction projects, accomplished by differing teams, and delivered via differing delivery models. This required establishment of a consistent method to present the data, and just as important, a framework to organize the decision making which underpins the data. The initial framework derived from the preliminary analysis of the case study projects is shown in Figure 4-1.[2] The next several sections of this chapter present the process used to create this proposed framework. It is broken down into four phases and depicted in Figures 4-2 through 4-5. Each of these phases connects to the previous phase and uses standard flowchart symbols to represent the function taking place in each step of each phase. The initial framework depicts weighting factors for the phases and factors, which when tested were found to be replicated in the nature of the interview questions. Correspondingly, the final cost impact framework presented in the next chapter does not use a weighting system.

Basic Cost Impact Framework For Sustainable Facilities*

		CONDITIONS	Small		Large		
	*Institutional, Commercial		Traditional Design Disciplines	Sustainable Design Disciplines	Traditional Design Disciplines	Sustainable Design Disciplines	Remarks
	0. Phase 0.0 Factor 0.0.0 Sub-factor	Weighting					
1	**Comprehensive Planning**	**15%**					The Context of the Project
1.1	Environmental Impact Analysis	1.25					
	1.1.1						
1.2	Economic Development Impact	1.5					
	1.2.1						
1.3	Physical Planning	1.75					
	1.3.1						
	SUBTOTAL 1	[Relative Impact of Comprehensive Planning]	0	0	0	0	
2	**Project Planning**	**25%**					The Project Development and Definition
2.1	Assessment & Objective Setting	1.5					
	2.1.1						
2.2	Preliminary Planning & Funding	1.75					
	2.2.1						
2.3	Project Definition Package	2					
	2.3.1						
	SUBTOTAL 2	[Relative Impact of Project Planning]	0	0	0	0	
3	**Project Design**	**50%**					The largest field of factors–by discipline
3.1	Conceptual & Schematic Design	2					
	3.1.1						
3.2	Design Development	1.5					
	3.2.1						
3.3	Contract Documents	1					
	3.3.1						
	SUBTOTAL 3	[Relative Impact of Design]	0	0	0	0	
4	**Construction** (Delivery Method)	**10%**					The relationship of the parties with respect to the project execution
4.1	Design Bid Build	1					
	4.1.1						
4.2	Design Build	1					
	4.2.1						
4.3	Design Build Own Operate Transfer	Varies					
	4.3.1.						
	SUBTOTAL 4	[Relative Impact of Construction]	0	0	0	0	
5	**Expert Outline Factors**	Weighting by Expert if warranted					
	5.1						
	SUBTOTAL 5	[Relative Impact of the Project Delivery Method]	0	0	0	0	
	TOTAL ALL RATINGS 1 through 5	Comparative Totals Traditional and Sustainable	0	0	0	0	
	TOTAL RATINGS 1 & 2	Comparative Total of the Planning	0	0	0	0	
	TOTAL RATINGS 3 & 4	Comparative Total of Design and Construction	0	0	0	0	
	TOTAL RATINGS 4 & 5	Comparative Total of the Project Delivery Method	0	0	0	0	

FACTORS

Figure 4-1 Initial Cost Impact Framework

The data collection approach will be discussed in more detail later. The analytical approach for working with the linguistic data is based on using Fuzzy Logic (Hguyen & Walker, 2000), which has been used in similar analysis where imprecise data comprises the majority of the analysis. Fuzzy Logic allowed the mapping of the linguistic values in a way that mimics precise numerical analysis by using a membership structure that organizes the data (Chang, Wen & Chen, 1997; Munda, Nijkamp & Rietveid, 1995; Opricovic & Tzeng, 2002; Reynolds, Johnson & Gordon, 2003).

The overall approach is further described and is organized into four phases, each of which is introduced and depicted with a process map. Subsequent sections describe each phase in more detail. The first phase is the process that was followed to select and finalize the methodology to analyze the linguistic data collected later and used to test the proposed cost impact framework. It was developed from a similar method to treat linguistic data for research conducted for the United States Air Force (Gregory & Kangari, 2000). Phase two is the process that was followed to develop and expand the proposed cost impact framework and determine if weighting the proposed framework would work or would require additional research (beyond the scope of this work). Phase three focused creating an organization structure for the alignment of sustainability strategies to the built environment model by phase and factor. This is necessary in order to understand who the typical and principal actor for each strategy is, and how to present each strategy for a consistent comparative analysis. This phase also identified the interviewee criteria, and was when the interviewee questionnaires were developed. Phase four was the process followed to finalize the cost impact framework, develop the protocol for conducting the interviews, the interviewee participation and data collection procedures, and the application of the data to the expanded framework. The following four processes maps were followed sequentially and together comprise the manner in which the cost impact framework was developed, expanded, and populated with linguistic data for testing. The testing of cost impact framework and the analysis of the linguistic data gathered in the interviews is described in Chapter 5.

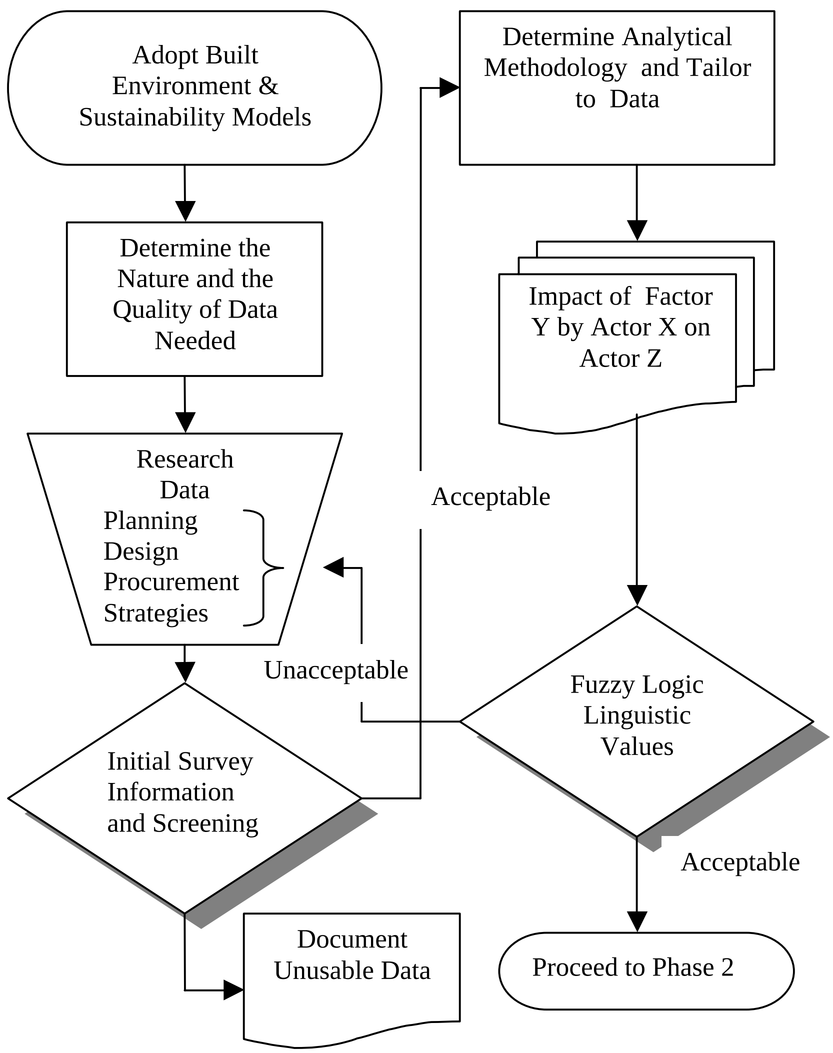

Figure 4-2 Phase 1-Select Type of Test Data and Finalize the Method of Analysis

The steps in Figure 4-2 and the resulting values represented the first phase of the development of the analytical process. The next phase further developed the proposed cost impact framework by comparing the case study project data to the proposed framework to determine if the concept of a framework based bridge of the built environment process and infrastructure sustainability models logically followed.

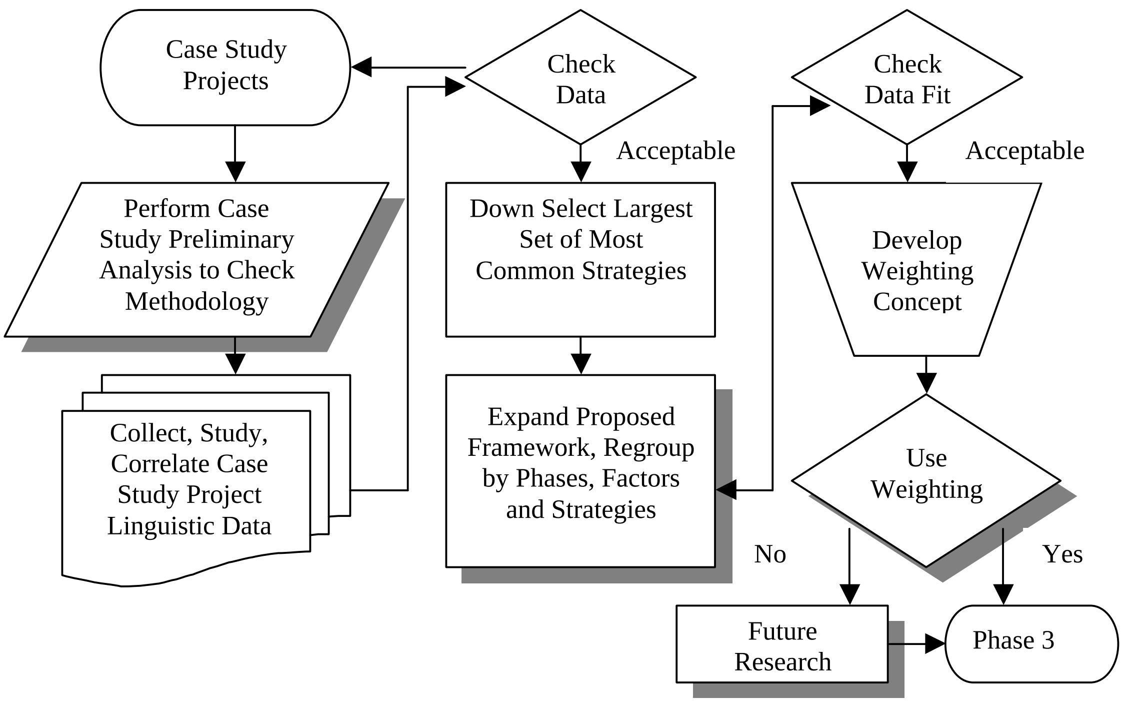

Figure 4-3 Phase 2-Develop and Expand the Framework of the Analysis

The steps in Figure 4-3 represent the expansion, alignment and trial weighting of the proposed cost impact framework and how it was to be used as the base for the formulation of the interviews for each set of actors across the full range of factors and strategies. A weighting of the framework was also proposed and later determined to be invalid. The result of this phase was the proposed cost impact framework. It has general alignment to the LEED V 2.0 criteria but extends beyond to incorporate project delivery methodology and expert factors derived from the case study project data.

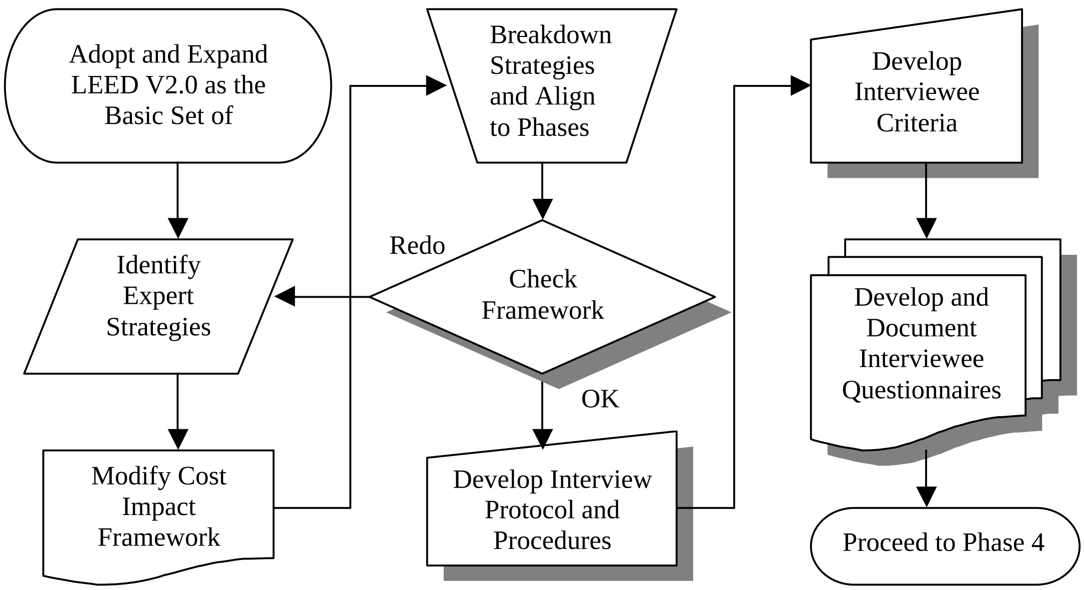

Figure 4-4 Phase 3-Finalize the Framework and Build the Discipline Based Interviews

The steps in phase three represent the process used to develop the approach to the test interviews and was developed by specifically targeting the heuristic and experiential knowledge about the impact of each strategy by a specific discipline or actor as it related to another specific actor within the process.

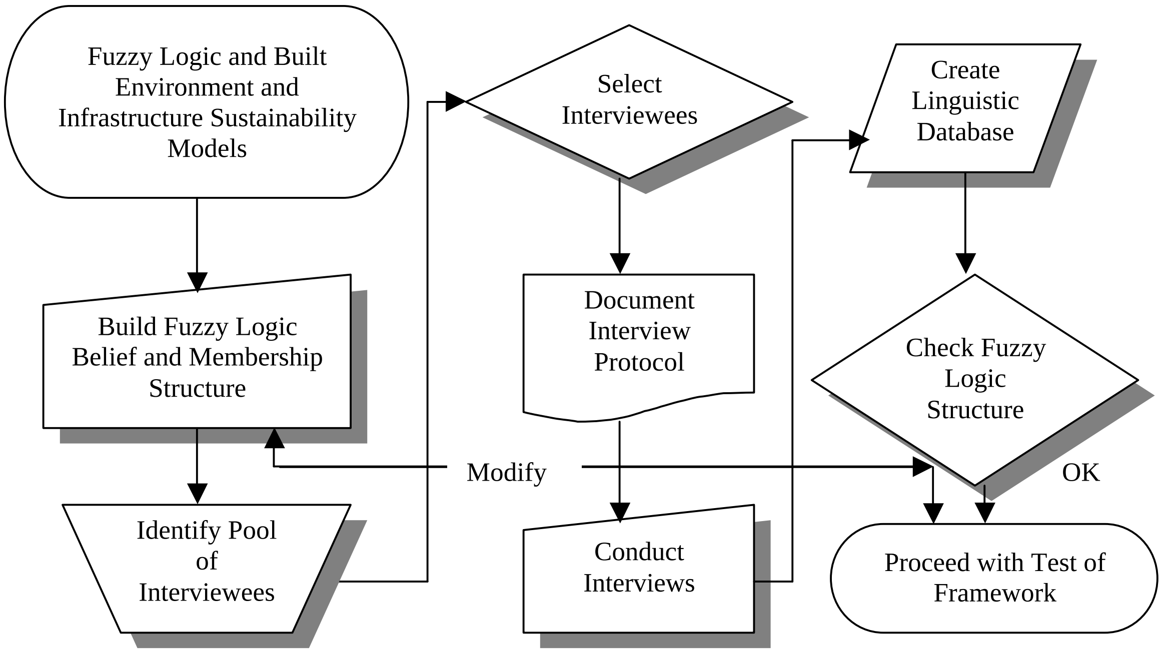

Figure 4-5 Phase 4-Finalize the Framework, Conduct Interviews, and Apply the Data

The phase four process represented the creation of the initial fuzzy logic structure for membership and belief values associated with the linguistic data to be collected, the development of the interview protocol and selection criteria, and the interviews. A total of 39 interviews were conducted across all disciplines and factors of the framework using nine basic interviews.

4.2.1 Phase 1 Discussion (Figure 4-2)

The determination of the nature and quality of the data needed was made over an extended period by synthesizing information from the literature review, conference participation, the initial survey information, study of the design guides, and the case study projects. Additionally, frequent interaction with allied practitioners through the

American Institute of Architects, Committee on the Environment, the U.S. Green Building Council's (USGBC) conferences and publications, the DOD Services needs, the GSA's needs and the CH2M HILL Sustainable Development Community of Practice provided additional insight. The outcome of this effort, over a period of 24 months, resulted in a determination that linguistic data was available and when coupled with an understanding of the issues, the challenges, and the market factors associated with the practice a practical understanding of the general topic of first costs could be achieved. Additionally, as indicated in Figure 4-2, the informal survey and screening information helped separate useful data from extraneous and unusable data. With an understanding of the data needed for the preliminary analysis the alignment of the data to the comparison and eventual testing method was begun. The logic of how to capture the cost impacting process decisions and actors for the proposed framework with respect to the research data then developed. The next step of the process was critical to the use of linguistic data and its alignment in the built environment process. The development of the logic for the questioning sought to establish the relative impact of one actor's decision about a particular strategy with respect to the next actor in the process. The initial survey and screening data was collected using a written questionnaire designed to provide consistent and comparable information. The actual questioning model later used in the more extensive linguistic interviews was modified from the theoretical built environment process model by incorporating the interviewee's stated role or discipline thus allowing for the interviewee's perception of their responsibilities as part of the built environment process model. For example, the architects largely viewed themselves as the ones who fundamentally influenced the mechanical, electrical and plumbing designers.

Correspondingly, the planners viewed themselves as the ones most likely to influence the site civil engineers and architects in the project definition phase of the model and so on. This sequence of actors generally validated the traditional influence flow within the built environment process model and is a left to right flow with some interactions between the phases and among the disciplines. This sequencing led to the adoption of the discipline centric approach and thus defined the actors and the acted upon relationships needed to apply the model. The next step was to check the fuzzy logic and linguistic values against the data sets and to determine if the alignment was acceptable. The sample case study project data, at this point had been fitted to the framework using a categorizing methodology, checked by inspection, and aligned to the desired data collection and analysis method using the fuzzy logic approach. The result of this phase was an acceptable alignment to the analytical approach of working with the data.

4.2.2 Phase 2 Discussion (Figure 4-3)

Developing and expanding the framework was comprised of eight steps. The application of the pilot case study data to the proposed framework discussed in phase one created the need to align the interviews by phase, factor and strategy, and then by discipline thus expanding the framework horizontally by introducing each set of actors. The case study project data also confirmed USGBC's LEED criteria as the more universal and widely used sustainable design guide in the U.S. and consequently it was adopted as the core set of sustainable strategies to base the preliminary analysis on. The LEED V2.0 had most of the strategies used in the case study projects but not all as discussed in the previous chapter. Additionally, while the LEED V2.0 had most of the strategies it was noted that several of those strategies (HVAC efficiency over 30%) have had only limited application in practice. The result of doing the case study projects as a preliminary analysis provided further validation that the design of the framework was valid and that the structure of the linguistic data gathering process needed to be precise, well thought out, and aligned to the proposed framework. The next step focused on collecting, studying, and aligning the strategies to be linguistically valued. This helped in understanding the relative importance of the built environment phases. The case study project data suggested that the earlier in the built environment process the decisions affecting the costs are made, the more impact (positive or negative) those decisions would have. It is not the intent of this work to definitively characterize a set of weighting values that reflects the relative impact of each phase and factor but to generally order the phases with respect to each other and then assign a set of possible weighting factors for the purpose of carrying out the analysis. This follows the assumption that the built environment process model is an accurate refection of how to enhance the quality cost and schedule delivery of capital projects (Vanegas, 2001). A more precise characterization (range of values) of the weighting for each of the phases and factors shown in this framework was not within the scope of this research but is a strong candidate activity for further research. The next step was to select the largest set of common strategies (used or considered) and then re-order the framework by aligning the strategies with the appropriate[3] factors and assign the actors by functional disciplines to each strategy. As mentioned earlier, the most common set of strategies at this point in the evolution of sustainable planning and design is the USGBC's LEED standard. LEED V2.0 was chosen because it is widely known and used, and it is regarded by most practitioners of sustainable design and construction as the emerging industry consensus standard (Katz et al., 2003; Cassidy, 2003b). A quick glimpse of the expanded framework however, suggested that while LEED V2.0 is likely the most widely used standard in the U.S., it is unlikely that many practitioners will use the high-end group of the mechanical and electrical strategies. These mechanical and electrical strategies propose reducing energy use by as much as 60%. The lack of wide spread use of these strategies is largely attributed to incomplete development of replacement systems capable of achieving these levels of efficiency (Cassidy, 2003b). The next step was to check the fit by inspection and alignment of the LEED strategies to a factor or factors in the framework to determine if it could be reasonably populated with intended interview data. Knowing that the likely experience of the future users, interviewees, and actual project data would likely be either LEED certified or certifiable, it made sense to apply them against the framework. The framework however, was developed to be adaptable for use with any design guide criteria, strategies or combinations of criteria and strategies. The fit and function of the framework proved satisfactory and together with this, the initial weighting factors were assigned to the framework.

4.2.3 Phase 3 Discussion (Figure 4-6)

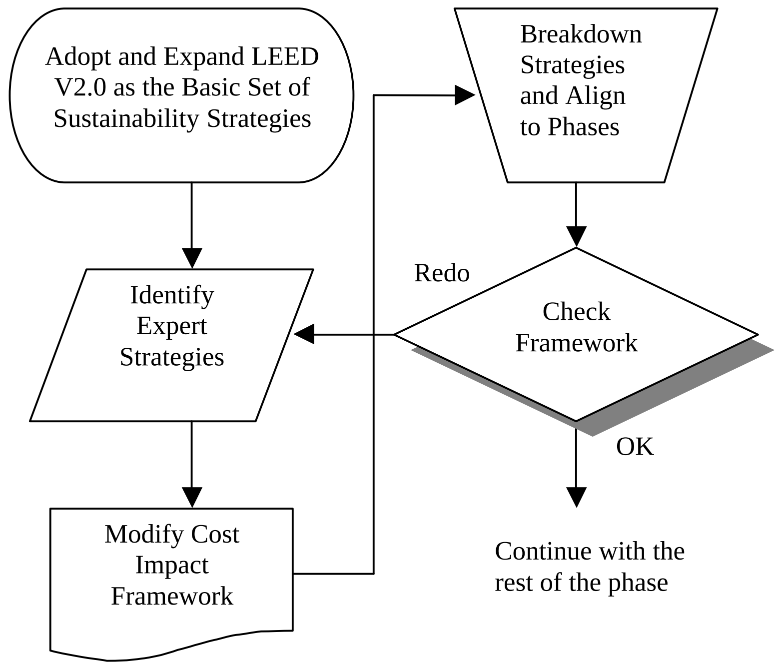

Figure 4-6 First Part of Phase 3

This phase will be described in two parts. The first part (shown in Figure 4-6) was an iterative process, which required further breakdown of the strategies where multiple actors were involved in a particular strategy or where multiple strategies were acted upon by different actors. For example, in the planning phase, the brown field redevelopment strategy is both an economic and physical planning factor with different principal actors. Another example transcending the project planning phase and relevant to design development in the design phase, is the percentage of MEP energy performance optimization sought. These types of common strategies associated with differing phases and factors resulted in further modifications to the framework.

While it is taken as an assumption that the USGBC's LEED rating system is the most prevalent in practice, there are other green planning, design, and construction criteria packages and guides (discussed earlier) that expand the opportunity set of strategies and might also drive the desired first cost and performance outcomes of sustainable practice. The cost impact framework therefore was expanded with the addition of phase five to acknowledge current and future expert strategies in addition to those used in the LEED versions. This phase differs from the others in as much as it does not have specific factors associated with it. It is a universal phase that captures expert and innovative strategies regardless of how or when they might occur in the built environment process. This additional phase allows for needed innovation and is important with respect to understanding first cost impacts (Mogge, 2001b). In the interview process to test the framework, described in the next chapter, six of the 39 interviews identified such expert or innovative strategies. These are in addition to the innovation in design criteria set forth by LEED V2.0. Additionally, the University of Minnesota, *Sustainable Design Guide* (www.sustainabledesignguide.umn.edu), along with other guides, had many strategies that were actually characterized as no to low cost impacting strategies. Allowing for these expert strategies in the framework expands its practicality and extends its applicability. It is important to note however that in the later test of the framework these types of strategies were not part of the comparative analysis because they did not have a repetitive basis for comparison. The next step was a thorough check of the redesigned framework with respect to the added strategies and their related actor's disciplines to ensure coverage of all strategies and to identify overlapping disciplines on some strategies. The overlapping strategies were primarily in the planning and project definition phases where the feasibility of a specific multidisciplinary strategy was in question. Another example of this is the re-use of partial or full building envelopes. An integrated view (architectural, structural, and mechanical engineer) was needed to qualify the cost impact. There were also some common strategies to all disciplines such as the use of unspecified innovation within each factor and the use of LEED Accredited Professionals. To the extent possible, the overlapping areas were assigned to a lead discipline based on a broad understanding and the author's experience of each strategy. Later this allowed the distribution of the interview questions to be technology based, and tended to preserve the intent of the strategy by aligning its result with the discipline most competent to deliver it.

The construction strategies (delivery and procurement method) focused on common strategies for the design-bid-build (DBB), the design-build (DB), and the design-build-operate-and-transfer (DBOT) delivery methods. By selecting these three delivery methods, this research incorporates the major parameters of built environment process delivery strategies and incorporates other stakeholders such as procurement officials, vendors, and suppliers. It does not limit the model since the construction related strategies are already present in the planning and design phases due to the nature of the LEED V2.0 criteria. The reason for researching delivery strategies was principally to understand, within the data, whether cost advantages of the delivery method were recognizable within the larger context of sustainable design. The owner's strategies were carefully selected from groups of strategies throughout the entire built environment process model (all phases) and based on the role the owner plays. Some strategies are heavily dependent upon the owner's input and interaction with the planners, designers, and constructors. The sets of strategies reflect the interdependent roles the owners play. The intent here was to try to separate the owner's perspectives regarding a project's first costs, and its life cycle costs—the latter more associated with an owner's focus and long term interest. (The Interview Breakdown by Factor and Groups information is located in Appendix E.)

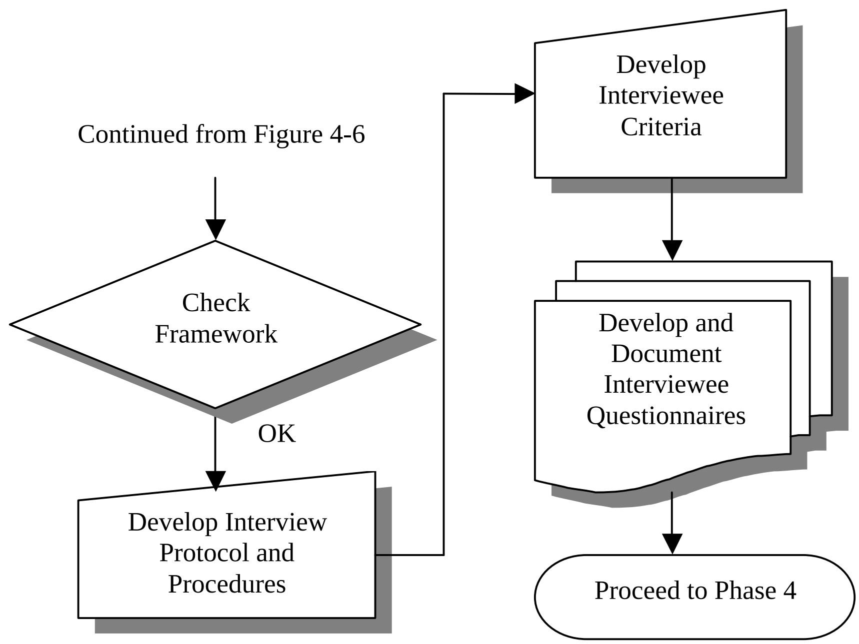

Figure 4-7 Second Part of Phase 3

The second part of this phase, shown in Figure 4-7, was to organize and develop the protocol for the interviews (using an actor, factor, actor format), the criteria to select the interviewees from the pool of practitioners, the interviewee questions, and to write the interview questionnaires. (See Appendix D for protocol and criteria.) It was determined that for the needed consistency in the interview process a written interview would be used. This also allowed the capturing and recording of the data in a manner so that it could be used for future reference and perhaps other follow-on research. Nine basic questionnaires were written with a varying number of questions for each. Appendix D contains the interview material and questionnaires.

4.2.4 Phase 4 Discussion (Figure 4-8)

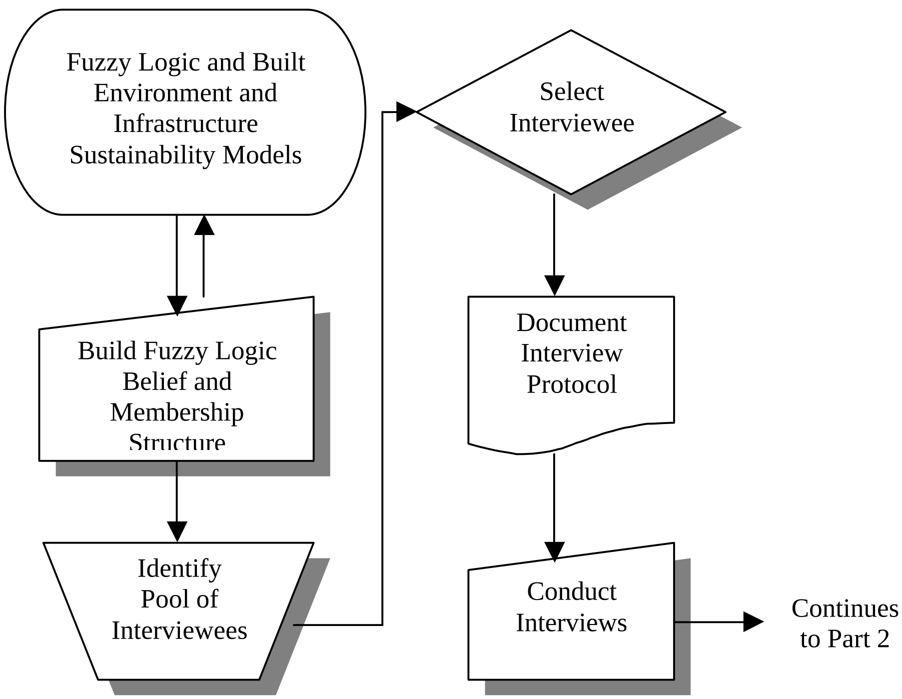

Figure 4-8 First Part of Phase 4

The final set of steps in the overarching approach focused on finalizing the framework with respect to its treatment of the linguistic data and the collecting, recording, mapping, and checking of the linguistic data.

Figure 4-8 depicts the first part of the process. The first step focused on building the structure of the fuzzy logic belief and membership values to be able to use the appropriate formulae to aggregate the translated linguistic values later. This is discussed in more detail in Section 4.6. Additionally, this involved finalizing the logic of how to associate the various strategies with each factor, and then sort it by discipline. The next four steps outline the approach that was used to identify and select the interviewees, and conduct and document the interviews according to the criteria and protocol. (See Appendix D for interview protocol and selection criteria used.)

A total of 109 potential interviewees were identified from project resumes and screened against the following general criteria: LEED accreditation, project experience, planning background and planning resume, design discipline, construction experience, and general familiarity with the concept and technology of sustainable facilities and infrastructure. From this pool, 43 were identified and agreed to provide their responses. Common to all of the interviewees was extensive experience in their chosen fields and most have recent hands-on experience with sustainable planning, design, and/or construction. Several are LEED Accredited Professionals, indicating an extensive understanding and status with respect to the subject matter. During or after the interview process, 4 of the 43 interviewees chose not to complete the process indicating knowledge shortcomings and/or personal preference as their reasons to discontinue participation. Interestingly, and what should be considered as having high value are multiple sets of additional comments (linguistic data and interpretations) from the interviewees in the form of anecdotal statements regarding both the questions and their responses. The more noteworthy comments are included in Appendix D. From this group of interviewees, an expert group was also selected by further identifying the most qualified of each discipline. The expert group is a multi-discipline set of interviewees who are expert practitioners and possess a notable status in their respective fields. The expert group's responses were identified as a baseline against which the remaining interviewee's data was evaluated. Additional interviewee time was spent with each of the expert group members to ensure complete and thorough understanding of the entire research approach as well as the questions. The sequential aspect of the built environment process was especially important for each interviewee to understand in order to consistently provide the values for the acted upon role in the process.

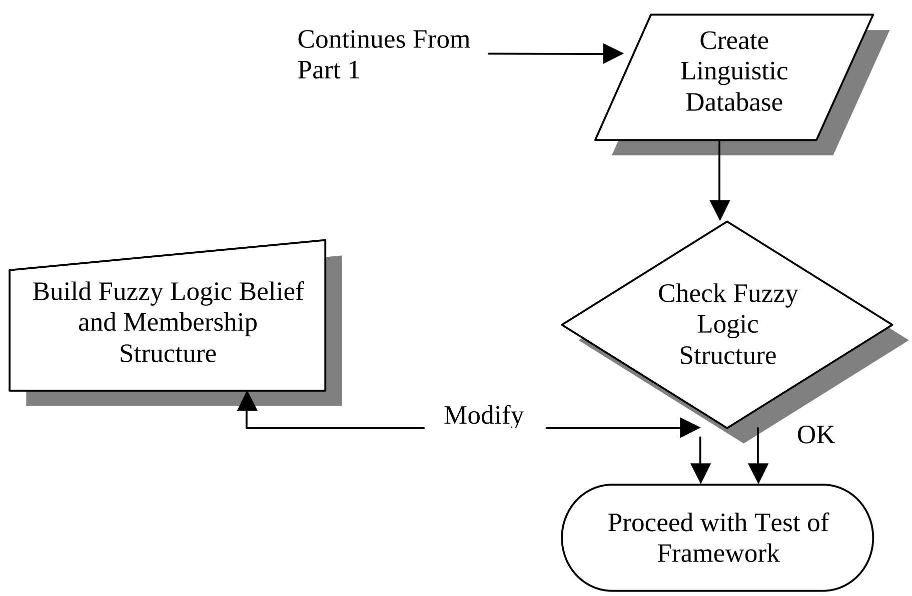

Figure 4-9 Second Part of Phase 4

The second part of phase four, shown in Figure 4-9, involved creating the linguistic database and populating the cost impact framework with the data, performing the addition and averaging calculations to aggregate values for each group and each strategy, and checking the entire framework for consistency, errors, and omissions. The last step of the phase was a check and modification of the initial fuzzy logic belief and membership structure through a comparison of the linguistic data collected, the compliance with interview protocol, and the actual conduct of the interviews. The results of the fuzzy logic structure check will be discussed in more detail in Section 4-6.

4.3 Constraints of Validity for the Analytical Approach

With the overarching analytical approach in place, the approach for analyzing the green building cost data must not only draw out the relational data for the most prevalent factors (strategies) that constitute green planning, design, and construction, but it must do this over a time frame (post 1996) that represents a valid period of evolution (as discussed in Chapter 1) vice the research and the initial applications of the theoretical development (1995–2000). The approach represented all of the actors through the three primary actors represented in the process of delivering green buildings—the planners, the designers, and the constructors. To do less would inappropriately exclude decisions and decision makers in other parts of the process, all of who contribute in an interrelated manner and sometimes significantly to the building's delivered and commissioned end state and therefore the first costs.

To satisfy the constraints of validity, a framework of analysis that captures linguistic data along a common baseline of sustainability factors broken into the three principal phases of planning, design, and construction over the period of 2000-2003 was chosen. Because the sustainability factors can be associated with widely varying costs, an initial weighting of the factors was attempted but was subsequently determined to be duplicative with the interview responses. As part of the scope, the linguistic data was limited to general commercial, federal, institutional, and industrial buildings. This limitation appropriately excludes the residential and multiple family housing building types whose basis of design varies widely by personal taste, geographic area, building code requirements, and climate. The framework design was to use the expert group selected for their sustainability experience, overall process knowledge, professional credentials, and depth of related experience to further test and validate the proposed framework through their responses. Additionally, their overall experience as expert process actors for both normative and sustainable planning, design, and construction practices allowed a balanced approached. (See Appendix C for their biographical sketches.)

4.4 Quality of the Data

The first cost impact data that existed relative to green building costs, existed in the thousands of planning, design, and construction decisions made by the design teams for the approximately 1,458 LEED registered, planned, under design or constructed (not including single and multi-unit housing) in the United States as of July 2004 (www.usgbc.org/leed/project/stats/projects_building_type.asp. Retrieved on September 25, 2004). At the 2003 USGBC Conference in Austin, Texas, attendees or presenters provided strong growth projections. The market projection data suggests there will be an additional 500-570 green buildings commissioned in 2004 (developed from Cassidy, 2003b; Kozlowski, 2003). Today's green planners, designers, and constructors, through their work, are constantly and mentally cost comparing each of their decisions with respect to conventional practices; weighing informally the cost to benefit as they go. Thus, it is reasonable to assume that among those who are establishing themselves as green building planners and providers who evolved from conventional practice (as the author has–more than 30 years experience to date) there already exists an understanding of the impact of first costs. Capturing this data then became the key to understanding the first cost impacts. To capture this linguistic data, a revised framework was needed. The second version of the cost impact framework, looks over time with respect to the associated phases and takes into account the principal actors with the rigor of an accepted analytical process that associates like data for comparable factors in ways that allow analysis, assessment, and thus understanding of the costs. This proposed cost impact framework is shown in Figure 4-10 and will be discussed further in the next section.

Cost Impact Framework For Sustainable Facilities*

*Institutional, Commercial

	0. Phase 0.0 Factor 0.0.0 Strategy	Planners	Site Civil Engineers	Landscape Architects	Architects	Structural Engineers	MEP Engineers	Constructors	Owners	Total	Remarks
		ACTORS									
1	**Comprehensive Planning**										The Context of the Project
1.1	**Environmental Impact Analysis**										
	1.1.1										
1.2	**Economic Development Impact**										
	1.2.1										
1.3	**Physical Planning**										
	1.3.1										
	SUBTOTAL 1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
2	**Project Planning**										The Project Development and Definition
2.1	**Assessment & Objective Setting**										
	2.1.1										
2.2	**Preliminary Planning & Funding**										
	2.2.1										
2.3	**Project Definition Package**										
	2.3.1										
	SUBTOTAL 2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
3	**Project Design**										The largest field of factors--by discipline
3.1	**Conceptual & Schematic Design**										
	3.1.1										
3.2	**Design Development**										
	3.2.1										
3.3	**Contract Documents**										
	3.3.1										
	SUBTOTAL 3	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
4	**Construction (Delivery Method)**										The relationship of the parties with repsect to the project execution
4.1	**Design Bid Build**										
	4.1.1										
4.2	**Design Build**										
	4.2.1										
4.3	**Design Build Own Operate Transfer**										
	4.3.1.										
	SUBTOTAL 4	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
5	**Expert Outline Factors**										
	5.1										
	SUBTOTAL 5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
	TOTAL ALL RATINGS 1 through 5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	TOTAL RATINGS 1 & 2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	TOTAL RATINGS 3 & 4	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	TOTAL RATINGS 4 & 5	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		

Figure 4-10 Revised Cost Impact Framework

4.5 The Cost Impact Framework and Linguistic Data

Fuzzy Logic lends itself to the analysis of sustainability more so than other methods because the WCED model of sustainability (Figure 1-1) relates three sets of criteria, which have been characterized through multi-criteria analysis using imprecise data. Fuzzy logic and its related fuzzy mathematics was developed largely in the past two decades (Hguyen & Walker, 2000; Kangari & Riggs, 1989), and the literature supports its use for multi-criteria analysis of topics pertaining to sustainability (Chang et al., 1997; Munda et al., 1995; Opricovic & Tzeng, 2002; Reynolds et al., 2003). Coupled with the interview-based first cost impact data, it presented a plausible approach to associating the linguistic values across the built environment process by different actors with respect to green building planning, design, and construction. The cost impact framework presented in Figure 4-10 aligns the phases of the overall process, the factors within the phases, and the strategies into a matrix with the actors associated with each phase for specific sizes and types of projects. The result is an organizational structure that can be used to array, manipulate, and analyze linguistic values as they relate to each actor's decisions in the process.

The principal functions to accomplish a project are planning, design, and construction. The distinction between and within the phases is important, as related earlier, because the phases and their sub processes (factors) have relative impacts on the costs, and thus require an understanding of both the phase itself and the factors comprising the phase. The factors were developed from the built environment process model and adapted to include the delivery methods discussed later in this chapter. The strategies are associated with a factor or factors and are thereby placed into the context in which they were evaluated in a relative linguistic sequence. The nomenclature shown in Figure 4-11 was adopted to clarify the terminology, sequence, subordinate relationships, and structure of the framework.

1.0 Phase

1.1 Factor

1.1.1 Strategy

Figure 4-11 Relationship and Structure of the Framework

4.5.1 Planners and Planning Factors

Chapter 3 presented the planning background and suggested that the sustainable project planning factors, as one would suspect, have the single most important impact on the outcome of a green project. Therefore, these factors will likely have a higher relative impact with respect to the design and construction factors and can be considered as probable first cost drivers.

There are three contextual planning factors, which also are likely to have significant impacts on the sustainability of building decisions and their first costs. For clarity, these are called comprehensive planning factors, vice project planning factors. For most state and federal projects, especially for large projects involving significant federal funding, these comprehensive planning factors set the stage for the decision to carry out the proposed project, alternatives to the project, or to take no action. In many cases, they constitute the basis for proceeding with the work from the standpoint of compliance with the National Environmental Policy Act, and/or Development of Regional Impact Reports for state and regional level project endorsement. Federal projects can demand significant additional costs of compliance when mitigation programs are required. Emphasizing the environmental stewardship inherent in sustainable planning can be one way of avoiding the causes for the mitigation measures and thus avoiding and/or adding some costs. In addition to the environmental considerations, there are economic development and physical planning factors. The aspects associated with the economic development planning suggest that projects planned with a focus on using local resources can actually stimulate local growth and development adding value to the project's locale and community. Value creation under these conditions can present cost offsets when managed appropriately. For example, in many projects a positive cost advantage of local purchasing saves significant transportation costs for goods and services associated with the project as well as reducing the burden on transportation systems supporting other needs of the project, and provides an economic multiplier effect on the local economy (Malizia & Feser, 1999). A focus on physical planning suggests that aspects of energy demand and supply, water, production of waste water, storm water/surface water management, and climatological considerations have significant impacts on building costs as one would conclude with a basic understanding of conventional buildings. Taken to the next level, as with sustainable building, these aspects can comprise the strategies to reduce first costs and life cycle costs by being planned in harmony with the physical aspects of the project's location.

To restate, the outline comprehensive planning factors for this phase of the framework are:

- Environmental Impact Analysis
- Economic Development Impact
- Physical Planning

The following breakdown of project planning factors was derived from the case study projects, and current and recent projects for the DOD (Mogge & Pedrick, 2003a, 2003b).

- Assessment and Objective Setting
- Preliminary Planning and Funding
- Project Definition Package

With a total of six planning factors, three comprehensive planning factors, and three project planning factors, it follows that the actors involved in the planning decisions, and thus the actors for the data collection, could include environmental regulatory officials, economic development officials, and environmental scientists in addition to the owner/financial team, the operators, the users, and the designers. To summarize, the likely actors for most aspects of understanding the costs of planning green building projects include:

- Environmental Officials
- Economic Development Officials
- Environmental Scientists
- Project Planners
- Owners and Users
- Financial Providers

- Operators and Maintainers

The nature of these factors and the importance of their likely impacts on first costs suggest it is important that the framework add another level of specificity. Additionally, given the wide range of actors for this part of the framework, a more specific set of strategies will help understand the likely first cost impacts by focusing the analysis relative to the actors. From case study projects and the literature review the generic and more widely used planning strategies consistent with these planning factors are:

<u>Relevant Environmental Planning Strategies</u>

- Direct Development to Environmentally Appropriate Areas
- Maintain and Enhance the Biodiversity and Ecology of the Site
- Use Microclimate and Environmentally Responsive Site Design Strategies
- Use Native Trees, Shrubs, and Plants
- Use Resource Efficient Modes of Transportation

<u>Relevant Economic Development Strategies</u>

- Development Grants
- Financial Assistance and Other Types of Loan Incentives
- Instruments of Economic Development, (tax increment financing, special tax status)

<u>Relevant Physical Planning Strategies</u>

- Optimize Building Placement and Configuration for Energy Performance
- Optimize Building Envelope Thermal Performance
- Provide Daylighting Integrated with Efficient Electric Lighting Systems
- Use Renewable or Other Alternative Energy Sources

- Manage Site Water
- Use Gray Water Systems
- Use Biological Waste Treatment Systems

These strategies include LEED, UMN, SWA and HOK design guide strategies. As discussed earlier the use of the LEED criteria within these strategies does not present a concern because these more generically stated strategies are embedded within the criteria with the exception of the economic development strategies, which are owner, project, use, and time sensitive. Therefore, applying the LEED criteria regardless of version [temporarily excluding the versions, Existing Buildings (EB), Core and Shell (CS), and Commercial Interiors (CI) under prototypical development] is a consistent and appropriate use of the framework for this phase.

4.5.2 Designers and Design Factors

The design factors fall into three major groups, which also generally reflect a higher to lower volume of cost impacting decisions, and they generally follow in a linear succession. They are Conceptual and Schematic Design, Design Development, and Contract (construction) Documents (CDs). In most design situations, it has been estimated that the conceptual and schematic design represents 25-35% of the overall design work effort, but as much as 50-70% of the design decisions impacting a project's costs[4] (Papamichael, 1998; USACE & Goradia, 2001). The numerous design criteria and design guides discussed in Chapter 2 and developed for sustainable design reflect this significant and relative cost impact in design decision making and emphasize the need for early decisions (Mendler & Odell, 2000). To a lesser degree, the design development factor represents the work and the associated design decisions needed to develop and validate the conceptual and schematic direction of a project from an engineering integration, cost, and constructability perspective. While not as significant as conceptual and schematic design, this factor is likely to be the next most significant factor with respect to a building's cost, in many cases representing from 20-30% of the design decisions.

The CDs generally are produced by adding standardized details, specifications, and notations concerning the design and the approach to the work as well as the materials to be used. In current practice, it is common for the basis of design to include the type of specifications to be used. Within the 14 case study projects, 9 of the projects defined the specifications in the conceptual design phase thereby lessening the impact of the materials and methods of construction decisions taken later on both the cost and sustainability of the projects. The construction contract documents however, were likely to represent important cost impact factors, but represented a correspondingly smaller set of design decisions.

An issue in the acceptance of sustainable design and construction today is the need for green specifications. Green specifications for larger buildings would reflect systematically thought out, and commonly available, building materials, finishes, systems and subsystems that can largely determine the sustainability of a project. LEED certification levels can be differentiated by the level of the sustainable materials and methods specified (Table 3-8). Likewise, the cost impacts associated with sustainable design and construction are significant with respect to the specifications decision. Standardizing green specifications for building projects could drive significant cost reductions as material suppliers compete for their share of the changing construction products markets. In 2002 and 2003, approximately 1,750 green construction materials (www.buildinggreen.com/products) were catalogued for the construction industry indicating greater awareness of these materials in the construction market. Restating, the outline Design Factors are:

- Conceptual and Schematic Design
- Design Development
- Contract (Construction) Documents

While in outline format these factors appear basic, their application when extended to include the very highly developed design strategies resident in the numerous design guides represent a significant part of the overall framework. The cost implications and the linguistic data available to analyze these strategies are significant and well developed. Overall, the design phase is likely to represent significant first cost impacts. However, in considering cost, each strategy deserved careful consideration within the overall framework. The case study project data suggested however, that just one design strategy inherent in this group can influence the overall first costs significantly. In the case of the Homestead Fire Station, the vehicle washing strategy was such an example. Therefore, in understanding the first costs of a green building, an understanding of all of the strategies used is required. The LEED criteria lend themselves to this purpose but must be supplemented with expert factors to account for the even greater innovation possible as sustainable design and construction continues to evolve.

Negative cost strategies exist as well. A negative cost example might be the early integration of HVAC systems to establish the building's envelope concept and orientation on site (see www.wbdg.org for more information). In some prototypical cases, this strategy negates the need for air conditioning and in others greatly reduced the scale of the system needed. Correspondingly, the positive cost impacting example of a green roof will likely add significant cost to the structural system as well as additional access requirements.

A key aspect of using the framework beyond this application is the selection of the design guide and the related strategies for the design phase, specifically for the concept and schematic design outline factor. As green building design matures, it is possible that the tools in the various toolboxes will become a mixed bag placing less importance on the nature of the guide used (LEED, USAF, UNM, HOK, BREEAM, etc.), and more importance on each individual strategy. Thus, this framework was extended to include the most common strategies used in these building types and scale of projects. The selection of the strategies that follow was based on how prevalent each of the strategies is used in the case studies and other relevant data.

The actors for these factors include the entire project team, but the principal actors are each of the disciplines (project planner, architectural, civil, structural, electrical, mechanical, etc.) as represented and needed for the design team. With such a broad array of actors, the framework was focused on relevant strategies with respect to specific actors. Where it was not possible to clearly assign a specific discipline to a strategy the framework uses the project manager or architect as the default actor. Supporting this default assignment, and in actual application, all of the disciplines were interviewed and their input included in the test of the framework as discussed in Chapter 5. This alignment drove the framework to focus on cost relative to design attributes with the understanding that the architect or project manager was a reasonable choice to represent any of the disciplines through the key integration role he or she carries in the design process. The actors, for understanding the cost impacts associated with the design factors therefore are:

- Project Manager or Architect
- Specific Design Discipline
- Owners
- Constructors

With the design factors and the default actors defined, and as previously discussed, the next level of the framework, the strategies for the design phase were identified by reviewing the most common design strategies used in the U.S. (Figure 3-3) with respect to identifying the most comprehensive set. Factoring in the case study projects and the literature review, the most prevalent and generic concept and schematic design strategies used in the United States for most building applications were in the University of Minnesota *Sustainable Design Guide* (www.sustainabledesignguide.umn.edu). In comparison and by contrast with the LEED V 2.0 the UMN criteria represented broader strategies which fit better with the conceptual focus of this phase of the framework. These are however also reflective of the LEED criteria, again allowing direct application of this more popular approach. The most prevalent generic and schematic design strategies from the UMN *Sustainable Design Guide* are as follows:

- Direct Development to Environmentally Appropriate Areas
- Use Native Trees, Plants, and Shrubs
- Use Resource Efficient Modes of Transportation
- Manage Site Water

- Optimize Placement and Configuration for Energy Performance
- Optimize Building Envelope Thermal Performance
- Provide Day-lighting Integrated with Electric Lighting Controls
- Provide Efficient Electric Lighting Systems and Controls
- Maximize Mechanical Systems Performance
- Integrate All Systems and Reduce Total Energy Use
- Provide Ample Ventilation for Pollutant Control and Thermal Comfort
- Provide Appropriate Thermal Conditions
- Provide Views, View-space and Connection to the Natural Environment
- Use Salvaged and Remanufactured Materials
- Use Recycled Content Products and Materials
- Use Materials from Renewable Sources
- Use Locally Manufactured Materials
- Use Low VOC-emitting Materials
- Design-for-less Material Use
- Design Building for Disassembly
- Salvage and Recycle Demolition Waste

In contrast however, the review of the design guides supported the LEED V2.0 strategies as more suited for the design development part of the outline (phase 3, factor 2) due to their more specific and measurable outcomes. They were the same or similar to many of the ones taken from the UMN guide so the duplications were removed to form the composite set and will need to be removed when setting up a project specific analysis. Likewise, there may be important new strategies being proposed including inherent innovation that should be added either in this phase or as expert factors if an understanding of their relative cost impact is known. Again, from the case studies and the literature review, the most widely used design development strategies include:

- Materials Minimization
- Elimination of Conventional Finishes
- Dramatic Day Lighting
- Light Shelf Integration Into Curtain Walls
- Super Tight Envelope
- High Tech Insulation
- Heat Reflectance
- Low “E” and Smart Glazing
- Material Durability
- Locally Produced and Natural Finishes
- Maintenance Free
- Limited to No Sealant or Paint
- Indoor Air Quality
- No-VOC Emission Products
- Life Cycle Costing
- Conservation Features, Waterless
- Energy DOE-2.1 [Integrated Envelop and HVAC Systems]

For this part of the framework, the actors are the specific design discipline associated with the nature of the design strategy. For example, if the strategy is an energy or HVAC based strategy the actor would be the electrical or mechanical engineer. These will be referred to as discipline specific strategies going forward.

The development of the construction contract documents, essentially the 90% to 100% design stage, presents multiple opportunities for impacting favorably the first costs of a green project. This factor in the design phase, by adding an additional pre-bid conference prior to finalization of the contract documents, can be the point when early alignment between the designer and the construction contractors in the design-bid-build delivery method provides clarity, removes risk, and simplifies the approach for the construction. It is also a point where the designer can best influence potential construction companies in how to carry out the work consistent with the design intent. While important in the sense that it reflects a risk transfer point, it generally is not a factor that generates design decisions that significantly impact the first costs (Mogge & Pedrick, 2003a, 2003b).

One of the more currently common financial strategies used in this factor is the attainment of grants, green tax incentives, and/or subsidies. Here the actors are the designer and the owner acting together to present the project to the proper authority. It should be noted that a significant grant can be a huge but artificial first cost offsetting impact. From a design perspective, these types of financial assistance strategies seem out of place but it is important that they are included in analyzing first costs until the use of green design and construction matures to higher level of use and they are no longer available.

4.5.3 Constructors and Construction Factors

The construction cost factors are a direct function of the project delivery method on which the project is based. The framework departs from traditional structure with these delivery method factors and uses strategies that reflect activities construction contractors would take in addition to the design strategies and/or in response to them. The first cost implications for this part of the framework can be significant. The complexity of this phase and the logic embedded in the project delivery choice goes beyond the sustainability of a project. The fundamental consideration when using this part of the overall framework for understanding first cost impacts is that the more seamless the transition between actors and phases, the less risk and less cost. The delivery methods reviewed for the case study projects (Table 3-10) suggested attributing cost impacts to these outline factors is difficult and that isolating the sustainable cost impacts from other cost drivers requires not only in-depth understanding of the basis of the delivery method decision, but also the capability and experience of the constructor in delivering green construction. This is also the case for the design-build-operate-and-transfer delivery method due to a more limited experience base and industry understanding of this delivery method. The construction outline factors are:

- Design-Bid-Build Low Cost
- Design-Build (to include)
- Design-Build, Low Cost
- Design-Build, Best Value
- Design-Build, Joint Venture (designer and the constructor)
- Project Solution (Design-Build-Operate-and-Transfer)

The actors are:

- Designers
- Constructors
- Operators
- Financiers/Contracting Officials
- Owners

Within the case study projects, the Homestead ARB Fire Station project offered the best actual first cost impact understanding of these factors (see Appendix F for more information). The project delivery method incorporated a construction contracting decision that was specifically designed to isolate the green design and construction strategies and therefore their incremental costs over normative design and construction approaches. A cost plus incentive award fee based contract was issued to a pre-qualified construction firm at the concept design stage, which required the contractor to work side by side with the designer through the design development process and to offer constructability input throughout the design process. This approach mimicked the design-build delivery method. The outcome was significant cost reductions and the savings largely reverting to the owner as additional scope and an overall lower total cost. Several strategies resulted in higher profitability for the contractor as well. One of which was the ability to retain all proceeds for the recycled construction wastes, and another was the cost differential between new materials and those salvaged in the process of carrying out the adaptive re-use concept. What this implies is that in the framework, the procurement and/or project delivery method, is an important variable to understanding and analyzing the first cost impacts for green design and construction. The actual cost study projects (presented in Chapter 5) at March ARB, procured as pre-qualified and non-competitive proposals from on-call construction firms late in the fiscal year showed a different outcome with significant incremental additional costs driven from what was perceived as design risk, and impending contract award deadlines for obligation of the monies. (The base had a specific end of fiscal year date by which the construction contract had to be awarded.) This critical timing issue for the base created pricing leverage for the construction companies being asked to quote the project. Specific project information for these pilot projects is in Appendices G and H.

4.5.4 Summary of the Cost Impact Framework's Phases and Factors

The relative distribution of the likely cost impact by phase and factor is summarized in Figure 4-12. This cost impact framework captures concisely the key elements that allow comparison of factors and strategies for green projects. The understandings that underpin each set of factors and actors are universal but complex. This is important in capturing sequentially, the relative first cost data from the various actors associated with each phase, but it is broad enough to adequately address the complexity of the process.

- Comprehensive Planning
  - Environmental Impact Analysis
  - Economic Development Impact
  - Physical Planning
  - Project Planning
  - Assessment and Objectives Setting
  - Preliminary Planning and Funding
  - Project Definition Package

Planning

Approximately 40% of the overall cost impact structure

- Project Design
  - Conceptual and Schematic Design
  - Design Development
  - Contract Documents

Design

Approximately 50% of the overall cost impact

- Construction
  - Design Bid Build [Low Cost]
  - Design-Build [Low Cost])
    - Design-Build [Best Value]
    - Design-Build [JV]
  - Design-Build-Operate-and-transfer

Construction

Approximately 10% of the overall cost impact structure

- Expert Outline Factors
  - Innovation in any aspect of the BE process

No value assigned

Figure 4-12 Summary of the Cost Impact Framework Phases and Factors[5]

4.6 Fuzzy Set Structure for the Analysis of the Linguistic Data

The structure of the Cost Impact Fuzzy Set is based on linguistic variables associated with the phases, factors, and strategies of the cost impact framework as presented by the actors associated with each part of the framework. The fuzzy restrictions for the variables ranged from no impact, to low, medium, or high impact and were further qualified with modifiers or hedges equating to a plus or minus for each restriction. The initial (anticipated) structure of the fuzzy set for the cost impact framework data and the test analysis is shown in Figure 4-13. This structure was modeled after a similar application for construction risk assessments (Kangari & Riggs, 1989) and was developed with the advice of Dr. Kangari and based on the work of Zadeh (Zadeh & Kacprzyk. 1992).

The structure of the fuzzy set is partially based on the system designer's selection of the relative association for each variable and a percentage based belief that the association will be valid. Thus, the system designer[6] must have expert level knowledge of the subject material in order to establish a representative association and reasonable belief values. Using a system based structural representation, the calculations for approximating a precise numerical value for each linguistic value are produced via an equation that uses an iterative procedure associating the likelihood of belief with the mapped membership value.[7] To develop this fuzzy set, the linguistic variable in the data quantified the first cost impacts. Therefore, the linguistic variable in this structure is: [first cost impact] by phase, factor, and strategy. The fuzzy restrictions were extended from the initial survey information and the case study projects, where the cost impacts ranged from low to high. As system designer, the author chose to continue with these and to add modifiers. Therefore, the universe of restrictions for the variables were: [no impact; - Low +; - Medium +; - High +]. Consistent with approximate reasoning theory, each restriction is mapped to a numerical value on a scale of zero to ten, which represents the level of impact. Zero is the lowest expected first cost impact, and ten is the highest. Then a membership value between zero and one was assigned to each branch coming out of the fuzzy restriction. These values show the author's degree of belief in that given level of first cost impact. For example, where the membership value of one is shown, there is 100 percent belief that is the highest level of the word medium, so on, and so forth.

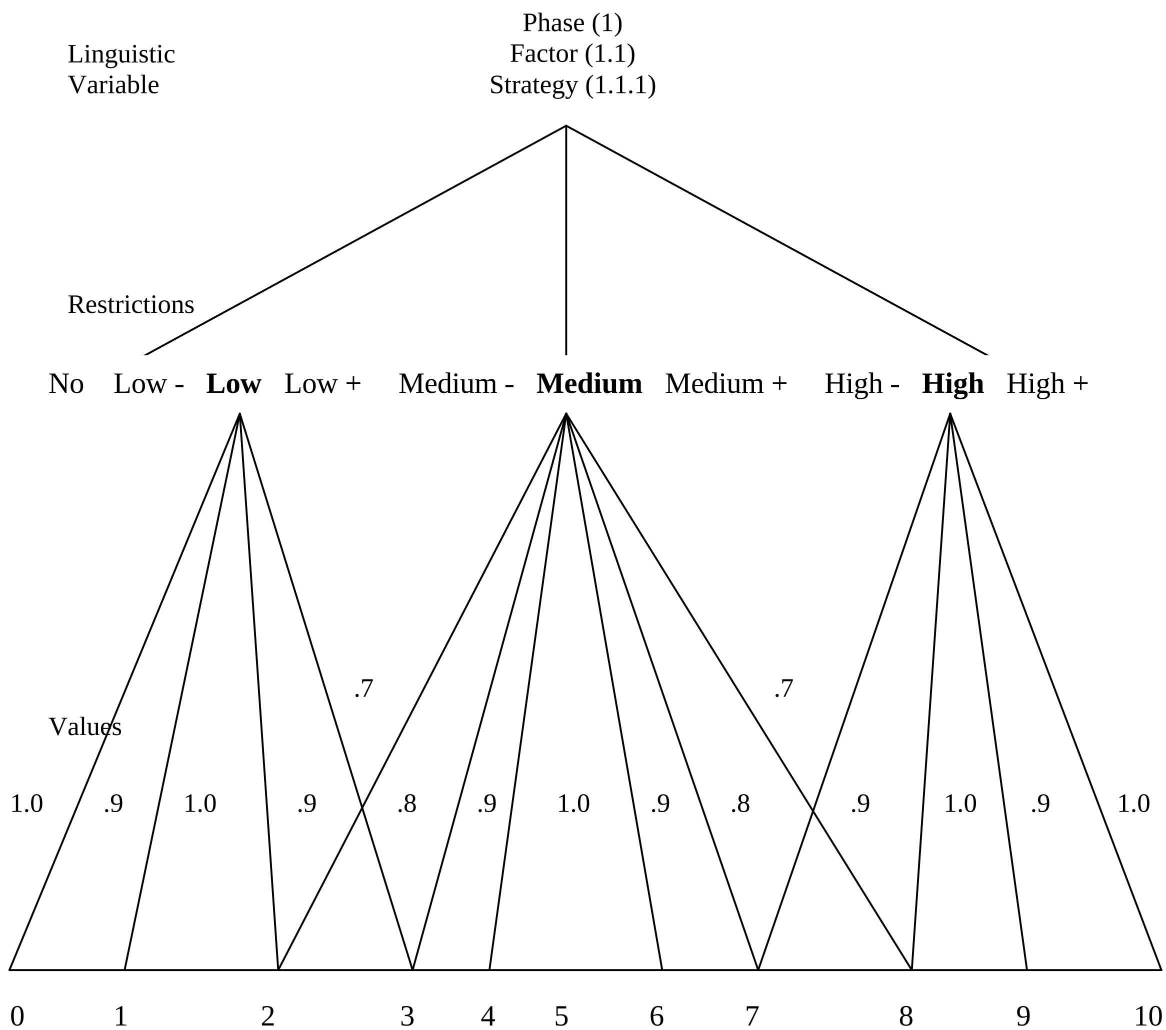

Figure 4-13 Initial Structure of the Cost Impact Fuzzy Set

The belief values and membership structure changed as a result of the expert interview process because of the structure associated with the discipline based alignment of the interview questions and the depth of understanding communicated by all of the interviewees. Accordingly, the author’s anticipated belief in their answers changed significantly and is shown in the final fuzzy set structure depicted in Figure 4-14. Each interviewee provided highly credible responses, using a uniform protocol. In a few instances where there was minor potential for miscommunications, the interviewees provided clarifying comments keeping the belief values high (see Appendix D). Every interviewee's responses were deemed highly credible, consequently the belief factor for the membership values was assigned a limited range with the least believable of the group assigned a 70% factor and the highest a 100% factor.

Further, the structure of the interviews and the interviewees all suggested that in their responses there was little to virtually no differentiation in the cost impact between the values of Low+ and Medium– on the left half of the scale, and Medium+ and High– on the right half of the scale. Accordingly, those values were treated with the same belief value. This common belief valuation for these variables was based on both direct feedback before, during, and after the interview process, and in a few situations by proactive feedback from the interviewees, where they commented that a differentiation for those values was negligible in their reasoning before they began their interviews.

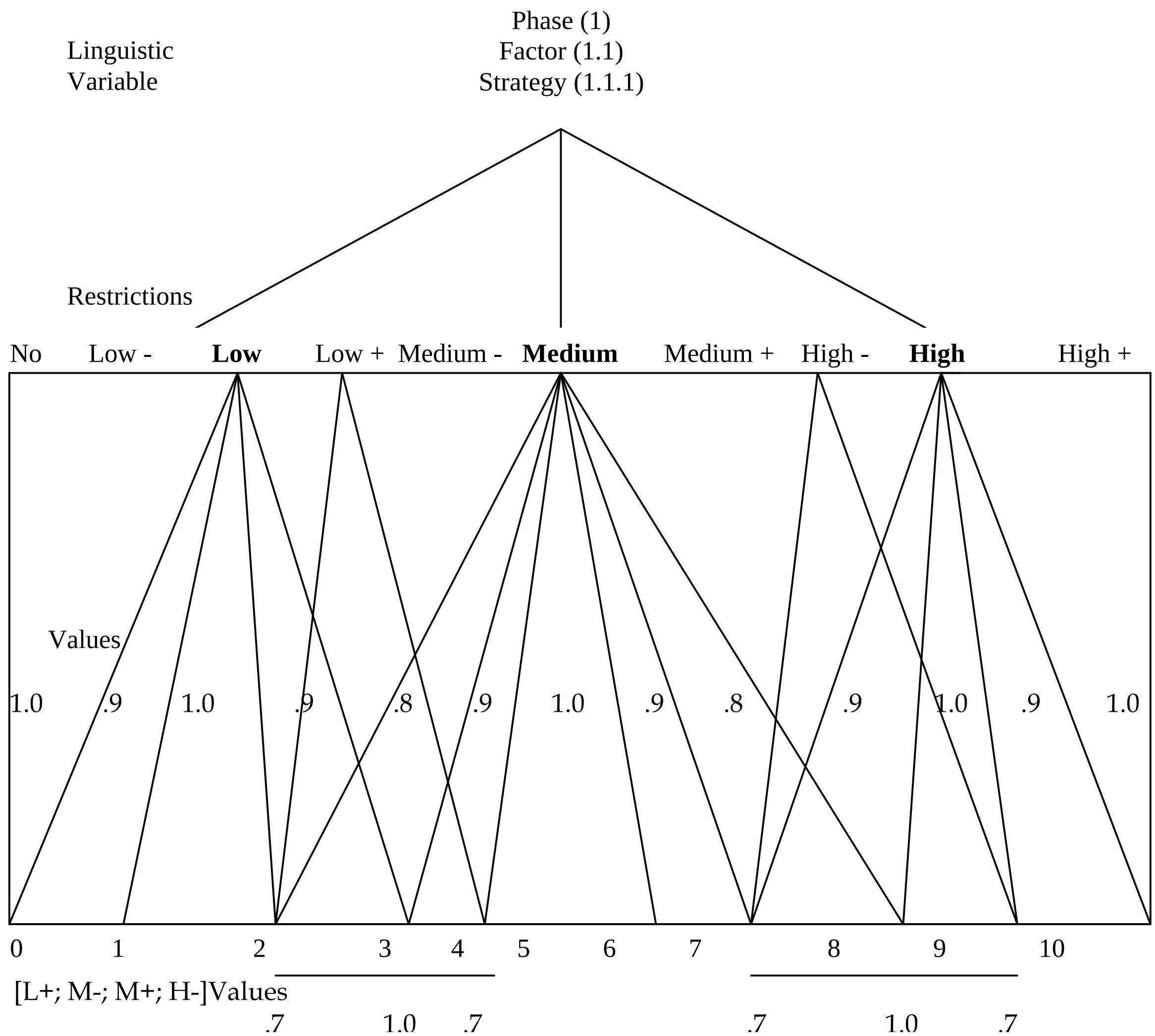

Figure 4-14 Final Structure of the Cost Impact Fuzzy Set

This completed the design of the fundamental elements of fuzzy set structure and method to evaluate the linguistic values to be placed in the cost impact framework and follow-on analysis of the phase, factor, and strategy values.

The next step in designing the application of fuzzy set theory as part of this methodology was to establish a consistent method to relate the fuzzy restrictions in the interview process. This was done by using a common question in an iterative format for every phase, factor and strategy, and corresponding actor. The answers to the questions then became the linguistic variables for the framework. To insure consistency, a fill-in-the-blank question format was developed. A total of nine interview questionnaires were created. The standard question protocol was:

What is the impact of factor x by actor y on actor z?

As an example with a strategy and actors, the question would read;

What is the impact on first cost from the use of envelope integration by the architects on the constructors?

Another would be;

What is the impact on cost from the use of waterless urinals by the project MEP designer on the planners?

From this approach a comprehensive matrix was designed that related the factors to the actors (see Appendix E). From this relationship matrix, the impacts on project costs by different actors throughout the phases of the work was calculated, analyzed, and summarized from different perspectives and are discussed in Chapter 5. Finally, a comprehensive assessment is provided in Chapter 6.

The Fuzzy Set Theory used and the fuzzy logic structure designed as part of this research is an effective approach for creating a framework for the analysis and resulting assessment of linguistic data and the forward projection of first cost impacts in sustainable planning, design, and construction. As stated earlier, approximate reasoning and fuzzy sets use is expanding and within the current sustainability literature there are several applications. This structure is based on an expert system approach, which takes as an assumption, that the normalization and maturation of sustainable planning, design, and construction is at the point where enough experience and consequently valid linguistic data is available to allow a meaningful understanding of the current cost impacts. The construction of composite scores further assumes that expert knowledge has matured to the point that the experts interviewed share a common value system. This overall approach provided a prototypical framework to gain a better understanding of where the drivers of first costs are likely to be found and what the first cost impacts are likely to be, and who the principal cost impacting actors are within the built environment process, thus potentially giving rise to far better insight into how to manage the first costs of sustainability for less overall impact and greater acceptance and use.

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1 The approach to this research uses expert systems as a key part of its formulation. The author validated both of these models from an expert approach based on over $3.5 billion of planning, design, and construction experience. Additionally, the built environment model, while not a refereed research effort, has been presented to the industry in several conference papers and is widely accepted as a valid representation of how projects proceed in the U.S. The conceptual model for sustainable infrastructure is also a widely held representation of the desired outcomes for sustainable outcomes. It does not have the depth of utility with respect to its use but, as described in Chapter 1, is based on solid and yet evolving theory. It however does have its roots in Dr. Pearce's research focus.

2 The initial framework proposed a weighting system based on the likelihood that greater impact earlier in the built environment process would occur. Later, as discussed in Chapter 5, the usefulness of the weighting system was determined to be redundant with the manner in which the linguistic data was derived. The weighting system for cost impact framework is an area for future research.

3 The alignment of the strategies to the factors was based on experience and an understanding of how each strategy was used to support project design objectives.

[4] Developed from the work of Papamichael (1998) and USACE and Goradia (2001). Papamichael's work suggests the majority of design decisions are made prior to design development. Gordia's and the USACE guidance affirm, as does Mendler and Odell (2000) that the majority of design decisions are taken by the 35% design reviews.

5 The values assigned to each phase of the structure represent the likely percentage of the entire processes cost impacting decisions. The values are experienced based and part of the expert systems approach to this work.

6 The author is the fuzzy set structure system designer.

7 See Appendix E for a sample equation.

CHAPTER 5

COST IMPACT FRAMEWORK
DATA AND QUALITATIVE ANALYSIS

5.1 Introduction

This chapter presents interpretive analysis[1] of the first cost impact values (linguistic and actual cost data) gathered in the interview process, including that of the expert group and actual project cost data from three completed projects (see Table 1-1 Data Used in the Investigation) to test the proposed cost impact framework. The three generally accepted qualitative approaches for this empirical investigation are language based, theory building, and descriptive/interpretive. The best suited approach was determined by considering the data and the objectives of the analysis and an interpretive approach was chosen (Fellows & Liu, 1997).

Using the basis of how the proposed cost impact framework was developed as described in Chapter 4, the linguistic data was inspected by actors and groups of actors, categorized by phase and factors, and then grouped and sorted to form the tables presented in this chapter. The composite values in the tables resulted from computations that associated the data to meet the requirements of the tables, which was by individual actors, groups of actors, all actors, and by phases, factors and strategies. Underlying the computations, which associated the discipline based groups of actors, were two broad assumptions. The first was that all values by all actors carried the same weighting. While this use of equal weighting in the fuzzy logic was to establish the validity of the framework, the framework does allow for weighting if future applications require. As the system designer, the author chose to make the weighting for each group of actors equal.

The second assumption was that a common method of averaging the values both horizontally and vertically (see Table E-1) was valid given the final fuzzy structure belief system used for all of the actors. The basis for the first assumption is that the belief and corresponding membership structure (Figure 4-14) can be uniformly applied for each discipline based grouping of actors, given equal weighting. This assumption was taken for four reasons. First, the groups are homogenous groups most of who have worked together and continue to do so. Second, the discipline based groups frequently interacted with each other and often their members comprised project teams with members of the other discipline based groups. Therefore, they shared common project experiences and their responses are largely based on these common experiences as well as their shared perceptions. Third, the range of values for their responses was not wide. As discussed later, the linguistic data suggests a tendency to low+ and medium– values for all groups further supporting the usefulness of associating the data from each group. Fourth, the protocol for conducting the interviews and precise nature of the questionnaires and the corresponding responses established an acceptable level of consistency for using a common belief system. If one cannot assume the actors share a common value rating system, the composite scores lose some validity. More research is needed in this area of multi-criteria analysis of fuzzy data across multiple data sets but is beyond the scope of this effort.

The chapter also presents a comparison of the linguistic data for each strategy and similar actual cost data gathered from the completed projects. To allow a uniform comparison, the framework presented in Chapter 4 is held constant by using the LEED V2.0 strategies without expert factors and compared to both the expert group as well as the actual project cost data. The interpretive qualitative analysis is presented in a broad to narrow format to allow the interrelated nature of the data to be better understood. Within the linguistic database is a further breakdown that separates the commonly used strategies from the entire opportunity set. (See Appendix E for the linguistic interview data arrayed in the cost impact framework.) In the process of collecting the interview data, the treatment of commonly used strategies surfaced as a question. Common usage of strategies, as discussed in this chapter, was an important aspect of interpreting the data to understand first cost impacts (EBN, 2003 December) at this point in the evolution of green design and construction because these strategies were likely to represent the strategies with lower first cost impacts. The commonly used strategies were treated the same as all other strategies, but were isolated within the analysis to determine if their suspected first cost impacts were actually present.

Five qualitative techniques were identified as the techniques to analyze the data arrayed in the following tables. They were; inspection, qualitative coding, pattern detection, causality, and dependency identification. In addition, the more common approaches of induction and deduction helped form the broader level summaries following each table. These techniques were identified from the literature on qualitative analysis and specifically from the work of Fellows and Lui (1997) as the most appropriate for the data obtained and the research objectives of this investigation. The techniques applied to each sort of the data and presented in the tables found in this chapter are discussed with each table. The manipulation of the data began broadly with the overall built environment phases, compared across the interdisciplinary set of actors (Section 5.2). The sorting method then narrowed to focus on the factors of each phase for each of the actors (Section 5.3). This aided in understanding how each set of actors viewed the cost of sustainability. The third sort of the data narrowed the data further to the strategies captured in each factor and again was arrayed by each group of actors (Section 5.4). This provided a closer inspection and pattern coding of each strategy with respect to its level of difficulty and allowed an understanding of why some strategies are commonly or rarely used.[2] The next level of the sorting reversed the axis of comparison and focused on the actors across all factors (Section 5.5). This sort of the data related the cost impacts from an interdisciplinary perspective to the factors and allowed yet another understanding of the cost impacts to emerge. The next level of the sorting was a comparison of the expert group across all factors and strategies with a further breakout of the commonly used strategies (Section 5.6). The expert group also functioned as part of the internal validation methodology and the data presented by the expert group was inspected and compared to the corresponding interviewee data for anomalies. The expert group represented a very articulate and highly experienced set of actors (see selection criteria in Appendix C) who had documented interest and experience in green planning, design, and construction as well as a strong understanding of its sustainability parent body of knowledge. The last level of the sorting categorized, compared, and contrasted the interview data to data from the actual projects (Section 5.7). This strategy level comparison of data was the second part of the internal validation method, using an interpretive correlation method. The comparison provided a basis for understanding the overall validity of the framework and created a deeper comprehension of the first cost impacts. Further, it provided a limited but useful initial basis for identifying the principal myths associated with understanding the first cost impacts. Finally, the multiple levels of the data manipulation and resulting qualitative analysis were tabulated and summarized in Section 5.8 to provide the departure point for the assessment presented in Chapter 6.

Each of the data sorts shown in Figure 5-1 and each of the tables in this chapter were extracted from the linguistic interview database through the application of inspection, pattern detection, categorization, and typology techniques. The results of applying these techniques are highlighted in the tables and are further analyzed in the narrative sections that follow. Each sort of the data is presented with a generalized word picture of the data followed with bullet type statements drawn from the data and generally uses the following investigative criteria to identify the findings.[3]

1. <u>How do the values **align** across the table</u>? Are there more than two value(s) differences? If so, what are they? What actor(s) provided them?
2. <u>Does the value **variance**(s) follow a discernable **pattern**(s)</u>? If so, does it relate to the **structure** of the framework? Is it relevant to the order of the **phases or factors**?
3. <u>How do they **compare** to the expert actor values</u>? Are there patterns, categories, or typology inferences?
4. <u>What strategies **indicate** lower relative cost impact values</u>? How do they **compare** to the commonly used set? What inferences can be drawn from this?
5. <u>Are there other **patterns** of relevance</u>? Within the data sort what **dependencies** appeared? How do the actors as groups compare?

The linguistic values shown in the tables that follow are consistent with the fuzzy set structure presented in Figure 4-14. The range of values are: No Impact, Low-, Low, Low+, Medium-, Medium, Medium+, High-, High, and High+.

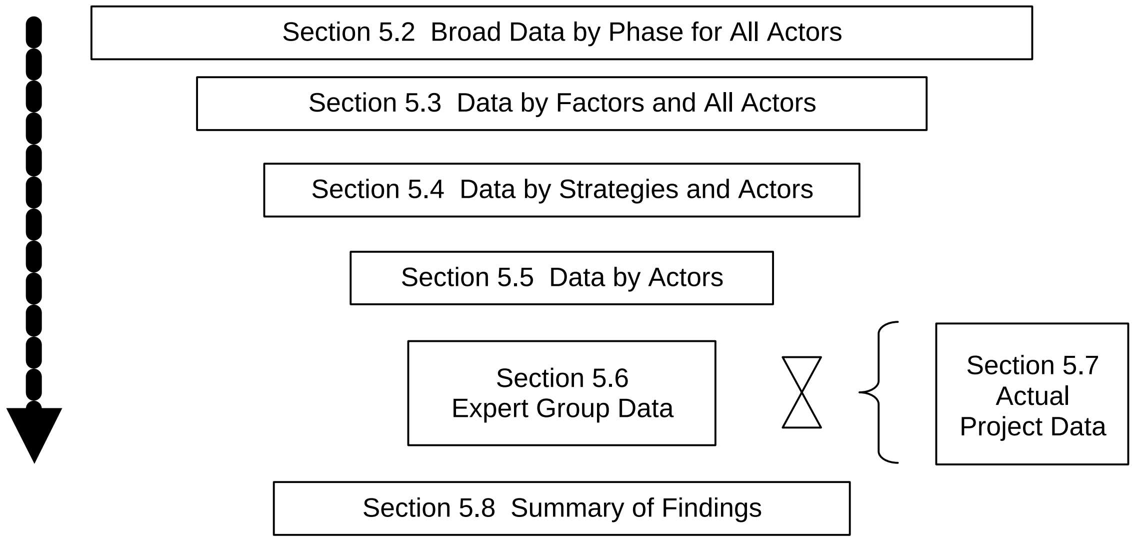

Figure 5-1 Data Array-Broad to Narrow (Sections 5.2-5.8)

5.2 Data by Phase for All Actors

Table 5-1 illustrates the array of the interview data when translated after computations from the interview database into an aggregate linguistic value, arrayed in the framework, and in its broadest form (see Figure 4-10 and Appendix E for an example computation). The phases are arrayed on the vertical axis and all of the actors (interviewees) on the horizontal axis. The data was further broken down to reflect the entire opportunity set, the commonly used strategies—those more readily known and practiced (developed from Cassidy, 2003b, and EBN, 2003 December), and the expert group data. The commonly used strategies generally reflected the EBN survey that is LEED based. Since the framework used more than LEED strategies, it was necessary to expand the set of commonly used strategies by incorporating other common but not

LEED specific strategies discussed by Cassidy (2003b) and also present in the case study projects and literature.

Table 5-1 First Cost Impacts by Phase, All Actors

Built Environment Phase 1.0	Impact All Strategies	Impact Commonly Used Strategies	Impact Expert Group
Comprehensive Planning	Medium	Low+	Medium
Project Planning	Medium	Low-	Medium-
Project Design	Medium-	Low+	Low
Construction	Medium	Medium-	Medium
Expert Outline	-	-	-

This array of the data was very broad. The highlighting indicates pattern-coded values relevant to the findings that are discussed later. The low- to medium range of impacts identified through inspection reflected the very broad nature of the phases and was generally consistent with the anticipated impacts. The variation between the all actors-all strategies and the expert group for phases 2.0 and 3.0 reflected an anticipated divergence of experience between the more experienced expert group (average of over 30 years) and the average experience of the all actors set (22 years). The variances in all phases for the commonly used strategies likely reflected the degree of difficulty, thus less first costs to achieve the more readily used strategies. By deduction, the inference was that frequency of use reduces the difficulty and thus tends to drive down the first costs.

5.2.1 Discussion of Data for All Actors for All Phases

The impacts in the two planning phases reflected the importance of framing the context of the project properly. The literature and early practice contain examples of green designs that were attempted without a corresponding green planning component (EDAW, 1999). These projects were loosely anchored to their environment, focused more on optimal outcomes for the environment and tended to maximize their first costs.

The impacts in the design phases reflected the importance of technical design and construction knowledge in the broadest sense. Here the actors (each design discipline individually and all acting collectively) played a pivotal role, because it is likely that the strategies that comprise the design decisions are where first costs are incurred or avoided. By inspection, the variations between the opportunity set impacts and the commonly used set impacts reflected the evolutionary trend of sustainable design and construction.

The impacts in the construction phase (all in the medium range) reflected the nature of the phase in as much that the likelihood of adding significant first costs with sustainable strategies in this phase is slightly higher than in the other phases. As shown later however, there are several material recycle and re-use strategies that tended to offset some first costs. As anticipated, the better one understands the construction first cost impacts during the planning and design phases, the better the chances are to impact the first costs in a favorable manner, or at a minimum employ a more balanced set of cost impacting strategies.

As stated earlier, there were no expert strategies (project unique or innovative solutions) analyzed at this level, but the expert phase was shown for consistency throughout the analysis. Taken collectively, the impacts at the very broad level of the data sorting revealed the need to focus on factors and strategies that are more specific in order to gain insight that is more useful. The next section summarizes the results of the analysis of the data from Table 5-1 through the application of pattern detection, inspection, and deduction techniques.

5.2.2 First Cost Impact Findings for All Actors All Phases (Table 5-1)

- The first cost impacts ranged from medium- to medium for all phases for all strategies and all actors.
- The planning phases had a slightly higher first cost impact than the design phase.
- The design phase had a lower first cost impact than the construction phase.
- The impact of the commonly used strategies ranged from low- to medium- for all actors.
- The planning and design phase for commonly used strategies had low first cost impacts.
- The construction phase for commonly used strategies had a medium first cost impact.
- The expert group variance for all phases, all strategies suggested a range of low to medium.
- The expert group assigned a higher first cost impact for the planning phase than the design phase, consistent with all actors.
- The expert group assigned a low first cost impact for the design phase and varied from the all actors rating of medium.

As a broad summary, there are two points that helped create a better understanding of first costs from this sort of the data. The first is that expert involvement seemed to matter for design with respect to both higher and lower cost impacts. The second point is that the context of the planning that surrounds a project is a likely first cost determinant. These points are carried forward to the assessment in Chapter 6.

5.3 Data by Factors and All Actors

Table 5-2 illustrates the sort of the interview data when translated after computations from the interview database by the factors within each phase and all actors associated with that phase. It provided another more general understanding of the first cost impacts but revealed less differentiation. By deduction, the principal reason for this central tendency was that this sort, like the previous sort, was a fuzzy calculation of the values associated with the strategies for each of the factors. This sort of the data reflected a logical and anticipated outcome with respect to first cost impacts because the factors were not as strongly associated with the primary actor. Many of the factors had multiple actors and were mutually executed or shared components of the built environment process model. This grouping of the data allowed a better understanding of the sub-processes within the phases. Through pattern detection, the factors with the same impact ratings suggested that, regardless of the actor, there existed a somewhat stronger consensus about the impact on first cost that each factor of the process bears.

Table 5-2 First Cost Impacts by Factor and All Actors

Factors	Impact All Strategies	Impact Commonly Used Strategies	Impact Expert Group
1.1 Environmental Impact Analysis	Medium-	Medium-	Medium
1.2 Economic Development Impact	Medium+	Medium	Medium
1.3 Physical Planning	Medium-	Low+	Medium-
2.1 Assessment and Objective Setting	Medium+	Medium-	Medium
2.2 Preliminary Planning and Funding	Medium	Medium-	Medium-
2.3 Project Definition Package	Medium-	Medium-	Medium-
3.1 Conceptual and Schematic Design	Medium-	Medium-	Low+
3.2 Design Development	Medium	Medium-	Medium
3.3 Contract Documents	Medium-	Low+	Low
4.1 Design-Bid-Build	Medium	Medium	Medium+
4.2 Design-Build	Medium	Medium	Medium+
4.3 Design-build-operate-and-transfer	Medium-	Medium-	Medium-

5.3.1 Discussion of the Data at the Factor Level for All Actors

Through inspection, the variance of first cost impact range at the factor level was wider than the phase level and ranged from low+ to a medium+. Two factors, 2.3 and 4.3, had strong consistency across the actors, with similar impacts identified by all groups of actors. The highlighting indicated pattern detected values relevant to the findings that are discussed later. Among the commonly used factors, physical planning was identified as having the lowest impact on first costs. The expert group ratings aligned closely (within one value in the range) with all actors for all factors. The construction factors (4.1-4.3) were tightly packed in the medium range. The application of inspection, pattern detection, and deduction resulted in the following findings.

5.3.2 Findings of the Data at the Factor Level for All Actors (Table 5-2)

- There was minor differentiation in first cost impact between all strategies and the most commonly used ones.
- The economic development, objective, and assessment factors had strategies in the all strategy set that had medium+ impacts on first costs.
- The commonly used strategies associated with the physical planning of a project had the lowest first cost impact of the planning factors.
- The contract document preparation factor for the design development phase had a consistent first cost impact of medium- among all groups.
- The design-bid-build project delivery factor was rated as medium+ by the expert group and varied positively from all groups.
- The design-build-operate-and-transfer (DBOT) project delivery factor had consistent first cost impact ratings of medium- among all groups.

By deduction, the more specific findings from this sort of the data revealed three broad points with respect to first costs. The first cost impacts were within the three values of medium for all strategies across the entire built environment process, which suggests that there is little differentiation among any of the groups of actors to significantly influence a first cost outcome. This requires further investigation and could likely support the need for higher discipline integration in the built environment process. The commonly used, but lower impact ratings for the design-build-operate-and-transfer method also suggests that integration of the phases may be an approach to reducing first costs and is worthy of further investigation. Finally, the rating for the planning and project planning factors suggests that an early focus on these factors is needed in understanding a project's first costs early in the planning factors.

5.4 Data by Strategies (Grouped by Actors)

The next four sections discuss the most detailed parts of the data sorting and analysis. They focus specifically on the multi-disciplinary decisions structured around strategies that are likely to create the first cost impacts. Each section addresses a common set of factors of the built environment process and all of their relevant actors. The investigation and sorting is based on exploring one question. How does each group of actors value the first cost impact for each strategy?

5.4.1 Discussion of Planning Strategies for Groups of Actors

Table 5-3 is the first of four tables that show the expanded phase and factor data sort to the strategy level for each phase and all actors. This level of the sorting was designed specifically to explore the data with respect to the comprehensive planning, economic planning, and environmental planning factors of a project. Thus, the principal actors were the planners and the owners. The factors were broad and had slightly different meanings for different actors. Consistent with the interview protocol, a verbal clarification of each of the terms[4] was made to each interviewee in order to achieve a consistent and common basis to analyze their responses.

Table 5-3 First Cost Impacts for Planning Strategies by Groups of Actors

Strategies 1.1.X	Planners	Designers	Owners	Expert Group	All	Commonly Used
Site Selection	Low+	-	Medium-	Low+	Low+	Yes
Alternative Transportation, Locate Near Public Transportation	Medium-	-	Low+	Medium	Medium-	Yes
Storm Water Management, No Net Increase or 25% Decrease	Medium-	Medium-	Low	Medium-	Medium-	Yes
Storm Water Management, Treatment Systems	Medium-	Medium-	Medium	High	Medium	Yes
Urban Redevelopment	High-	-	Medium	Medium	Medium	Yes
Brown Field Redevelopment (Economic)	Medium+	-	Medium	Medium+	Medium	No
LEED Accredited Professional	Medium-	-	Medium-	Medium-	Medium-	Yes
Reduced Site Disturbance, Development Footprint	Medium	-	Low+	Medium-	Medium-	Yes
Providing Sustainable and Innovative Landscape Design Strategies	Low	-	Low-	Medium-	Low	Yes
Brown Field Redevelopment (Environmental)	Medium	-	Medium	Medium	Medium	No

By inspection, the range of ratings for the first cost impacts was wide. There were two strategies that are less commonly used (Sections 3.2-3.3 and developed from Cassidy, 2003b). Both dealt with brown field development planning. In the framework they were separated into two planning factors (economic and environmental) to associate their cost impact issues with the actors most aligned with those issues. The first use focused on the economic aspects of brown field development such as the quality and comprehensiveness of property site transfer assessments and property transfer legal liability. The second strategy was associated with the environmental aspects of brown field development. The issues likely to affect first costs embedded in this strategy included are best represented in the following questions. How clean is clean? What is the best available or achievable remediation technology? Are there contamination pathways that might affect species and human long-term health? The frequency of the use of this strategy based on the USGBC December 2003 report on LEED strategies (EBN, 2003 December) and the lack of its use was assumed to deal with the economic and technical challenges inherent in brown field development. Later in the analysis however, the Homestead Fire Station project will be discussed with respect to the use of these two strategies to add further understanding with respect to first cost impacts. The application of inspection, pattern detection, and deduction resulted in the following findings.

5.4.2 Findings for the Planning Strategies for Groups of Actors (Table 5-3)

- Site selection had a low+ first cost impact.
- Alternative transportation options had higher first cost impacts by the expert group.
- No net increase, or a 25% decrease in storm water was consistently rated as having a medium- or lower first cost impact by all actors.
- On-site storm water treatment systems were rated high by the expert group and varied from all of the other actors.
- Planners rated the urban redevelopment strategy as high- in first cost impacts varying from a consistent medium rating by the other actors.
- Brown field redevelopment, while not commonly used, had medium+ economic first cost impact and a medium environmental first cost impact.
- Innovative sustainable landscape and site selection strategies had low- to medium- first cost impacts and were commonly used.

Through deduction, a broader observation came from this sort of the data. The strategy level analysis supported the potential utility of a framework-based approach to cost optimization for this factor and its strategies, and logically supports the extension of the built environment process to the functionality of a strategy use comparison tool. The rationale for this was that the specific strategies taken individually and in groups, provided useful insight into potential trade-off decisions that could offer lower potential first costs. This observation is carried forward to the assessment in Chapter 6.

5.4.3 Discussion of Project Planning Strategies for Groups of Actors (Table 5-4)

Table 5-4 is the second table of four strategy level data sorts and is differentiated from Table 5-3 by its focus on project planning as a factor. It presents the project planning strategies that more specifically frame and define a project. The actors for this factor shifted from the planners to the project developers and designers. The set of actors, collectively described as designers, for this table and the rest of the tables included the planner (PL), the landscape architect (LA), the architect (ARCH), the site and civil (SC), and the mechanical, electrical, and plumbing (MEP) disciplines. Each rating is attributed to the appropriate discipline in the strategy description by use of the initials above. In this part of the project planning phase, the outcome is typically an interdisciplinary-based project definition within the context of the preceding factors. In typical projects many of the broad circumstances are known. Trade-off analysis and option development are appropriate and needed activities. The strategies for this factor are largely interdependent, but have a sequence that begins with the situational assessment and an objective setting activity. Many times in this phase, and in an iterative fashion, the preliminary project planning and funding is adjusted to be responsive to the situation and objectives of the project. The strategies employed are therefore specific and more measurable with respect to first cost impacts than the earlier set of planning factors. In this part of the process, the first cost impacts can be more precisely anticipated.

Table 5-4 Project Planning Strategies by Groups of Actors

Strategies 2.1.X	Planners	Designers	Owners	Expert Group	All	Commonly Used
Design-MEP Minimum Energy Performance	-	Medium	-	Low-	Medium-	Yes
Design-ARCH Storage & Collection of Recyclable Materials	-	Medium-	Low	Low	Low+	Yes
Design-MEP Renewable Energy, 5%	-	Medium	-	High	Medium	Yes
Design-MEP Renewable Energy, 10%	-	Medium+	-	High+	Medium+	No
Design-MEP Green Power	-	Medium	-	High	Medium	No
Design-ARCH Recycle Content, Specify 15%	-	Medium	Medium-	Medium-	Medium-	Yes
Design-SC Reduced Site Disturbance, Protect or Restore Open Space	Medium	Medium-	-	Medium	Medium	Yes
Design-ARCH Alternative Transportation, Bicycle Storage & Changing Rooms	-	Low+	Low+	Low+	Low+	Yes
Design-SC Alternative Transportation, Alternative Fuel Refueling Stations	-	Medium-	-	Low	Medium	Yes
Design-SC Alternative Transportation, Parking Capacity	-	Medium	-	Medium-	Medium	Yes
Design-SC Reduce Heat Islands, Non-roof	-	Low+	-	Medium+	Medium-	Yes
Design-ARCH Rapidly Renewable Materials	-	Medium-	Medium-	Medium-	Medium-	Yes
Design-ARCH Reduce Heat Islands, Roof	-	Medium	Medium-	Low+	Medium-	Yes
Design-ARCH Building Re-use, Maintain 50% of Existing Shell	-	Medium	Low+	Low+	Medium	No
Design-ARCH Building Re-use, Maintain 75% of Existing Shell	-	Medium	Medium-	Low+	Medium	No

Table 5-4 (continued).

Strategies 2.1.X	Planners	Designers	Owners	Expert Group	All	Commonly Used
Design-ARCH Building Re-use, Maintain 100% of Existing Shell	-	Medium+	Medium+	Medium-	Medium+	No
Design-ARCH Recycle Content, Specify 50%	-	Medium	Medium	Low	Medium	No
Design-MEP Elimination of HCFCs and Halons	-	Low	-	Medium	Low+	Yes
Design-MEP Minimum IAQ Performance	-	Medium	-	Low	Medium-	Yes
Design-MEP Environmental Tobacco Smoke (ETS) Control	-	Low	-	Medium	Low+	Yes
Design-LA Water Efficient Landscaping, Reduce by 50%	Medium-	-	-	-	Medium-	Yes
Design-LA Water Efficient Landscaping, No Irrigation	Medium-	-	-	-	Medium-	Yes
Design Innovation in Design-Multiple Strategies	Medium	Medium	Medium	Medium-	Medium	Yes
Design LEED Accredited Professional	Medium	Medium-	Low	Medium-	Medium-	Yes

The application of inspection, pattern detection, and deduction techniques for the analysis of table 5-4 resulted in the following findings.

5.4.4 Findings of the Project Planning Strategies for Groups of Actors

- All actors rated the strategy of providing reduced site disturbance, protecting or restoring open space as a medium or lower first cost impact.
- Attaining minimum energy performance (DOE standard) was rated slightly higher for first cost impact by designers than by the expert group.
- Achieving 5%, 10%, or green power, had a significant impact (high-, high, and high+) on first costs according to the expert group.

- The first cost impact of providing alternative fuel, refueling stations (predominately electric) was rated low by the expert group and varies negatively from the designer rating.
- All actors rated the commonly used project planning strategy of using rapidly renewable materials as a medium- first cost impact.
- Planners and designers rated the first cost impact for reusing 75% or 100% of an existing building shell higher than the expert group.
- The project planning strategy of specifying 50% recycled content was rated low by the expert group, medium by the planners and designers.
- The project planning strategy of eliminating HCFCs and Halons had a low first cost impact rating by the designers and varied negatively from the expert group.
- The strategy of meeting minimum Indoor Air Quality performance standards in project planning had a low first cost impact rating by the expert group and varied negatively from the designers' rating. However, a converse rating of first cost impacts for providing tobacco smoke control existed.
- Owners rated the first cost impact of using a LEED Accredited Professional for project planning low.

Through deduction, causality association, and pattern coding, these findings provided additional support for a need to achieve a high level of integration among the disciplines for project planning to aid in cost impact optimization. They also reinforced the potential of the cost impact framework as a useful tool for first cost optimization. They added yet another dimension that reflected a need for more research and technology to create cost effective energy related MEP strategies as prerequisites for going beyond a 20%

efficiency threshold. They added more support to the importance of the project definition phase as a first cost determinant.

5.4.5 Discussion of Design Development Strategies for Groups of Actors (Table 5-5)

Table 5-5 illustrates the third of four strategy level data sorts for analysis. It presents the design development strategies for all actors of this phase. At this point in the built environment process, typically the project planning context of the project is established and the project is defined in terms of its objectives and funding. Additionally, it is the point where the planner's and owner's roles begin to shift from decision maker to advisor, and the principal actors become the design team. The first focus of the design team is to develop and gain alignment on a conceptual and schematic design solution. Commonly this is done via a charrette process and generates one or more feasible options as project concepts. Most experts agree that at this phase in the built environment process as much as 50 to 70% of the decisions that comprise a project's first costs have been made. (Papamichael, 1998; USACE & Goradia, 2001)

As the phase continues into design development, the design decisions are more detailed and generally reflect the down selection of two or three possible courses of action for the major systems of the project. The complexity of the design process is very high at this point in the process with multiple simultaneous and near-simultaneous decisions being taken in independent manners. As the design proceeds through the traditional 65% stage, almost 80 to 90% of the first cost impacts are likely to be in a committed state. The final set of factors comprising this phase reflects the preparation of the contract documents needed for procurement of the construction. In the design-build and design-build-operate-and-transfer delivery methods, this final stage may transition to a shared value engineering process between the designers and the constructors where additional design options are presented as a function of improving quality, reducing costs, reducing schedule or other more traditional project delivery measures of merit.

The actors in this sort of the data are the disciplines of the design team and the expert group. In the next phase the actors shift to the constructors. However, as the practice of sustainable design evolves it is likely that the constructors may play a more prominent role in the design development phase if a higher percentage of all projects are delivered through the design-build delivery method. Later in the analysis, and as indicated earlier, the Homestead Fire Station project will be discussed as an example of the potential for significant first cost reductions when the constructors are involved earlier as an integral part of the design development process. The results shown in Table 5-5 were analyzed with the preceding discussion as context for the application of pattern detection, dependencies association, and inspection techniques.

Table 5-5 Design Development Strategies by Groups of Actors

Strategies 3.1.X	Planners	Designers	Expert Group	All	Commonly Used
Design-MEP Innovative Wastewater Technologies	Medium-	Medium	Low+	Medium	Yes
Design-MEP Water use Reduction, 20% Reduction	Low+	Low+	Medium	Medium-	Yes
Design-MEP Water use Reduction, 30% Reduction	Medium-	Medium-	Medium+	Medium-	No
Design-ARCH Lighting Pollution Reduction	-	Low+	Low-	Low+	Yes
Design-MEP CFC Reduction in HVAC&R Equipment	-	Medium-	Low+	Medium-	Yes
Design Measurement & Verification	-	Medium	Low	Medium	Yes
Design-MEP Carbon Dioxide (CO2) Monitoring	-	Low	Medium	Low+	Yes
Design-MEP Increase Ventilation Effectiveness	-	Medium	Low+	Medium	Yes
Design-ARCH Controllability of Systems, Operable Windows	-	Medium	Low	Medium	No
Design-MEP Controllability of Systems, Individual Controls	-	Medium+	Low-	Medium	No
Design-MEP Optimize Energy Performance, 15% New 5% Existing	-	Medium	Low-	Medium	Yes
Design-ARCH Resource Re-use, Specify 5%	-	Low+	Low	Low+	Yes
Design-ARCH Resource Re-use, Specify 10%	-	Medium-	Low+	Low+	Yes
Design-ARCH Certified Wood	-	Medium-	Medium-	Medium-	Yes
Design-ARCH Low-Emitting Materials, Adhesives	-	Low	Low	Low	Yes
Design-ARCH Low-Emitting Materials, Paints	-	Low	Low	Low	Yes
Design-ARCH Low-Emitting Materials, Carpets	-	Low	Low-	Low	Yes
Design-ARCH Low-Emitting Materials, Composite Wood	-	Low+	Low	Low+	Yes
Design-ARCH Indoor Chemical and Pollutant Source Control	-	Medium	Low+	Medium	Yes
Design-MEP Optimize Energy Performance, 20% New 10% Existing	-	Medium	Medium	Medium	Yes
Design-MEP Optimize Energy Performance, 25% New 15% Existing	-	Medium+	Medium	Medium+	No
Design-MEP Optimize Energy Performance, 30% New 20% Existing	-	Medium+	Medium+	Medium+	No

Table 5-5 (continued).

Strategies 3.1.X	Planners	Designers	Expert Group	All	Commonly Used
Design-MEP Optimize Energy Performance, 35% New 25% Existing	-	High-	High-	High-	No
Design-MEP Optimize Energy Performance, 40% New 30% Existing	-	High-	High	High-	No
Design-MEP Optimize Energy Performance, 45% New 35% Existing	-	High-	High	High	No
Design-MEP Optimize Energy Performance, 50% New 40% Existing	-	High	High+	High	No
Design-MEP Optimize Energy Performance, 55% New 45% Existing	-	High	High+	High	No
Design-MEP Optimize Energy Performance, 60% New 50% Existing	-	High+	High+	High+	No
Design-MEP Thermal Comfort, Comply with ASHRAE 55-1992	-	Low	Low	Low	Yes
Design-MEP Thermal Comfort, Permanent Monitoring System	-	Medium-	Low	Medium-	Yes
Design-ARCH Daylight and Views, Diffuse Sunlight to 90%	-	Medium	Low	Medium	Yes
Design-ARCH Daylight and Views, Direct Line of Site 90%	-	Medium	Low+	Medium	Yes
Design Innovation in Design-Multiple Strategies	-	Medium	Medium	Medium	Yes
Design Sign and Seal - LEED Accredited Professional	-	Low	Low-	Low	Yes
Design Innovation in Contract Procurement-Multiple Strategies	-	Medium-	Low+	Medium-	Yes
Design Green Tax Incentives, Federal Grants, & Subsidies	-	Medium	Low	Medium	No
Owner Operator Green Tax Incentives, Federal Grants, & Subsidies	-	Medium	Low	Medium	No

5.4.6 Findings of Design Development Strategies for Groups of Actors

- The first cost impact of employing a 20% water use reduction strategy was rated low by planners and designers and varied negatively from that of the expert group.

- The first cost impact of employing the uncommon 30% water use reduction strategy varied positively from the 20% strategy.
- The architectural lighting reduction strategy had a low first cost impact rating.
- The design measurement and verification strategy had a low first cost impact rating from the expert group, which varied negatively from the designers' rating.
- The carbon dioxide monitoring strategy was rated low for first cost impacts by designers and varied negatively from the expert group rating.
- Both of the individual controllability strategies for operable windows and HVAC controls were rated low for first cost impacts by the expert group, which varied negatively with the designers' rating.
- The four commonly used indoor air quality (off-gassing) material substitution emission control strategies had consistent, low first cost impact ratings.
- The uncommon energy optimization strategies at the 25% and 30% levels had medium+ ratings for first cost impacts.
- The uncommon energy optimization strategies from 35% to 60% had high first cost impact ratings.
- Compliance with the commonly used ASHRAE 55-1992 Standard for thermal comfort has a low first cost impact rating.
- The diffusion of sunlight by 90% had a low first cost impact rating by the expert group and varied negatively from the designers' rating.
- The use of a LEED Accredited Professional to design, sign, and seal had a low first cost impact rating.

- The uncommon use of green tax incentives, grants, and subsidies by designers for and by owners had a low first cost impact rating.

Through interpretation, deduction, and in contrast to the strategies in the previous phase, these impacts were collectively lower with the exception of the MEP strategies above 30% efficiency. This suggested that in the design development there was still a good opportunity to influence first cost, but in comparison, the opportunity was not as likely as phases earlier in the built environment process. The findings tended to sustain the usefulness of the framework for first cost optimization. The findings reflected important research needs in the high end of the MEP efficiency rates.

5.4.7 Discussion of Construction Strategies for Groups of Actors (Table 5-6)

The last sort of the strategies is shown in Table 5-6. It presents the construction strategies for analysis with respect to groups of actors. At this point in the built environment process, the project planning context of the project has been established and the project has been defined in terms of its objectives and funding. The design development is completed. In the case of the design-build project delivery method, the conceptual design and project requirements statement has been completed. Additionally, it is the point where the designer's role shifts from decision maker to advisor, the owner's role shifts to construction contract participant. The principal actor becomes the construction team operating under the terms and conditions of the construction contract documents; therefore, the actors listed in Table 5-6 reflect this shift.

The three most common project delivery methods are selected to comprise this part of the analysis consistent with the design of the framework discussed in Chapter 4. The design-bid-build method is the normative method for most design and construction in the

United States. In the last ten to twelve years however, the design-build method has gained acceptance and appears to be on a path to eventually eclipse the traditional project design-bid-build delivery method.[5] The solutions method, or design-build-operate-and-transfer method, is an emerging approach gaining acceptance for the delivery of large complex private sector and public projects. This latter method approximates an optimized built environment process model because it tends to minimize the barriers between the phases and integrates the actors across the phases. As a parallel model to the proposed cost impact framework, the DBOT method allows a more seamless progression from phase to phase by actors who, while different and performing different functions, have a common goal of completing and transferring the project to an owner in an operating status. In this solutions method, the inherent risk of claims and other issues associated with a discrete transfer of contractual and fiscal responsibility tends to be minimized.

The principal actors for this sort of the data shift from the constructor to the owner. The expert group is the same for each delivery method analyzed. Within the framework, there are nine strategies for this phase. The sort of the data holds the strategies as constant for each delivery method by repeating the inspection, pattern detection, and comparison of the same nine strategies for each method. This approach allowed the analysis to isolate the delivery methods and control for impact beyond the impacts of sustainability. With a 100% design complete/contract documents in hand, the constructor likely has little latitude in deciding how to employ sustainable construction strategies with respect to first costs. The design-build approach provides more opportunity to employ sustainable design and construction strategies to leverage first cost impacts. The solutions method allows the most flexibility to employ planning, design, and life cycle cost construction strategies consistent with the goal of transferring the project as soon as possible in an operable state to an owner and likely creates the greatest incentive to leverage lower first cost strategies into the project.

Table 5-6 Construction Strategies by Groups of Actors

Strategies	Constructors	Owners	Expert Group	All	Commonly Used
Design-Bid-Build Delivery					
Construction LEED Accredited Professional	Low+	-	High-	Medium-	Yes
Owner Operations Fundamental Building Commissioning	Medium+	-	Medium	Medium+	Yes
Owner Operations Minimum Energy Performance	Medium-	-	Medium	Medium	Yes
Construction, Construction Waste Management, Salvage or Recycle 50%	Medium	-	High-	Medium	Yes
Construction, Construction Waste Management, Salvage Additional 25%	Medium	-	High-	Medium	Yes
Construction Local/Regional Materials, of 20% Manufactured Locally	Medium-	-	Medium	Medium-	Yes
Construction Local/Regional Materials, of 20% Above 50% Harvested Locally	Medium	-	Medium	Medium	No
Construction, Construction IAQ Management Plan, During Construction	Medium	-	Medium	Medium	No
Owner Operator Construction IAQ Management Plan, Post Construction	Medium	-	Medium+	Medium	No
Design-Build Delivery					
Construction LEED Accredited Professional	Low+	-	High-	Medium-	Yes
Owner Operations Fundamental Building Commissioning	Medium+	-	Medium+	Medium+	Yes
Owner Operations Minimum Energy Performance	Medium	-	Medium+	Medium	Yes

Table 5-6 (continued).

Strategies	Constructors	Owners	Expert Group	All	Commonly Used
Design-Build Delivery Continued					
Construction, Construction Waste Management, Salvage or Recycle 50%	Medium	-	Medium	Medium	Yes
Construction, Construction Waste Management, Salvage Additional 25%	Medium	-	Medium	Medium	Yes
Construction, Local/Regional Materials, of 20% Manufactured Locally	Medium-	-	Medium	Medium	Yes
Construction, Local/Regional Materials, of 20% Above 50% Harvested Locally	Medium	-	Medium	Medium	No
Construction, Construction IAQ Management Plan, During Construction	Medium	-	Medium	Medium	No
Owner Operations Construction IAQ Management Plan, Post Construction	Medium	-	Medium	Medium	No
Design-Build-Operate-and-Transfer Delivery					
Owner Operations LEED Accredited Professional	-	Low	Low+	Low	Yes
Owner Operations Fundamental Building Commissioning	-	Medium-	Medium-	Medium-	Yes
Owner Operations Minimum Energy Performance	-	Medium	Medium	Medium	Yes
Owner Operations Construction Waste Management, Salvage or Recycle 50%	-	Low+	Medium	Medium-	Yes
Owner Operations Construction Waste Management, Salvage Additional 25%	-	Medium-	Medium+	Medium-	Yes
Owner Operation Local/Regional Materials, of 20% Manufactured Locally	-	Low+	Low+	Low+	Yes
Owner Operations Local/Regional Materials, of 20% Above 50% Harvested Locally	-	Medium	Medium-	Medium	No
Owner Operations Construction IAQ Management Plan, During Construction	-	Medium	Low	Medium-	No
Owner Operations Construction IAQ Management Plan, Post Construction	-	Medium+	Medium	Medium+	No

The application of inspection, pattern detection, comparison, and deduction analysis techniques resulted in the following findings by delivery method for the construction strategies.

5.4.8 Findings of Construction Strategies for Groups of Actors

Design-Bid-Build

- The first cost impact of using a LEED Accredited Construction Professional was rated high by the expert group and varied positively from the constructors.
- The first cost impact of salvaging or recycling 50% of construction waste was rated medium by the constructors and varied negatively to the expert group rating.
- The first cost impact rating for an additional 25% of construction waste salvage or recycling was rated the same as the first 50%.
- The uncommon use of local materials above the 50% level had a medium first cost impact.
- Uncommon use of concurrent and post construction IAQ plans had a medium or greater first cost impact.

When placed in the context of the actors for this delivery method, and in comparison with the two other methods, deduction suggests the findings support the opportunity to effect first cost savings during construction only if recognized by the owner and designer as cost offsetting opportunities. The findings support the importance of addressing waste control, recycling, and IAQ standards in the planning and design phases of the processes because of the variance of impacts between the all actors rating and the constructors.

Design-Build

- The first cost impact of using a LEED Accredited Construction Professional was rated high by the expert group and varied positively from the constructors.
- The first cost impact of salvaging or recycling 50% of construction waste was rated medium by the constructors and the expert group.
- The first cost impact rating for an additional 25% of construction waste salvage or recycling was rated the same as the first 50% for both the constructors and the expert group.
- The uncommon use of local materials above the 50% level construction strategy had a medium first cost impact.
- The uncommon use of under construction and post construction IAQ plans had a medium first cost impact.

In comparison and by pattern detection, these findings were not consistent with some of the higher impact design related strategies in the design-bid-build delivery method. By deduction, the lack of variance in ratings was not surprising and brings into question the likeliness of opportunities for optimizing first cost impacts for this delivery method.

Design-Build-Operate-and-Transfer

- The first cost impact of using a LEED Accredited Construction Professional was rated low by the expert group and the constructors.
- The first cost impact of salvaging or recycling 50% of construction waste was rated low+ by the constructors and varied negatively to the expert group rating.
- The first cost impact rating for an additional 25% of construction waste salvage or recycling was rated medium- and varies negatively to the first 50%.

- The uncommon use of local materials above the 50% level had a medium first cost impact.
- Use of construction concurrent IAQ plans had low first cost impact ratings from the expert group.

Through pattern detection and in contrast to the previous delivery methods, the design-build-operate-and-transfer method suggests performance related strategies more closely aligned to life cycle savings have a lower first cost impact if the delivery method requires initial operations. This suggests system commissioning costs should be researched further to determine if they can be reduced when the constructor bears the owner's initial operational burden.

5.4.9 Discussion of Expert Factors

The linguistic interviews were designed to collect data to test the cost impact framework using the strategies that were developed to bridge the built environment process model and the sustainable infrastructure model. Chapters 2 and 3 presented the knowledge base and specific planning, design, and construction strategies used by other rating methods or developed as project unique strategies through innovation.

For more discussion about innovation in sustainable design and construction and how innovative strategies could be presented as expert factors for this cost impact framework please refer to the HOK *Guide to Sustainable Design* (Mendler & Odell, 2000) or the Air Force Center for Environmental Excellence Headquarters (HQ AFCEE) Guidance Letter, *Guide to Sustainable Design and Construction* (2001).

As introduced in Chapter 4, the intent of this phase was to allow flexibility in the framework for innovation and experimental strategies and to frame them within the larger context of the more common practices. This creates the opportunity to isolate innovation for cost analysis impact. Commonly, it will be the planners and/or the designers who contribute new strategies through innovation and experimentation in their work. There are many such strategies being tested in practice today,[6] and countless others to be developed in the years to come as the practice of green planning, design, and construction matures. Therefore, having the ability to include these types of strategies in future analysis was important. Because of the ad hoc nature and limited cost data associated with their use, hypothetical strategies were not provided in the interviews for rating. The actual cost project data, which will be discussed later, includes relevant expert strategies. This data was extracted and associated to some of the interview strategies or the expert factors. The correlation of that data and the linguistic values are discussed in section 5.6.

5.5 All Data by Sets of Functional Actors

The built environment process, for even the most modest projects, is a highly complex process involving multiple stakeholders and key actors associated with each phase. Analyzing how the actors' functional decisions (planning, design, and construction) impact the first costs of sustainable planning, design, and construction within and among the functionality of the overall process and specifically commonly used strategies within the phases yielded yet another set of findings that helped further understand first cost impacts.

Table 5-7, All Data by Sets of Functional Actors, was organized to collect first cost impact ratings by collapsing the framework to its fundamental elements for the universe of strategies and then for controlling factor, isolating the subset of corresponding commonly used strategies. The vertical axis associates the phase into functional alignment to reflect the disciplines as functions even though they had multiple roles and sometimes overlapped into each phase. For example, the site civil engineers had physical planning, project definitional, and project design development roles. The data is arrayed to reflect the role they played (function) based on the strategy vice the discipline or type of degree they hold. This sort of the data attempted to uncover any discipline-based bias and was part of the validation approach. The values shown are the average impact ratings for all disciplines operating in each phase and in two combinations of phases.

Referring back to the framework, Phases 1.0 (Planning) and 2.0 (Project Planning) were combined to yield a composite rating for the overall planning functionality. Phases 3.0 (Design Development) and 4.0 (Construction) were combined to yield a composite rating for the design and construction functionality. In cases like the HARB Fire Station project, which used a design-build like delivery method, the cost impact associated with the role of the constructors in project planning and design development are captured in the delivery method factor of the framework.

Table 5-7 All Data by Sets of Functional Actors

	Planners	Designers	Constructors	Owners	Expert Group
All Phases	Medium-	Medium	Medium	Medium-	Medium
Commonly Used-All	Medium-	Medium-	Medium	Low+	Medium
Phases 1.0 & 2.0 Planning	Medium-	Medium	No Data	Medium-	Medium-
Commonly Used 1 & 2	Medium-	Medium-	No Data	Low+	Medium-
Phases 3.0 & 4.0 Design & Construction	Medium-	Medium	Medium	Medium-	Medium-
Commonly Used 3 & 4	Medium-	Medium-	Medium	Low+	Medium-

Through inspection and pattern detection, the following findings were identified. The data also suggested that there was no appreciable discipline based bias present regardless of the role the actor played. The owners group however presented an unanticipated lower collective impact for commonly used strategies.

5.5.1 Findings of All Data for Functional Sets of Actors

- The planners and owners ratings of first cost impacts for all strategies were slightly lower than those of the designers and constructors.
- The expert group ratings of first cost impacts for all strategies were consistent with those of the designers and constructors.
- For the commonly used strategies in all phases, the owners and the designers first cost ratings varied negatively to the universal set. The planners, constructors, and expert group's ratings remained constant.
- The designers, owners, and expert group's first cost impact ratings for commonly used strategies varied negatively to the universe of planning strategies.
- The designers and owners first cost impact rating for the commonly used design and construction ratings varied negatively to the universe of design and construction strategies.
- The planners consistently rated each breakdown of the built environment process as having a medium- first cost impact.
- The designers consistently rated each set of the commonly used strategies lower than its corresponding universal set.

- For elements where ratings were collected, the constructors consistently rated each element of the built environment process as having a medium first cost impact.
- The owner's ratings varied from low+ to medium- for each element and overall had the lowest first cost impact ratings of any of the functional groupings.
- The expert group's first cost impact rating varied from medium to medium- and varied consistently within each grouping of the universal set and the commonly used set.
- There were no overall functional first cost impact ratings higher than medium.

Through deduction and pattern coding the findings supported the importance of the commonly used planning and project planning strategies as the part of the built environment process with a higher potential to impact first cost decisions. The findings supported the divergence of first cost impacts when assessed from a discipline perspective and thus the need for cross-discipline integration in understanding first costs. The findings supported the earlier statement that experience, especially with respect to commonly used strategies, aids in understanding the first cost impacts and possibly overcoming the cost barriers to their use.

5.6 All Data by Expert Group Members

The next sort of the linguistic data was focused only on the expert group ratings and was analyzed by comparison and pattern detection to the rest of the interviewee data. The purpose of this data sort and comparison was to identify, by person, any anomalies within the set of expert group members to be taken into account during the assessment of the findings in the Chapter 6. A secondary purpose was to gain insight into each of the expert group member's ratings for their specialty area because they were generally regarded as having highly specialized experience within their fields.

Table 5-8, All Data by Expert Group Members, is organized with the expert group on the vertical axis and their first cost rankings displayed horizontally. Both the universal set and the commonly used set of rankings were included. The commonly used set was used as a control because the previous table of impacts for the expert group provided no appreciable differentiation.

Table 5-8 All Data by Expert Group Members

Expert Group Members	Expert Group Impact for All Related Rankings	Expert Group Impact for Commonly Used Related Rankings	Expert's Impact by Discipline for All Related Rankings	Expert's Impact by Discipline for Commonly Used Related Rankings	Remarks
Ms. Linda Morse Planning	Medium	Medium	Medium -	Medium -	Consistent positive variance, normalization possible—1 ranking separation
Mr. Tom Orlowski Architecture	Low	Low	Medium-	Medium-	Consistent negative variance—2 ranking separation
Mr. Bob Pontek Site/ Civil	Medium	Medium	Medium-	Medium-	Consistent positive variance, normalization possible—1 ranking separation
Mr. Norm Nelson Mechanical, Electrical, Plumbing	Medium	Medium-	Medium	Medium-	Strong functional consistent rankings
Mr. Larry Hurley Construction	Medium+	Medium+	Medium	Medium	Consistent positive variance, normalization possible—1 ranking separation
Mr. Hilton Culpepper Owner	Medium-	Medium-	Medium-	Medium-	Strong functional consistent rankings

The following findings were developed through pattern detection of like responses by discipline related interviewees and by comparison of differing responses. Additionally, the expert's discipline based rating was compared to its respective discipline based actor group.[7]

5.6.1 Findings for All Data by the Expert Group Members

- Each expert group member's first cost related rankings for the universal set and the commonly used set were the same.
- Mr. Orlowski's related rankings consistently varied by two ranking separations.
- Ms. Morse's and Mr. Pontek's ratings loosely correlated to the interviewee ratings.
- Mr. Culpepper's, Mr. Nelson's, and Mr. Hurley's ratings strongly correlated to the interviewee ratings.

This expert group was identified and recruited by the author. As such, the author has in depth professional knowledge of each individual, which included their beliefs with respect to the research topic and their professional competencies in the area. Mr. Orlowski is a principal project architect with significant experience in green design. He holds a common perspective that green design is fundamentally good design and consequently not extraordinarily special, consistent with the principles presented in Chapter 3, Section 1. Therefore, the larger variance in Mr. Orlowski's ratings appears to be consistent but lower than the related disciplines. Overall, the expert group's ratings provided an important component for the validity of this investigation given its expert system basis.

5.7 Actual Project First Cost Data

Three completed projects were included in this research to correlate the linguistic interview data and to help develop a stronger understanding of how the theoretical first cost impact research compares to actual first cost impact. The projects were planned, designed, and constructed or were nearing completion during this investigation, and used many of the proposed cost impact framework LEED V2.0 strategies. A further comparison of the three projects' actual cost data to the linguistic values allowed yet another level of understanding of first cost impacts to emerge. The circumstances surrounding the actual data are outlined below as limitations for the comparison. By induction, they were factored into the resulting assessment of the actual cost data correlation with the interview data.

The projects examined were USAF projects and tied to the USAF's capital replacement requirements. The three projects were initially programmed and budgeted as normative design-bid-build projects, without specific sustainability goals but were later re-planned and executed as sustainable projects. The projects were industrial/ administrative projects and their designs were based on the LEED V2.0 concept of strategies and similar to those in the proposed cost impact framework. The construction cost estimates were prepared using the DOD standard construction cost estimating data and guidance (originally developed from OASD, 1993). Therefore, a further breakdown of the cost estimates was required for the mapping of the actual first cost deltas to the cost impact framework. The mapping used the LEED V2.0 criteria as the organizational tool and is shown in Table 5-9.

The projects were certifiable under LEED V2.0, but were not yet certified and some obtainable points were not obtained. Therefore, there remained some uncertainty whether the LEED credits would in fact be achieved. For the purpose of this correlation, it was assumed all of the claimed credits would be achieved. Another limitation is that the comparison of interview data and actual cost data necessarily could introduce other first cost drivers beyond the scope of this analysis. An example of this might be the procurement method and bid climate during the time of the projects. Another example is the skill and knowledge level of the government procuring official. While some understanding of these limitations was achieved, they were set aside as not central to the scope of this investigation and remain potential areas for future research. Another consideration was that the principal actors for each of the actual projects were not the same people. The headquarters owner was the same for all of the actual projects, but the user (base-level owner), the locations, the planners, the designers, and the constructors all varied.

The comparative analysis approach used follows. The cost differentials were calculated using the final bid set and corrected for changes during construction. In most situations, each line item reflected the specific material, method, and labor costs associated with the green strategy, and was compared to a normative construction approach using Construction Specifications Institute (CSI) and parametric cost estimating data to arrive at the delta in cost. In most cases, some measure of design judgment was needed to establish the comparison.[8] Nonetheless, the correlation of the data provided by this comparison, within these limitations, was valuable in determining and understanding the validity of the linguistic data collected for this investigation and verification of the usefulness of the cost impact framework for analyzing and optimizing design decisions for first cost impacts.[9]

The first project was the replacement Crash Fire Rescue Station at Homestead Air Reserve Base, Florida, introduced earlier (see also Appendix F). It was conceived and programmed as a green field project, and changed to an adaptive re-use approach in the initial project planning phase.

The second project, Addition to and Alteration of a Squadron Operations Facility at March Air Reserve Base (ARB), California, was also an adaptive re-use project (see also Appendix G). It was an interior re-configuration and replacement of major systems while re-using the existing shell of the original building.

The third project was also at March ARB and involved the adaptive re-use of the original and historic cold storage commissary warehouse for a combined C-135 and C-17 Aircraft Life Support Facility. The Aircraft Life Support Facility housed the survival equipment (life rafts, helmets, parachutes, and other similar equipment) issued to aircrews. The spaces included equipment maintenance, storage, and administrative space (see also Appendix H).

Table 5-9 Linguistic Data and Actual Project Cost Data Comparison

Phase and Factor	Sustainable Strategy (LEED V2.0)	Linguistic Impact	Firestation First Cost Delta	Squadron Ops First Cost Delta	Life Support First Cost Delta	UNK = Unknown NU = Not Used Remarks
1	Planning (Environmental, Economic, and Physical)					
1.1	Environmental Impact Analysis		% of the Total	% of the Total	% of the Total	
	Site Selection	Low +	0.02	0.01	0	
	Alternative Transportation, Locate Near Public Transportation	Medium -	Existing	Existing	Existing	
	Storm Water Management, No Net Increase or 25% Decrease	Medium -	0.08	0.2	NU	
	Storm Water Management, Treatment Systems	Medium	0.1	0.02	NU	
1.2	Economic Development Impact					
	Urban Redevelopment	Medium	NU	NU	NU	
	Brown Field Redevelopment	medium	NU	NU	NU	
1.3	Physical Planning					
	LEED Accredited Professional	Medium -	0.01	0.02	0.02	
	Reduced Site Disturbance, Development Footprint	Medium -	NU	NU	NU	
	Providing Sustainable and Innovative Landscape Design Strategies	Low	0.02	0.04	0.02	
	Brown Field Redevelopment	Medium	NU	NU	NU	
2	Project Planning (Project Definition and Development)					
2.1	Assessment & Objective Setting					
	Design-MEP Minimum Energy Performance	Medium -	0.4	0.3	0.4	
	Design-Arch Storage & Collection of Recyclable Materials	Low +	0.01	0.01	Existing	
	Design-MEP Renewable Energy, 5%	Medium	NU	NU	NU	
	Design-MEP Renewable Energy, 10%	Medium +	0.8	0.1	NU	Lightwells
	Design-MEP Green Power	Medium +	0.2	NU	NU	Photovoltaics for BU power
	Design-Arch Recycle Content, Specify 15%	Medium -	0	0	0	
2.2	Preliminary Planning & Funding					
	Design-SC Reduced Site Disturbance, Protect or Restore Open Space	Medium	0	0	0	
	Design-Arch Alternative Transportation, Bicycle Storage & Changing Rooms	Low +	NU	NU	NU	
	Design-SC Alternative Transportation, Alternative Fuel Refueling Stations	Medium -	0.02	0.1	0.02	Sq Ops--6 electric carts
	Design-SC Alternative Transportation, Parking Capacity	Medium	0.1	0.05	0.02	
	Design-SC Reduce Heat Islands, Non-roof	Medium -	NU	0.03	NU	
	Design-Arch Rapidly Renewable Materials	Medium -	UNK	UNK	UNK	
	Design-Arch Reduce Heat Islands, Roof	Medium -	NU	NU	NU	
	Design-Arch Building Reuse, Maintain 50% of Existing Shell	Medium	NU	NU	NU	
	Design-Arch Building Reuse, Maintain 75% of Existing Shell	Medium	2..0	NU	NU	FS--required expansion
	Design-Arch Building Reuse, Maintain 100% of Existing Shell	Medium +	NU	3.4	4.2	
	Design-Arch Recycle Content, Specify 50%	Medium -	0.1	0.2	0.2	
2.3	Project Definition Package					
	Design-MEP Elimination of HCFCs and Halons	Low	0	0	0	
	Design-MEP Minimum IAQ Performance	Medium -	0.04	0.06	0.07	
	Design-MEP Environmental Tobacco Smoke (ETS) Control	Low +	NU	NU	NU	
	Design-LA Water Efficient Landscaping, Reduce by	Medium -	0.05	NU	0.05	
	Design-LA Water Efficient Landscaping, No Irrigation	Medium	NU	0.3	NU	
	Design Innovation in Design-Multiple Strategies	Medium	see 5	see 5	see 5	
	Design LEED Accredited Professional	Medium -	0.01	0.01	0.04	Historic was more
3	Design (Conceptual Design, Design Development, Contract Documents)					
3.1	Conceptual & Schematic Design					
	Design-MEP Innovative Wastewater Technologies	Medium	NU	NU	NU	
	Design-MEP Water use Reduction, 20% Reduction	Low +	0.04	NU	NU	
	Design-MEP Water use Reduction, 30% Reduction	Medium -	NU	0.1	0.1	
	Design-Arch Lighting Pollution Reduction	Low +	NU	UNK	UNK	
	Design-MEP CFC Reduction in HVAC&R Equipment	Medium -	0.02	UNK	UNK	req'd n CA
	Design Measurement and Verification	Medium	0.02	0.03	0.08	
	Design-MEP Carbon Dioxide (CO2) Monitoring	Low +	0.02	NU	NU	
	Design-MEP Increase Ventilation Effectiveness	Medium	0.05	0.1	0.12	
	Design-Arch Controllability of Systems, Operable Windows	Medium	NU	NU	UNK	included in re-manufacturing
	Design-MEP Controllability of Systems, Individual Controls	Medium	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 15% New 5% Existing	Medium -	0.07	NU	Nu	
3.2	Design Development					
	Design-Arch Resource Reuse, Specify 5%	Low +	0	UNK	UNK	
	Design-Arch Resource Reuse, Specify 10%	Medium -	0.05	0.03	0.03	
	Design-Arch Certified Wood	Medium -	NU	NU	NU	
	Design-Arch Low-Emitting Materials, Adhesives	Low	UNK	UNK	UNK	
	Design-Arch Low-Emitting Materials, Paints	Low	UNK	UNK	UNK	
	Design-Arch Low-Emitting Materials, Carpets	Low	UNK	UNK	UNK	
	Design-Arch Low-Emitting Materials, Composite Wood	Low +	UNK	UNK	NU	
	Design-Arch Indoor Chemical and Pollutant Source Control	Medium	0	UNK	UNK	
3.2 cont.	Design Development					
	Design-MEP Optimize Energy Performance, 20% New 10% Existing	Mediium	0.1	NU	NU	
	Design-MEP Optimize Energy Performance, 25% New 15% Existing	Medium +	NU	0.2	0.2	
	Design-MEP Optimize Energy Performance, 30% New 20% Existing	Medium +	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 35% New 25% Existing	Medium +	NU	NU	NU	

Table 5-9 (continued).

Phase and Factor	Sustainable Strategy (LEED V2.0)	Linguistic Impact	Firestation First Cost Delta	Squadron Ops First Cost Delta	Life Support First Cost Delta	UNK = Unknown NU = Not Used Remarks
	Design-MEP Optimize Energy Performance, 40% New 30% Existing	High -	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 45% New 35% Existing	High	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 50% New 40% Existing	High	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 55% New 45% Existing	High	NU	NU	NU	
	Design-MEP Optimize Energy Performance, 60% New 50% Existing	High	NU	NU	NU	
	Design-MEP Thermal Comfort, Comply with ASHRAE 55-1992	Low +	0	UNK	UNK	
	Design-MEP Thermal Comfort, Permanent Monitoring System	Medium -	0	UNK	UNK	
	Design-Arch Daylight and Views, Diffuse Sunlight to 90%	Medium	0	0.3	NU	
	Design-Arch Daylight and Views, Direct Line of Site 90%	Medium	0.08	NU	NU	
	Design Innovation in Design-Multiple Strategies	Medium	see 5	see 5	see 5	
3.3	Contract Documents					
	Design Sign and Seal - LEED Accredited Professional	Low	UNK	0.03	0.03	
	Design Innovation in Contract Procurement-Multiple Strategies	Medium -	0	2	2	USACOE On-call Contractor Premium
	Design Green Tax Incentives, Federal Grants & Subsidies	Medium	NU	NU	NU	
	Owner Operator Green Tax Incentives, Federal Grants, & Subsidies	Medium	NU	NU	NU	
4	Construction (Project Delivery Method)					
4.1	Design Bid Build					
	Construction LEED Accredited Professional	Medium	0	0.2	0.2	
	Owner Operations Fundamental Building	Medium +	0.5	UNK	UNK	Commissioning costs TBD
	Owner Operations Minimum Energy Performance	Medium	UNK			
	Construction Construction Waste Management, Salvage or Recycle 50%	Medium	-0.02	-0.03	0	
	Construction Construction Waste Management, Salvage Additional 25%	Medium	0	0	-0.04	75% recycle or reuse for Life Support
	Construction Local/Regional Materials, of 20% Manufactured Locally	Medium -	UNK	UNK	UNK	
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally	Medium	NU	UNK	UNK	
	Construction Construction IAQ Management Plan, During Construction	Medium	0.2	0.4	0.4	
	Owner Operator Construction IAQ Management Plan, Post Construction	Medium	0.2	UNK	UNK	
4.2	Design Build		Not Used	Not Used	Not Used	
	Construction LEED Accredited Professional	Medium -				
	Owner Operations Fundamental Building	Medium +				
	Owner Operations Minimum Energy Performance	Medium				
	Construction Construction Waste Management, Salvage or Recycle 50%	Medium				
	Construction Construction Waste Management, Salvage Additional 25%	Medium				
	Construction Local/Regional Materials, of 20% Manufactured Locally	Medium -				
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally	Medium				
	Construction Construction IAQ Management Plan, During Construction	Medium				
	Owner Operations Construction IAQ Management Plan, Post Construction	Medium				
4.3	Design Build Own Operate Transfer		Not Used	Not Used	Not Used	
	Owner Operations LEED Accredited Professional	Low				
	Owner Operations Fundamental Building	Medium -				
	Owner Operations Minimum Energy Performance	Medium				
	Owner Operations Construction Waste Management, Salvage or Recycle 50%	Low +				
	Owner Operations Construction Waste Management, Salvage Additional 25%	Medium -				
	Owner Operations Local/Regional Materials, of 20% Manufactured Locally	Low +				
4.3 cont.	Design Build Own Operate Transfer		Not Used	Not Used	Not Used	
	Owner Operations Local/Regional Materials, of 20% Above 50% Harvested Locally	Medium				
	Owner Operations Construction IAQ Management Plan, During Construction	Medium -				
	Owner Operations Construction IAQ Management Plan, Post Construction	Medium +				
5	Expert Outline Factors					
	Firestation --Wash water recapture system		0.05			Reused driveways
	Firestation --Reuse/Remanufacture of Bay Doors		0.3			After production run
	Sq Ops--Clearstory ceiling realignment for daylighting			0.3		
	Life Support--remanufacture of historic windows				0.2	Known Vendor
	Total as a percent of the first cost construction value		3.64	8.51	8.36	

5.7.1 Discussion of Actual Project Costs

Table 5-9 is the depiction of the proposed cost impact framework with both linguistic interview data and actual cost project data. The correlation technique used allowed by inspection, pattern detection, and comparison, the identification of the six findings that follow. Additional observations were also made and are useful in understanding this correlation analysis. The actual project cost data, through comparison with the linguistic values by strategy, depicted a potential issue of scale with respect to the linguistic values and their correlation to actual project cost data. If both sets of data are reasonably valid, then the framework, as a decision support tool to manage first cost impacts as portrayed through the interviews, is sound. With the limitations discussed earlier, it was reasonable to assume that the far broader sets of actual project cost data should correlate more directly to the linguistic values and they did. There were useful observations from the actual cost projects within each strategy that added further insight to the understanding of first cost impacts. One such observation was the application of the more commonly used strategies. Another was a higher level of use for the strategies in the planning and project planning phases of the built environment process.

The actual cost project data was also helpful in understanding how the linguistic data parallels actual data. An issue of scale, defined by the way the linguistic value could be associated with a percentage based normative value as an incremental first cost delta. It also introduced a level of experienced based judgement that requires future analysts using this method to have a high degree of experience with the methods and materials components of the strategies. The alignment of the actual cost project data, after it was broken down into its materials and methods components and translated back into strategy based costs to the framework, was encouraging. While the scale of the impacts might be questioned, the method to compare them was sound. As a correlation and validity tool, the actual project cost data provided insight and suggested that a schedule of comparative first cost values (linguistic and actual) for various building types would be a helpful tool. Such a tool is beyond the scope of this investigation, but it is a strong candidate topic for further research.

5.7.2 Linguistic Value and Actual Project Cost Findings

Through the comparative technique previously described, the following findings were identified with respect to table 5-9.

- The linguistic values for the planning strategies had a weak correlation to the actual project cost data for similar strategies. This was likely due to the planning surrounding the projects occurred concurrently with the development of each project. (See project information in Appendices F, G, and H.)
- The linguistic values for the project definitional strategies had a stronger correlation to the actual project cost data for similar strategies.
- The linguistic values for the 75 and 100% re-use of existing shell strategies correlated with the actual project first cost data within the strategy but the actual cost data was out of scale (far larger) then the other actual cost data points as absolute values. This is likely due to the savings for not building new were withheld from the construction authorization by the government when the projects were re-programmed.
- The linguistic values for the actual project cost data for the design development strategies correlated within strategies, but showed less correlation within factor or

phase. This is likely because the planning and design phases for these projects were overtaken by the late decision to do them as sustainable projects.

- The framework allowed mapping of cost data for comparison purposes and aligned with the most commonly used rating criteria with enough specificity to be useful.
- The framework was broad enough to be reasonably inclusive of most green project strategies.

Within the concept of an expert system based approach, the researcher was intimately familiar with the circumstances of the planing, design, and construction of these projects as well as the circumstances surrounding their development and advocacy as green projects. This allowed the researcher to reasonably separate other issues impacting the first costs that were not cost impact framework, sustainable, or built environment process driven. Correspondingly, this comparative analysis provided correlation validity for the utility of the framework as an extension of the built environment process and supported the general alignment of the linguistic data with respect to the findings discussed throughout this chapter.

Additionally, the actual project cost data correlation of the proposed cost impact framework helps support the following objectives of this investigation and presents the needed foundation to help form the follow-on assessment in Chapter 6.

The proposed framework helps *identify the principal drivers of the suspected higher first costs (barriers) for green design and construction***.**

The proposed framework helps *compare and analyze the drivers that significantly differentiate green design and construction from traditional (normative) design and construction.*

5.8 Summary of Analysis and Findings

The interpretive methods for this qualitative analysis and the organizational process for the sorting and analysis of the data (Figure 5-1, broad to narrow) generated findings through inspection, pattern detection, categorization, and typology at all levels that were not previously understood or known. These findings represented elements of potential information that, when taken collectively, created valuable insight into the first costs of green planning, design, and construction. Findings at the broader level supported subjective thinking found in the literature and held by some practitioners. One such finding is that the commonly used strategies are generally presented as lower first cost impacts, but common use did not always equate to lower cost. Other findings were not anticipated. For example, the less common use of brown field redevelopment was not reflective of high cost impacts, suggesting other issues exist with respect to its acceptance. When assessed holistically, these findings created valuable insight into understanding the first cost impacts of most sustainable planning, design, and construction strategies.

Table 5-10 was developed by consolidating the attributes of the preceding tables as they presented the linguistic and actual cost project data. Presented for summary purposes it provides a tabulation of the range and numerical recap of the data, with respect to the number of findings derived from each level of the data sorting process.

There are potentially many more findings that can be drawn from this data that might prove relevant, and are areas for future research.

Table 5-10 Summary of First Cost Impact Findings

Data Set by Table	First Cost Impact Relationship to Framework	Range of First Cost Impacts		Number of Findings
5.1	By Phase All Actors	Low-	Medium	9
5.2	By Factors All Actors	Low	Medium+	6
5.3	Planning Strategies All Actors	Low	High	7
5.4	Project Planning All Actors	Low-	High	10
5.5	Design Development All Actors	Low-	High+	13
5.6	Construction All Actors	Low	High-	15
5.7	Phases by Disciplines	Low+	Medium	11
5.8	Strategies by Expert Group	Low	Medium+	4
5.9	Linguistic to Actual Cost	Low/0	Med+/4.2%	6

The 81 findings drawn from the data range from no impact to a high+ first cost impact. The nine data sorts further illustrated that the complexity of first cost impacts represents an algebra of actors, phases, strategies, and timing. This complexity of the process however, was better understood within the context of the proposed cost impact framework as functions of patterns, typologies, causalities, and interpretations.

Figure 5-2 provides a graphical representation of this complexity. The breadth of the criteria used to sort the data is on the top. The complexity of the impacts is on the bottom, the number of findings are represented by the width of the vertical arrows and the range of the impacts as associated with their corresponding fuzzy structure value (0 –10; no impact to high+ impact) on the left axis.

By re-categorizing, Figure 5-2 relates the data sorting and findings in another way, and revealed that beyond the complexity of the proposed cost impact framework, there was also a breadth of criteria association with the first cost impact findings. In the broader data sorts, the impacts appeared to have fewer findings and those findings had a more limited range of impact. By deduction, what this suggested is that when the criteria was more specific, with respect to the analysis of the strategies by actors (Table 5-4), the range of the impacts increased and thus allowed the isolation of the impacts in order for a more specific understanding to be developed.

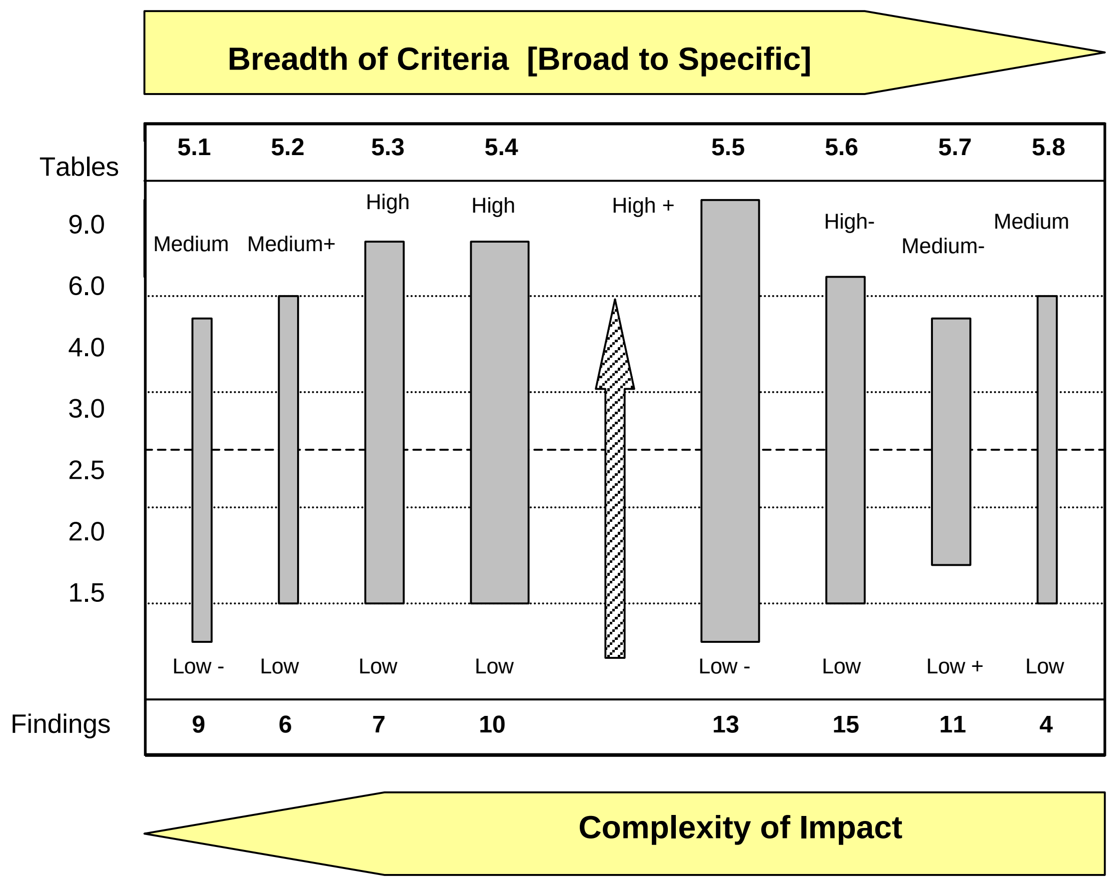

Figure 5-2 Relationship of Level of Impact to Specificity of Framework

Figure 5-2 also portrays an inverse relationship between the complexities of the first cost impacts to the breadth of the criteria as defined by the number of strategies. While the findings did not allow a statistically relevant understanding as an expert system investigation, however they did suggest that the first cost impacts might actually be easier to address when the specificity of the criteria is high. Restated, the greater the detail, the more was known, and consequently the easier it was to identify the first cost impacts and consequently avoid, manage, or eliminate them, if done early in the built environment process.

Following the model presented in Figure 5-1 and this summary, Chapter 6 develops the main points of this analysis, and creates a broader, high level assessment of the analysis and in so doing, captures the essence of the research contribution.

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[1] As described by Fellows and Liu in *Research Methods for Construction* (1997, p. 79), the qualitative approach of interpretive analysis attempts to develop a coherent and comprehensive view of the subject material from the perspective of those who are being researched; the practitioners, in this case all of the discipline based designers, the constructors and the planners; the respondents the actual people interviewed and the owners; or subjects.

[2] Level of difficulty does not equate to higher cost but is likely to be less commonly used due to the technologies and skill level of the designers required to employ. An example of a difficult strategy could be achieving 60% MEP efficiency.

[3] The expert system approach to this investigation necessarily relied on ad hoc criteria as well as these more general questions. The findings reflect these criteria but not exclusively. There was no significance to the order of presentation for the findings, which largely followed the order of the questions where applicable. Where expert exceptions to this set of criteria were present, they have been identified.

[4] The working definitions were from the author's experience, based on the National Environmental Policy Act of 1969, and general federal approaches to environmental planning. These working definitions are broadly used throughout the U.S.

[5] According to industry projection data from the Design Build Institute of America (DBIA), courtesy of CH2M HILL, the sponsor of this research, the shift of delivery methods in the U.S. is expected to rapidly accelerate as the 27 remaining states without implementing legislation or which have prohibitive legislation provide the legal pathway for change. Obstacles remain, but 9 of the 27 states have enabling legislation pending, more states than at any time in the past.

[6] The case study project discussed in Chapter 3 presented numerous examples of innovation beyond the specific rating criteria. While LEED V2.0 allows for innovation, it artificially controls the number of points possible in the scoring system. This framework does not set a limit.

[7] For the planners, the landscape architect and planner disciplines were include in the planner's comparison with Ms. Morse's ratings. For the designers, the structural and architect disciplines were combined to compare with Mr. Orlowski's ratings. For the constructors, the at risk and CM for fee disciplines were combined to compare with Mr. Hurley's ratings. For the owners, all disciplines were combined when the specific interviewee was an owner to compare with Mr. Culpepper's ratings. These combinations were based on the background and experience of each expert.

[8] In these instances, the author, as a principal and registered architect, exercised his experience to make this translation. This is part of the expert systems approach for this investigation. Additionally, the author's translation was checked by Mr. Orlowski, an architect and expert group member.

[9] The correlation and breakdown of the actual cost data and alignment to a strategy did not account for the actual cost delta benefiting other strategies. The alignment of the cost data was to the strategy that reflected the breakdown of costs better than others. This introduced the possibility that the actual costs may have more sustainability benefit than is shown in the table. Further research into multiple strategy benefits might be helpful.

CHAPTER 6

ASSESSMENT, CONTRIBUTION, AND OTHER OUTCOMES

6.1 Introduction

Chapter 5 presented multiple tables of cost impact data that reflected consolidated values sorted from the practitioner interviews and placed in the proposed cost impact framework as a test of the framework's ability to bridge between the built environment process model and sustainability. Figure 6-1 is the conceptual model of the integrated elements that comprise the framework. As a conceptual model, the fullest integration of the framework is represented in Figure 6-2 with the process essentially enveloping the conceptual elements of the WCED sustainability construct (Figure1-1).

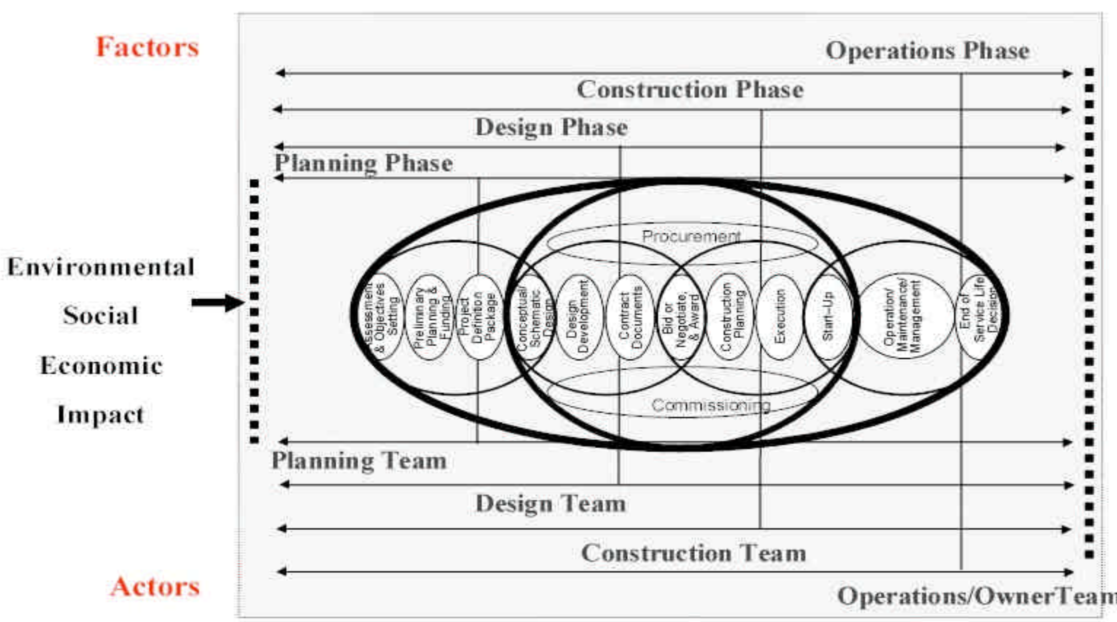

Figure 6-1 Integrating Sustainability and Process to Create a Framework

The assessment of the cost impact framework as a tool must have necessarily included the conceptual understanding of whether it actually operated in the fashion that is represented by the model in Figure 6-2 where the factors and actor's decisions were related with respect to first cost impacts to better uncover ways to reduce or eliminate the first cost impacts.

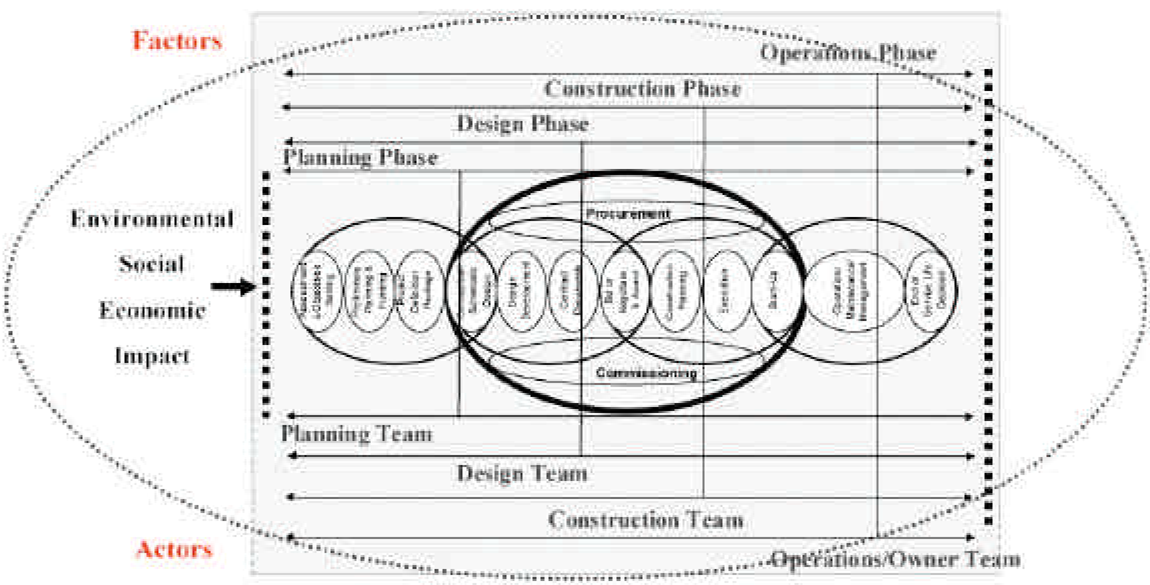

Figure 6-2 Conceptual Model of Integration Throughout the Process

Further, the analysis compared the sustainability strategies as characterized by linguistic data with actual cost project data to determine if the linguistic data correlated with the actual cost data thus supporting the utility of the framework as a tool. The results of the test supported that the framework achieved both the intent of the conceptual model and a reasonable correlation with the actual cost data in a manner that uncovered

81 findings that help to understand the first costs of sustainable design and construction. Additionally, it created a new understanding of how the process and the actors as depicted in Figure 6-3, both individually and as a team, can impact the first costs of sustainable planning, design, and construction when organized within a process based framework.

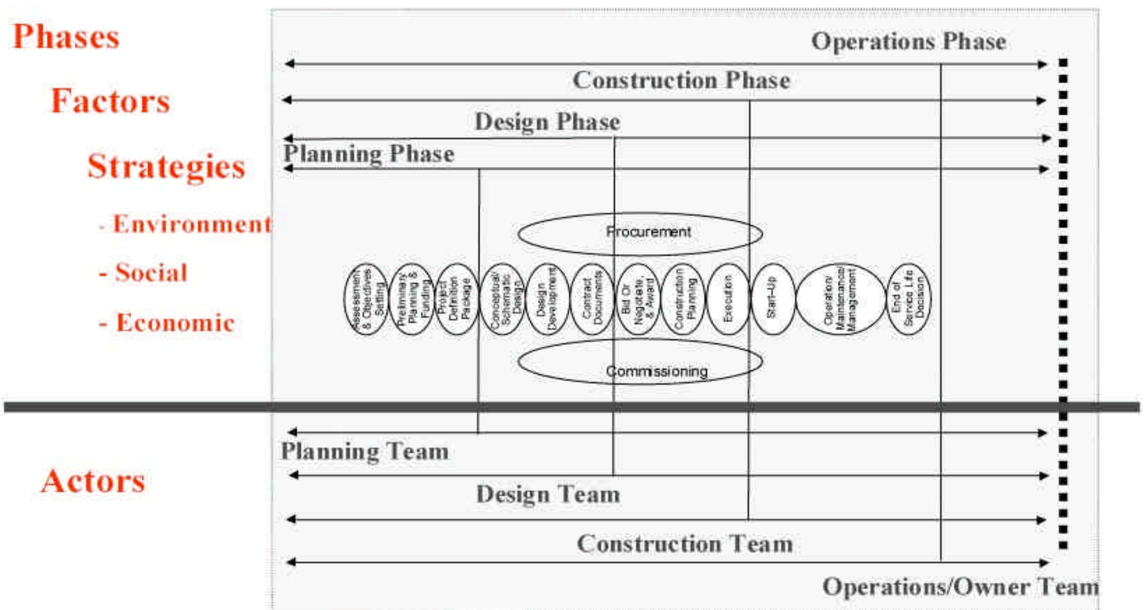

Figure 6-3 Conceptual Model of the Cost Impact Framework

This chapter expands the discussion of the results, presents a more thorough discussion of the research contribution, and other outcomes of this investigation for the sustainability, planning, design, and construction body of knowledge.

6.2 Contribution: The Cost Impact Framework

The cost impact framework was developed as a tool to aid in understanding the costs of sustainable planning, design, and construction and can best be thought of as a bridge to connect the built environment process and sustainability as shown in Figure 6-4.

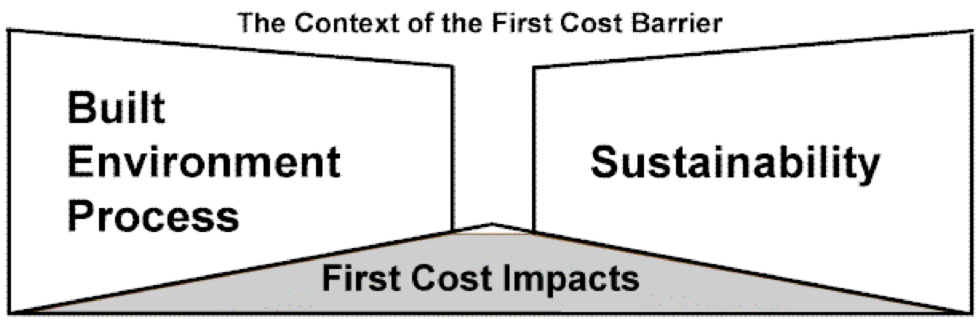

Figure 6-4 The Context of the Framework as Bridge

The framework's construct was discussed in Chapters 2 and 3. The methodology used to test the framework and the results of the test were presented in Chapters 4 and 5. Given the correlation of the actual project cost data with the linguistic data there is evidence that the framework is an effective decision support tool to understand first cost impacts, and by extension, a tool that can be used in new ways to understand how to approach a sustainable project where first cost barriers must be bridged or managed.

The framework is comprehensive in nature, in that it can be used with multiple sets of criteria or strategies (various versions of LEED, UMN, USAF, HOK, BREEAM, etc.). The framework allows for innovation and is inclusive of the planning, design, construction, owner actors, and of the built environment process. Additionally, it is a logical extension of the built environment process that presented a unifying application of multi-disciplinary integration beyond that of whole building design state of the art. The framework is also a tool that can be adapted to most facility and infrastructure applications because it functions as a process decision support system forming the foundation and structure to bridge between the elements of the built environment process and sustainability for the actors of the built environment process regardless of the typology of requirement. Figure 6-5 is a graphical representation of this.

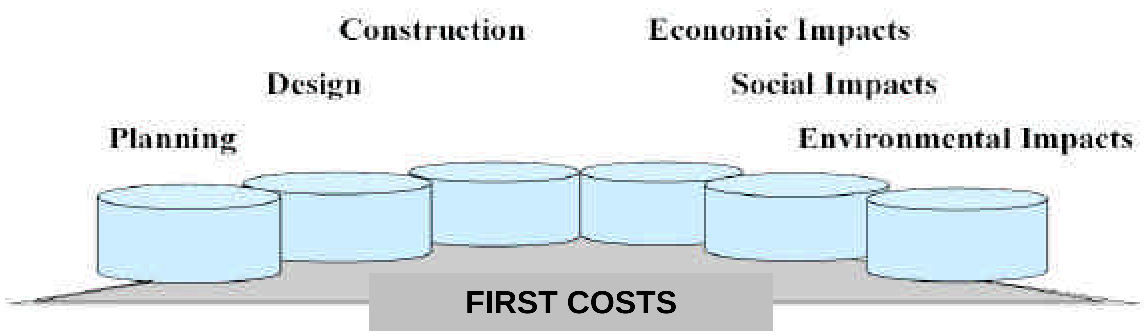

Figure 6-5 The Foundation of the Framework as a Bridge

The framework presents a way to understand how cost impacts are interconnected throughout the process, and how integration of the planning, design, and construction (phases) through a breakdown structure of their key sub-processes (factors) can be further extended to the cost impact decisions (strategies) present in all of the factors of each of the phases. It allows a more comprehensive understanding beyond the normative disciplines of the built environment process in ways that the actors can better predict how each specific activity of the process impacts the costs of the other actors throughout the process. As such, the cost impact framework introduces a new tool for professionals in each of the built environment phases to communicate the planning, design, and construction strategies of a project and how each might impact the first costs of the project. Further, it allows an owner to understand when and how to leverage an investment as a green outcome. The overall structure for the interconnected elements of the framework as bridge is shown in Figure 6-6.

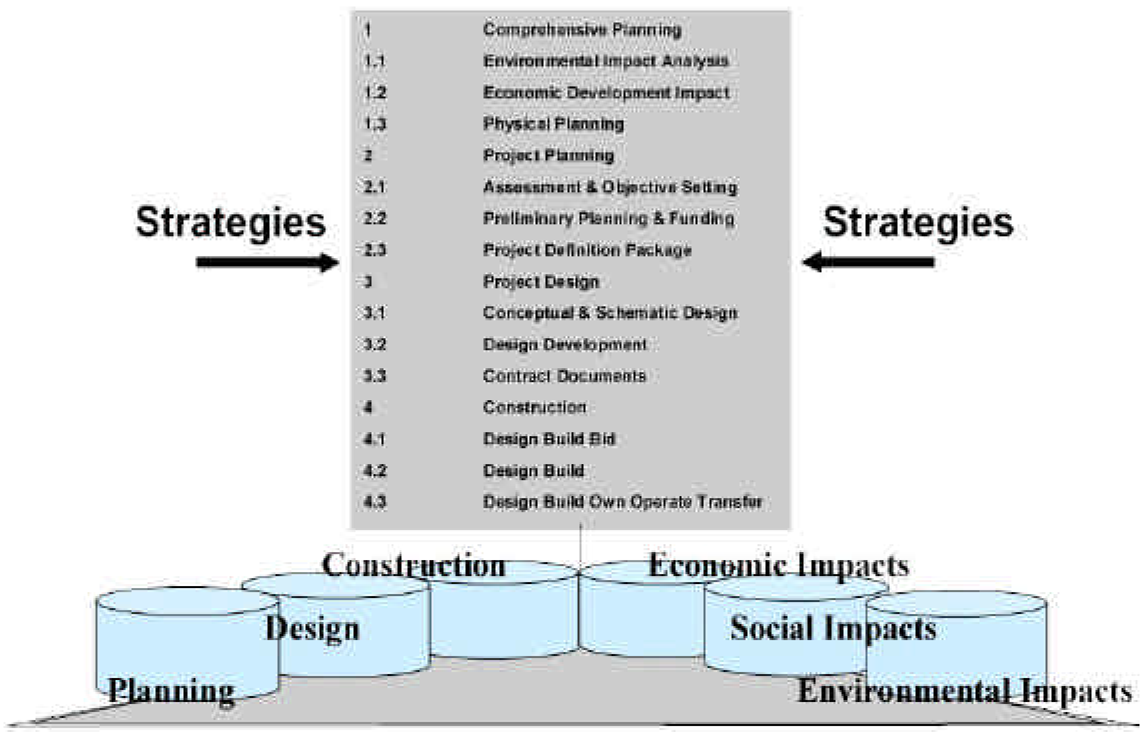

Figure 6-6 The Cost Impact Framework as a Bridge

The three contrasting arrays of actual project cost data with the linguistic cost data gathered through the interviews (Table 5-9), exemplify that the framework is universal in its application. Additionally, it shows that regardless of the nature of the data, it presents a new way to understand first cost impacts. The framework can be used by planners as a communications tool (Table 5-3), by designers as a project planning tool (Table 5-4), and by constructors and owners (Table 5-6) as a management tool for any phase of the process. The data collected and analyzed for this investigation supports that its more contributory use might be for planners and designers who have the intent to introduce greater economic acceptance for sustainable projects and or manage first cost impacts for already planned sustainable projects (Tables 5-3 and 5-4). The next sections discuss outcomes from this work but were not defended as contribution.

6.3 Outcome: Extending the Built Environment Process for Cost Optimization

This investigation extends and reinforces the logic of using the built environment process (Figure 2-1) with respect to capital project performance (Vanegas, 2001). The literature and Dr. Vanegas' previous work set the stage for this aspect of the contribution. Inherent in the built environment process, was a realization that at each step of the process, risk and cost was introduced and accumulates as the process transitions from factor to factor and from actor to actor (Figure 3-1). By tracking the increments of first costs through the built environment process, a clearer understanding of the overall first cost impacts was created. Thus, a fundamental aspect of the design of the framework was the conceptualization of the framework around the fundamental elements of the built environment process. The cost elements and risk generators across the process are not fully or readily understood today. The adaptation and extension of the built environment process to a framework allowed the cost and risk generators to be presented with respect to each other, manifested as values for sustainability strategies, and associated with each part of the process and its accountable actor, resulting in a more comprehensive understanding at the project level. The data in Table 5-7 and subsequent analysis illustrated that this is very likely for the planning, and project planning phases, likely for the follow-on design and less conclusive for the construction phase. This is an area beyond the scope of this investigation where more research is warranted.

The broader aspect of the framework as a cost optimization process is that it extends the general theory of whole building design and design integration (intra- and inter-disciplinary) to the entire process and that this is needed for sustainable design to be optimized. Cassidy (2003b) and Mendler (2000) briefly introduced this notion but did not present it as such. There was little evidence in the literature and in practical application of how best to do this with respect to first cost optimization or that by doing so, first costs could be reduced. This investigation supports that, not only is it optimal, but that within the built environment process, first cost elements can be isolated successfully. The underlying principle for this extension was presented in Chapter 2 as one of several principles—that sustainable design is more about process and resource driven efficiency for planners, designers, and constructors, than a movement. This investigation supports the principle that sustainability with respect to design and construction is more about resource efficiency, by understanding its first costs and treating them integrally in the context of their delivery processes and the built environment process as a whole.

Elements of the analysis support findings that present and defend this as the case. An example proves helpful in communicating this aspect of the built environment process extension. In the project planning factor, the task is to define the objectives, parameters, scope, and context for a project. When this approach is taken by the designer and the owner as a logical integrated activity in harmony with the environmental and comprehensive planning factors, inefficiencies can be avoided. Specifically, a project planner typically is the sole internal actor for permitting. If this role is shared with the environmental planners and the owner, typical permitting issues and delays can be minimized by introducing project context and definitional alternatives for the permits thus reducing process costs, delays, and possibly introducing synergized outcomes to solve multiple issues like storm water management, targeted economic development needs, or other environmental issues.

The findings (Tables 5-3 and 5-4) support that the most significant negative first cost impacts occur among the integration of the planning and project planning factors where a large percentage of the first cost impacting strategies and decisions are typically made. This is an example of a fundamental tenet in the theory of sustainability, extended to the built environment sometimes referred to as a *factor multiplier* (Hawken et al., 1999). There are potentially significant first cost drivers that can become resolved concurrently, and mutually, through integration and by understanding cost issues in harmony rather than through isolated process actions (Dunn & Steinemann, 1998). The apparent self fulfilling prophecy that *sustainability costs more*, is a myth when one considers that this research presents a more straightforward explanation that a comprehensive process flow of cost impact information leads to lower first costs when the entire process is optimized for first cost through framework based activity and actor integration.

6.4 Outcome: The Planning Phase and the Planners

The analysis of the planing phase presents supporting evidence that the opportunities to reduce the first costs of a green project occur far earlier in a comprehensive and integrated delivery process than in a normative project delivery process. The knowledge outcome resident for planning is that an earlier and integrated focus on how projects and growth can be synergized rather than authorized, controlled, or allowed through permitting or other control mechanisms, is warranted. Stated as a process integration mandate, public planners should move beyond the more common regulatory stance, and see themselves as integral actors impacting all phases of the built environment process to encourage planning outcomes for less cost.

This mandate is further complicated when it comes to sustainability because of the three competing values present within the WCED concept of sustainability. For planners and the planning community, the elements of environment, economics, and, social equity must be harmonized, as well as fulfilling their larger role in the shaping of the first cost impacts for green design and construction. Figure 2-2 presents this sustainability planning concept and suggests that as a consensual framework, planning had reached a turning point sometime around 1992-1995. Planning professionals are long overdue in finding more effective tools to integrate these competing values. When this is further examined using the first cost impact framework, the cost impact findings suggest that even with broad agreement in place, this framework remains unconnected from the typical planner's agenda as a mechanism to make a difference. The first cost impact framework presents an opportunity to be the mechanism to better connect the planning actors to ways to carry out their planning aims and achieve the harmony inherent in the sustainability model. The analysis supports the need for a much higher level of planning integration with respect to breaking through for first costs. An integrated process perspective for planning can reduce first costs and create positive synergistic planning outcomes. Additionally, a planner should recognize through the built environment based framework of cost impact analysis that the desired planning outcomes can be delivered without significant additional first costs, and perhaps even negative first costs, if they are operating integrally as part of the process rather than as a largely independent part in the initial sequence of the process. There are some exceptions however.

A specific example as an exception to this is presented in the findings (using the LEED V2.0 planning strategies). Normative experience suggests that urban redevelopment and in-fill development (commonly used and current planning strategies) should have a lower first cost impact than brown field development (less common). The data indicates otherwise and is an area where more extensive first cost research should be conducted. This exception while not conclusive, does suggest that integrating planners in the entire built environment process can yield synergistic outcomes. In this case the re-use of a blighted brown field for potentially less first cost than an urban in-fill site might prove synergistic.

Planners within the planning process and across the specialty disciplines of planning, should adopt an inclusive perspective and operate integral to the built environment process as a means to achieve their ends as well as support designers, constructors and owners of green projects.

6.5 Outcome: The Project Planning and Design Phases

The project definition phases, compared to the planning phase, are more integrated within the built environment process. This is also reflected in the current literature and in actual practice today. Within the project planning phase however, the findings support that it is the point in the process where the lowest first cost impacts can be achieved. Understanding and focusing on the costs associated with the project planning decisions is likely to yield the first cost breakthroughs more so than any other part of the process. For example, the Homestead AFB Fire Station (discussed in more detail in Chapter 3) requirement was developed, with two project planning alternatives. This would not generally have been done, but was accomplished with the decision to champion a green project on the base. Option one was a complete green field replacement on an adjacent site and removal of the existing facility. The second was an adaptive re-use planning concept and an integrated delivery approach on the same site, re-using 80% of the reinforced concrete framing, the foundations, and utility corridors, and re-manufacturing the vehicle bay doors. The working scope and features were similar beyond these elements. The cost difference for the integrated solutions delivery of the adaptive re-use plan was a negative 28%, demonstrating that preliminary project planning (to include the delivery methodology), when focused within the built environment process, can yield first cost breakthrough results.

This is not necessarily the case throughout the entire phase of the process. There is little differentiation in first cost impacts between the factors of preliminary funding strategies and project schematic design strategies when executed in the traditional design-bid-build delivery methodology. The findings of the research in this area suggest that regardless of the strategies employed, whether common or not, the first cost impacts are relatively the same. Taken a step further, it also suggests that decisions made with respect to schematic alternatives include a much more comprehensive understanding of the costs associated with each alternative or at least the preferred alternative.

Methodologies exist to do such costing without the benefit of the more refined design development information. A useful capability of the sustainable cost impact framework is the ability to analyze and compare project definition strategies. Continued use of the framework to capture and synthesize project data over time will allow comparative costing among strategies for the project definition and within varying delivery strategies.

The findings suggest the project design development phase presents the opportunity to address first cost impacts on a very wide scale, at differing scopes. The ranges of impacts are stratified by discipline and technology. In the mechanical, electrical and plumbing (MEP) area, the higher cost impacts and less common use suggest more research and development are needed to overcome the technology gaps that differentiate optimizing energy performance at the 20% versus the 60% levels. While it stands to reason, it is nonetheless a fruitful area for reductions in first costs, because of the operating costs of energy and the complexity and initial costs of many HVAC systems today. Significant first cost breakthroughs will likely result when the high level optimizing MEP technologies proposed for development now are mature in the market place.[1] In Chapter 2, a likely maturation curve was presented (Figure 2-3). The literature suggests that optimal and mature MEP systems are the likely critical path technologies to achieving normative status by 2015. A relative question for academic research in the area of the built environment today is whether current research programs are reflective of this need. While beyond the scope of this research, a comprehensive assessment of facility energy research is needed across the related disciplines and bodies of knowledge to focus on this question.

Other disciplines within the design development phase present higher levels of development, which suggests correspondingly lower first cost impacts for the strategies reflective of their knowledge base. A relatively mature set of strategies with low to no first cost impacts have evolved rapidly in the past two years. The architectural strategies of low or no volatile organic compound (VOC) emitting materials, be it paint, carpet, adhesives or wood products are good examples. These strategies and other similar ones tie directly into the topic of Indoor Air Quality (IAQ) and human health. IAQ liability for designers is the fastest growing area of professional responsibility across the entire built environment process (Jackson, 2003). As the linkage between the emissions from other materials becomes better known, the first cost impacts are likely to decrease reflecting a growing demand in the U.S. commercial building market. Currently however, the analysis of the findings support uniform lower first cost impacts for most strategies except the MEP optimizations. This is indicative of a phase in the process that is maturing and approaching a normative plateau. Taken collectively, from the first cost impact data, it is becoming clear that green design and construction is already reflecting a major shift for the industry.

The path forward for the designers calls for a focused development of technical strategies that support higher levels of innovation. The LEED V 2.0 strategies used in this analysis represent the start of literally thousands of design strategies that will ultimately comprise the palette of green design over the next ten years. Designers today should begin with a fundamental understanding of how the materials they specify are representative of the fundamental elements of a larger construction process as well as resources from their environments. Knowing the composition of the materials they specify, the impacts generated by their creation and use, and the waste streams associated with their depletion is a necessary expansion of the sustainable design body of knowledge.

6.6 Outcome: The Construction Phase, the Constructors, and the Owners

Experience and interview responses suggest the construction phase is moving forward rapidly to form a solid interconnectedness to the fundamental tenets of sustainability. Necessarily dependent on the design phase and the designers, the construction phase appears to be pacing its prerequisite phases in applications theory, strategy development, and advanced technology within the construction strategies. As this rapid shift continues, the construction industry will enjoy expansion in many areas, as it remains specifically focused on sustainable outcomes.[2]

Concurrent with the rapid growth of green construction is the expansion of design-build as an interdependent shift in project delivery methodology. Consequently, attribution of the sustainable design and construction cost impacts in meaningful ways require analysis with respect to the principal project delivery methodologies of Design-Bid-Build, Design-Build, and Design-Build-Operate-and-Transfer. The findings associated with each methodology reveal several consistent themes that should help frame the agenda of forward progress for the construction phase and its actors with respect to first cost impacts.

Construction waste management practices, markets for re-use materials and recyclable materials have a consistent but high first cost impact. What this suggests is that normalization of the new strategies, methods, and markets are needed. The U.S. is currently experiencing the emergence of such a recycling industry by the Chinese development of a strong recycle and re-smelting market for steel. Gypsum, cement, and other mineral based construction products thought to have little re-use or recycle value are being sought for some applications in emerging markets where the understanding of their constituent elements generates potential re-use.[3] Materials engineering and science should be more connected to the project delivery process of future construction as competition finds new ways to create value and reduce costs through the elimination and re-use of far higher quantities of materials than ever before. More targeted research is needed in this area.

Another consistent finding across the construction delivery methodologies is the use of concurrent and post construction IAQ programs. Conversely, with the growing desire of owners and users, the construction industry as represented by the interviewees, sees these as not common and with a high first cost impact. While IAQ is an emerging science in and of itself (Cassidy, 2003b; Kozlowski, 2003), this view and the first cost impacts associated with it need to be more fully researched to determine what the cost issues really are. New IAQ conformance strategies, and a greater understanding of the substitute materials and methods to achieve the higher IAQ standards are needed as well. There appears to be limited preventive or new construction related training or education available to the construction industry to keep up with the demand for better IAQ construction outcomes.[4] This is an immediate need, as health related research continues to tie human health issues to impacts from the built environment. Health research, except as a building typology is not a likely partner in the general built environment process today, but very well might be a significant indirect partner in the near future.

Building commissioning has a higher first cost impact for the design-bid-build, and design-build delivery methodologies. As anticipated, the limited data reflects a relative lower first cost impact when viewed within the design-build-operate-and-transfer method. While the rationale might seam obvious, the respondents, when asked to elaborate, did not associate uncertainty or risk with the lower first cost, but did indicate time as a factor. What this suggests is that there is a need to evaluate more extensively how building commissioning methods are developed and what time constraints are imposed. The analysis of the findings suggest that performance based delivery is a shift in thinking within the built environment process model. As owners become more involved in their building investments, one can logically expect the commissioning strategy within the construction phase to garner more attention and demand (von Paumgartten, 2003). Like the IAQ area, performance based building commissioning is a relatively new aspect of construction. It demands a far closer and more in-depth understanding of the design intent and a much higher integration of specialists, designers, constructors, and owners. Commissioning as a professional service is in its advent.[5] It follows that as a green strategy more research into how best to achieve the designed performance of the systems comprising the built environment will be needed. Until better ways to integrate the process, formulate effective performance based compliance strategies and standards are developed and adopted by state regulators, the first costs impacts for building commissioning will likely remain high.

Owner's roles as actors across the built environment process are evolving. As anticipated, the owner's expectations of the construction phase for the design-build and design-build-operate-and-transfer methods for their green facilities vary significantly from that of the constructors. The issues of IAQ, commissioning, and resource efficient outcomes spring from the desire to see their investments in different ways than past normative practice. The limited interview data suggests that a shift to a more involved and cognizant owner is underway. The impacts will likely be felt across the entire process. Creating new and responsive business practices within the traditional professional activities to this more engaged and demanding client-owner will be needed and is yet another area for future research. The first cost impact of this shift in roles requires some focused research beyond the scope of this investigation. Regardless, as better informed and more active owners enter the built environment process, these client-owners will bring new challenges to the traditional ways that will impact the normative planning, design, and construction business and profitability. Business practices will necessarily have to react to survive. Clearly more understanding is needed in this area as well.

6.7 Outcome: The Sustainable P-D-C as a Virtual Team

Built environment process integration has emerged as an important outcome of this research into first cost impacts analysis for sustainable facilities. Specifically, within the concept of process integration is a strong need for adequate communication about the planing environment, the context of the project requirement, the intent of the project, the goals inherent in the concept designs, the strategies, the technologies, and the ways to transform mental processes into tangible results (developed from Roberts, 1994).

The built environment process model is comprised with multiple transition points where communications about a project should happen seamlessly from actor to actor. Understanding how these various actors linguistically value the first cost impacts creates a pattern of findings that upon reflection suggest that the first cost impact framework can also function as the common denominator for seamless project first cost communications. Essentially, it has the potential to be a virtual team *play book* for a pattern of communications that closes the gaps around the first cost impacts if used by all of the actors in a consistent and meaningful way. Some gaps in understanding will always be present, because the actors in the process are only human. Creating the correct fabric or pattern of communication that generates opportunities for each actor to reach across their traditional functional or discipline based boundary is one of the biggest challenges to overcoming the first cost impacts.[6] A focused research effort in behavioral science and interpersonal communications might be a way to begin to understand how such a pattern could be developed and bring new thinking to the process of communication within the set of actors of the built environment. Regardless, it stood out as a transactional issue separate from any particular factor or strategy that holds significant implications with respect to the first costs of sustainable projects. The need exists for greater teamwork developed around clear and consistent communications that are focused on the desired goals and outcomes especially for green projects. When the actions of the planners, the designers, the constructors, and the owners are integrated across the process, significant progress will be made in advancing and normalizing green design and construction with respect to its first costs.

The next chapter presents a recap of the research design, the overall contribution and it's use, and provides a high level summary of the investigation. Additionally, it provides a short discussion on parallel efforts with respect to understanding the first costs of green design along with topics warranting further research uncovered in the investigation.

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[1] The National Renewable Energy Laboratory R&D programs are supporting prototypical MEP systems beyond the narrow field of renewable energy. They have developed robust grant programs for efficiency and optimization needs as well. (http://www.eere.energy.gov/buildings/highperformance. Retrieved on September 27, 2004.)

[2] The Associated General Contractors (ACG) of America web site is replete with information on how the construction industry is pushing forward in this area. From high level awards to firms like Skanska and Turner, to sustainable construction technology applications for project execution. As this continues, the opportunities to break through the first cost barriers will continue to grow for this phase of the framework (http://www.agc.org/ page.ww?section=Green+Construction&name=Green+Construction+Website+Links. Retrieved on September 27, 2004).

[3] The standards and material specs for these types of recyclables are fast becoming endorsed within the Federal procurement guidelines driving up their acceptance within the construction industry (http://www.epa.gov/epaoswer/non-hw/procure/products/cement.htm. Retrieved on September 27, 2004).

[4] While the focus on constructor's IAQ training appears to be limited, the forensics and design related training is robust.

[5] This site discusses the origin and start of the Building Commissioning Association, the first professional association for practitioners of this service (http://www.bcxa.org/about/start.shtm. Retrieved on September 27, 2004).

[6] Experience and feedback from the experts during the interview process brought the need for better project team communications to light.

CHAPTER 7

SUMMARY AND AREAS FOR FUTURE RESEARCH

7.1 Overview

This chapter summarizes the flow of the work from the basis of the research design, the objectives, and the results of the preliminary analysis, to the proposed cost impact framework, and the analysis and findings of its test. The discussion progresses to the framework and its use, and provides a self-assessment of the research with respect to its design, method, and assumptions. Additionally, it discusses the parallel investigation initially introduced in Chapter 3, in the form of a draft white paper on sustainable design with a section dedicated to first and life cycle cost issues. The white paper, produced by a volunteer committee of advocates was commissioned by the Building Design and Construction Magazine (Cassidy, 2003b). This chapter then presents some brief but relevant comments received on the framework and its application following a presentation made to the Corporate Advisory Board for the Civil Engineer Research Foundation of the American Society of Civil Engineers (ASCE). The chapter concludes with some thoughts on green design and construction rating systems, and a re-capitulation of the areas identified throughout the work warranting further research.

7.2 The Flow of the Research

The design of the research chose boundaries that were intentionally broad in as much as the work was based on four bodies of knowledge (Figure 1-5), a very complex and yet evolving process (Figure 2-1), a conceptual model of sustainability (Figure 1-2), and multiple functional actors as the elements for creating a framework for first cost analysis of sustainable planning, design, and construction projects (Figure 4-6). The flow of the work was to develop an understanding of first cost impacts from a preliminary analysis where largely only relative linguistic case study project data was available (Chapter 3) and by extension, create a framework based approach (Chapter 4) for broader project first cost analysis. This design approach for the framework was presented in Chapter 4, Figures 4-2 through 4-5. A broad-to-narrow-to-broad analytical approach hourglass model, (Chapter 5) was used to test the framework by populating it with linguistic and actual cost data and analyzing the results. Finally, the assessment (Chapter 6) of the findings and analysis created a broader understanding, and further developed and articulated the knowledge contribution. In working with the linguistic data, approximate reasoning, fuzzy set theory and mathematics, were used to manipulate the data. While uncommon, it is not unique and is a valid analytical tool for the data available and the topic of sustainability. Four other researchers have completed investigations involving the topic of sustainability with imprecise data using fuzzy sets as the basis for their analysis (Chang et al., 1997; Munda et al., 1995; Opricovic & Tzeng, 2002; Reynolds et al., 2003).

7.3 The Research Objectives

The research objectives sought through this investigation and presented in Chapter 1 (Section 1.4) have been achieved. Some of the principal drivers of higher first costs have been identified through a comparative approach with normative design and construction across a common process model. The preliminary analysis presented in Chapter 3, the data gathered and its analysis in Chapter 5 presented these drivers and discussed their first cost impacts using the framework created through this investigation. This investigation of the built environment process activity and embedded design decision communications led to a way to create a higher level of process integration, which led to the cost impact framework presented in Chapter 4. The collective outcome of achieving the research objectives (contribution) was the framework and its use.

Throughout the investigation the cost drivers were studied with respect to the actors, and those actors acted upon, which yielded insight into ways to begin to optimize the built environment process for use in first cost impact analysis. For example, when the planners who form the context for a project are included in the project definition activities, first cost impacts can be optimized through the adoption of mutually synergistic strategies. The cost impact framework created a tool to allow this higher level of coordination and cost impact analysis to occur. The same level of integration is designed to occur through the rest of the factors in the framework. More detailed work in the area of process optimization at the factor level is needed, but was beyond the scope of this investigation.

The process changes needed in normative practice to create more comprehensively integrated planning, design and construction teams are resident in the cost impact framework and no longer compartmentalized and limited by functional boundaries. The process improvements are embedded in the framework by integrating the functional and discipline-specific activities through the use of robust project communications for the project planning design and construction decisions. Dr. Pearce also makes this point in her work at Georgia Tech, promoting higher levels of integration among design professionals (Becker, 2004). However, the path to more integration is not solely more communication. Educational models need to be changed as well so that future practitioners have the opportunity to avoid today's first cost barriers. This is yet another important area for further research. With respect to today's challenge however, project management tools like chartering the entire project delivery team and gaining team endorsement for the desired outcomes should be undertaken far earlier in the process than they are typically done today. While basic, this investigation did reveal a strong need for green project teams to focus far greater multi-functional and cross-discipline effort on the initial phases of the built environment process where many of the committed costs are framed.

7.4 Cost Impact Framework and Its Use

As a bridge, the framework connected two models, the built environment and the sustainable infrastructure models. Operating like a decision support system, the framework in effect, bridged the models with a structure of sustainable strategies that are reflective of the many planning, design and construction decisions taken in the course of delivering a project (Figure 6-6). The bridge should be viewed and used as a two-way bridge, with both directions leading to accelerated use of sustainable planning, design, and construction. One direction through forward chaining, is for the use of planners, designers and constructors, and the opposite direction, through back chaining, is for the use of owners, and policy makers. This allows the framework to be used both as an actual project tool, and as a support tool for policy decisions regarding sustainable outcomes. To understand this use more completely refer back to Figure 2-1. The model depicts multiple stakeholders, many more than the principal process actors. It is in this larger context where the framework has its greatest value. It allows a method to communicate complex decisions to many stakeholders by linking the decisions of the process in a holistic but largely sequential manner.

Practical use of the framework is best described through a scenario. Assume the military service had a requirement to plan and build facilities as a new use for an existing installation. Because the framework is scalable, the process would start in the planning phase with the planners assigning desired cost and technical parameters to the planning factors and strategies to be used based on the need for the change and all other relevant constraints. A meeting of the actors with accountability for the new use (owners), the stakeholders with decision influence for the change (non-planners and other functional actors), and the planners would occur to map their current state cost impacts to each factor and strategy. This would be followed with a similar mapping for the desired state. Alignment within the meeting participants, perhaps with the aid of chartering or endorsement techniques, while analyzing the mapped data, would then result in an existing and desired end state and the technical and cost gaps differentiating the before and the desired states. This would be followed with a series of preliminary trade up, trade off, trade down decisions, linking the technical and cost impacts and reflecting their decisions in a meaningful way. This creates an integrated view of the planning strategies, which then would be carried forward and linked to the project definition phase of the process following similar integrated option analysis and trade off exercise, except for using the appropriate group of actors for the project definition phase. The method would continue for the remaining phases and actors until the entire process is framed for technical and cost impact. With respect to a building, the planning state would likely be a given set of assumptions and the trade off process of mapping cost impact by design strategies would begin in the project definition phase and be focused on technical design decisions rather than planning decisions since the cost impacts for the planning are already part of the overall framework. The process would continue in a similar fashion for the remaining phases and factors.

Outside of a scenario based application, a project team for a facility project with all of the actors present would begin the use of the framework with the desired strategies in the framework and their understanding of the cost impact for each strategy mapped to it. With the entire process mapped, inspection, pattern detection, qualitative coding, and perhaps causality techniques of analysis, similar to the test presented in Chapter 5 would be followed and used to form the integrated project decisions with respect to cost impacts. This is essentially a design to cost approach but executed across the entire delivery process and within the framework.

7.5 Assessment

The following assessment of this investigation is focused on its base, the research design, the method of analysis, the choice of design criteria, the way innovation was incorporated, and the data used. The intent of this section is to offer the reader a point of departure for the work, and set the stage for the areas of future research uncovered in the work.

7.5.1 The Research Base, Design, and the Methodology

The research was based on a generally accepted theory of how sustainability relates to facility and infrastructure projects – Sustainable development as a conceptual framework (Figure 1-3). This Georgia Tech pioneered effort (Pearce, 1999) has been widely taught, challenged, and accepted over the past several years. It has been the object of mimicry in propriety frameworks and has been adopted in part and in total by many sustainable development practitioners. As theory, it is the most concise in the literature today. The second model underpinning the work is that the research incorporates and extends the built environment process model also pioneered at Georgia Tech and extended by Dr. Vanegas and is the continued focus of refinement and development. This model was recently extended into a more complex model of capital project performance enhancement (Vanegas, 2001, 2003) that captures in diagrammatic format a system of systems. It too, represents a strong base with respect to modeling and process analysis. The third element of this work's base is its research design. As depicted in Figure 1-5, the design of this research involved sequential and interdependent steps. The point of departure and preliminary analysis allowed a conceptual framework to emerge upon which the research hypothesis could be tested. The application of imprecise data through a qualitative approach using multiple analytical techniques supported a test of the framework and validation of the framework as a contribution. This overall approach developed with the advice of the author's research committee, along with the application of fuzzy set theory to manipulate the data allowed assimilation of the data into meaningful assortments that in current literature has been used as an appropriate approach when working with the sustainability body of knowledge.

7.5.2 The Choice of Design Criteria, the Project Typology, and Innovation

There are, as in any complex investigation, key assumptions underpinning this work. As discussed in Chapter 3, there are many possible sets of sustainable design and construction criteria used in the U.S. After review, the LEED™ Version 2.0 was chosen as the basis for the development of a larger set of strategies for the framework. It was selected because of its high level of acceptance in the U.S, its broad base of interdisciplinary use, and its familiarity for use in the interview process. Additionally, and as discussed in Chapter 3, it incorporates in concept most of the other strategies resident in other rating systems. Similar to the other non-governmental standards like the National Fire Protection Association standards, the owner-developer of the LEED Rating Systems, the United States Green Building Council (USGBC) reports that it is rapidly nearing a consensus standard status.

There are three other assumptions in this research that warrant further discussion. The first is the typology of the projects undertaken by the interviewees. Most interviewees have professional practice associated with the Federal Departments of Defense, Energy and Transportation. Accordingly, the work relies on this federal experience, which may not carry over to the private sector. The second assumption was to test the framework in the absence of expert strategies. While innovation was in the list of LEED V2.0 strategies it may not fully account for expert based high end innovation. To elaborate, the interview process by design, did not allow the interviewees to address innovation directly as a strategy because the data would be stand alone and without a basis for comparison. However, the interviewees were asked to provide additional comments. Several of their comments presented innovation strategies to offset first cost impacts. Broad innovation in planning, design, and construction methodology can quite possibly generate significant negative first cost impacts. [The Homestead Fire Station project was discussed precisely to raise this point (Tables 3-10 and 3-11).] As a mitigating measure, the cost impact framework was supplemented with a final section for the expert phase. This phase is where project specific innovative strategies beyond the

LEED V2.0 strategies should be added. As the practice of sustainable planning, design, and construction matures, one can expect to see innovation alter the first cost impacts, as rapidly and significantly as value engineering does in normative design and construction today. The third assumption is in the analysis of the construction phase of the framework, specifically factor 4.3 (Design-Build-Operate-and-Transfer). Typically, it is the purview of the largest of construction companies and the government. Linguistic data on first cost impacts for projects that transcend the entire built environment process would likely be yet another separate research effort in itself. The data for this factor should only be thought of as possible and not predictive. Further research is needed to understand first cost impacts when the actor is a large firm who is also the owner prior to transfer, and the cost impacts are governed more by life cycle analysis then first cost impact.

7.5.3 The Projects and the Data

The complexity of the topic was the basis for the considerable effort to create a specific research design. Narrowing the topic was accomplished to the point where the data was available to carry out the work. The test of the framework was largely based on linguistic data derived from federal work accomplish in the past five years (1998-2003) for industrial/administrative project types ranging from $4 million to $21 million in constructed value including new construction, renovation, and historic projects. While the foundation (sustainability, and the built environment models) is solid, the available data requires an expert systems approach and was not a statistically based analysis. As an expert system, the interviewees and their data were assumed to be reflective and inclusive of all actors for all disciplines associated with the design and construction of principally green projects. The interviews included architects, planners, ecologists, landscape architects, civil engineers, site-civil engineers, electrical engineers, mechanical engineers, plumbing engineers, construction managers—both for fee and at-risk, and owners with varying engineering backgrounds. Additionally, the expert group members all had at least 26 years of relevant experience with most over 30 years. (The interview selection criteria and interview protocol are located in Appendix C and D.) This expert systems approach is an acceptable approach given the complexity of the research and current state-of-the-art for sustainable design and construction as a body of knowledge. Additionally, because of the dynamic nature of the topic, the literature search was continued throughout the entire investigation and care was taken to supplement and qualify the 81 principal findings when the literature provided the basis for such. A final consideration is that the data gathering approach was time sensitive to the experience of the interviewees, their time constraints and willingness to elaborate on their answers and valuations at the time of their interview.

7.6 Parallel Research and the Sustainability Rating Systems

Reflecting on Figure 1-5, the four principal bodies of knowledge that comprised this investigation represent a collective knowledge base that is added to almost daily in many significant ways. The body of knowledge for sustainability alone is one of the fastest growing research areas for the government, academia, and even the private sector. The interest in exploring, promoting, and accelerating sustainable planning, design, and construction is pervasive and intriguing for professionals as well as educators and researchers. The intrigue for many of the interviewees of this work stemmed from its sensibility as an intuitive understanding that there are better ways to use our resources for the built environment. Across the United States, the shift to providing some level of initial education regarding sustainability can be readily seen in the curricula of our high schools and universities. More specifically, the leading design and engineering institutions have grasped the sustainability principles and are incorporating them into the science and the art, which help form their base. This appears to be leading a change in the way we think about sustainability (Steinemann, 2003). It is this paradigm shift (Pearce, 1999) that warrants the engagement of the best in both academia and professional practice.

The professional practice arena recognizes the importance and the need for research in this area. At the invitation of the Chairman of the Corporate Advisory Board for the Civil Engineering Research Foundation (CERF), ASCE, this research was included in a half-day panel on the topic of advancing the practice of sustainability. Specific and positive feedback included the strength of its base with the use of the Pearce and Vanegas conceptual models, the cost impact framework as a useful decision support tool, and many of the more relevant findings with respect to specific strategies (Mogge, 2004).

In yet another similar initiative, the editor of *Building Design and Construction*, Robert Cassidy, led the development of a White Paper on Sustainability (2003b). The paper presented survey information from his magazine's readership and addressed many of the currently debated topics regarding sustainability. In one specific section, the question of, *Do green buildings cost more to build?* was addressed. The answers parallel this research remarkably well. It was found that there is a general pricing premium in the market for green buildings that ranged from 2.5% to 7.0% in the 2000 to 2003 time frame. The White Paper also cited the work of Geof Syphers (Syphers, et al., 2003, cited in Cassidy 2003b), a building services manager with KEMA Xenergy in Oakland, California, who offered five reasons (shown in Table 7-1) for this pricing differential.

Table 7-1 KEMA Xenergy's Findings for Green Building Cost Deltas

1.	Lack of a clear green design goal.
2.	Incorporating green design in mid-project.
3.	Lack of a single point of responsibility for the LEED process.
4.	Lack of experience with or knowledge of LEED.
5.	Lack of time to research materials and technologies options.

Syphers' findings are not surprising, and are consistent with this research. This author's investigation extended beyond these findings and confirmed that there are many aspects of the built environment process that when optimized by use of the cost impact framework, will yield first cost break through opportunities. The development and use of the cost impact framework can also be modified to be independent of a specific set of strategies and offers an enduring and transformational approach to breaking through the barriers through process re-engineering. Nonetheless, it is helpful that this important parallel effort has come to similar conclusions.

Another parallel effort going beyond the first cost topic but related, is the work of Gregory Katz (Katz, et al., 2003). Katz, the founder of the firm Capital E, based in Washington DC, concluded through his work that, it is possible to achieve a Certified (LEED) rating at little to no added cost while a LEED Silver or Gold rating requires a 1.5-2.0% premium over the certified building (Katz, et al, 2003). He also presented a strong life cycle cost [Net Present Value (NPV)] argument citing leverage ratios of 10:1 over a 20-year term with an average 5% real inflation value.

There are some challenges created by this focus on first costs that warrant some final cautions and discussion. Embedded in much of this parallel work is a very strong reliance on the USGBC's LEED™ Rating System. Along with a LEED V2.1 update in 2004, the pilots LEED Existing Buildings (EB), Core and Shell (CS), and Commercial Interiors (CI) will be introduced soon.[1] This revolutionary expansion of the now defacto rating system in the U.S. will likely drive an inordinate amount of attention to the system versus the purpose of the system. In much of the current literature, one gets the impression that getting the Silver or getting the Gold is the quest. If the rating is strictly just a symbol of performance then perhaps this is acceptable, but there is more than this happening in the market. The commercialization of green buildings is on the verge of eclipsing a fundamental part of the original purposes (1) to achieve higher resource efficiency in the built environment, and (2) to advance the practical and theoretical basis for the art and science of green planning, design, and construction consistent with the tenets of sustainability. It can not be solely about getting the silver, it must fundamentally be about good planning, design, and construction outcomes that are far more resource efficient, healthy, and productive places to live, work, and play.

7.7 Areas for Further Research

Reflecting on the bodies of knowledge comprising this investigation, and the scope of this work, there remains a huge need and much value to be gained from more research and advancements on the topic of sustainability and first cost breakthroughs. Throughout this work, these areas have been identified. When taken collectively it is clear there remains much work to do. The need to continue to explore, extend, and advance the topic area is certainly present, as is the case for the multiple topics in the area of sustainable planning. The design and construction areas are also equally fertile, be it the functional relationships and risk transfers in delivery methods, the criteria used, or the development and incorporation of new and better strategies.

The following list has been created to summarize all of the areas for further research identified in this work. It also attempts to honor the fundamental principle offered by Hawken (Hawken et al., 1999), by establishing an order that reflects an approach of the right thing, in the right order, at the right time, thereby establishing a loose priority through logical relationships of these topics for the future researchers and readers.

- A need exists for a complimentary framework to guide sustainable planning in a way that allows a far stronger conceptual connection to the built environment process (Section 2.10).
- A need exists to create the project requirement and definitional process for owners that does not necessarily default to the traditional facility solution model (Section 2.10).
- A need exists to re-engineer a business and communication process that allows the players in the earlier phases of the built environment process to collaborate at much higher levels (Section 2.10).
- A need exists to develop a new set of project planning principles with respect to green design and first costs with the aim of extending this work and enhancing the potential for break through (Section 3.4).

- A need exists to develop materials optimization concepts and methods to drive higher efficiencies into the design and construction phases (Section 3.7).
- A need exists to model the risk and uncertainty transfers from actors within the process in the latter phases of the process (Section 3.9).
- A need exists to create technology for MEP systems that can cost effectively achieve 30-60% efficiencies over today's technology. The DOE 2.0-1E grant program supports this need (Section 5.4.4).
- A need exists in the operations research area to better understand how commissioning costs are created and when they should be introduced in the built environment process (Section 5.4.8).
- A need exists to develop and extend this work with a comparative cost model for other building types that links their linguistic values to known actual costs (Section 5.7.1).
- An urgent need continues to exist to better and more rapidly understand how the indoor environmental quality of the built environment relates to current and future human health issues (Section 6.6).

This research is only the start; perhaps it is a bold first strike at the challenge of transformational change for our industry and the owners we serve. The enduring challenge to engage, study, and contribute is present for all who are willing, able, and ready.

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[1] info@usgbc.org email response retrieved on May 13, 2004.

APPENDIX A

INITIAL SURVEY INFORMATION AND SAMPLE OF LITERATURE REVIEW DOCUMENTATION

INITIAL SURVEY INFORMATION

This survey was developed in May of 2000 in the problem definition stages of the research to informally gather expert practitioner views of the barriers to sustainable design. As an informal survey, it was given to the 24 practitioners of the initial Austin, Texas working meeting on Greening Federal Facilities conducted by the Department of Energy. The author participated as the representative for the United States Air Force. The survey questions were developed around the announced meeting agenda and discussion. The survey was performed at the conclusion of the meeting. 21 of 24 meeting participants responded.

Sustainable Planning, Design, and Construction Survey

1. Current professional literature on sustainable design and construction practices in the U.S. suggests the following are barriers to their broad use. Please rate (1-5) the relative significance of each barrier (five is the most significant).

   A. Project Definition ___________
   B. Building Owner's Acceptance ___________
   C. A-E Expertise ___________
   D. Green Material Availability ___________
   E. Initial Cost ___________

2. Please list any additional barriers to the broad use of sustainable design and construction in the U.S. you believe are more relevant than the lowest of those above.

3. A competitive business advantage for building owners of sustainable facilities in the U.S. might result from the following outcomes. Please rate (1-5) the relative importance of each outcome (five is the most important).

   A. Life Cycle Cost Savings ____________
   B. Greater Stakeholder Satisfaction ____________
   C. Innovative Facility Solution ____________
   D. Ecological Correctness ____________
   E. Initial Cost ____________

4. Please list any other possible outcomes for owners of sustainable facilities in the U.S. you believe are more important of than the lowest of those above.

5. Current professional literature on sustainable planning and development in the U.S. suggests the following barriers to their broad use. Please rate (1-5) the relative significance of each barrier (five is the most significant).

   A. Limited Public Policy _______________
   B. Commercial Support _______________
   C. Professional Expertise _______________
   D. Demands for Growth _______________
   E. Political Reasons _______________

6. Please list any additional barriers to the broad use of sustainable planning and development in the U.S. you believe are more relevant than the lowest of those above.

Please provide any additional comments regarding the use of sustainable planning, development, design and construction you wish to offer.

If you would like to receive a summary of these surveys, please provide your e-mail address below. Thank you very much for your help.

SUSTAINABLE PLANNING, DESIGN, AND CONSTRUCTION SURVEY RESULTS

These results were compiled by simple arithmetic averaging and are not presented as a statistically based study. They are simply indicators from 21 of 24 workshop participants. [The responses were totaled then ordered as to relative significance. Comments from the participants were paraphrased and consolidated for similar responses.]

1. Current professional literature on sustainable design and construction practices in the U.S. suggests the following are barriers to their broad use. Please rate (1-5) the relative significance of each barrier (five is the most significant).

   A. Project Definition **5**

   B. Building Owner's Acceptance **2**

   C. A-E Expertise **4**

   D. Green Material Availability **1**

   E. Initial Cost **3**

2. Please list any additional barriers to the broad use of sustainable design and construction in the U.S. you believe are more relevant than the lowest of those above.

   - **Discount rates-2**
   - **Operating budgets vice capital construction budgets-2**
   - **Business practices and a lack of education by architects on the construction aspects**

- **Building site suitability-2**
- **Owners interest-2**
- **Lack of real health and energy comfort data to determine how to design-3**
- **Management mindset that green costs more/construction agent or company that green cost more-2**
- **Not enough A-E fee to spend hours researching solutions-2**
- **Education of clients and building owners-2**

3. A competitive business advantage for building owners of sustainable facilities in the U.S. might result from the following outcomes. Please rate (1-5) the relative importance of each outcome (five is the most important).

   A. **Life Cycle Cost Savings** **5**

   B. **Greater Stakeholder Satisfaction** **3**

   C. **Innovative Facility Solution** **1**

   D. **Ecological Correctness** **2**

   E. **Initial Cost** **4**

4. Please list any other possible outcomes for owners of sustainable facilities in the U.S. you believe are more important of than the lowest of those above.

- **Productivity of building occupants**
- **Perception that sustainable facilities are more valuable and command higher lease rates**
- **Perception that building owners (management) really cares about their employees**
- **Harmony with the natural site and its surroundings**

- **Environmental leadership**
- **Possible investment advantage by the financial community-NPV to PPV**
- **Reducing operating costs for energy and other non renewable energy sources-2**
- **Integration of the installation development plan for reduction of utility costs**
- **Social influence on non-believers**

5. Current professional literature on sustainable planning and development in the U.S. suggests the following barriers to their broad use. Please rate (1-5) the relative significance of each barrier (five is the most significant).

    A. **Limited Public Policy** **4**

    B. **Commercial Support** **5**

    C. **Professional Expertise** **2**

    D. **Demands for Growth** **3**

    E. **Political Reasons** **1**

6. Please list any additional barriers to the broad use of sustainable planning and development in the U.S. you believe are more relevant than the lowest of those above.

- **Lack of knowledge**
- **Belief that green cost more**
- **Current master planning rules**
- **Not taken seriously**
- **Planners not given the time or the funds to analyze alternatives**
- **Not integrated with design teams-3**
- **Few good widely publicized examples-2**

- **Owners/stakeholders don’t realize the tradeoffs**
- **A-E understanding of integrated design-3**
- **Bench marking or rating system for macro-planning-3**
- **Commitment of Congress**

Please provide any additional comments regarding the use of sustainable planning, development, design and construction you wish to offer.

- **To be successful it all (design and PLANNING) must be integrated**
- **More international cooperation—many European countries are far ahead of us**
- **Constant monitoring of commissioned buildings to actually achieve the LC savings**
- **Lack of public awareness—in the country of abundance**
- **Need one integrated DOD program vice separate service programs**
- **They are all needed to solve the density problems of older installations**
- **Issues of incorporation, need to provide education as a tax credit for the construction community to learn how to do sustainable construction**

If you would like to receive a summary of these surveys, please provide your e-mail address below. Thank you very much for your help.

12 of the 21 respondents wanted to receive a summary of this informal survey.

jwm 08/2000

SAMPLE OF ON-GOING DOCUMENTATION OF LITERATURE REVIEW

Basic Reference Locator Data: GTEC **Control No** B-1

Research Topic: Sustainable Design and Construction

Type of Reference: Book ISBN 0 273 62207 2

Reference ID Number: HD 30.255.F87 1996

Location: Georgia Tech Library

Data Entry (Books): **Publication Date:** 1996 **Hardcopy:** Yes

Author(s): Claude Fussler with Peter James

Book Title: Driving Eco-Innovation

Book Subtitle n/a **Volume** n/a **Edition** n/a

Publisher: Pitman Publishing

Location (City/State) 128 Long Acre, London UK, WC2E 9AN

REMARKS: 9 March 2000

Summary

Essence:

The book makes the point that businesses producing sustainable goods and services will gain a competitive advantage over status quo businesses and eventually overtake then in the market. It represents an approach to innovation through eco-efficiency and advanced quality process evaluation to assist businesses to start the sustainable journey.

Highlights:

-Business builds competitive advantage through radical and generational innovations

-Business sustains advantage through incremental product improvements

-Financial considerations are constraints vice determinants

--Determine the pace and the approach
--Are ultimate measures of performance

<u>Driving Eco-Innovation</u> continued

Business in the future will be shaped by aspirations for sustainable development

--Irresistible forces of population growth, consumer aspirations in convergence with non-renewable resources and complex eco-systems
--Unsustainable processes and products will end
-Eco-innovation can change products and processes to enhance customer service, improve quality of life, and radically reduce environmental impacts

-Business benefits of sustainable development

--Ecological Security
--Resources Security
--Socio-economic Security

-"Sustainability is a business language", the three securities create three imperatives

--Reconcile environmental care, quality of life with consumption
--Build environmental care into goods and services through clean processes and distribution systems
--Create value through goods and services which provide quality of life

-Accept the eco-efficiency challenge; use the eco-compass to design

Shortcomings:

-An advocacy approach which needs more of an objective balance

-Broad assumptions, specifically applied offer room for debate

-Absence of differing views and reasons to discount them

-Demographic extrapolations are clearly debatable

-Advanced quality process improvement applications are not really advanced, they are more appropriately current state of the art

-Difficult to move from chapter to chapter, some logic gaps

-Not really a comprehensive "business book"

-Virtually unknown in business literature, although the author is a Dow Chemical VP

Evaluation and Analysis

Why this reference?

-This book was chosen specifically from the business collection to determine the state of the art for sustainable development. It was found through a key word search starting with; sustainable development, and competitive advantage. Additionally, this author has published similar articles in technical journals on the subject.

<u>Driving Eco-Innovation</u> continued

-I hope to use aspects of the competitive advantage achieved for sustainable development and apply them to my area of research

Is the reference relevant?

-The book is very relevant with respect to sustainable design and construction and incorporates the business perspective of competitive advantage I am looking for.

-The development of sustainable goods and services actually extends directly in the construction arena in terms of materials manufacturing and materials engineering. It is a natural extension, although incomplete, to the building design and construction sector.

-The aspects of service life extension, adaptive reuse, recycling, and life cycle assessment are virtually the same in concept.

-The book presents an excellent framework to help put the environmental issues in context with the business issues.

What was learned?

-Sustainability through technical development or innovation requires a long term view

--Can take decades to travel from idea to products

--"S" curve can help predict when innovation can be pushed at the least cost in the conservative building technology sector

--Early innovators/adapters must be cautious about when uninformed customers will accept innovation in facility ownership

--Three actions to make innovation work in facility design are needed

---Address the fundamental long term needs

---Reinvent winners before they slow down

---Replace winners before the competition does

-Technology explosion will migrate to all aspects of the design and construction sector paralleling the demographic growth

-Look to technology to help drive eco-innovation

-Sustainable development (manufacturing) asks a key question that has an important "competitive advantage" for design and construction processes

-How can we change our designs and construction processes to enhance (customer service) facility quality while radically reducing environmental impacts and improving quality of (life) the built environment?

<u>Driving Eco-Innovation</u> continued

-The agenda of the 70's 'Limits to Growth" proved untrue and the challenge is to embrace growth by

--Finding ways to grow in sustainable ways, the aspect of sustainability and consumption as difficult partners is the challenge

-Beliefs that income drives happiness (consumption spending and quality of life) are not supported by the data

-In a "Nat Cap" world there should be growing markets for products and services (built environment). This would drive a fundamental economic shift from

--Supply to demand
--Products to service
--Over supply to lean service
--Articulated to unarticulated needs

-Four principles for sustainable lifestyles also apply to the aspects of competitive advantage for design and construction

--Rationalize access (work from home vice commute)
--Act communally (create desirable communal facilities that reduce cost, energy and use materials more efficiently)
--Circulate goods (durability and service life extension)
--Buy service not products (own carpet/lease carpet)

-Customer/clients need to help through sustainable marketing to articulate their needs

--Successfully progressive (i.e. competitive advantage holders) will rarely wait to see all of the answers but will instead set out to create the market of the future

-Where does competitive advantaged sustainable design and construction start?

--Primary function to be served
--Other benefits the function offers
--Is there a long term need /demand
--What is its potential value (impact ratio per product)
--Is it sustainable in a population of 8 billion
--Are there more sustainable ways of meeting this facility need

-Better accounting methods are needed to take into consideration

--Savings on raw materials and energy
--Elimination of expensive end of the pipe solutions
--Increased competitiveness through new technology

-Most environmental costs are not allocated to products (designs) therefore existing financial structures are distorted (overhead takes away from profit)

<u>Driving Eco-Innovation</u> continued

-By using activity based costing (ABC) and costing based on full visibility and unit cost per output, light is shed on the true environmental costs and would drive different behavior. ABM and sustainability are business languages.

-Clean production is parallel to clean construction

--Changing to clean construction requires
---Changing attitudes
---Applying know how
---Improving technology

-A competitive advantage is gained in design and construction by creating additional value through environmental actions (re-use, recycle, reduce etc)

-The Eco-compass or a similar concept could be used as a design tool/guide

-The "Factor System" of exponential value and environmental impacts (ways to quantify decisions based on anticipated outcomes, "a factor 10 decision")

-Universal currency is energy

-The principle dimensions of designing for the environment in manufacturing are closely parallel in design and construction

--Reduce material mix
--Design for commonality
--Durability and disassembly
--Recyclability

--Environmental Health
--Safety Standards
--Customer environmental needs

-Do not under-estimate the "feel good" factor in business

-Approach design as an eco-efficiency challenge (translated for design and construction)

--How can you redesign the facility to significantly improve its performance?
--Select options that create the maximum value for the company/client
---Find ways to extend service and function
---Increase the use of renewable resources and conservation
---Increase the use/reuse and revalorization of wastes
---Decrease the energy intensity
---Reduce the human health and environmental risk
---Reduce the mass intensity

-Competitive Advantage is not just about money but greatly depends on innovation based on creating value through the application of sustainable design and construction principles

-Competitive Advantage can be gained through linking innovation and eco-efficiency

-Customer demand and short-term value creation are prerequisite drivers of sustainable design and construction.

<u>Driving Eco-Innovation</u> continued

-Business development integrates three orbits, the market domain, the monetary domain and the governance domain and (adapted for design and construction) balances customer needs with affordability of design to create innovations that leverage capabilities while managing costs

Contributions To The Research

-Book represents the most current thinking on sustainable development that closely parallels sustainable design and construction

-Fundamental discussions on business development can be readily adapted to my research

-Principles offered by the author are useful in thinking about design and construction approaches to cost effective sustainable design

-An overarching theme that anticipation of market demands, integrated with an understand of material challenges supports a parallel sustainable design and construction concept of better up-front planning and management of customer expectations

--This can be one of the keys to developing a competitive advantage

-The author supports life cycle assessment as an effective and necessary tool in all sustainable enterprises (some of the literature in the technical journals doesn't)

-The principle theme of "Driving Eco-Innovation" can be adapted and used effectively in the sustainable design and construction arena and the manners in which competitive advantage are generated for sustainable development (business) are indirectly applicable

-As a business collection book, it brings together the parallels of profit, market, customer needs, competition, and innovation I needed to better understand the fundamentals that drive competitive advantages for business and that result in value creation and profit for business

Citations for Use

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APPENDIX B

ALIGNMENT OF FRAMEWORK AND STRATEGIES TO INTERVIEWS

ALIGNMENT OF FRAMEWORK AND STRATEGIES TO INTERVIEWS

Alignment of the disciplines with phases, factors, and strategies was based on the qualifications of each interview candidate and generally followed their current professional occupation with respect to the phases of the framework.

In general, the strategies provided the fundamental criteria to align the design discipline based on the nature of the strategy (see Figure 2-1). For example, mechanical engineers were aligned to the project planning and design development strategies for MEP optimization at differing percentages of performance.

With respect to the planning and construction phases and factors, the general qualifications of the interviewee candidate were aligned to the phase and factor. Planners were screened for their specific planning strengths and assigned accordingly. Landscape architects, planners, and site civil engineers rated the planning and project planning phases as appropriate. Architects were assigned to project planning, conceptual development and design development factors. Civil engineers with site development expertise and civil engineers with structural expertise were assigned to the design development and so on and so forth. For example, the constructors were aligned to the construction phases and rated all delivery methods with the assumption that both at risk and construction management for fee experience was not a distinguishing aspect of their understanding of first cost impacts. This approach allowed the factor rating to be focused on the delivery method as it was integral with the strategy (see Chapter 4 for additional discussions). The owners were assigned to multiple phases, factors, and strategies reflecting their likely decision making roles through out the process. Finally, the experts were broadly assigned to factors and strategies reflecting their qualifications and backgrounds—thus experts for those strategies. For example, Mr. Nelson is a noted expert on indoor environmental quality. Ms. Morse is a noted expert in sustainable planning, the natural step, and other ecological technologies tied to sustainable planning.

ALIGNMENT OF FRAMEWORK AND STRATEGIES TO INTERVIEWS

BE Phase	Factors (Strategies)	Actor(s)
1.0 Planning (Environmental, Economic, and Physical)		
1.1 Planning	Site Selection	Planner
1.1 Planning	Alternative Transportation, Locate Near Public Transportation	Planner
1.1 Planning	Storm water Management, No Net Increase or 25% Decrease	Site Civil
1.1 Planning	Storm water Management, Treatment Systems	
1.2 Planning	Urban Redevelopment	Planner
1.2 Planning	Brown field Redevelopment	Planner
1.3 Planning	LEED Accredited Professional	All
1.3 Planning	Reduced Site Disturbance, Development Footprint	Arch, Civil, LA
2.0 Project Planning (Project Definition and Development)		
2.1 Design-MEP	Minimum Energy Performance	Arch, Elec, Mech
2.1 Design-Arch	Storage & Collection of Recyclable Materials	Arch
2.1 Design-MEP	Renewable Energy, 5%	Elec, Mech
2.1 Design-MEP	Renewable Energy, 10%	Elec, Mech
2.1 Design-MEP	Green Power	
2.1 Design-Arch	Recycle Content, Specify 15%	Arch, ID
2.2 Design-SC	Reduced Site Disturbance, Protect or Restore Open Space	Planner, Civil, LA
2.2 Design-Arch	Alternative Transportation, Bicycle Storage & Changing Rooms	Arch
2.2 Design-SC	Alternative Transportation, Alternative Fuel Refueling Stations	Site Civil; Mech
2.2 Design-SC	Alternative Transportation, Parking Capacity	Site Civil
2.2 Design-SC	Reduce Heat Islands, Non-roof	Site Civil
2.2 Design-Arch	Rapidly Renewable Materials	Arch
2.2 Design-Arch	Reduce Heat Islands, Roof	Arch, Struct

2.2	Design-Arch	Building Reuse, Maintain 50% of Existing Shell	Arch, Struct
2.2	Design-Arch	Building Reuse, Maintain 75% of Shell	Arch, Struct
2.2	Design-Arch	Building Reuse, Maintain 100% Shell & 50% Non-Shell	Arch, Struct
2.2	Design-Arch	Recycle Content, Specify 50%	Arch, ID
2.3	Design-MEP	Elimination of HCFC's and Halons	Mech
2.3	Design-MEP	Minimum IAQ Performance	Mech, ID
2.3	Design-MEP	Environmental Tobacco Smoke (ETS) Control	Mech, ID
2.3	Design-LA	Water Efficient Landscaping, Reduce by 50%	Land Arch
2.3	Design-LA	Water Efficient Landscaping, No Irrigation	Land Arch
2.3	Design	Innovation in Design—Multiple strategies	All
2.3	Design	LEED Accredited Professional	All
3.0	**Design (Conceptual Design, Design Development, Contract Documents)**		
3.1	Design-MEP	Innovative Wastewater Technologies	Civil, Mech
3.1	Design-MEP	Water Use Reduction, 20% Reduction	Arch, Mech
3.1	Design-MEP	Water Use Reduction, 30% Reduction	Arch, Mech
3.1	Design-Arch	Lighting Pollution Reduction	Arch
3.1	Design-MEP	CFC Reduction in HVAC&R Equipment	Mech
3.1	Design	Measurement and Verification	Arch, Civil, Mech
3.1	Design-MEP	Carbon Dioxide (CO2) Monitoring	Elec,
3.1	Design-MEP	Increase Ventilation Effectiveness	Arch, Mech
3.1	Design-Arch	Controllability of Systems, Operable Windows	Arch
3.1	Design-MEP	Controllability of Systems, Individual Controls	Arch, Mech, Elec
3.1	Design-MEP	Optimize Energy Performance, 15% New 5% Existing	Arch, Mech
3.2	Design-Arch	Resource Reuse, Specify 5%	Arch
3.2	Design-Arch	Resource Reuse, Specify 10%	Arch
3.2	Design-Arch	Certified Wood	Arch
3.2	Design -Arch	Low-Emitting Materials, Adhesives	Arch, ID
3.2	Design-Arch	Low-Emitting Materials, Paints	Arch, ID
3.2	Design-Arch	Low-Emitting Materials, Carpets	ID

3.2 Design-Arch	Low-Emitting Materials, Composite Wood	Arch
3.2 Design-Arch	Indoor Chemical and Pollutant Source Control	Arch
3.2 Design-MEP	Optimize Energy Performance, 20% New 10% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 25% New 15% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 30% New 20% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 35% New 25% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 40% New 30% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 45% New 35% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 50% New 40% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 55% New 45% Existing	Arch, Mech
3.2 Design-MEP	Optimize Energy Performance, 60% New 50% Existing	Arch, Mech
3.2 Design-MEP	Thermal Comfort, Comply with ASHRAE 55-1992	Mech
3.2 Design-MEP	Thermal Comfort, Permanent Monitoring System	Mech
3.2 Design-Arch	Daylight and Views, Diffuse Sunlight to 90%	Arch
3.2 Design-Arch	Daylight and Views, Direct Line of Site 90%	Arch
3.2 Design	Innovation in Design—Multiple strategies	All
3.3 Design	Sign and Seal -- LEED Accredited Professional	All
3.3 Design	Innovation in Contract Procurement—Multiple strategies	All
3.3 Design	Green Tax Incentives, Federal Grants, & Subsidies	All
3.3 Owner Operator	Green Tax Incentives, Federal Grants, & Subsidies	All

4.0 Construction (Project Delivery Method)

(Design-Bid-Build)

4.1 Construction	LEED Accredited Professional	
4.1 Owner Operations	Fundamental Building Commissioning	Com Authority
4.1 Owner Operations	Minimum Energy Performance	Arch, Elec, Mech
4.1 Construction	Construction Waste Management, Salvage or Recycle 50%	
4.1 Construction	Construction Waste Management, Salvage Additional 25%	
4.1 Construction	Local / Regional Materials, of 20% Manufactured Locally	

4.1 Construction	Local / Regional Materials, of 20% Above 50% Harvested Locally	
4.1 Construction	Construction IAQ Management Plan, During Construction	Com Authority
4.1 Owner Operator	Construction IAQ Management Plan, Post Construction	Com Authority

(Design-Build)

4.2 Construction	LEED Accredited Professional	
4.2 Owner Operations	Fundamental Building Commissioning	Com Authority
4.2 Owner Operations	Minimum Energy Performance	Arch, Elec, Mech
4.2 Construction	Construction Waste Management, Salvage or Recycle 50%	
4.2 Construction	Construction Waste Management, Salvage Additional 25%	
4.2 Construction	Local / Regional Materials, of 20% Manufactured Locally	
4.2 Construction	Local / Regional Materials, of 20% Above 50% Harvested Locally	
4.2 Construction	Construction IAQ Management Plan, During Construction	Com Authority
4.2 Owner Operations	Construction IAQ Management Plan, Post Construction	Com Authority

(Design-Build-Own-Operate-Transfer)

4.3 Owner Operations	LEED Accredited Professional	Constructor
4.3 Owner Operations	Fundamental Building Commissioning	Com Authority
4.3 Owner Operations	Minimum Energy Performance	Arch, Elec, Mech
4.3 Owner Operations	Construction Waste Management, Salvage or Recycle 50%	Constructor
4.3 Owner Operations	Construction Waste Management, Salvage Additional 25%	Constructor
4.3 Owner Operations	Local / Regional Materials, of 20% Manufactured Locally	Constructor
4.3 Owner Operations	Local / Reg Materials, of 20% Above 50% Harvested Locally	Constructor
4.3 Owner Operations	Construction IAQ Management Plan, During Construction	Com Authority

4.3 Owner Operations	Construction IAQ Management Plan, Post Construction	Com Authority

5.0 Expert Outline Factors

APPENDIX C

PARTICIPANT SELECTION CRITERIA, FINAL LIST OF INTERVIEWEES, AND EXPERT GROUP BIOGRAPHICAL SKETCHES

PARTICIPANT AND EXPERT INTERVIEWEE PROCESS

The following steps outline the process used to identify, narrow, recruit and select the interviewees and experts for the test of the cost impact framework. The process will be described in more detail and the process relationships are shown in Figure C-1.

- Identify pools of potential interviewees (3 pools).
- Develop master list of interview candidates from the pools (109 candidates).
- Establish selection criteria for candidates (5 filters) and experts.
- Recruit and screen potential candidates.
- Finalize candidate and expert participation.
- Conduct interviews and clarify responses if needed.

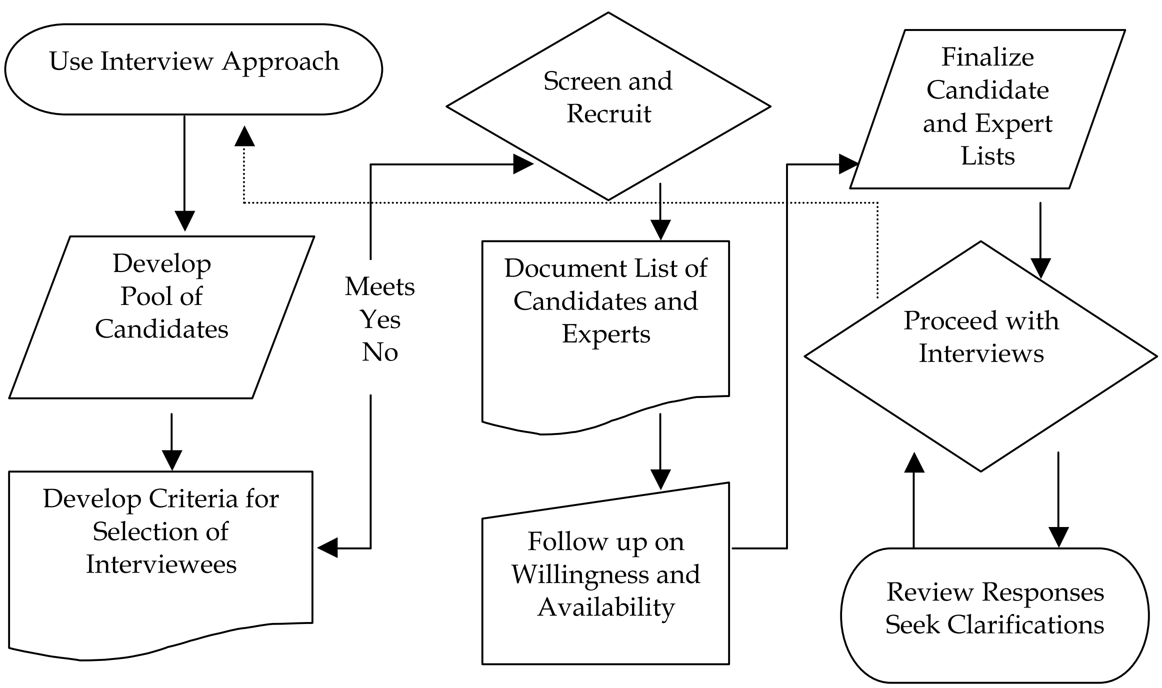

Figure C-1 Participant and Expert Interview Selection Process

The potential pool of interviewees was developed from three primary sources of practitioners; 1) AIA Committee on the Environment, 2) CH2M HILL Sustainability Community of Practice, and 3) general green building practitioners, other consultants, constructors and owners who the author was either knowledgeable of or has worked with on green building projects.

This initial filter was to ensure the potential candidates had experience with green building. The second filter was to determine each candidate's interest in and availability to participate in the survey. The third filter was to determine if each candidate was a LEED accredited professional and if yes, what their general level of acceptance was for the USGBC's rating systems. The fourth filter was to determine their level of expertise with respect to their primary and secondary role(s) as an actor in the proposed cost impact framework. The final filter was to determine if their work had included any in depth focus on first costs of sustainable building and if that work predisposed their objectivity.

For the expert group three additional filters were employed. From the first screening of candidates, potential expert group candidates were then filtered by more than 4 years of related experience with green building. The four year period, prior to 1999 through 2003, would give this group both exposure to the developmental period and the start of the growth period and thus significant experience beyond just the LEED rating systems. The next filter was willingness to provide more depth to their responses and review responses from other similar disciplines. (This step later proved unnecessary.) The final filter was a qualitative one as being generally recognized within their field for their experience in this area. The lists were then finalized and aligned to the framework based interview sets.

INTERVIEW LIST & EXPERT GROUP BIOGRAPHICAL SKETCHES

Table C-1 Interviewee List

Phase	Name *	Location **	Discipline	Yrs/LEED
Planner		DFB	E. Planner	20/N
		ATL	E. Planner	14/N
		CCP	S. Planner	25/N
		WPB	Land Arch	4/N
		WPB	Land Arch	16/N
Designer		WPB	Arch	22/Y
		WPB	Arch	20/N
		WPB	Arch	16/Y
		WPB	Arch	21/Y
		SFO	Arch	25/N
		WPB	Arch	12/N
		LAX	Arch	30/Y
		WPB	Civil	21/N
		WPB	Civil	16/N
		WPB	Civil	26/N
		WPB	Struct	10/N
		GNV	Struct	22/N
		GNV	Elec	23/N
		GNV	Elec	20/N
		CVO	Mech	15/Y
		CVO	Mech	16/Y
		GNV	Mech	15/N
		GNV	Mech	20/N
Constructor		DEN	CM At Risk	26/N
		GNV	3rd Party CM	28/N
		DEN	CM At Risk	28/N
		GNV	CM At Risk	20/N
		ATL	3rd Party CM	18/N
Owner		ATL	Planner	30/N
		USAF	Programmer	26/N
		USAF	Planner	16/N
		USAF	Arch	33/N
		USAF	MEP	25/N
		USAF	Operations	20/N
Expert Group	Morse L.	SFO	Planner	26/N Planner
	Orlowski T.	WPB	Arch	30/N Designer
	Pontek B.	WPB	Civil	30/N Designer
	Nelson N.	RDH	MEP	33/Y Designer
	Hurley L.	DEN	CM at Risk	30/N Constructor
	Culpepper H	USAF	Owner	33/N Owner

* *Names masked by request.*

** *Location is nearest major airport designator or organization*

EXPERT GROUP BIOSKETCHES

Hilton Culpepper, P.E. (Owner)

- HQ Air Force Reserve Command (AFRC) Assistant Civil Engineer
- BSCE Electrical Engineering, Auburn University

Mr. Culpepper is a career federal civil servant and functions as the assistant to the MAJCOM Civil Engineer. He provides direction for the representative ownership, stewardship, and operation of 12 military installations consisting of more than 10,000 acres, 1,000 buildings and 12 million square feet of facilities. The plant replacement value of these installations is $4.5 billion. From these installations and 55 other locations from which AFRC units operate, the command provides 20 percent of the Air Force's total capability at a cost of 4 percent of the Air Force budget.

Mr. Culpepper began his professional career as an electrical operations engineer with Georgia Power. In 1970, he transferred to federal service and began as an electrical design engineer with the Robins base civil engineer organization. In 1973, he transferred to Headquarters Air force Reserve Command as an electrical design manager. In 1983, he became Chief of Facilities and Utilities Branch at the headquarters. Mr. Culpepper was promoted to program manager (O&M and MILCON) for 11 bases and units in 1986 and subsequently again promoted to Chief of Civil Engineer Operations for the Command in 1990. Mr. Culpepper assumed his present duties in 1994.

Mr. Culpepper manages the Air Force Reserve military construction requirements of more than $683 million. Additionally, he provides day-to-day management of a professional headquarters staff functionally organized into five divisions, planning and programming, engineering design, environmental management, operations, and readiness.

Lawrence G Hurley (Constructor)

- Senior Vice President CH2M HILL
- Bachelor of Science - Iowa State University, 1981
- Professional Engineer, TX

Special Qualifications

- Managed development of over $2 billion in transportation design-build highway projects over the past 7 years.
- More than 25 years experience managing heavy civil and petrochemical projects.
- Directed the administrative controls for a five-company parent organization within the transportation industry.
- Successfully managed multi-district organization with more than 500 employees.

Experience Record

Senior Vice President for CH2M Hill–Constructors, Denver, Colorado. Responsible for developing CH2M Hill's "at-risk" transportation construction division by identifying and securing design-build and joint venture opportunities within the transportation industry.

Director of Design-Build for Zachry Construction Corporation, Civil Group, San Antonio, Texas (2000–2001). Responsible for identifying and developing design-build and joint venture opportunities within the United States and specifically in Texas. Within the last 12 months secured short listed positions on two EDA projects in Austin, Texas and currently have a third sole-source project under negotiations with the Texas Department of Transportation. These three projects reflect over $1.25 billion in EDA transportation projects within central Texas. In addition to the development of EDA projects in Texas, currently investigating joint venture opportunities in Nevada, Missouri, Florida, and Louisiana.

Manager of Design-Build for Washington Group International (formerly Morrison Knudsen Corporation), Heavy Civil Group, Boise, Idaho. Responsible for developing technical proposals for heavy civil finance-design-build projects with values ranging from $30 million to $850 million. During this period, he also served as Manager of Engineering/Estimating Services where he coordinated pre-bid documents for the estimating department which was composed of 27 estimators bidding in excess of $5 billion per year; Contracts Claims Manager with responsibilities for developing and coordinating construction claims involving heavy civil projects; and served as Chairman of Morrison Knudsen Heavy Civil Group Steering Committee charged with helping in the development of communications among group employees following a three-company merger.

Linda F. Morse (Planner)

- Environmental Planner
- Master of Architecture – University Of California, Berkeley, 1974
- B. A. Mathematics - Middlebury College, 1967

Relevant Experience

Ms. Morse is a senior project manager with specialized experience in solid waste, hazardous waste, and energy projects. She has 23 years of progressively increasing responsibility in the environmental planning field in both the public and private sectors. She has conducted facility feasibility and siting studies and assisted with permitting for solid and hazardous waste facilities, managed environmental impact reports for solid waste and bio-mass facilities, and prepared hazardous waste management plans under California's Tanner Act. She has also managed source reduction and recycling plans for several California counties and cities. She is experienced in directing and implementing public participation programs and has worked closely with city and county governments on solid waste planning projects.

Sustainability

Ms. Morse has advanced training in principles of The Natural Step and has given courses to coworkers in TNS and sustainability principles. Director of CH2M HILL's Sustainable Development Practice Group, a core team designing and implementing CH2M HILL's sustainability initiative. She serves on the City of Oakland's Sustainable Community Working Group.

Norman L. Nelson (Mechanical, Electrical and Plumbing-MEP)

- Senior Project Manager
- Bachelor of Science Mechanical Engineering - Oregon State University, 1976
- Associate Engineer Drafting Technician - Oregon Institute Tech, 1967
- Certified Engineer Technician, UNREC
- Mechanical Engineer, ID, OR, WS, CA, FL, MS

Relevant Experience

- More than 30 years experience in HVAC system design and resolving IAQ problems.
- Co-inventor of a hybrid fan coil unit (patent pending) that improves occupant comfort, increases energy efficiency, and substantially decreases initial construction cost over currently available equipment.
- Technical reviewer of two manuals on IAQ problems and building commissioning in conjunction with the Disney Development Company.
- Co-author and board reviewer for design handbook of laboratory facilities.
- Technical peer review of new facility design, representing more than $500 million dollars in construction costs.
- Expert witness for HVAC system contributions to IAQ and moisture related building failures, resulting in more than $40,000,000 in claims awarded.

Mr. Nelson has over 10 years of experience solving building-related IAQ and moisture and mildew problems. During his 30 years of engineering experience, he has been responsible for the technical issues regarding IAQ services related to building design, remediation, construction, and operation. The building types include hospitals, schools, courthouses, hotels and resorts, dormitories, convention centers, sports complexes, laboratories, clean rooms, and a variety of commercial, institutional and industrial facilities. Projects he has been responsible for, were completed throughout the 48 contiguous states, Hawaii, Alaska, the Caribbean, as well as in several foreign countries; including France, England, Egypt and Saudi Arabia. Mr. Nelson has the unique ability of combining "hands-on" field experience and in depth design engineering experience, to provide the best engineering solutions available to meet project needs.

Peer Reviews and Building Commissioning

For new building owners seeking to avoid future building problems, Mr. Nelson has been a technical reviewer of more than 30 problem avoidance (peer) reviews of facilities under design. In addition, he has been the designated commissioning agent on several commercial facilities, including; design review, construction observation, pre-commissioning test procedures, detailed commissioning test procedures, field testing, O&M manual review and training. As design engineer of record, he has participated in building commissioning and pre-occupancy performance testing of heating, ventilating, and air conditioning (HVAC) systems in more than 20 buildings over the past six years.

Robert S. Pontek (Site/Civil)

- Master of Science Sanitary Engineering - Michigan State University, 1975
- Bachelor of Science Chemical Engineering - Michigan State University, 1971
- Professional Engineer, FL, MI

Relevant Experience

Since 1973, Robert Pontek has shared his years of experience in the private sector and in the administration, operations, organization, and maintenance of municipal utilities. He has a wide range of regulatory experience including regulatory compliance and state agency involvement. As utilities director of Martin County, Mr. Pontek was responsible for the operations, administration, maintenance, permitting, Capital Improvement Programs, design, and construction of a new municipal utilities facilities consisting of water and wastewater plants, alternative supply wells, and advanced water treatment reverse osmosis and membrane softening treatments. He has extensive experience with the managed competition process and construction programs, as well as working with elected officials and municipal staff. Mr. Pontek's more recent projects include:

Fire Station No. 7 with Passive Park Facilities, City of West Palm Beach, FL. Responsible for all site civil, utilities, drainage and roadway modifications and associated permitting for this new facility located in West Palm Beach. The site is heavily saturated with wetlands and exotic species that limit the site for development purposes. There are future roadway improvements that are being examined to offer options for access by the fire equipment as well as separating park access. The site will be used by local area residents for passive recreational purposes; however, there will be connective pathways that allow walking and bike riding from this site to adjacent linear park trails and boardwalks.

Cholee Regional Park Master Plan, Palm Beach County, FL. Project scope includes surveying, environmental analysis and permitting, conceptual development of alternatives and final Master Plan. Coordination with a citizens advisory committee, Parks and Recreation Department staff, other County governmental agencies, and the adjacent community of Green acres City was required. The first design phase of this project included a $1.4 million entry roadway with water, sewer, and storm water systems.

Cholee Equestrian Center, Palm Beach County, FL. Project Manager for Phase I of a multiple phase equestrian center that serves a wide variety of equestrian needs in the Palm Beach County area. Phase I includes parking for horse trailers, trucks and transport vans, infrastructure, restrooms, covered show arena, schooling rings, support facilities, best management practices for horse waste, and master planning for future barns, show rings, and schooling rings. The facilities are unique, as they will support a wide variety of equestrian events with western, dressage, hunter, jumper, and similar events.

Thomas C. Orlowski (Architecture)

- Bachelor of Architecture - University Of Illinois, 1966
- Architect, TX, AL, FL, WI

Relevant Experience

- Experienced in alternative project delivery including design build and Construction Management at Risk.
- Expertise in the analysis and solutions of problems ranging from strategic planning to physical design.
- Responsibilities have included programming, design criteria, conceptual design, design development, working drawings, and cost estimates.
- Has provided all phases of design and production for airport and military/DoD projects.

Mr. Orlowski has over 35 years of professional experience providing all phases of design and production for private, public, and military facilities. His experience includes comprehensive planning, design, and construction administration on projects for commercial and industrial facilities, which include distribution, operations, maintenance and storage facilities, warehouses, mail and pressrooms, and military testing control centers. As a Business Vice President and the Regional Market Segment Leader for CH2M HILL's Southeast Transportation Facilities, he is responsible for overall design, coordination, contract administration, and supervision of architectural staff. Mr. Orlowski's more recent projects include:

Sumter Electric Cooperative Headquarters Facility, Sumterville, FL. Principal-in-Charge of three-story, 45,000 SF administrative headquarters facility. Building is hurricane hardened, includes an emergency operations center/auditorium, a SCADA operations center, executive offices and boardroom, open office planning for flexibility, and expansion and includes emergency generator system.

Miami International Commerce Center (M.I.C.C.), Office/Warehouse, Miami, FL. Principal-in-Charge. Oversaw the design, coordination, and completion of construction documents for six tilt-up office/warehouse facilities totaling 203,100 SF. These facilities included 1,020 linear feet of truck well dock access, and 85,360 SF of retail and office space, set in an industrial office park in the heart of the Miami trade zone.

Sarasota Commerce Park, Bradenton Development Corporation, Bradenton, FL. Principal-in-Charge. Oversaw the design, coordination, and completion of construction documents for seven tilt-up warehouse facilities totaling over 600,000 SF and two office buildings totaling 20,000 SF. The facilities included 4,225 linear feet of truck well dock access.

Field Station and District Offices Complex, South Florida Water Management District, West Palm Beach, FL. Project Manager. Responsible for programming, design criteria, conceptual design, design development, working drawings, and cost estimates. Project included a field station (82,500 SF) comprised of an office building and six pre-engineered metal buildings for maintenance of vehicles and equipment. Special features included bridge and monorail cranes, paint booths, welding shops, blasting shops, and dust collection systems.

APPENDIX D

INTERVIEW FORMS AND SUMMARY OF ADDITIONAL DATA

COST IMPACT FRAMEWORK INTERVIEW PROTOCOL

The protocol for this part of the expert based qualitative analysis began with the screening and selection process described in Appendix C and Chapter 4. This section describes the remaining part of the protocol that involved the presentation, execution and submission of the questionnaire.

Each interviewee received a phone call from the author explaining that they would receive a written questionnaire either in the mail, by email, or by fax. In every case, the interviewee had already been given verbally, and in most cases, an in-person explanation of the research, its objectives and had been told that they fit the desired criteria as an interviewee.

On receipt of the questionnaire, the interviewee already knew and had agreed to provide their responses on the questionnaire and 39 of 43 were returned. Four interviewees declined to continue citing various reasons.

The instructions were provided in writing on each questionnaire. The interviewee was asked to contact the author if he or she had any questions with respect to the instructions. Two of the 43 interviewees called with clarifying questions regarding the actor to factor to actor impact both of which were satisfactorily answered.

The interviewees answered the questions in writing and returned them to the author by email or by fax. In six cases follow up calls were made and responses provided thereafter.

1.0 Sustainable Planning, Design, and Construction—First Costs

Interview for "Planners"

Name: ____

Please answer the following questions by characterizing (your experience or opinion) the first cost impact of the following 9 sustainable planning strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project as viewed by (another or the same actor)

1. The first cost impact of *analyzing a site for sustainability* is (X) as viewed by the owner operator.

   Value:

2. The first cost impact of *alternative transportation for a facility by locating it near public transportation* is (X) as viewed by the owner operator.

   Value:

3. The first cost impact of *no net increase in storm water management requirements* on a project is (X) for the site civil designer.

   Value:

4. The first cost impact of *on-site stormwater treatment systems* on a project is (X) for the site civil designer.

   Value:

5. The first cost impact of an *urban in-fill or urban re-development* site for a project is (X) for the owner/operator.

   Value:

6. The first cost impact of *a brown field re-development* site for a project is (X) for the owner/operator.

   Value:

7. The first cost impact of *reduced site disturbance requirements* for a project is (X) as viewed by the project site civil designer.

   Value:

8. The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) for the design team.

   Value:

9. The first cost impact of *using a LEEDÔ Accredited professional* for a project is (X) as viewed by other planners.

   Value:

2.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for " Designers"

Name: ____ (HQ AFRC)

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 11 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing for the storage and collection of recyclables on a project* is (X) as viewed by the design architect.

   Value:

2. The first cost impact of *specifying 15% recycled content for a project 's materials* is (X) for the constructor.

   Value:

3. The first cost impact of *providing bicycle storage and changing rooms* for a project is (X) for the design architect.

   Value:

4. The first cost impact of *specifying rapidly renewable materials* for a project is (X) for the constructor.

   Value:

5. The first cost impact of *reducing heat reflectance by using roof heat islands* for a project is (X) for the structural designer.

   Value:

   The next several questions assume an existing site and structure is adaptively reused.

6. The first cost impact of *re-using 50% of a building's shell* for a major expansion project is (X) as viewed by all other project designers.

   Value:

7. The first cost impact of *re-using 75% of a building's shell* for a major expansion project is (X) as viewed by all other project designers.

   Value:

8. The first cost impact of *maintaining 100% of a building shell and reusing 50% of it s non-shell materials* is (X) as viewed by the other project designers.

   Value:

9. The first cost impact of *specifying 50% recycled content for a building's materials* is (X) as viewed by the other project designers.

   Value:

10. The first cost impact of *providing innovative green architectural design strategies* is (X) as viewed by the constructor.

    Value:

11. The first cost impact of *using a LEEDÔ Accredited professional* for a project is (X) as viewed by the owner operator.

    Value:

2.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Designers—Architects"

Name: ____

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 11 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing for the storage and collection of recyclables on a project* is (X) as viewed by the design architect.

   Value:

2. The first cost impact of *specifying 15% recycled content for a project 's materials* is (X) for the constructor.

   Value:

3. The first cost impact of *providing bicycle storage and changing rooms* for a project is (X) for the design architect.

   Value:

4. The first cost impact of *specifying rapidly renewable materials* for a project is (X) for the constructor.

   Value:

5. The first cost impact of *reducing heat reflectance by using roof heat islands* for a project is (X) for the structural designer.

   Value:

   The next several questions assume an existing site and structure is adaptively reused.

6. The first cost impact of *re-using 50% of a building's shell* for a major expansion project is (X) as viewed by all other project designers.

   Value:

7. The first cost impact of *re-using 75% of a building's shell* for a major expansion project is (X) as viewed by all other project designers.

   Value:

8. The first cost impact of *maintaining 100% of a building shell and reusing 50% of it s non-shell materials* is (X) as viewed by the other project designers.

   Value:

9. The first cost impact of specifying 50% recycled content for a building's materials is (X) as viewed by the other project designers.

   Value:

10. The first cost impact of *providing innovative green architectural design strategies* is (X) as viewed by the constructor.

    Value:

11. The first cost impact of *using a LEEDÔ Accredited professional* for a project is (X) as viewed by the owner operator.

    Value:

2.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Landscape Architects"

Name: ____

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 8 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing innovative on-site natural waste water technologies* (X) as viewed by the design team.

   Value:

2. The first cost impact of *irrigation water use reduction of 20%* is (X) for the constructor.

   Value:

3. The first cost impact of *irrigation water use reduction of 30%* is (X) for the constructor.

   Value:

4. The first cost impact of *reducing site disturbance and restoring open space* is (X) as viewed by the constructor.

   Value:

5. The first cost impact of *irrigation water use reduction by 50%* is (X) for the constructor.

   Value:

6. The first cost impact of *using water efficient landscaping that requires no irrigation* is (X) for the constructor.

   Value:

7. The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) as viewed by the constructor.

   Value:

8. The first cost impact of *using a LEEDÔ Accredited MEP professionals* for a project is (X) as viewed by the owner operator.

   Value:

2.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Designers—MEP"

Name: ____

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 10 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing for the minimum energy performance on a project* is (X) as viewed by the design architect.

   Value:

2. The first cost impact of *specifying 5% renewable energy for a project 's power* is (X) for the constructor.

   Value:

3. The first cost impact of *specifying 10% renewable energy for a project's power* is (X) for the constructor.

   Value:

4. The first cost impact of *specifying "green power" for a project* is (X) for the owner operator.

   Value:

5. The first cost impact of *eliminating HCFC’s and Halons* for a project’s systems is (X) for the constructor.

   Value:

6. The first cost impact of *providing for minimum IAQ performance* for a project is (X) as viewed by all other project designers.

   Value:

7. The first cost impact of *providing environmental tobacco smoke control* for a project is (X) as viewed by the constructor.

   Value:

8. The first cost impact of *providing innovative green mechanical-electrical and plumbing design strategies* is (X) as viewed by the constructor.

   Value:

9. The first cost impact of *using a LEEDÔ Accredited MEP professional* for a project is (X) as viewed by the owner operator.

   Value:

2.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Designers—Site Civil"

Name: ____

Please answer the following questions by characterizing (your experience or opinion) the first cost impact of the following 8 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project as viewed by (another or the same actor)

1. The first cost impact of *protecting or restoring open space on a project site* is (X) as viewed by the site civil designer.

   Value:

2. The first cost impact of *providing alternative refueling stations* for a project *is* (X) as viewed by the site civil designer.

   Value:

3. The first cost impact of *no net increase in storm water management requirements* on a project is (X) for the site civil designer.

   Value:

4. The first cost impact of *on-site storm water treatment systems* on a project is (X) for the site owner operator.

   Value:

5. The first cost impact of parking *capacity for alternative transportation* for a project is (X) for the owner/operator.

   Value:

6. The first cost impact of *reducing parking lot heat with landscaped islands* for a project is (X) for the owner/operator.

   Value:

7. The first cost impact of *using innovative "green" site civil design* on a project is (X) as viewed by all other project designers.

   Value:

8. The first cost impact of *using a LEEDÔ Accredited professional* for a project is (X) as viewed by site civil designers.

   Value:

3.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Designers—Architects"

Name: ____

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 18 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing for lighting pollution reduction* is (X) as viewed by the design team.

   Value:

2. The first cost impact of *incorporating sustainable measurement and verifications in integrated design* is (X) for the design team.

   Value:

3. The first cost impact of *providing controllability of systems with operable windows* is (X) for the constructor.

   Value:

4. The first cost impact of *specifying 5% resource re-use in a building's materials* is (X) for the constructor.

   Value:

5. The first cost impact of *specifying 10% resource re-use in a building's materials* is (X) for the constructor.

   Value:

6. The first cost impact of *specifying certified sustainable wood* is (X) for the constructor.

   Value:

7. The first cost impact of *specifying low emitting (VOCs) adhesives* is (X) for the constructor.

   Value:

8. The first cost impact of *specifying low emitting (VOCs) paints* is (X) for the constructor.

   Value:

9. The first cost impact of *specifying low emitting (VOCs) carpets* is (X) for the constructor.

   Value:

10. The first cost impact of *specifying low emitting (VOCs) composite wood* is (X) for the constructor.

    Value:

11. The first cost impact of requiring indoor chemical and pollutant source control is (X) for the constructor.

    Value:

12. The first cost impact of *building window design that enhances daylight and views, but diffuses sunlight to 90%* is (X) for the design team.

    Value:

13. The first cost impact of *building window design that enhances daylight and views, but eliminates 90% of direct line of site sun* is (X) for the design team.

    Value:

14. The first cost impact of *innovation in architectural design with new sustainable design strategies* is (X) for the constructor.

    Value:

15. The first cost impact of *signing and sealing construction drawings as a LEEDÔ accredited professional* is (X) for the design team.

    Value:

16. The first cost impact of *innovation in sustainable construction contract procurement strategies* is (X) for the owner operator.

    Value:

17. The first cost impact of *applying for green tax incentives, federal grants, & subsidies* is (X) for the design team.

    Value:

18. The first cost impact of *applying for green tax incentives, federal grants, & subsidies* is (X) for the owner operator.

    Value:

3.0 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Designers—MEP"

Name: ____

Please answer the following questions by characterizing (by using your experience or opinion) the first cost impact of the following 21 sustainable design strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

1. The first cost impact of *providing innovative waste water technologies* (X) as viewed by the design team.

   Value:

2. The first cost impact of *water use reduction of 20%* is (X) for the constructor.

   Value:

3. The first cost impact of *water use reduction of 30%* is (X) for the constructor.

   Value:

4. The first cost impact of *total CFC Reduction in HVAC&R equipment* is (X) for the constructor.

   Value:

5. The first cost impact of providing for carbon dioxide (CO_2) Monitoring is (X) for the constructor.

   Value:

6. The first cost impact of *providing for increased ventilation effectiveness* is (X) for the constructor.

   Value:

7. The first cost impact of *providing for the individual controllability of systems (HVAC)* is (X) for the constructor.

   Value:

8. The first cost impact of *optimizing energy performance by at 15% (new)* is (X) for the design team.

   Value:

9. The first cost impact of *optimizing energy performance by at 20% (new)* is (X) for the design team.

   Value:

10. The first cost impact of *optimizing energy performance by at 25% (new)* is (X) for the design team.

    Value:

11. The first cost impact of *optimizing energy performance by at 30% (new)* is (X) for the design team.

    Value:

12. The first cost impact of *optimizing energy performance by at 35% (new)* is (X) for the design team.

    Value:

13. The first cost impact of *optimizing energy performance by at 40% (new)* is (X) for the design team.

    Value:

14. The first cost impact of *optimizing energy performance by at 45% (new)* is (X) for the design team.

    Value:

15. The first cost impact of *optimizing energy performance by at 50% (new)* is (X) for the design team.

    Value:

16. The first cost impact of *optimizing energy performance by at 55% (new)* is (X) for the design team.

    Value:

17. The first cost impact of *optimizing energy performance by at 60% (new)* is (X) for the design team.

    Value:

18. The first cost impact of *compliance with ASHRAE 55 - 1992 Thermal Comfort* is (X) for the design team.

    Value:

19. The first cost impact of *providing a permanent monitoring system for thermal comfort* is (X) for the constructor.

    Value:

20. The first cost impact of *providing innovative mechanical, electrical, and plumbing design strategies* is (X) as viewed by the constructor.

    Value:

21. The first cost impact of *using a LEEDÔ Accredited MEP engineers* for a project is (X) as viewed by the owner operator.

    Value:

4.1 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Constructors"

Name: ____

Please answer the following questions by characterizing (using your experience or opinion) the "first cost" impact of the following 9 sustainable strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

Design-Bid-Build Delivery Method.

1. The first cost impact of *providing for LEEDÔ Accredited Professionals* is (X) as viewed by the owner operator.

   Value:

2. The first cost impact of *providing for fundamental building commissioning* is (X) for the constructor.

   Value:

3. The first cost impact of *providing for the DOE (also LEED) minimum energy performance* is (X) for the constructor.

   Value:

4. The first cost impact of *salvaging or recycling 50% of construction waste* is (X) for the constructor.

   Value:

5. The first cost impact of *salvaging or recycling 75% of construction waste* is (X) for the constructor.

   Value:

6. The first cost impact of *using 20% local/regional manufactured materials* is (X) for the owner operator.

   Value:

7. The first cost impact of *using 50% local, and 20% regional manufactured materials* is (X) for the owner operator.

   Value:

8. The first cost impact of *providing and implementing an IAQ management plan during construction* is (X) for the owner operator.

   Value:

9. The first cost impact *of meeting the minimum requirement of an IAQ management plan after construction* is (X) for the constructor.

   Value:

4.2 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Design-Builders"

Name: ____

Please answer the following questions by characterizing (using your experience or opinion) the "first cost" impact of the following 9 sustainable strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

Design-Build Delivery Method.

1. The first cost impact of *providing for LEEDÔ Accredited Professionals* is (X) as viewed by the owner operator.

   Value:

2. The first cost impact of *providing for fundamental building commissioning* is (X) for the design-builder.

   Value:

3. The first cost impact of *providing for the DOE (also LEED) minimum energy performance* is (X) for the design-builder.

   Value:

4. The first cost impact of *salvaging or recycling 50% of construction waste* is (X) for the design-builder.

   Value:

5. The first cost impact of *salvaging or recycling 75% of construction waste* is (X) for the design-builder.

   Value:

6. The first cost impact of *using 20% local/regional manufactured materials* is (X) for the owner operator.

   Value:

7. The first cost impact of *using 50% local, and 20% regional manufactured materials* is (X) for the owner operator.

   Value:

8. The first cost impact of *providing and implementing an IAQ management plan during construction* is (X) for the owner operator.

   Value:

9. The first cost impact *of meeting the minimum requirement of an IAQ management plan after construction* is (X) for the design-builder.

   Value:

4.3 Sustainable Planning, Design, and Construction—"First Costs"

Interview for "Owner Operators"

Name: ____ (HQ AFRC)

Please answer the following questions by characterizing (using your experience or opinion) the "first cost" impact of the following 9 sustainable strategies on a specific actor of the built environment process.

Values: **[No, Low-, Low, Low +, Medium -, Medium, Medium +, High -, High, High +]**

Linguistic Model: (Interview Actor) Characterize the impact (X) of (*sustainability strategy*) on the first cost of a project for or as viewed by (another or the same actor)

Design-Build-Own-Operate-Transfer Method.

1. The first cost impact of *providing for LEEDÔ Accredited Professionals* is (X) as viewed by the final owner operator.

   Value:

2. The first cost impact of *providing for fundamental building commissioning* is (X) for the final owner operator.

   Value:

3. The first cost impact of *providing for the DOE (also LEED) minimum energy performance* is (X) for the final owner operator.

   Value:

4. The first cost impact of *salvaging or recycling 50% of construction waste* is (X) for the final owner operator.

   Value:

5. The first cost impact of *salvaging or recycling 75% of construction waste* is (X) for the final owner operator.

   Value:

6. The first cost impact of *using 20% local/regional manufactured materials* is (X) for the final owner operator.

   Value:

7. The first cost impact of *using 50% local, and 20% regional manufactured materials* is (X) for the final owner operator.

   Value:

8. The first cost impact of *providing and implementing an IAQ management plan during construction* is (X) for the final owner operator.

   Value:

9. The first cost impact *of meeting the minimum requirement of an IAQ management plan after construction* is (X) for the final owner operator.

   Value:

ADDITIONAL LINGUISTIC DATA

Selected Practitioner Comments Captured during the First Cost Impact Interviews. In the data recording, some inconsistent answers were clarified by phone or by email.

<u>Planners</u>

The first cost impact of *alternative transportation for a facility by locating it near public transportation* is (X) as viewed by the owner operator.

Value: Low-Medium – Usually alternative transportation such as a bus system or rail system are located within urban areas. Infrastructure and utilities are usually already in place. Parking requirements are reduced when an alternative form of transportation is introduced. The cost really depends on site selection. If a site is contaminated (brown field) the costs could be high (see #6).

The first cost impact of an *urban in-fill or urban re-development* site for a project is (X) for the owner/operator.

Value: Low-Medium – In urban in-fill areas and/or redevelopment areas usually infrastructure and utilities are already in place. These sites sometimes have easy access to mass transit, which reduces the costs associated with required parking. The cost really depends on site selection. If a site is contaminated (brown field) the costs could be high (see #6).

The first cost impact of *a brown field re-development* site for a project is (X) for the owner/operator.

Value: High – Even though land acquisition cost is much lower for a brown field, the costs for remediation, legal fees, consultants (primarily environmental), and the carrying *costs for construction loans are much higher for brown fields versus a green field. Many times brown fields involve many stakeholders (land owners) and often come with a high liability to the developer/owner. Some banks will not finance brown field projects because their name would be within a title trail of any potential litigation. Government agencies are recognizing the need for brown field redevelopment and are offering many different financing options especially when there is job creation involved. Brown field development could potentially be low for the owner/operator if the right avenues are taken.*

The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) for the design team.

Value: Low. The design team has a list of familiar plants and construction methods to reduce future problems. Attending seminars and classes, in order to maintain a current level of knowledge, could be a potential cost to the design team.

The first cost impact of *using a LEED Accredited professional* for a project is (X) as viewed by other planners.

Value: Low – Planners are advocates of sustainability

The first cost impact of *analyzing a site for sustainability* is (X) as viewed by the owner operator.

Value: Defining the owner operator as one who has a long-term interest (~20+ years) in the project, the first cost impact value is low…

The first cost impact of *alternative transportation for a facility by locating it near public transportation* is (X) as viewed by the owner operator.

Value: If the public transportation is a fixed route and the owner operator has a long-term interest, then the first cost value is low…

The first cost impact of an *urban in-fill or urban re-development site for a project is (X) for the owner/operator.*

Value: Defining the owner/operator as one who has a long-term interest in the project and that the project economics require a location in an existing urban area, then the first cost value is high- (different sites will have different costs of development and that will impact the decision making process).

The first cost impact of *a brown field re-development* site for a project is (X) for the owner/operator.

Value: Defining the owner/operator as one who has a long-term interest in the project and who has experience in brown field re-development, the first cost impact is low (the owner/operator understands the risks and benefits and therefore the costs have little impact on the decision making process. If the owner/operator has no experience in brown field re-development, the first cost impact will be high (the owner/operator has no experience and therefore is more cautious).

The first cost impact of *reduced site disturbance requirements* for a project is (X) as viewed by the project site civil designer.

Value: Defining the civil designer as an individual with no financial interest in the project, the first cost value is high. (Site disturbance is usually a function of meeting governmental regulations. Reducing those disturbances requires extensive negotiations *with the governmental bodies and trying to achieve consensus among the various agencies, who each have different objectives and personalities. Therefore, the unknowns are extensive and the risk is high…*

The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) for the design team.

Value: Defining the design team as a group with no financial interest in the project, the first cost value is low-. Most regulatory types want to see sustainable and innovative design strategies and therefore preparing such a design has very low risk and cost for the design team.

The first cost impact of *using a LEED Accredited professional* for a project is (X) as viewed by other planners.

Value: Define planner as a member of the project team, the first cost value depends on the professional. If that individual understands the local regulatory process and what it takes to get a project approved, the first cost value is low (there are no delays in the process and may actually enhance the process). If the individual does not understand the process, the cost is high (delays and infighting).

<u>Designer--Site Civil</u>

The first cost impact of *protecting or restoring open space on a project site* is (X) as viewed by the site civil designer.

Value: [HIGH -]. Although required in most water management districts these days, the first cost are certainly expected to be higher than simply planning to use every inch of a site without protection of the resources.

The first cost impact of *on-site storm water treatment systems* on a project is (X) for the site owner operator.

Value: [MEDIUM -]. Because storm water treatment systems have become so commonplace the costs are slowly decreasing. I have been using a 15% mark-up on the underground costs models to account for the expected storm water treatment systems.

The first cost impact of parking *capacity for alternative transportation* for a project is (X) for the owner/operator.

Value: [HIGH +]. The cost to put in a garage of high volume can be $10,000 a space plus the cost of the land, engineering, permitting and all other cost associated with building the project.

The first cost impact of *reducing parking lot heat with landscaped islands* for a project is (X) for the owner/operator.

Value: [LOW -]. This is another item that is traditionally required by most municipalities now as a result of the local landscape code. The owner is going to landscape anyway if required by the code. The expected added cost will be as a result of any increase in the amount of landscaping to the project for heat reduction that is above and beyond the landscape code. With landscaping traditional comes irrigation.

The first cost impact of *using innovative "green" site civil design* on a project is (X) as viewed by all other project designers.

Value: [LOW]. The small amount of green projects I have done have not added large amounts of cost in most areas except drainage. The use of recycled asphalt products has in some cases been the preferred method of site contractors because of its lower cost.

The first cost impact of *using a LEED Accredited professional* for a project is (X) as viewed by site civil designers.

Value: [MEDIUM]. Requires part time involvement by a LEED Accredited professional that would not traditionally be required including more field visits and coordination with the contractor's LEED Accredited Staff.

<u>Designer—Landscape Architect</u>

The first cost impact of *providing innovative on-site natural waste water technologies* (X) as viewed by the design team.

Value: Defining the design team as a group with no finical interest in the project, the first cost value is high. (Local regulations may not allow "innovative on-site waste water technologies," therefore the costs in negotiating and permitting high and there is a high uncertainty.

The first cost impact of *irrigation water use reduction of 20%* is (X) for the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is low-. Someone else does the design, he gets paid no matter what, and the risk is low.

The first cost impact of *irrigation water use reduction of 30%* is (X) for the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is low-. Someone else does the design, he gets paid no matter what, and the risk is low.

The first cost impact of *reducing site disturbance and restoring open space* is (X) as viewed by the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is low-. Someone else does the design, someone else accomplishes the plan approvals, he gets paid no matter what, and the risk is low.

The first cost impact of *irrigation water use reduction by 50%* is (X) for the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is low-. Someone else does the design, he gets paid no matter what, and the risk is low.

The first cost impact of *using water efficient landscaping that requires no irrigation* is (X) for the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is high +. I am not aware of any design that requires no irrigation. Even in Xeriscape, one of the seven principals is efficient irrigation. Without irrigation there is a high probability of plan failure and therefore the need to replace the plants usually at the constructors costs.

The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) as viewed by the constructor.

Value: Defining the constructor as an individual with no financial interest in the project, the first cost value is low +. The constructor may have some good practical ideas that will enhance the project, the design will probable be done by someone else (an LA) and therefore the constructor has little risk.

The first cost impact of *using a LEED Accredited MEP professionals* for a project is (X) as viewed by the owner operator.

Value: Defining the owner operator as someone with a long-term interest, the first cost value may be low if the professional has good local botanical knowledge and a good working relationship with the local regulatory agencies…

The first cost impact of *using water efficient landscaping that requires no irrigation* is (X) for the constructor.

Value: Low. The use of Best Management Practices and Xeriscape plants can be utilized.

The first cost impact of *providing sustainable and innovative landscape design strategies* is (X) as viewed by the constructor.

Value: Low. The design team has a list of familiar plants and construction methods to reduce future problems. Attending seminars and classes, in order to maintain a current level of knowledge, could be a potential cost to the design team.

The first cost impact of *using a LEED Accredited MEP professionals* for a project is (X) as viewed by the owner operator.

Value: Medium – In the long run using a LEED Accredited professional will save a lot of time and money in the design/development process.

<u>Designer—MEP</u>

The first cost impact of *providing for the minimum energy performance on a project* is (X) as viewed by the design architect.

Value: To provide for the minimum energy performance on a project, which is assumed to be code minimum (ASHRAE 90.1.1-1999), would normally assumed to be *included as part of the standard building, since most codes today legislate the minimum energy performance. X = No.*

The first cost impact of *specifying 5% renewable energy for a project's power* is (X) for the constructor.

Value: Contractors most likely would view the addition of 5% renewable energy sources as expensive. X = High

The first cost impact of *specifying 10% renewable energy for a project's power* is (X) for the constructor.

Value: Contractors most like would view the addition of 10% renewable energy sources as very expensive. X = High+

The first cost impact of *specifying "green power" for a project* is (X) for the owner operator.

Value: Owner's typically view green power as an expensive option. X = High

The first cost impact of *eliminating HCFC's and Halons* for a project's systems is (X) for the constructor.

Value: Constructors would view elimination of HCFC's as a moderate cost as equipment is readily available to provide this feature. Halons can also be replaced in fire suppression systems with readily available alternatives. X = Medium.

The first cost impact of *providing for minimum IAQ performance* for a project is (X) as viewed by all other project designers.

Value: Project designers are used to providing this type of IAQ performance in their practice, and would view this requirement as low cost. X = Low.

The first cost impact of *providing environmental tobacco smoke control* for a project is (X) as viewed by the constructor.

Value: The Constructor will view providing environmental tobacco smoke control as a moderate costs. X = Medium

The first cost impact of *providing innovative green mechanical-electrical and plumbing design strategies* is (X) as viewed by the constructor.

Value: The Constructor would view providing an innovative green MEP design strategies as expensive. X = High.

The first cost impact of *using a LEED Accredited MEP professional* for a project is (X) as viewed by the owner operator.

Value: Owner's will view the LEED MEP Professional for a project is about the same as standard design professional as moderate, since the fee increases are not apparent for completing the LEED design. X = Medium.

The first cost impact of *providing innovative waste water technologies* (X) as viewed by the design team.

Value: For innovative drainage systems (gray water collection, rain water collection and reuse) the designer would expect to spend more time in layout design, but little additional time in specification production. In the schematic and DD phases the costs should be about the same as standard design approaches. X = Low+, or Medium-

The first cost impact of *water use reduction of 20%* is (X) for the constructor.

Value: The constructor would view the additional system installation costs as moderate, since the systems are simple and installation normal. X = Moderate.

The first cost impact of *total CFC Reduction in HVAC&R equipment* is (X) for the constructor.

Value: The constructor would not view the CFC reduction as a major component, since systems are readily available and have equal installation costs. X = Low+ or Medium-

The first cost impact of providing for carbon dioxide (CO2) Monitoring is (X) for the constructor.

Value: The constructor would view CO2 monitoring for demand controlled ventilation as not a large change in costs. The added costs for sensors and control is about $1500 per air handling unit. X = Moderate.

The first cost impact of *providing for increased ventilation effectiveness* is (X) for the constructor.

Value: Increased ventilation is typically accomplished by using more ceiling diffusers with high primary-secondary induction characteristics. For typical commercial buildings, the cost adder for more units would be a 25% increase in air distribution costs, which would increase mechanical costs and average 1%. X = Low+

The first cost impact of *optimizing energy performance by at 20% (new)* is (X) for the design team.

Value: Design costs for Schematic and DD would be seen as only higher than normal design. Most of the additional design costs would occur in CD phase. X = Moderate

The first cost impact of *compliance with ASHRAE 55 - 1992 Thermal Comfort* is (X) for the design team.

Value: Most designers would feel that their standard design complies with ASHRAE 55. X = Low.

The first cost impact of *providing a permanent monitoring system for thermal comfort* is (X) for the constructor.

Value: Most commercial buildings today incorporate Building Automation Systems, so the cost of providing a permanent monitoring system would be seen as no cost increase. X = Low.

The first cost impact of *providing innovative mechanical, electrical, and plumbing design strategies* is (X) as viewed by the constructor.

Value: In the aggregate, the Constructor would view innovative MEP design strategies as higher first costs. X = High.

The first cost impact of *using a LEEDÔ Accredited MEP engineers* for a project is (X) as viewed by the owner operator.

Value: Owner's would view their design professionals as needing to be LEED Accredited in order to remain viable in the market place. Therefore, cost impact would be low. X = Low.

APPENDIX E

SAMPLE CALCULATION,
INTERVIEW BREAKDOWN BY FACTOR AND GROUP, AND
COST IMPACT FRAMEWORK DATA BASE

SAMPLE CALCULATION SET UP FOR HORIZONTAL SUM OF PLANNERS VALUES FOR THE STRATEGY OF SITE SELECTION (PHASE 1, FACTOR1, STRATEGY 1)[1]

Basic Equation for 1.1.1: Cost Impact Value = CI; Belief Value = BV ; Final Fuzzy

Logic Structure

∑ of Planners 1 + 2 + 3 + 4 + 5 = Cost Impact of Site Selection-Planners

Planner 1	+	Planner 2	+	Planner 3	+	Planner 4	+	Planner 5
CI=**M**		CI=**L +**		CI=L		CI=**L**		CI=**L**
BV=**H**		BV=**H**		BV=H		BV=**H**		BV=**H**

Set of values: [L, L+, M, H]

Low equation

[1|0.9, 2|1.0, 3|0.9, 4|0.0, 5|0.0, 6|0.0, 7|0.0, 8|0.0, 9|0.0, 10|0.0]

Low + equation

[1|0.0, 2|0.7, 3|1.0, 4|0.7, 5|0.0, 6|0.0, 7|0.0, 8|0.0, 9|0.0, 10|0.0]

Medium equation

[1|0.0, 2|0.0, 3|0.8, 4|0.9, 5|1.0, 6|1.0, 7|0.9, 8|0.8, 9|0.0, 10|0.0]

High equation

[1|0.0, 2|0.0, 3|0.0, 4|0.0, 5|0.0, 6|0.0, 7|0.0, 8|0.9, 9|1.0, 10|0.9]

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[1] See Chapters 4 and 5 for assumptions governing the application of fuzzy logic across multiple actors with respect to this use.

$$[CI] = \frac{\sum [BV] \bullet [CI\ ?]}{\sum [BV\ i]}$$

$$\mathbf{S} = \frac{[H \times M] + [H \times L+] + [H \times L] + [H \times L] + [H \times L]}{H + H + H + H + H}$$

14 Iterations of values for: [H x M]; [H x L+]; 3 iterations [H x L]; 3 iterations [H + H] results in:

S = [10917.6|0, 99.39|0.7, 66.12|0.8, 132.37|0.9, 4|1.0]. The 100% belief value is 4.

Converted back to a Linguistic on the final scale (Figure 4-14) the summary value is <u>Low +; Medium -</u>.

Table E-1 Interview Breakdown by Factor and Groups
Cost Impact Framework

Interview Breakdown by Factor (Summary)	Name Discipline Yrs/LEED	Planners	Designers	Constructors	Owners	Expert Group	ALL
1	**Planning (Environmental, Economic, and Physical)**						
1.1	**Environmental Impact Analysis**						
	Site Selection						
	Alternative Transportation, Locate Near Public Transportation						
	Storm Water Management, No Net Increase or 25% Decrease						
	Storm Water Management, Treatment Systems						
	Commonly Used						
	All						
1.2	**Economic Development Impact**						
	Urban Redevelopment						
	Brown Field Redevelopment						
	Commonly Used						
	All						
1.3	**Physical Planning**						
	LEED Accredited Professional						
	Reduced Site Disturbance, Development Footprint						
	Providing Sustainable and Innovative Landscape Design Strategies						
	Brown Field Redevelopment						
	Commonly Used						
	All						
2	**Project Planning (Project Definition and Development)**						
2.1	**Assessment & Objective Setting**						
	Design-MEP Minimum Energy Performance						
	Design-Arch Storage & Collection of Recyclable Materials						
	Design-MEP Renewable Energy, 5%						
	Design-MEP Renewable Energy, 10%						
	Design-MEP Green Power						
	Design-Arch Recycle Content, Specify 15%						
	Commonly Used						
	All						
2.2	**Preliminary Planning & Funding**						
	Design-SC Reduced Site Disturbance, Protect or Restore Open Space						
	Design-Arch Alternative Transportation, Bicycle Storage & Changing Rooms						
	Design-SC Alternative Transportation, Alternative Fuel Refueling Stations						
	Design-SC Alternative Transportation, Parking Capacity						
	Design-SC Reduce Heat Islands, Non-roof						
	Design-Arch Rapidly Renewable Materials						
	Design-Arch Reduce Heat Islands, Roof						
	Design-Arch Building Reuse, Maintain 50% of Existing Shell						
	Design-Arch Building Reuse, Maintain 75% of Existing Shell						
	Design-Arch Building Reuse, Maintain 100% of Existing Shell						
	Design-Arch Recycle Content, Specify 50%						
	Commonly Used						
	All						
2.3	**Project Definition Package**						
	Design-MEP Elimination of HCFCs and Halons						
	Design-MEP Minimum IAQ Performance						
	Design-MEP Environmental Tobacco Smoke (ETS) Control						
	Design-LA Water Efficient Landscaping, Reduce by 50%						
	Design-LA Water Efficient Landscaping, No Irrigation						
	Design Innovation in Design-Multiple Strategies						
	Design LEED Accredited Professional						
	Commonly Used						
	All						
3	**Design (Conceptual Design, Design Development, Contract Documents)**						
3.1	**Conceptual & Schematic Design**						
	Design-MEP Innovative Wastewater Technologies						
	Design-MEP Water use Reduction, 20% Reduction						
	Design-MEP Water use Reduction, 30% Reduction						
	Design-Arch Lighting Pollution Reduction						
	Design-MEP CFC Reduction in HVAC&R Equipment						
	Design Measurement and Verification						
	Design-MEP Carbon Dioxide (CO2) Monitoring						
	Design-MEP Increase Ventilation Effectiveness						
	Design-Arch Controllability of Systems, Operable Windows						
	Design-MEP Controllability of Systems, Individual Controls						
	Design-MEP Optimize Energy Performance, 15% New 5% Existing						
	Commonly Used						
	All						
3.2	**Design Development**						
	Design-Arch Resource Reuse, Specify 5%						
	Design-Arch Resource Reuse, Specify 10%						
	Design-Arch Certified Wood						
	Design-Arch Low-Emitting Materials, Adhesives						
	Design-Arch Low-Emitting Materials, Paints						
	Design-Arch Low-Emitting Materials, Carpets						

Table E-1 (continued).

Interview Breakdown by Factor (Summary)	Name Discipline Yrs/LEED	Planners	Designers	Constructors	Owners	Expert Group	ALL
	Design-Arch Low-Emitting Materials, Composite Wood						
	Design-Arch Indoor Chemical and Pollutant Source Control						
	Design-MEP Optimize Energy Performance, 20% New 10% Existing						
	Design-MEP Optimize Energy Performance, 25% New 15% Existing						
	Design-MEP Optimize Energy Performance, 30% New 20% Existing						
	Design-MEP Optimize Energy Performance, 35% New 25% Existing						
	Design-MEP Optimize Energy Performance, 40% New 30% Existing						
	Design-MEP Optimize Energy Performance, 45% New 35% Existing						
	Design-MEP Optimize Energy Performance, 50% New 40% Existing						
	Design-MEP Optimize Energy Performance, 55% New 45% Existing						
	Design-MEP Optimize Energy Performance, 60% New 50% Existing						
	Design-MEP Thermal Comfort, Comply with ASHRAE 55-1992						
	Design-MEP Thermal Comfort, Permanent Monitoring System						
	Design-Arch Daylight and Views, Diffuse Sunlight to 90%						
	Design-Arch Daylight and Views, Direct Line of Site 90%						
	Design Innovation in Design-Multiple Strategies						
	Commonly Used						
	All						
3.3	**Contract Documents**						
	Design Sign and Seal - LEED Accredited Professional						
	Design Innovation in Contract Procurement-Multiple Strategies						
	Design Green Tax Incentives, Federal Grants, & Subsidies						
	Owner Operator Green Tax Incentives, Federal Grants, & Subsidies						
	Commonly Used						
	All						
4	**Construction (Project Delivery Method)**						
4.1	**Design Bid Build**						
	Construction LEED Accredited Professional						
	Owner Operations Fundamental Building Commissioning						
	Owner Operations Minimum Energy Performance						
	Construction Construction Waste Management, Salvage or Recycle 50%						
	Construction Construction Waste Management, Salvage Additional 25%						
	Construction Local/Regional Materials, of 20% Manufactured Locally						
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally						
	Construction Construction IAQ Management Plan, During Construction						
	Owner Operator Construction IAQ Management Plan, Post Construction						
	Commonly Used						
	All						
4.2	**Design Build**						
	Construction LEED Accredited Professional						
	Owner Operations Fundamental Building Commissioning						
	Owner Operations Minimum Energy Performance						
	Construction Construction Waste Management, Salvage or Recycle 50%						
	Construction Construction Waste Management, Salvage Additional 25%						
	Construction Local/Regional Materials, of 20% Manufactured Locally						
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally						
	Construction Construction IAQ Management Plan, During Construction						
	Owner Operations Construction IAQ Management Plan, Post Construction						
	Commonly Used						
	All						
4.3	**Design Build Own Operate Transfer**						
	Owner Operations LEED Accredited Professional						
	Owner Operations Fundamental Building Commissioning						
	Owner Operations Minimum Energy Performance						
	Owner Operations Construction Waste Management, Salvage or Recycle 50%						
	Owner Operations Construction Waste Management, Salvage Additional 25%						
	Owner Operations Local/Regional Materials, of 20% Manufactured Locally						
	Owner Operations Local/Regional Materials, of 20% Above 50% Harvested Locally						
	Owner Operations Construction IAQ Management Plan, During Construction						
	Owner Operations Construction IAQ Management Plan, Post Construction						
	Commonly Used						
	All						
5	**Expert Outline Factors**						
	ALL RATINGS 1 through 4						
	Commonly Used						
	RATINGS 1 & 2						
	Commonly Used						
	RATINGS 3 & 4						
	Commonly Used						

Table E-2 Interview Breakdown by Factor and Group
Cost Impact Framework with Linguistic Data

	Interview Breakdown by Factor (Summary) Name Discipline Yrs/LEED	Planners	Designers	Constructors	Owners	Expert Group	ALL
1	**Planning (Environmental, Economic, and Physical)**					M	**M**
1.1	**Environmental Impact Analysis**					M	**M-**
	Site Selection	L+			M-	L+	**L+**
	Alternative Transportation, Locate Near Public Transportation	M-			L+	M	**M-**
	Storm Water Management, No Net Increase or 25% Decrease	M-	M-		L+	M-	**M-**
	Storm Water Management, Treatment Systems	M-	M-		M	H	**M**
	Commonly Used						**M-**
	All						
1.2	**Economic Development Impact**					M	**M+**
	Urban Redevelopment	H-			M	M	**M**
	Brown Field Redevelopment	M+			M	M+	**M**
	Commonly Used						**M**
	All						
1.3	**Physical Planning**					M-	**M-**
	LEED Accredited Professional	M-			M-	M-	**M-**
	Reduced Site Disturbance, Development Footprint	M			L+	M-	**M-**
	Providing Sustainable and Innovative Landscape Design Strategies	L+			M-	M-	**L**
	Brown Field Redevelopment	M			M-	M	**M**
	Commonly Used						**L+**
	All						**L+**
2	**Project Planning (Project Definition and Development)**					M-	**M**
2.1	**Assessment & Objective Setting**					M	**M+**
	Design-MEP Minimum Energy Performance		M			L-	**M-**
	Design-Arch Storage & Collection of Recyclable Materials		M-		L	L	**L+**
	Design-MEP Renewable Energy, 5%		M			H	**M**
	Design-MEP Renewable Energy, 10%		M+			H+	**M+**
	Design-MEP Green Power		M			H	**M**
	Design-Arch Recycle Content, Specify 15%		M		M-	M-	**M-**
	Commonly Used						**M-**
	All						
2.2	**Preliminary Planning & Funding**					M-	**M**
	Design-SC Reduced Site Disturbance, Protect or Restore Open Space	M	M-			M	**M**
	Design-Arch Alternative Transportation, Bicycle Storage & Changing Rooms		L+		L+	L+	**L+**
	Design-SC Alternative Transportation, Alternative Fuel Refueling Stations		M-			L	**M**
	Design-SC Alternative Transportation, Parking Capacity		M			M-	**M**
	Design-SC Reduce Heat Islands, Non-roof		L+			M+	**M-**
	Design-Arch Rapidly Renewable Materials		M-		M-	M-	**M-**
	Design-Arch Reduce Heat Islands, Roof		M		M-	L+	**M-**
	Design-Arch Building Reuse, Maintain 50% of Existing Shell		M		L+	L+	**M**
	Design-Arch Building Reuse, Maintain 75% of Existing Shell		M		M-	L+	**M**
	Design-Arch Building Reuse, Maintain 100% of Existing Shell		M+		M+	M-	**M+**
	Design-Arch Recycle Content, Specify 50%		M		M	L	**M**
	Commonly Used						**M-**
	All						
2.3	**Project Definition Package**					M-	**M-**
	Design-MEP Elimination of HCFCs and Halons		L+			M	**L+**
	Design-MEP Minimum IAQ Performance		M			L	**M-**
	Design-MEP Environmental Tobacco Smoke (ETS) Control		L+			M	**L+**
	Design-LA Water Efficient Landscaping, Reduce by 50%	M-					**M-**
	Design-LA Water Efficient Landscaping, No Irrigation	M-					**M-**
	Design Innovation in Design-Multiple Strategies	M	M		M	M-	**M**
	Design LEED Accredited Professional	M	M-		L	M-	**M-**
	Commonly Used						**M-**
	All						**L-**
3	**Design (Conceptual Design, Design Development, Contract Documents)**					M-	**L**
3.1	**Conceptual & Schematic Design**					L+	**M-**
	Design-MEP Innovative Wastewater Technologies	M-	M			L+	**M**
	Design-MEP Water use Reduction, 20% Reduction	L+	L+			M	**M-**
	Design-MEP Water use Reduction, 30% Reduction	M-	M-			M+	**M-**
	Design-Arch Lighting Pollution Reduction		L+			L-	**L+**
	Design-MEP CFC Reduction in HVAC&R Equipment		M-			L+	**M-**
	Design Measurement and Verification		M			L	**M**
	Design-MEP Carbon Dioxide (CO2) Monitoring		L+			M	**L+**
	Design-MEP Increase Ventilation Effectiveness		M			L+	**M**
	Design-Arch Controllability of Systems, Operable Windows		M			L	**M**
	Design-MEP Controllability of Systems, Individual Controls		M+			L-	**M**
	Design-MEP Optimize Energy Performance, 15% New 5% Existing		M			L-	**M**
	Commonly Used						**M-**
	All						
3.2	**Design Development**					M	**M**
	Design-Arch Resource Reuse, Specify 5%		L+			L	**L+**
	Design-Arch Resource Reuse, Specify 10%		M-			L+	**L+**
	Design-Arch Certified Wood		M-			M-	**M-**
	Design-Arch Low-Emitting Materials, Adhesives		L			L	**L**
	Design-Arch Low-Emitting Materials, Paints		L			L	**L**
	Design-Arch Low-Emitting Materials, Carpets		L			L-	**L**

Table E-2 (continued).

Interview Breakdown by Factor (Summary)	Name Discipline Yrs/LEED	Planners	Designers	Constructors	Owners	Expert Group	ALL
	Design-Arch Low-Emitting Materials, Composite Wood		L+			L	L+
	Design-Arch Indoor Chemical and Pollutant Source Control		M			L+	M
	Design-MEP Optimize Energy Performance, 20% New 10% Existing		M			M	M
	Design-MEP Optimize Energy Performance, 25% New 15% Existing		M+			M	M+
	Design-MEP Optimize Energy Performance, 30% New 20% Existing		M+			M+	M+
	Design-MEP Optimize Energy Performance, 35% New 25% Existing		H-			H-	H-
	Design-MEP Optimize Energy Performance, 40% New 30% Existing		H-			H	H-
	Design-MEP Optimize Energy Performance, 45% New 35% Existing		H-			H	H
	Design-MEP Optimize Energy Performance, 50% New 40% Existing		H			H+	H
	Design-MEP Optimize Energy Performance, 55% New 45% Existing		H			H+	H
	Design-MEP Optimize Energy Performance, 60% New 50% Existing		H+			H+	H+
	Design-MEP Thermal Comfort, Comply with ASHRAE 55-1992		L			L	L
	Design-MEP Thermal Comfort, Permanent Monitoring System		M-			L	M-
	Design-Arch Daylight and Views, Diffuse Sunlight to 90%		M			L	M
	Design-Arch Daylight and Views, Direct Line of Site 90%		M			L+	M
	Design Innovation in Design-Multiple Strategies		M			M	M
	Commonly Used						**M-**
	All						
3.3	**Contract Documents**					M+	M-
	Design Sign and Seal - LEED Accredited Professional		L			L-	L
	Design Innovation in Contract Procurement-Multiple Strategies		M-			L+	M-
	Design Green Tax Incentives, Federal Grants, & Subsidies		M			L	M
	Owner Operator Green Tax Incentives, Federal Grants, & Subsidies		M			L	M
	Commonly Used						**L+**
	All						**L+**
4	**Construction (Project Delivery Method)**					M	M
4.1	**Design Bid Build**					M+	M
	Construction LEED Accredited Professional			L+		H	M-
	Owner Operations Fundamental Building Commissioning			M+		M	M+
	Owner Operations Minimum Energy Performance			M-		M	M
	Construction Construction Waste Management, Salvage or Recycle 50%			M		H	M
	Construction Construction Waste Management, Salvage Additional 25%			M		H	M
	Construction Local/Regional Materials, of 20% Manufactured Locally			M-		M	M-
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally			M		M	M
	Construction Construction IAQ Management Plan, During Construction			M		M	M
	Owner Operator Construction IAQ Management Plan, Post Construction			M		M+	M
	Commonly Used						**M**
	All						
4.2	**Design Build**					M+	M
	Construction LEED Accredited Professional			L+		H	M-
	Owner Operations Fundamental Building Commissioning			M+		M+	M+
	Owner Operations Minimum Energy Performance			M		M+	M
	Construction Construction Waste Management, Salvage or Recycle 50%			M		M	M
	Construction Construction Waste Management, Salvage Additional 25%			M		M	M
	Construction Local/Regional Materials, of 20% Manufactured Locally			M-		M	M
	Construction Local/Regional Materials, of 20% Above 50% Harvested Locally			M		M	M
	Construction Construction IAQ Management Plan, During Construction			M		M	M
	Owner Operations Construction IAQ Management Plan, Post Construction			M		M	M
	Commonly Used						**M**
	All						
4.3	**Design Build Own Operate Transfer**					M-	M-
	Owner Operations LEED Accredited Professional				L	L+	L
	Owner Operations Fundamental Building Commissioning				M-	M-	M-
	Owner Operations Minimum Energy Performance				M	M	M
	Owner Operations Construction Waste Management, Salvage or Recycle 50%				L+	M	M-
	Owner Operations Construction Waste Management, Salvage Additional 25%				M-	M+	M-
	Owner Operations Local/Regional Materials, of 20% Manufactured Locally				L+	L+	L+
	Owner Operations Local/Regional Materials, of 20% Above 50% Harvested Locally				M	M-	M
	Owner Operations Construction IAQ Management Plan, During Construction				M	L-	M-
	Owner Operations Construction IAQ Management Plan, Post Construction				M+	M	M+
	Commonly Used						**M-**
	All						**M-**
5	**Expert Outline Factors**						
	ALL RATINGS 1 through 4	**M-**	**M**	**M**	**M-**	**M**	
	Commonly Used	**M-**	**M-**	**M**	**L+**	**M**	
	RATINGS 1 & 2	**M-**	**M**	**ND**	**M-**	**M-**	
	Commonly Used	**M-**	**M-**	**ND**	**L+**	**M-**	
	RATINGS 3 & 4	**M-**	**M**	**M**	**M-**	**M-**	
	Commonly Used	**M-**	**M-**	**M**	**L+**	**M-**	

APPENDIX F

HOMESTEAD ARB, FL, FIRE STATION PROJECT SUPPORTING INFORMATION

Used with permission of HQ AFRC/CE-2, September 27, 2004

Project Description

15 Oct 99

1.0 Title: Fire Station, KYJM 99-9022

2.0 Scope: Renovation of existing 10,000 SF
New addition area 65,000 SF

3.0 Estimated Cost: $2,400,000.00

4.0 Purpose: To provide a facility to fulfill the base fire fighting requirements and commitments necessary to support the mission of the 482 FW. The existing station must be upgraded and enlarged to meet the Air Force requirements for fire protection vehicle storage, maintenance, repair and supply support, administration and training areas and living areas. This building will be designed as sustainable architecture.

5.0 Description: The existing Fire Station will be partially demolished as part of this project and the administrative and sleeping areas will be renovated on its current site. One new apparatus stall to include a washrack will be added to the northeast end of the building. A new addition will be constructed in the back courtyard of the facility so that administrative and living areas can be rearranged and sized to meet current Air Force standards. A new fire sprinkler system will be installed throughout the facility. Existing electrical and mechanical systems must be evaluated and upgraded or replaced as needed. Existing apparatus floor drains must be routed to an existing oil water separator. Standing seam metal roof will be installed to cover the renovated facility.

6.0 The project will be designed to meet the requirements of the US Air force Fire Station Design Guide.
Design Standards for Homestead Air Reserve Base are attached. (See Original RAMP)
Portions of the Base Comprehensive Plan are also attached. (See Original RAMP)
The following apparatus will be assigned to the Fire Station:

- P-10
- P-18
- P-19 2 each
- P-20
- P-22 2 each
- P-23
- Hazmat Trailer
- Confined Space Trailer
- Foam Trailer
- 2 Carry All Vehicles
- 1 Utility Vehicle

A Comprehensive Interior Design (CID) is required for this project.
An emergency generator to supply back up power will be included in the project.

7.0 Environmental issues: There are no current lead paint or asbestos surveys for the building. Past work has shown the presence of both in the facility.

LEED Rating Summary

Sustainable Design Rating Table
Green Building Rating System on version 2.0, U.S. Green Building Council
ADAL Fire Station, Homestead ARS, Florida

Realistic	Optimistic
27	41
Certified	*Gold*

Sustaining Site and Safeguarding Water

	Realistic	Optimistic
Site Selection (Base Planning)	1	1
The Fire Station Project is a renovation and addition. The addition is sited within an existing utility yard. The land being developed does not fall under any of the following land uses: Prime agricultural land as defined by the Farmland Trust. Land whose elevation is lower than 5 feet above the 100 year flood as defined by FEMA Land that provides habitat for endangered species Land within 100 feet of any wetland Land which was formerly a parkland		
Urban Redevelopment (Base Planning & HOK)	1	1
Since the proposed addition and renovation project will fill an existing underutilized central yard, it will minimize the impact on open areas thereby preserving Greenfield sites and preserving natural habitat. Only 20% of the total project will affect unbuilt or pervious areas. The project will also take advantage of all of the existing infrastructure systems to accommodate the new requirements. These systems include electrical services, potable water lines, waste lines, road and storm drainage swales. The completed project will provide a dense plan that is efficient and is an appropriate scale to complement the base comprehensive plan.		
Alternative Transportation (HOK Fire Station Users)	3	3
While the use of automobiles and fire trucks is an integral part of the facility's mission, minimizing the daily use of automobiles is a goal of this project. In order to encourage use of alternative transportation, the project will include locations to secure bicycles as well as showers and changing rooms for bicycle users. The facility will also include locations to recharge and store electric utility vehicles for transportation around the base (3% of total vehicles). An ensuing phase will create a dedicated to electric vehicles, bicycles and pedestrian to further encourage alternative transportation. No additional parking will be added as a part of this project despite enlarging the facility by 20%. Spaces will be dedicated to car and van pool parking.		
Reduce Site Disturbance (HOK Landscape)	1	1
Sustaining the natural terrain and vegetation on and around the proposed project site is a priority. The construction will be limited to within fifty feet around the building, soil removed for the new construction will be kept on site and all existing vegetation will be relocated elsewhere on the site only when absolutely necessary. Further, additional native and adapted vegetation will be added. With this vegetation little maintenance and no irrigation will be required.		
Storm Water Management (LAW Eng.)	2	2
The responsible distribution of storm water runoff is critical in the project area. It is the intent of the design to accommodate rain water runoff from 100% of the building footprint and immediate paved aprons in a groundwater recharge system in effect eliminating all of the current storm water runoff. This system by its design filters the storm water, and introduces it into the substrata around the building in a perforated pipe (exfiltration gallery). This approach is highly desirable in South Florida to help mitigate the infiltration of salt water in the ground water.		
Landscape and Exterior Design to Reduce Heat Islands (HOK Landscape)	1	1
Light color/high albedo paving will be used on all of the site's non-impervious surfaces.		
Light Pollution Reduction (HOK & Pyramid)	1	1
Proper exterior lighting is critical to the fire fighting mission. Currently the lighting for the apparatus bay aprons is mounted on the building. This project will eliminate this outwardly directed illumination and provide pole mounted, solar powered down lights. These fixtures will greatly reduce the off site impact. Additionally, landscape and architectural lighting will be minimized.		

Water Efficiency

Water Efficient Landscaping (HOK Landscape)	**2**	**2**
The landscape design will only utilize plant materials that are indigenous or thrive in local conditions, which will eliminate the need for an irrigation system. Thus, all irrigation will be natural rain fall.		
Water Use Reduction (HOK & Pyramid)	**1**	**2**
A number of measures have been implemented to reduce the amount of municipally provided potable water used at the facility. These include: a. Installation of low flow showers and toilets. b. not use landscape irrigation systems. c. landscape irrigation systems are planned. d. No landscape irrigation system has been included in this work. Only indigenous and adapted plant material has been specified.		

Energy and Atmosphere

Optimize Energy Performance (Pyramid)	**2**	**4**
Energy efficiency is one of the key issues addressed in the mechanical systems design. The goal is to achieve a 20 percent reduction in energy consumption to the more stringent of ASHRAE 90.1 or energy model comparison between the existing building conditions and the proposed design.		
Renewable Energy (Pyramid)	**0**	**1**
Implementing sources such as solar energy can reduce a fraction of the building's total energy load. Renewable energy options for the proposed building include: Solar energy use for site lighting.		
Additional Commissioning (Pyramid)	**0**	**1**
The HVAC systems and associated controls will undergo testing to ensure that the systems are operating at their peak design efficiency and capacity while providing occupancy comfort as prescribed in the design.		
Elimination of HCFC's and Halons	**1**	**1**
The base building HVAC and Refrigerant and fire suppression system will be free of HCFC's and Halon.		
Measurement and Verification (Pyramid)	**0**	**1**
The building automation system (BAS) is to provide for the ongoing accountability and optimization of building energy and IEQ performance over time. The BAS will include the following features: Distributed Direct Digital Control (DDC). Multiple man-machine interface points. Programmable control. Effective management of the facility through report generation, histories, logs, and dynamic color-graphic displays. Optimization and energy management software such as time scheduling, demand limiting, optimum start-stop and duty cycling. Capable of unattended operation with manual interaction. Capable of monitoring system's integrity. Capable of monitoring and reporting an alarm condition for each input point.		
Green Power	**0**	**1**
The base is encouraged to purchase power generated from a renewable source that meets the Center for Resource Solutions (CRS) Green-E requirements.		

Materials and Resources

Storage & Collection of Recyclable (Users & HOK)	**0**	**0**
To promote recycling, areas will be provided in the kitchen and living area for the separation and storage of recyclable materials.		
Building Reuse (Entire Team)	**1**	**1**
The renovation project will significantly reuse the existing structure. At this time, at least 75% of the building envelope will be retained and reused. This measure will minimize new materials, cost and		
Construction Waste (Kalex & HOK)	**1**	**1**
A construction materials recycling program will be part of the requirements included in the project specifications. Materials such as cardboard, iron, copper wire, plastic, glass and gypsum will be separated and recycled by the construction contractor. The goal for the project is to recycle 50% of the waste materials.		
Resource Reuse (Entire Team)	**0**	**1**
5% of the total building materials will be refurbished.		
Recycled Content (Entire Team)	**2**	**2**
A total of 20% to 50% of the materials used will have a minimum average weight of 20% post consumer recycled content.		
Local/Regional Materials (Entire Team)	**1**	**2**
In an effort to reduce the impact or transportation of building materials and support the local economy, the project will recommend the use of locally manufactured material. The project goal will be to procure a minimum of 20% from local manufacturers.		

Indoor Environmental Quality

Carbon Dioxide Monitoring (Pyramid)	**0**	**1**
It is the intent of the proposed building systems design to include carbon dioxide monitoring to areas of high occupant densities and at the ends of distribution ductwork. It will be recommended that the calibration of all of the sensors be performed on a quarterly basis.		
Increased Ventilation Effectiveness (Pyramid)	**1**	**1**
Outdoor air ventilation will be dictated by the amount of outdoor air required to satisfy the more stringent of: a. ASHRAE 62 b. South Florida Building Code c. Exhaust plus pressurization d. Government criteria		
Construction IAQ Management Plan (Entire Team)	**1**	**1**
A construction IAQ management will be implemented to reduce air quality problems in the building after occupancy. The A&E and the contractor will work together to develop this strategy.		
Select Low-Emitting Materials (Entire Team)	**1**	**3**
Interior material finish-out shall include materials not only developed and produced to match the maximum efficiency for sustainable practices, they shall match standard building materials for overall lifecycle and durability. See below for low emitting materials: Flooring: Interface Deja' Vu Carpet Interface Solenium Linoleum (vs. VCT) sealers, adhesives, primers Clean, reuse and seal existing concrete flooring areas 100% recycled rubber tile flooring for fitness/recreation are no adhesive necessary		

Walls:
No wall covering specified, no adhesives necessary
Water base paints, primers and special coatings specified throughout the facility

Base:
Recycled rubber-base used only

Cabinetry:
Medium density fiberboard used
Specify: MEDITE II, MEDITE FR., MEDEX

All above listed products are formaldehyde free.

Eliminate most use of plastic laminate and adhesives by using approved zero to low VOC stains and finishes for MDF.

Ceilings:

Use tectum ceiling tiles where tiles are needed. Paint and leave ceilings exposed where possible.

Miscellaneous:
Furniture and countertop areas can be fabricated out of recycled fabricated board, plastic bottles and yogurt containers.
Use upholstery from recycled collections i.e. DesignTex, William McDonough Collection or fabrics containing 100% natural fiber.

Finish Philosophy:
HOK will minimize the finish types used on this job to reinforce full circle sustainable practices.

This consideration is worth one point in the LEED rating system.

Thermal Comfort (Pyramid) **1** **1**

Thermal comfort as a result of supply air ventilation to each space will be the greater of:
The calculated sensible cooling load using a 20-degree F temperature difference between the supply air and the room air.
A 15 minute air change based on the space volume.
That required to comply with ASHRAE 55.
That required to comply with Government Criteria.

The relative humidity shall not exceed 50 percent, coincident with the maximum inside temperature.

Innovative Credits and Design/Build Process

Unique Project Type and Location **2** **4**

Based on the unique project delivery process selected for this building, it is believed that we may receive credits based on other factors. These factors include:
This project is a seed project for a larger, base wide and regional sustainable Air Force initiative.
The project approach of pre-selection of an 8A contractor, bringing them into the process in design in order to thoroughly communicate the sustainable intent.
Including a full time onsite inspector despite the project's small size to reinforce the sustainable intent.

Homestead ARB Fire Station Project
Estimate Notes

This estimate has been prepared using the Windows version of PACES version 1.5.1A with an area location of Homestead AFB in Florida in program year 2002. The fire station is a parametric model based on an actual project that meets the requirements of the USAF Fire Station Design Guide and retains all of the design character of the original project except for modifications that specifically address design assumptions made in this report.

The estimate work breakdown structure includes three elements, renovation, addition and support facilities. PACES project default values for contingency (10.0% for renovation) and SIOH (5.7%) were used. Contingency was set at 10% to address recycling of demolished materials and premiums for sustainable design materials. Estimate assumes competitive bidding and a normal schedule.

Functional space areas (FSAs) were measured from sketches prepared for estimating purposes to generate input quantities for the PACES fire station model. The resulting estimates were then edited to include demolition and renovation of the existing space and attachment of the addition. Not all PACES generated quantities were revised but significant items were measured or counted and revised in the estimate. These revisions can occur in both the FSAs and the building shell categories of the estimate.

No environmental or hazardous materials abatement has been included.

All roofing has been replaced and the high bay area roofs have been replaced with standing seam metal roofs supported by new sloping roof structures. No modifications of the foundations or new columns have been included.

Supporting facilities includes paving replacement only in those areas requiring changes in drainage. The electrical service entrance has been moved and the equipment replaced. The emergency generator has been replaced in a new location. The generator building has been demolished. The wash areas in front of the vehicle apparatus bays have been interconnected and routed to the oil/water separator.

Other exclusions include furnishings, design fees, movable equipment, and municipal impact fees, utility tap fees and any items not specifically identified in the itemized report.

Parametric Building Models

ASSEMBLY CONSTRUCTION COST REPORT

(Full estimate available upon requiest and release from the USAF.)

Project Name :	Homestead AFB Fire Station
Project Description :	Renovations & Addition
Project Comment	
GEOLOCATION	HOMESTEAD AFB, FLORIDA
Estimate by:	Senseman
Estimate Date:	01/14/2000

ESCALATION MODIFIER: MID-POINT OF CONSTRUCTION

ASSEMBLY CONSTRUCTION COST REPORT

Facility ***Site Development***

UM	QUANTITY	MATERIAL	LABOR	EQUIPMENT	TOTAL
Total Construction Cost		$1,335,974	$849,639	$42,968	$2,228,581

**** End of Report ****

Homestead ARB Fire Station Cost Breakdown

Parametric Building Models 02/02/2000

Table F-1 Homestead ARB Fire Station Cost Breakdown

SECTION MAIN BLDG	SYSTEM TOTAL	SYSTEM TOTAL ADDITION
01 Substructure	13,675	32,169
02 Superstructure	185,267	56,789
03 Ext Closure	21,751	102,648
04 Roofing	77,928	24,610
05 Int Construction	96,869	37,346
06 Int Finishes	158,511	47,448
07 N/A		
08 Plumbing	49,735	14,476
09 HVAC	271,933	52,334
10 Fire Protection	51,931	13,317
11 Electric Power & Lighting	291,942	42,426
12 Fire Alarm, PA, Cable	106,816	25,135
13 Equipment	5,315	--
14 Furnishings	523	--
15 Special Const	60,384	--
16 Selective Demolition	154,344	--
FACILITY TOTAL	**1,546,924**	**448,692**
17 Site Work	86,919	--
18 Site Improvement	59,910	--
19 Site Mech	39,081	12,134
20 Site Elec	34,919	--
SITE TOTAL	**220,829**	**12,134**

APPENDIX G

MARCH ARB, CA, C-17 SQUADRON OPERATIONS FACILITY SUPPORTING INFORMATION

Used with permission of HQ AFRC/CE-2, September 27, 2004

Architectural Design Narrative

Squadron Operations Facility

Introduction

The number of aircrew will increase as a result of the C-17 beddown. The existing squadron operations facility has adequate overall square footage, although the current space configuration will not adequately function for the C-17 aircrews. Planning, scheduling, and other rooms are being reconfigured to satisfy the need for appropriate working space.

The renovations of the facility have been designed in compliance with applicable Air Force Reserve requirements, including the DD1391, as well as current fire, building, and energy codes for the state of California.

Building Analysis / Design Concepts

The building is a single story with a clerestory structure built around a central courtyard.

A review of the building addressed a variety of interior reconfigurations necessary to support the C-17 mission, as well as the improvement of finishes and some furnishings. A general scope of these improvements includes

- Reconfiguration of the Operations Group areas
- Construction of a new lounge
- A rework of the conference room located in the southeast corner of the building
- Expansion and total renovation of the existing Men's and Women's Locker Rooms/Latrines
- Expansion of the Mission Planning area
- Reconfiguration of the Current Operations area
- Reconfiguration of the Pilots/Aircrew Briefing area
- Renovation of the main Conference Room
- Improvements to the front Lobby and rear entry to the building (Improvements will include floor, wall, and ceiling finishes.)

Several ceilings are being raised, primarily in large rooms to provide a better quality environment.

Finishes, primarily floor and wall, are being improved throughout the building due to the extent of the functional changes.

Code Review

Building Location

Riverside, CA

Applicable Building Codes

2001 California Building Code, (1997 UBC based)
NFPA 101-Life Safety Code, 2000
Uniform Federal Accessibility Standards

Occupancy Classifications

Primary Classification is Group B – Offices, assembly areas with occupant load less than 50 persons

Secondary Classification is Group A, Division 3 – Briefing Room # 132 and Lounge # 121 (accessory as less than 10%)

Building Area

Total: 38,000 SF

Number of Stories: 1

Building Height: Approximately 30'

Type of Construction: Type II-1-Hr, Sprinkled

Maximum Allowance Floor Area Per Floor (Table 5-B): 12,000 SF

Area Increase Allowance (505.2): Unlimited as the building is provided with an approved automatic sprinkler system and entirely surrounded and adjoined by public ways or yards not less than 60 feet in width.

Occupancy Loads

Conference Room:	48
Lounge and Briefing:	192
Offices:	255
Mech/Elec/Tel.:	4
Lockers/Latrines:	34
Total Occupant Load	**533**

Occupancy Separations
A-3/B: None Required

Fire Ratings

Exterior Walls:	1Hr
Columns:	1Hr
Beams:	1Hr

Roof/Ceiling:	1Hr
Interior Bearing:	1Hr

Means of Egress Requirements

Maximum Travel Distance:	250 ft., Sprinkled
Maximum Dead-end Corridors:	20 ft.
Minimum Corridor Width:	44 inches

Corridors not required to be of 1-hr construction where sprinkled and with smoke detectors (1004.3.4.3 exception 6).

Minimum Plumbing Fixtures (Appendix Chapter 29)

(Assume 50% Female)

Required

	Male	**Female**
Water Closets	6	6
Lavatories	4	4

(Up to half of male waterclosets may be urinals).

Provided

Water Closets	8	6
Urinals	7	
Lavatories	9	6

Sustainability

Sustainability incorporates economically sound, ecologically protective, and socially supportive approaches, products, and services into the facility. The design has been done to incorporate Leadership in Energy and Environmental Design (LEED) Green Building Rating System version 2.1 to achieve a Silver rating. Current code and guideline compliance incorporate some of these measures and additional approaches include those listed below identified by topic. Other strategies were considered but not incorporated due to cost or appropriateness.

Project Data

Site location:	Riverside, California
Project type:	Alterations/Renovations
Scope of work:	Building Interior
Building type:	Office/Administrative Building
Building size:	38,300 square feet
Number of floors:	One floor
Type of construction:	Masonry/Steel
Foundation:	Slab on grade

Window coverage: Typical number of windows

Sustainable Site

Safe access and storage areas, as well as showers and changing areas for bicycle and pedestrian commuters
Alternative refueling stations
Vehicle access to support car-and van-pooling
minimizing areas of open pavement (non-roof heat islands)

Water Efficiency

Water efficient landscaping to reduce potable water irrigation usage 50% below conventional means
Water use reduction with appropriate toilet fixtures and fittings.

Energy and Atmosphere

Energy performance optimized to 10% above prerequisite standard to reduce environmental impacts

Additional commissioning to verify building project is constructed and calibrated to operate as intended

HCFC's use eliminated to reduce ozone deletion

System metering power, air-conditioning, and water for ongoing accountability and optimization of building energy and water consumption performance over time

At least 50% of project's energy consumption to meet the definition of renewable energy

Materials and Resources

100% of existing building shell maintained for reuse

Salvage or recycle of 50% of construction waste

Use of 25% recycle content materials

Use 20% local / regionally produced materials

Of materials local / regionally produced, 50% are to be of locally harvested materials

Rapidly renewable materials used

Environmental Quality

Increased ventilation effectiveness

Indoor Air Quality Management Plan during construction

Indoor Air Quality Management Plan, post construction

Low-emitting materials for adhesives, paints, carpets and composite wood

Indoor chemical and pollutant controls

Individual user controls on environmental systems

Compliance with ASHRAE 55-1992 thermal comfort guidelines

Codes and Standards

The following code and standard publications were referenced for the design of this facility:

- 2001 California Building Code (1997 UBC based).
- Military Handbook MIL-Hdbk-1008C and Life Safety Code NFPA 101.
- Uniform Federal Accessibility Standards.
- American Disabilities Act Architectural Guidelines (ADAAG) as amended through January 1998.
- Department of Defense Antiterrorism/Construction Standards (AT/CS) draft dated August 30, 2001.

Table G-1 March ARB Squadron Operations Building
Project Planning Phases Initial LEED Test Scoring

MARCH AIR RESERVE BASE - Squadron Operations Building #2240
Initial LEED v2.1 Test Scoring
13-Dec-02

Summary: Obtainable **35** Obtainable+Possible: **48** Not Possible **21** Total Possible Points: **69**

LEED Certified: 26 - 32 Silver Rating: 33 - 38 Gold Rating: 39 - 51 Platinum Rating: 52+

		Available Points	Obtainable	Possible	Not Possible
Sustainable Sites:		14	5	3	6
SS Prerequesite 1	Erosion and Sediment Control	0			
SS Credit 1	Site Selection	1			1
SS Credit 2	Urban Redevelopment	1			1
SS Credit 3	Brownfield Redevelopment	1			1
SS Credit 4.1	Alternative Transportation, Locate Near Public Transportation	1		1	
SS Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	1	1		
SS Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations	1	1		
SS Credit 4.4	Alternative Transportation, Parking Capacity	1	1		
SS Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space	1			1
SS Credit 5.2	Reduced Site Disturbance, Development Footprint	1		1	
SS Credit 6.1	Stormwater Management, No Net Increase or 25% Decrease	1	1		
SS Credit 6.2	Stormwater Management, Treatment Systems	1			1
SS Credit 7.1	Reduce Heat Islands, Non-roof	1		1	
SS Credit 7.2	Reduce Heat Islands, Roof	1			1
SS Credit 8	Lighting Polution Reduction	1	1		
		Available Points	Obtainable	Possible	Not Possible
Water Efficiency:		5	4	1	0
WE Credit 1.1	Water Efficient Landscaping, Reduce by 50%	1	1		
WE Credit 1.2	Water Efficient Landscaping, Reduce Additional 50% or No Irrigation	1	1		
WE Credit 2	Innovative Wastewater Technologies	1		1	
WE Credit 3.1	Water Use Reduction, 20% Reduction	1	1		
WE Credit 3.2	Water Use Reduction, Additional 10% Reduction	1	1		
		Available Points	Obtainable	Possible	Not Possible
Energy & Atmosphere		17	7	2	8
EA Prerequisite 1	Fundamental Building Commissioning	0			
EA Prerequisite 2	Minimum Energy Performance	0			
EA Prerequisite 3	CFC Reduction in HVAC&R Equipment	0			
EA Credit 1.1	Optimize Energy Performance, 15% New 5% Existing	1	1		
EA Credit 1.2	Optimize Energy Performance, 20% New 10% Existing	1	1		
EA Credit 1.3	Optimize Energy Performance, 25% New 150% Existing	1	1		
EA Credit 1.4	Optimize Energy Performance, 30% New 20% Existing	1	1		
EA Credit 1.5	Optimize Energy Performance, 35% New 25% Existing	1	1		
EA Credit 1.6	Optimize Energy Performance, 40% New 30% Existing	1	1		
EA Credit 1.7	Optimize Energy Performance, 45% New 35% Existing	1			1
EA Credit 1.8	Optimize Energy Performance, 50% New 40% Existing	1			1
EA Credit 1.9	Optimize Energy Performance, 55% New 45% Existing	1			1
EA Credit 1.10	Optimize Energy Performance, 60% New 50% Existing	1			1
EA Credit 2.1	Renewable Energy, 5%	1			1
EA Credit 2.2	Renewable Energy, 10%	1			1
EA Credit 2.3	Renewable Energy, 20%	1			1
EA Credit 3	Additional Commissioning	1		1	
EA Credit 4	Elimination of HCFC's and Halons	1	1		
EA Credit 5	Measurement and Verification	1		1	
EA Credit 6	Green Power	1			1

Table G-1 (continued).

MARCH AIR RESERVE BASE - Squadron Operations Building #2240 Initial LEED v2.1 Test Scoring 13-Dec-02					
Summary:	Obtainable **8** Obtainable+Possible: **12** Not Possible **2**	Total Possible Points: **14**			
	LEED Certified: 26 - 32 Silver Rating: 33 - 38 Gold Rating: 39 - 51 Platinum Rating: 52+				
		Available Points	Obtainable	Possible	Not Possible
Materials & Resource		13	7	4	2
MR Prerequisite 1	Storage & Collection of Recyclables	0			
MR Credit 1.1	Building Reuse, Maintain 75% of Existing Shell	1	1		
MR Credit 1.2	Building Reuse, Maintain Additional 25% of Shell	1	1		
MR Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell	1			1
MR Credit 2.1	Construction Waste Management, Salvage or Recycle 50%	1	1		
MR Credit 2.2	Construction Waste Management, Salvage Additional 25%	1	1		
MR Credit 3.1	Resource Reuse, Specify 5%	1	1		
MR Credit 3.2	Resource Reuse, Specify 10%	1			1
MR Credit 4.1	Recycle Content, Specify 25%	1	1		
MR Credit 4.2	Recycle Content, Specify 50%	1		1	
MR Credit 5.1	Local / Regional Materials, of 20% Manufactured Locally	1	1		
MR Credit 5.2	Local / Regional Materials, of 20% Above 50% Harvested Locally	1		1	
MR Credit 6	Rapidly Renewable Materials	1		1	
MR Credit 7	Certified Wood	1		1	
		Available Points	Obtainable	Possible	Not Possible
Environmental Quality		15	11	2	2
EQ Prerequisite 1	Minimum IAQ Performance	0			
EQ Prerequisite 2	Environmental Tabacco Smoke (ETS) Control	0			
EQ Credit 1	Carbon Dioxide (CO2) Monitoring	1	1		
EQ Credit 2	Increase Ventilation Effectiveness	1	1		
EQ Credit 3.1	Construction IAQ Management Plan, During Const	1	1		
EQ Credit 3.2	Construction IAQ Management Plan, Post Const	1	1		
EQ Credit 4.1	Low-Emitting Materials, Adhesives	1	1		
EQ Credit 4.2	Low-Emitting Materials, Paints	1	1		
EQ Credit 4.3	Low-Emitting Materials, Carpets	1	1		
EQ Credit 4.4	Low-Emitting Materials, Composite Wood	1	1		
EQ Credit 5	Indoor Chemical and Pollutant Source Control	1		1	
EQ Credit 6.1	Controllability of Systems, Operable Windows	1			1
EQ Credit 6.2	Controllability of Systems, Individual Controls	1	1		
EQ Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992	1	1		
EQ Credit 7.2	Thermal Comfort, Permanent Monitoring System	1	1		
EQ Credit 8.1	Daylight and Views, Diffuse Sunlight to 90%	1		1	
EQ Credit 8.2	Daylight and Views, Direct Line of Site 90%	1			1
		Available Points	Obtainable	Possible	Not Possible
Design Excellence:		5	1	1	3
DE Credit 1.1	Innovation in Design	1		1	
DE Credit 1.2	Innovation in Design	1			1
DE Credit 1.3	Innovation in Design	1			1
DE Credit 1.4	Innovation in Design	1			1
DE Credit 2	LEED Accredited Professional	1	1		

Table G-1 (continued).

MARCH AIR RESERVE BASE - Squadron Operations Building #2240 LEED v2.1 Responsibility Matrix 13-Dec-02										
		LEED Accredited Professional	Architect	Structural	Mechanical, Plumbing, FP	Electrical	Civil	Other	AFRC	MARB
Sustainable Sites:										
SS Prerequesite 1	Erosion and Sediment Control	x					x			
SS Credit 1	Site Selection								x	x
SS Credit 2	Urban Redevelopment									
SS Credit 3	Brownfield Redevelopment									
SS Credit 4.1	Alternative Transportation, Locate Near Public Transportation	x								x
SS Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms		x							
SS Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations						x			
SS Credit 4.4	Alternative Transportation, Parking Capacity						x			
SS Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space						x			
SS Credit 5.2	Reduced Site Disturbance, Development Footprint		x				x			
SS Credit 6.1	Stormwater Management, No Net Increase or 25% Decrease						x			
SS Credit 6.2	Stormwater Management, Treatment Systems				x		x			
SS Credit 7.1	Reduce Heat Islands, Non-roof						x			
SS Credit 7.2	Reduce Heat Islands, Roof		x							
SS Credit 8	Lighting Polution Reduction		x			x	x			
Water Efficiency:										
WE Credit 1.1	Water Efficient Landscaping, Reduce by 50%						x			
WE Credit 1.2	Water Efficient Landscaping, Reduce Additional 50% or No Irrigation						x			
WE Credit 2	Innovative Wastewater Technologies				x					
WE Credit 3.1	Water Use Reduction, 20% Reduction				x					
WE Credit 3.2	Water Use Reduction, Additional 10% Reduction				x					
Energy & Atmosphere:										
EA Prerequisite 1	Fundamental Building Commissioning								x	
EA Prerequisite 2	Minimum Energy Performance		x		x	x				
EA Prerequisite 3	CFC Reduction in HVAC&R Equipment				x					
EA Credit 1.1	Optimize Energy Performance, 15% New 5% Existing		x		x	x				
EA Credit 1.2	Optimize Energy Performance, 20% New 10% Existing		x		x	x				
EA Credit 1.3	Optimize Energy Performance, 25% New 150% Existing		x		x	x				
EA Credit 1.4	Optimize Energy Performance, 30% New 20% Existing		x		x	x				
EA Credit 1.5	Optimize Energy Performance, 35% New 25% Existing		x		x	x				
EA Credit 1.6	Optimize Energy Performance, 40% New 30% Existing		x		x	x				
EA Credit 1.7	Optimize Energy Performance, 45% New 35% Existing		x		x	x				
EA Credit 1.8	Optimize Energy Performance, 50% New 40% Existing		x		x	x				
EA Credit 1.9	Optimize Energy Performance, 55% New 45% Existing		x		x	x				
EA Credit 1.10	Optimize Energy Performance, 60% New 50% Existing		x		x	x				
EA Credit 2.1	Renewable Energy, 5%								x	x
EA Credit 2.2	Renewable Energy, 10%								x	x
EA Credit 2.3	Renewable Energy, 20%								x	x
EA Credit 3	Additional Commissioning								x	
EA Credit 4	Elimination of HCFC's and Halons				x					
EA Credit 5	Measurement and Verification								x	x
EA Credit 6	Green Power								x	x

Table G-1 (continued).

MARCH AIR RESERVE BASE - Squadron Operations Building #2240 LEED v2.1 Responsibility Matrix 13-Dec-02		LEED Accredited Professional	Architect	Structural	Mechanical, Plumbing, FP	Electrical	Civil	Other	AFRC	MARB
Materials & Resources:										
MR Prerequisite 1	Storage & Collection of Recyclables	x	x							
MR Credit 1.1	Building Reuse, Maintain 75% of Existing Shell		x							
MR Credit 1.2	Building Reuse, Maintain Additional 25% of Shell		x							
MR Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell		x							
MR Credit 2.1	Construction Waste Management, Salvage or Recycle 50%	x								
MR Credit 2.2	Construction Waste Management, Salvage Additional 25%	x								
MR Credit 3.1	Resource Reuse, Specify 5%	x								
MR Credit 3.2	Resource Reuse, Specify 10%	x								
MR Credit 4.1	Recycle Content, Specify 25%		x							
MR Credit 4.2	Recycle Content, Specify 50%		x							
MR Credit 5.1	Local / Regional Materials, of 20% Manufactured Locally	x	x	x	x	x	x			
MR Credit 5.2	Local / Regional Materials, of 20% Above 50% Harvested Locally	x	x	x	x	x	x			
MR Credit 6	Rapidly Renewable Materials		x	x	x	x	x			
MR Credit 7	Certified Wood		x							
Environmental Quality:										
EQ Prerequisite 1	Minimum IAQ Performance		x		x					
EQ Prerequisite 2	Environmental Tabacco Smoke (ETS) Control								x	x
EQ Credit 1	Carbon Dioxide (CO2) Monitoring				x				x	x
EQ Credit 2	Increase Ventilation Effectiveness				x					
EQ Credit 3.1	Construction IAQ Management Plan, During Const	x							x	
EQ Credit 3.2	Construction IAQ Management Plan, Post Const	x							x	
EQ Credit 4.1	Low-Emitting Materials, Adhesives		x							
EQ Credit 4.2	Low-Emitting Materials, Paints		x							
EQ Credit 4.3	Low-Emitting Materials, Carpets		x							
EQ Credit 4.4	Low-Emitting Materials, Composite Wood		x							
EQ Credit 5	Indoor Chemical and Pollutant Source Control		x		x		x			
EQ Credit 6.1	Controllability of Systems, Operable Windows		x		x	x				
EQ Credit 6.2	Controllability of Systems, Individual Controls		x		x	x				
EQ Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992				x					
EQ Credit 7.2	Thermal Comfort, Permanent Monitoring System				x					
EQ Credit 8.1	Daylight and Views, Diffuse Sunlight to 90%		x			x				
EQ Credit 8.2	Daylight and Views, Direct Line of Site 90%		x			x				
Design Excellence:										
DE Credit 1.1	Innovation in Design, Heat Recovery Duct	x	x	x	x	x	x	x	x	x
DE Credit 1.2	Innovation in Design, Thermal / CO2 Sensor, Window Controls	x	x	x	x	x	x	x	x	x
DE Credit 1.3	Innovation in Design, Meeting Room Moveable Exterior Wall	x	x	x	x	x	x	x	x	x
DE Credit 1.4	Innovation in Design, TBD	x	x	x	x	x	x	x	x	x
DE Credit 2	LEED Accredited Professional	x								

MARCH AIR RESERVE BASE

RIVERSIDE CALIFORNIA

SQUADRON OPERATIONS - BUILDING 2240

DEFINITIVE COST ESTIMATE

DATE: 05/19/03

	ITEM	*COST*
1	SQUADRON OPERATIONS BUILDING 2240	$1,448,400
2	BUILDING 2240 ADDITIVE ALTERNATE 1- BERM	$26,600
3	BUILDING 2240 ADDITIVE ALTERNATE 2- PAINT BUILDING EXTERIOR	$23,200
4	BUILDING 2240 ADDITIVE ALTERNATE 3- ADDITIONAL SITE PV LIGHTING	$81,100
5	BUILDING 2240 ADDITIVE ALTERNATE 4- PARKING ISLANDS LANDSCAPE IRRIG	$4,400
6	BUILDING 2240 ADDITIVE ALTERNATE 5- PARKING ISLAND TREES	$7,400
7	BUILDING 2240 ADDITIVE ALTERNATE 6- LIGHTING CONTROLS	$56,500
8	BUILDING 2240 ADDITIVE ALTERNATE 7- LANDSCAPING	$44,100
9	BUILDING 2240 ADDITIVE ALTERNATE 8- REMOVE EXIST SKYLIGHTS & REPLACE W/NEW	$22,800
10	BUILDING 2240 ADDITIVE ALTERNATE 9- (INTERNALLY ILLUM. CURVED GLASS WALL IN LIEU OF PERF MTL PANEL WALL)	$15,400
11	BUILDING 2240 ADDITIVE ALTERNATE 10- SOUND ABSORBING PANELS @ ROOM 120 & 132	$28,700
12	BUILDING 2240 ADDITIVE ALTERNATE 11- REPLACE EXISTING AHU	$40,300
13	BUILDING 2240 ADDITIVE ALTERNATE 12- REPLACE EXISTING PNEUMATIC HVAC Control Systen	$32,900
14	BUILDING 2240 ADDITIVE ALTERNATE 13- NEW LOCKERS & BENCHES	$42,200
15	BUILDING 2240 ADDITIVE ALTERNATE 14- 2" WIDE ALUMINUM HORIZONTAL LOUVER BLINDS	$1,000
15	TOTAL Incl. All Options	$1,875,000

APPENDIX H

MARCH ARB, CA, C-17 LIFE SUPPORT FACILITY SUPPORTING INFORMATION

Used with permission of HQ AFRC/CE-2, September 27, 2004

Architectural Design Narrative

Life Support Facility

Introduction

Work on this existing building consists primarily of removal of interior partitions, finishes, ceilings, and fixtures and the installation of new building components in order to satisfy the C-17 Life Support functions. This building is located in the Historic District and has significant historic issues with regard to fenestration and openings on the Graeber Street side and to a lesser extent on the other three façades.

The renovations of the facility have been designed in compliance with applicable Air Force Reserve requirements, including the DD1391, as well as current fire, building, and energy codes for the state of California.

Building Analysis / Design Concepts

The building is a former cold storage building. The roof structure appears to be steel with wood plank roof decking. The base civil engineer reported that the membrane roof was replaced within the last 6 years and is in good condition.

Life support activities from buildings 300 and 2308 will be moved to this building, in addition to modification of some existing building functions. Mission requirements include mobility, chemical defense training, weapons issue, helmet storage, kits, locker rooms for both men and women, administrative, and flight line storage.

Work includes a complete rework of the building interior to accommodate the C-17 mission requirements. Restoration of the historically designated exterior windows has been included. Exterior modifications (door replacement, painting, masonry pointing) have been included in a manner sympathetic to the historical implications of the building.

Code Review

Building Location

Riverside, CA

Applicable Building Codes

2001 California Building Code, (1997 UBC based)
NFPA 101-Life Safety Code, 2000
Uniform Federal Accessibility Standards

Occupancy Classifications

Primary Classifications are Group B: Offices, assembly areas with occupant load less than 50 persons and Group S-2: Low-hazard storage occupancy.

Secondary Classification is Group A-3: Small Assembly (accessory as less than 10%)

Building Area

Total: Approximately 28,000 SF

Number of Stories: 1

Building Height: Approximately 30'

Type of Construction: Type II-Noncombustible, sprinkled

Maximum Allowance Floor Area Per Floor (Table 5-B): Unlimited as the building is provided with an approved automatic sprinkler system and entirely surrounded and adjoined by public ways or yards not less than 60 feet in width.

Occupancy Loads

Offices:	146
Mech/Elec.:	4
Lockers/Latrines:	38
Conference/Break Room:	57
Classroom	60
Storage:	17
Total Occupant Load	**322**

Occupancy Separations
B/S-2/A-3: None Required

Fire Ratings

Exterior Walls:	Noncombustible
Columns:	Noncombustible
Beams:	Noncombustible
Roof/Ceiling:	Noncombustible
Interior Bearing:	Noncombustible

Means of Egress Requirements

Maximum Travel Distance:	250 ft., Sprinkled
Maximum Dead-end Corridors:	20 ft.
Minimum Corridor Width:	44 inches

Minimum Plumbing Fixtures (Appendix Chapter 29)

(Assume 20% Female)

Required

	Male	Female
Water Closets	6	3
Lavatories	4	2

(Up to half of male waterclosets may be urinals).

Provided

Water Closets	3	2
Urinals	3	
Lavatories	6	3

Sustainability

Sustainability incorporates economically sound, ecologically protective, and socially supportive approaches, products, and services into the facility. The design has been done to incorporate Leadership in Energy and Environmental Design (LEED) Green Building Rating System version 2.1 to achieve a Silver rating. Current code and guideline compliance incorporate some of these measures and additional approaches include those listed below identified by topic. Other strategies were considered but not incorporated due to cost or appropriateness.

Project Data

Site location:	Riverside, California
Project type:	Alterations/Renovations
Scope of work:	Rework Building Interior/Exterior Painting
Building type:	Administrative/Storage/Training Building
Building size:	28,000 square feet
Number of floors:	One floor
Type of construction:	Masonry/Wood
Foundation:	Slab on grade
Window coverage:	High number of historically significant windows

Sustainable Site

Safe access and storage areas, as well as showers and changing areas for bicycle and pedestrian commuters
Alternative refueling stations
Vehicle access to support car-and van-pooling

Water Efficiency

Water use reduction with appropriate toilet fixtures and fittings.

Energy and Atmosphere

Energy performance optimized to above 50% above prerequisite standard to reduce environmental impacts

Additional commissioning to verify building project is constructed and calibrated to operate as intended

HCFC's use eliminated to reduce ozone deletion

Materials and Resources

100% of existing building shell maintained for reuse

Salvage or recycle of 50% of construction waste

Use of 50% recycle content materials

Use 20% local / regionally produced materials

Of materials local / regionally produced, 50% are to be of locally harvested materials

Rapidly renewable materials used

Environmental Quality

Carbon dioxide (CO2) monitoring equipment

Increased ventilation effectiveness

Indoor Air Quality Management Plan during construction

Indoor Air Quality Management Plan, post construction

Low-emitting materials for adhesives, paints, carpets and composite wood

Indoor chemical and pollutant controls

Individual user controls on environmental systems

Compliance with ASHRAE 55-1992 thermal comfort guidelines

Codes and Standards

The following code and standard publications were referenced for the design of this facility:

- 2001 California Building Code (1997 UBC based).
- Military Handbook MIL-Hdbk-1008C and Life Safety Code NFPA 101.
- Uniform Federal Accessibility Standards.
- American Disabilities Act Architectural Guidelines (ADAAG) as amended through January 1998.
- Department of Defense Antiterrorism/Construction Standards (AT/CS) draft dated August 30, 2001.

Table H-1 March ARB Life Support Facility
Project Planning Phases Initial LEED Test Scoring

MARCH AIR RESERVE BASE - Life Support Building #420
Initial LEED v2.1 Test Scoring
13-Dec-02

Summary: Obtainable **34** Obtainable+Possible: **54** Not Possible **15** Total Possible Points: **69**

LEED Certified: 26 - 32 Silver Rating: 33 - 38 Gold Rating: 39 - 51 Platinum Rating: 52+

		Available Points	Obtainable	Possible	Not Possible
Sustainable Sites:		14	4	5	5
SS Prerequesite 1	Erosion and Sediment Control	0			
SS Credit 1	Site Selection	1			1
SS Credit 2	Urban Redevelopment	1			1
SS Credit 3	Brownfield Redevelopment	1			1
SS Credit 4.1	Alternative Transportation, Locate Near Public Transportation	1			1
SS Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	1	1		
SS Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations	1	1		
SS Credit 4.4	Alternative Transportation, Parking Capacity	1	1		
SS Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space	1			1
SS Credit 5.2	Reduced Site Disturbance, Development Footprint	1		1	
SS Credit 6.1	Stormwater Management, No Net Increase or 25% Decrease	1	1		
SS Credit 6.2	Stormwater Management, Treatment Systems	1		1	
SS Credit 7.1	Reduce Heat Islands, Non-roof	1		1	
SS Credit 7.2	Reduce Heat Islands, Roof	1		1	
SS Credit 8	Lighting Polution Reduction	1		1	
		Available Points	Obtainable	Possible	Not Possible
Water Efficiency:		5	4	1	0
WE Credit 1.1	Water Efficient Landscaping, Reduce by 50%	1	1		
WE Credit 1.2	Water Efficient Landscaping, Reduce Additional 50% or No Irrigation	1	1		
WE Credit 2	Innovative Wastewater Technologies	1		1	
WE Credit 3.1	Water Use Reduction, 20% Reduction	1	1		
WE Credit 3.2	Water Use Reduction, Additional 10% Reduction	1	1		
		Available Points	Obtainable	Possible	Not Possible
Energy & Atmosphere		17	7	6	4
EA Prerequisite 1	Fundamental Building Commissioning	0			
EA Prerequisite 2	Minimum Energy Performance	0			
EA Prerequisite 3	CFC Reduction in HVAC&R Equipment	0			
EA Credit 1.1	Optimize Energy Performance, 15% New 5% Existing	1	1		
EA Credit 1.2	Optimize Energy Performance, 20% New 10% Existing	1	1		
EA Credit 1.3	Optimize Energy Performance, 25% New 150% Existing	1	1		
EA Credit 1.4	Optimize Energy Performance, 30% New 20% Existing	1	1		
EA Credit 1.5	Optimize Energy Performance, 35% New 25% Existing	1	1		
EA Credit 1.6	Optimize Energy Performance, 40% New 30% Existing	1	1		
EA Credit 1.7	Optimize Energy Performance, 45% New 35% Existing	1		1	
EA Credit 1.8	Optimize Energy Performance, 50% New 40% Existing	1		1	
EA Credit 1.9	Optimize Energy Performance, 55% New 45% Existing	1		1	
EA Credit 1.10	Optimize Energy Performance, 60% New 50% Existing	1		1	
EA Credit 2.1	Renewable Energy, 5%	1			1
EA Credit 2.2	Renewable Energy, 10%	1			1
EA Credit 2.3	Renewable Energy, 20%	1			1
EA Credit 3	Additional Commissioning	1		1	
EA Credit 4	Elimination of HCFC's and Halons	1	1		
EA Credit 5	Measurement and Verification	1		1	
EA Credit 6	Green Power	1			1

Table H-1 (continued).

MARCH AIR RESERVE BASE - Life Support Building #420 Initial LEED v2.1 Test Scoring 13-Dec-02					
Summary:	Obtainable **7** Obtainable+Possible: **12** Not Possible **2**	Total Possible Points: **14**			
	LEED Certified: 26 - 32 Silver Rating: 33 - 38 Gold Rating: 39 - 51 Platinum Rating: 52+				
		Available Points	Obtainable	Possible	Not Possible
Materials & Resource		13	6	5	2
MR Prerequisite 1	Storage & Collection of Recyclables	0			
MR Credit 1.1	Building Reuse, Maintain 75% of Existing Shell	1	1		
MR Credit 1.2	Building Reuse, Maintain Additional 25% of Shell	1	1		
MR Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell	1			1
MR Credit 2.1	Construction Waste Management, Salvage or Recycle 50%	1	1		
MR Credit 2.2	Construction Waste Management, Salvage Additional 25%	1		1	
MR Credit 3.1	Resource Reuse, Specify 5%	1		1	
MR Credit 3.2	Resource Reuse, Specify 10%	1			1
MR Credit 4.1	Recycle Content, Specify 25%	1	1		
MR Credit 4.2	Recycle Content, Specify 50%	1	1		
MR Credit 5.1	Local / Regional Materials, of 20% Manufactured Locally	1	1		
MR Credit 5.2	Local / Regional Materials, of 20% Above 50% Harvested Locally	1		1	
MR Credit 6	Rapidly Renewable Materials	1		1	
MR Credit 7	Certified Wood	1		1	
		Available Points	Obtainable	Possible	Not Possible
Environmental Quality		15	12	2	1
EQ Prerequisite 1	Minimum IAQ Performance	0			
EQ Prerequisite 2	Environmental Tabacco Smoke (ETS) Control	0			
EQ Credit 1	Carbon Dioxide (CO2) Monitoring	1	1		
EQ Credit 2	Increase Ventilation Effectiveness	1	1		
EQ Credit 3.1	Construction IAQ Management Plan, During Const	1	1		
EQ Credit 3.2	Construction IAQ Management Plan, Post Const	1	1		
EQ Credit 4.1	Low-Emitting Materials, Adhesives	1	1		
EQ Credit 4.2	Low-Emitting Materials, Paints	1	1		
EQ Credit 4.3	Low-Emitting Materials, Carpets	1	1		
EQ Credit 4.4	Low-Emitting Materials, Composite Wood	1	1		
EQ Credit 5	Indoor Chemical and Pollutant Source Control	1	1		
EQ Credit 6.1	Controllability of Systems, Operable Windows	1		1	
EQ Credit 6.2	Controllability of Systems, Individual Controls	1	1		
EQ Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992	1	1		
EQ Credit 7.2	Thermal Comfort, Permanent Monitoring System	1	1		
EQ Credit 8.1	Daylight and Views, Diffuse Sunlight to 90%	1		1	
EQ Credit 8.2	Daylight and Views, Direct Line of Site 90%	1			1
		Available Points	Obtainable	Possible	Not Possible
Design Excellence:		5	1	1	3
DE Credit 1.1	Innovation in Design	1		1	
DE Credit 1.2	Innovation in Design	1			1
DE Credit 1.3	Innovation in Design	1			1
DE Credit 1.4	Innovation in Design	1			1
DE Credit 2	LEED Accredited Professional	1	1		

Table H-1 (continued).

MARCH AIR RESERVE BASE - Life Support Building #420 LEED v2.1 Responsibility Matrix 13-Dec-02		LEED Accredited Professional	Architect	Structural	Mechanical, Plumbing, FP	Electrical	Civil	Other	AFRC	MARB
Sustainable Sites:										
SS Prerequesite 1	Erosion and Sediment Control	x					x			
SS Credit 1	Site Selection								x	x
SS Credit 2	Urban Redevelopment									
SS Credit 3	Brownfield Redevelopment									
SS Credit 4.1	Alternative Transportation, Locate Near Public Transportation	x								x
SS Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms		x							
SS Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations						x			
SS Credit 4.4	Alternative Transportation, Parking Capacity						x			
SS Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space						x			
SS Credit 5.2	Reduced Site Disturbance, Development Footprint		x				x			
SS Credit 6.1	Stormwater Management, No Net Increase or 25% Decrease						x			
SS Credit 6.2	Stormwater Management, Treatment Systems				x		x			
SS Credit 7.1	Reduce Heat Islands, Non-roof						x			
SS Credit 7.2	Reduce Heat Islands, Roof		x							
SS Credit 8	Lighting Polution Reduction		x			x	x			
Water Efficiency:										
WE Credit 1.1	Water Efficient Landscaping, Reduce by 50%						x			
WE Credit 1.2	Water Efficient Landscaping, Reduce Additional 50% or No Irrigation						x			
WE Credit 2	Innovative Wastewater Technologies				x					
WE Credit 3.1	Water Use Reduction, 20% Reduction				x					
WE Credit 3.2	Water Use Reduction, Additional 10% Reduction				x					
Energy & Atmosphere:										
EA Prerequisite 1	Fundamental Building Commissioning								x	
EA Prerequisite 2	Minimum Energy Performance		x		x	x				
EA Prerequisite 3	CFC Reduction in HVAC&R Equipment				x					
EA Credit 1.1	Optimize Energy Performance, 15% New 5% Existing		x		x	x				
EA Credit 1.2	Optimize Energy Performance, 20% New 10% Existing		x		x	x				
EA Credit 1.3	Optimize Energy Performance, 25% New 150% Existing		x		x	x				
EA Credit 1.4	Optimize Energy Performance, 30% New 20% Existing		x		x	x				
EA Credit 1.5	Optimize Energy Performance, 35% New 25% Existing		x		x	x				
EA Credit 1.6	Optimize Energy Performance, 40% New 30% Existing		x		x	x				
EA Credit 1.7	Optimize Energy Performance, 45% New 35% Existing		x		x	x				
EA Credit 1.8	Optimize Energy Performance, 50% New 40% Existing		x		x	x				
EA Credit 1.9	Optimize Energy Performance, 55% New 45% Existing		x		x	x				
EA Credit 1.10	Optimize Energy Performance, 60% New 50% Existing		x		x	x				
EA Credit 2.1	Renewable Energy, 5%								x	x
EA Credit 2.2	Renewable Energy, 10%								x	x
EA Credit 2.3	Renewable Energy, 20%								x	x
EA Credit 3	Additional Commissioning								x	
EA Credit 4	Elimination of HCFC's and Halons				x					
EA Credit 5	Measurement and Verification								x	x
EA Credit 6	Green Power								x	x

Table H-1 (continued).

MARCH AIR RESERVE BASE - Life Support Building #420
LEED v2.1 Responsibility Matrix

13-Dec-02

		LEED Accredited Professional	Architect	Structural	Mechanical, Plumbing, FP	Electrical	Civil	Other	AFRC	MARB
Materials & Resources:										
MR Prerequisite 1	Storage & Collection of Recyclables	x	x							
MR Credit 1.1	Building Reuse, Maintain 75% of Existing Shell		x							
MR Credit 1.2	Building Reuse, Maintain Additional 25% of Shell		x							
MR Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell		x							
MR Credit 2.1	Construction Waste Management, Salvage or Recycle 50%	x								
MR Credit 2.2	Construction Waste Management, Salvage Additional 25%	x								
MR Credit 3.1	Resource Reuse, Specify 5%	x								
MR Credit 3.2	Resource Reuse, Specify 10%	x								
MR Credit 4.1	Recycle Content, Specify 25%		x							
MR Credit 4.2	Recycle Content, Specify 50%		x							
MR Credit 5.1	Local / Regional Materials, of 20% Manufactured Locally	x	x	x	x	x	x			
MR Credit 5.2	Local / Regional Materials, of 20% Above 50% Harvested Locally	x	x	x	x	x	x			
MR Credit 6	Rapidly Renewable Materials		x	x	x	x	x			
MR Credit 7	Certified Wood		x							
Environmental Quality:										
EQ Prerequisite 1	Minimum IAQ Performance		x		x					
EQ Prerequisite 2	Environmental Tabacco Smoke (ETS) Control								x	x
EQ Credit 1	Carbon Dioxide (CO2) Monitoring				x				x	x
EQ Credit 2	Increase Ventilation Effectiveness				x					
EQ Credit 3.1	Construction IAQ Management Plan, During Const	x							x	
EQ Credit 3.2	Construction IAQ Management Plan, Post Const	x							x	
EQ Credit 4.1	Low-Emitting Materials, Adhesives		x							
EQ Credit 4.2	Low-Emitting Materials, Paints		x							
EQ Credit 4.3	Low-Emitting Materials, Carpets		x							
EQ Credit 4.4	Low-Emitting Materials, Composite Wood		x							
EQ Credit 5	Indoor Chemical and Pollutant Source Control		x		x		x			
EQ Credit 6.1	Controllability of Systems, Operable Windows		x		x	x				
EQ Credit 6.2	Controllability of Systems, Individual Controls		x		x	x				
EQ Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992				x					
EQ Credit 7.2	Thermal Comfort, Permanent Monitoring System				x					
EQ Credit 8.1	Daylight and Views, Diffuse Sunlight to 90%		x			x				
EQ Credit 8.2	Daylight and Views, Direct Line of Site 90%		x			x				
Design Excellence:										
DE Credit 1.1	Innovation in Design, Heat Recovery Duct	x	x	x	x	x	x	x	x	x
DE Credit 1.2	Innovation in Design, Thermal / CO2 Sensor, Window Controls	x	x	x	x	x	x	x	x	x
DE Credit 1.3	Innovation in Design, Meeting Room Moveable Exterior Wall	x	x	x	x	x	x	x	x	x
DE Credit 1.4	Innovation in Design, TBD	x	x	x	x	x	x	x	x	x
DE Credit 2	LEED Accredited Professional	x								

March ARB, Life Support Final Costs   Bldg 420 ($000.0K rounded)

Site Work	
Paving	
Misc	40.0
Landscaping	45.3
Facility	
Removal	47.3
Doors & Windows	119.0
Interior walls	110.0
Ceilings	68.0
Finishes	37.9
Floors	118.9
Special work	42.6
HVAC	363.3
Fire Systems	56.3
Plumbing	19.0
Electrical	419.5
Furnishings/Milwork	311.6
Subtotal	1,798.7
SIOH&P	458.6
TOTAL	2,257.3

A further breakdown is available upon request and approval to release by the USAF

REFERENCES

American Institute of Architects (AIA) National Convention. (2004, June). *Building a legacy of sustainable public buildings*. Chicago, IL: GSA & HOK.

AIA National Convention. (2004, June). Greening architecture**.** *The Architectural Review*. London, UK & Malaysia Architects. Chicago, IL.

Air Force Center for Environmental Excellence Headquarters (HQ AFCEE). (2001, January 20). Sustainable design and construction services. *Guidance Letter from HQ AFCEE/CC to ALMAJCOM/CE*.

American Planning Association (APA). Journal of the American Planning Association Web site: www.planning.org/japa/archive.html.

Anderson, R. (1998). *Mid-course correction.* Atlanta, GA: Peregrinzilla Press.

Barnett, Diana L. & Browning, William D. (1995). *A primer on sustainable building*. Snowmass, CO: Rocky Mountain Institute.

Beatley, T. (1995). Planning and sustainability: The elements of a new (improved?) paradigm. *Journal of Planning Literature*, *9* (4), 383-395.

Becker, T. J. (2004, Spring/Summer) Taking sustainability to the streets [Electronic version]. *Research Horizons.* Retrieved on August 8, 2004, from www.gtresearchnews.gatech.edu/reshor/rh-ss04/sustain.html.

Berke, P. & Conroy, M. (2000). Are we planning for sustainable development? An evaluation of 30 comprehensive plans. *APA Journal*, *66* (1), 21-34.

Berry, Leonard L. (1999). *Discovering the soul of service, the nine drivers of sustainable business success*. New York: Free Press, Division of Simon and Schuster.

BNP Media. Environmental Design + Construction Magazine Web site: www.EDCmag.com.

Browning, William D. & Romm, Joseph J. (1998). *Greening the building and the bottom line: Increasing productivity through energy-efficient design.* Snowmass, CO: Rocky Mountain Institute.

BuildingGreen, Inc. Green Building Advisor Web site: www.buildinggreen.com.

BuildingGreen, Inc. (2003). Spotlight on LEED; Which LEED credits are being achieved? [Electronic version]. *Environmental Building News*, *12* (12). Retrieved from www.buildinggreen.com/ebn/sum/12-12.cfm.

Cassidy, Robert. (2003a). What next for the sustainability movement? [Electronic version]. *Building Design & Construction.* Retrieved on June 29, 2004 from www.bdcmag.com/magazine/articles/b0306edit.asp.

Cassidy, Robert. (2003b, November). What next for the sustainability movement [Electronic version]. *Building Design & Construction.* Retrieved from www.bdcmag.com.

CH2M HILL, Inc. (2000). *Green buildings*. Denver: CH2M HILL Ltd.

CH2M HILL, Inc. (2001). *Project delivery system* (4th ed). Denver: CH2M HILL Ltd.

Chang, Ni-Bin, Wen, C. G., & Chen, Y. L. (1997). A fuzzy multi-objective programming approach for optimal management of the reservoir watershed. *European Journal of Operational Research, 99* (2), 289-302.

Cole, Raymond, J. (2000). Editorial: cost and value in building green. *Building Research & Information, 28* (5), 304-309.

Coplen, Lonnie. (2004, February 1). Green design and construction makes good common sense. *New York Construction News, 51* (8), 111-112.

David, William, E. (1996). *Environmental scarcity as a cause of violent conflict.* Fort Leavenworth, KS: Army Command & General Staff College.

Dunn, Bryna C. & Steinemann, Anne. (1998). Industrial ecology for sustainable communities. *Journal of Environmental Planning and Management, 41* (6), 661-672.

EDAW, Inc. (1999). *Sustainable planning: A multi-service assessment 1999* [Electronic version]. EDAW Incorporated, Alexandria VA. Retrieved from www.denix.gov.

Federal Facilities Council (FFC). (2001). *Sustainable federal facilities, a guide to integrating value engineering, life cycle costing, and sustainable development.* (FFC Technical Report no. 142). Washington: National Academy Press.

Fellows, Richard & Liu, Anita. (1997). *Research methods for construction*. Malden, MA: Blackwell Science.

Fussler, C. & James, P. (1996). *Driving eco-innovation.* London: Pitman Publishing.

Gallaher, Michael P., O'Connor, Alan C., Dettbarn, John L. & Gilday, Linda T. (2004). *Cost analysis of inadequate interoperability in the U.S. capital facilities industry* [Electronic version]. Retrieved from National Institute of Standards and Technology, Office of Applied Economics, Building and Fire Research Laboratory (NIST Publication No. GCR 04-876). www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf

Godfried, Augenbroe, Pearce, Annie R., & Kibert, Charles J. (1998, June). Sustainable construction in the United States of America, A perspective to the year 2010. *CIB-W82 Report*, Georgia Institute of Technology, College of Architecture.

Godschalk, David R. (2004). Land use planning challenges. *Journal of the American Planning Association, 70* (1), 5-13.

Goldratt, E. (1997). *Critical chain*. Great Barrington, MA: North River Press.

Greening of Federal Facilities Workshop. (2000, April). Sponsored by the Department of Energy and the National Renewable Energy Laboratory. Dallas, TX.

Greenprints. (2000, February). Sponsored by Southface Energy Institute & GEFA. Atlanta, GA.

Gregory, Rita, A. & Kangari, Roozbeh. (2000). Cost/benefits of robotics in infrastructure and environmental renewal. *Journal of Infrastructure Systems, 6* (1), 33-40.

Hanley Wood, LLC. Project and materials research [Electronic version]. *ebuild.com*. Retrieved from www.ebuild.com/Orders/GBA_announce.html.

Hawken, P. (1993). *The ecology of commerce.* London: Weidenfeld and Nicolson.

Hawken, P., Lovins, A. & Lovins, H. (1999). *Natural capitalism: Creating the next industrial revolution.* Boston: Little Brown and Company.

Hellmuth, Obata & Kassabaum. *Sustainable design database*. Retrieved from www.hok.com/sustainabledesign/database/welcome.html.

Hguyen, Hung T. & Walker, Elbert A. (2000). *A first course in fuzzy logic* (2nd ed.). Washington: Chapman & Hall.

Holmes, Susan. (1994). *Process improvement guide* (2nd ed.). Maxwell AFB, AL: Air Force Quality Institute.

Jackson, Richard J. (2003, December). Physical spaces, physical health [Electronic version]. *The Journal of Architecture*. www.aia.org/aiaj

Kangari, Roozbeh & Riggs, Leland S. (1989). Construction risk assessment by linguistics. *IEEE Transactions on Engineering Management*, *36* (2), 126-131.

Katz, G., Alevantis, L., Berman, A., Mills, E., & Perlman, J. (2003). The costs and financial benefits of green buildings; a report to California's sustainable building task force. [Electronic version]. Retrieved on June 21, 2004 from www.cap-e.com/open/NewsPrintable.cfm.

Kozlowski, David. (2003). Green gains: Where sustainable design stands now. *Building Operating Management, 50* (7), 26-32.

Krizek, K. & Power, J. (1996). A planner's guide to sustainable development. *PAS Report No. 467*. Chicago: American Planning Association Planners Book Service.

Landman, Miriam. (1999). Breaking through the barriers to sustainable building– insights from building professionals on government initiatives to promote environmentally sound practices (Thesis Abstract, Tufts University, Medford Massachusetts, 1999). Retrieved October 11, 2004 from www.egret.net/tufts/summary.htm.

Lowenthal, Jeffrey N. (1994). *Reengineering the organization: A step-by-step approach to corporate revitalization*. Milwaukee: ASQC, Quality Press.

Maclaren, V. (1996). Urban sustainability reporting. *Journal of the American Planning Association, (62)* 2, 184-203.

Malizia, Emil E. & Feser, Edward J. (1999). *Understanding local economic development*. New Brunswick, NJ: Center for Urban Policy Research Press.

Matthiessen, Lisa F. & Morris, Peter. (2004). Costing green: a comprehensive cost database and budgeting methodology [Electronic version]. Retrieved from Davis Langdon Seah International website on August 8, 2004. www.dladamson.com/publications.html.

Mendler, Sandra & Odell, William. (2000). *The HOK guidebook to sustainable design*. New York: John Wiley & Sons.

Mogge, John W. (2000, May). Special studies report CP 8900. *Unpublished Technical Report, August 4, 2000*. Georgia Institute of Technology.

Mogge, John W. (2001a, January). Technical report, materials and methods unique to sustainable construction. *CEE 6140*. Georgia Institute of Technology.

Mogge, John W. (2001b, March). Technical report, planning factors for sustainable design and construction. *CEE 6140.* Georgia Institute of Technology.

Mogge, John W. (2001c, April). Technical report, advanced project delivery and cost estimating and scheduling. *CEE 6140*. Georgia Institute of Technology.

Mogge, John W. (2004, May 11). Sustainable development costs. *Presentation to the Corporate Advisory Board, Civil Research Foundation, American Society of Civil Engineers.* www.cerf.org

Mogge, John W. & Pedrick, Andrew. (2003a, May). CH2M HILL basis of sustainable design for additions to and alterations of squadron operations facility, building 2240, March AFB, CA. *Final Deliverable and Engineer Opinion of Costs*.

Mogge, John W. & Pedrick, Andrew. (2003b, May) CH2M HILL Basis of Sustainable Design for the Alterations Of Life Support Facility, Building 420, March AFB, CA. *Final Deliverable and Engineer Opinion of Costs*.

Molenaar, K., Vanegas, J., & Martinez, H. (2000). Appropriate risk allocation in design-build request for proposals (rfp's). *Proceedings, Construction Congress VI*. ASCE, Orlando, Florida.

Munda, G., Nijkamp, P. & Rietveid, P. (1995). Qualitative multi-criteria methods for fuzzy evaluation problems: An illustration of economic-ecological evaluation. *European Journal of Operational Research, 82*, 79-97.

National Center for Appropriate Technology. *Center for Resourceful Building Technology e-Guide.* Retrieved from www.crbt.org/index.html.

National Center for Appropriate Technology. *Guide to Resource Efficient Building Elements* [Electronic version]. Retrieved from www.crbt.org/index.html.

National Town Hall Meeting for a Sustainable America. (May 1999). [Online participation]. Sponsored by the President's Council on Sustainable Development.

Naval Facilities Engineering Command & Paradis, R. (undated). *Whole building design guide.* NAVFAC, Criteria Office Code 15, 1510 Gilbert Street Norfolk, VA.

Neumayer, Eric. (1999). *Weak versus strong sustainability, exploring the limits of two opposing paradigms* (2nd ed.). Cheltenham, Glos, UK: Edward Elgar Publishing.

OASD. (1993, March 1). Parametric facility cost estimating, a report to congress. Rep. Office, Deputy Assistant Secretary of Defense, The Pentagon, Washington, D.C.

Opricovic, Serafim & Tzeng, Gwo-Hshiung. (2002, May). Multi-criteria planning of post-earthquake sustainable reconstruction. *Computer-Aided Civil and Infrastructure Engineering, 17* (3), 211-220.

Papamichael, K. (1998). *Application of information technologies in building design decisions.* Building Technologies Department, Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, CA.

Pearce, Annie R. (1999, April). *Sustainable facilities & infrastructure.* Paper presented at the Shaping the Sustainable Millennium-Collaborative Approaches conference, Brisbane, Australia.

Pearce, Annie R. (1999). Sustainability and the built environment: a metric and process for prioritizing improvement opportunities. (Doctoral dissertation, School of Civil & Environmental Engineering, Georgia Institute of Technology, 1999).

Price Waterhouse Coopers LLP [PWC] (forward by Savitz, Andrew W). (2002). 2002 sustainability survey report [Electronic version]. Retrieved on December 15, 2002 from www.pwcglobal.com/eas.

Re-imaging the Suburbs: Smart Growth and Choices for Change. (2000, January). Sponsored by the National Building Museum. Washington DC.

Reynolds, Keith M., Johnson, Norman K. & Gordon, Sean N. (2003). The science/policy interface in logic-based evaluation of forest ecosystem sustainability. *Forest Policy and Economics, 5* (4), 433-446.

Roberts, Lon. (1994). *Process reengineering: The key to achieving breakthrough success*. Milwaukee: ASQC, Quality Press

Rose, Ewen. (2003, Nov/Dec). All Our Buildings are Rubbish. *HAC Journal,* p. 8-9.

Steinemann, Anne. (2003). Implementing sustainable development trough problem-based learning: Pedagogy and practice. *Journal of Professional Issues in Engineering Education and Practice, 129* (4), 216-224.

Steinemann, Anne & Ortolano, Leonard. (1996). Strategic environmental assessment for sustainable urban development. *Environmental Impact Assessment Review 1996, 16,* 321-335.

Steven Winter Associates, Inc. *Sun City CARB project* [Electronic version]. Project information research. Retrieved from www.swinter.com/projects/sun_city_carb_.

Stratfor Forecasting, Inc. (2004, June 21). *Premium global intelligence report*. [Electronic e-mail notification]. www.stratfor.com.

Terralogos: Eco Architecture PC. (2001). Green building template. A guide to sustainable design renovating for Baltimore rowhouses [Electronic version]. Retrieved from GTRI/SFI Library at www.terralogos.com/residential/htm.

United States Air Force Headquarters (HQ USAF). (2000, December 15). Implementing sustainable design in the USAF MILCON program. *Policy Letter*. *Guidance for the Major Commands From HQ USAF/ILE to ALMAJCOM/CE.*

United States Air Force Reserve Command Headquarters, Directorate of Civil Engineering. (2001, January). *Sustainable facility design statement of work.*

United States Air Force Reserve Command Headquarters (HQ AFRC). (2001, February 15). Sustainable Design and Construction Program - Implementation Goals by Fiscal Year. *From HQ AFRC/CE to all Wing/CC/CE.*

United States Army, Corps of Engineers & Goradia, Harry. (2001). Sustainable design and development [Electronic version]. *Public Works Digest, (13)* 5. www.hq.usace.army.mil/isd/PUBS/DIGEST/PWDigest_AugSept_01.pdf.html.

United States Department of Energy. Building Technologies Program Web site: www.eren.doe.gov/buildings/

United States Department of Energy, Federal Energy Management Program [FEMP]. (2003). The business case for sustainable design in federal facilities [Electronic version]. www.eere.energy.gov/femp/

United States Department of Energy. Smart Communities Network [Electronic version]. Retrieved from www.sustainable.doe.gov/articles/ptipub.htm.

United States Department of the Interior, National Park Service. (1999). Guiding principles of sustainable design [Electronic version]. Retrieved from www.nps.gov/dsc/dsgncnstr/gpsd/toc.html.

United States Green Building Council [USGBC] & Smith, April. (2003, February). *Building momentum, national trends and prospects for high-performance green buildings*. Washington DC: USGBC.

United States Green Building Council. Green Building Resource Center Web site: www.usgbc.org.

United States Green Building Council. (Undated). *Making the business case for high performance green buildings*. Washington DC: USGBC.

University of Minnesota. *Minnesota sustainable design guide* [Electronic version]. Retrieved from www.sustainabledesignguide.umn.edu/SustDesGuideContent/

Vanegas, Jorge A. (1999). *A conceptual framework for research.* Atlanta, GA: Georgia Institute of Technology, College of Engineering.

Vanegas, Jorge A. (2000). An integrated design/construction program for infrastructure rehabilitation. *Close-out Report Grant MSS-9396314, Engineering Directorate*. Washington: National Science Foundation.

Vanegas, Jorge A. (2001). The project definition package: a cornerstone for enhanced capital project performance. *Paper Number 097*. Wellington New Zealand: CIB World Building Congress.

Vanegas, Jorge A. (2003). Road map and principles for built environment sustainability. *Environmental Science and Technology, 37* (23), 5363-5372.

Vanegas, J., Hastak, M., Pearce, A., & Maldonado, F. (1998). A framework and practices for cost-effective engineering in capital projects in the A/E/C industry. *CII Research Report RR112-11*. Austin, TX: CII, University of Texas at Austin.

von Paumgartten, Paul. (2003). The business case for high-performance green buildings: Sustainability and its financial impact. *Journal of Facilities Management, 2* (1), 26-34.

Ward, Barbara & Dubos, Rene. (1972). *Only one earth: The care and maintenance of a small planet*. New York: W W Norton & Company.

Whole Building Design Guide (WBDG). Research on integrated whole building design WBDG Web site: www.wbdg.org.

Wilson, Alex, et al. (1998). *Green development: Integrating ecology and real estate.* New York: John Wiley & Sons.

World Commission on Environment and Development. (1987). *Our common future.* Oxford: Oxford University Press.

Zadeh, Lotfi A. & Kacprzyk, Janusz. (Eds.). (1992). *Fuzzy logic for the management of uncertainty*. New York: Wiley and Sons.

Zadeh, Lotfi A. (speaker), & IEEE Educational Activities Board (Producer). (1992). *Fuzzy logic advanced concepts and structures* [video recording]. Piscataway, NJ: Institute of Electrical and Electronics.

VITA

John W. Mogge Jr. was born in Cincinnati, Ohio on March 29, 1951. He received his Bachelor of Architecture degree from the University of Florida in 1973, and his Master's of Architecture (with emphasis in construction) in 1974. After graduation Mr. Mogge was commissioned in the USAF and served on active duty for 26 years as an Air Force Civil Engineer officer and registered architect, retiring from active duty in the rank of colonel in 2001. Throughout his military career Mr. Mogge became known for his experience in technical and executive leadership, change management in infrastructure and environmental planning, programming, budgeting, design, construction, operations, and maintenance. In addition to over 14 years of technical experience, he has had more than 16 years of leadership experience directing three production and four corporate level engineering, operations, and construction organizations ranging from 20 to 900 people. Mr. Mogge has more than $3.5 billion in worldwide planning, design, operation, maintenance, and construction-related experience.

Currently Mr. Mogge is a senior registered principal architect who serves as CH2M HILL's Southeast Regional Business Group Manager for Transportation. Mr. Mogge's professional and research interests are focused on business growth through sustainable development.

He is married to the former Catherine Logan of Forest City, North Carolina. John and Cathy have two sons. Jay is a graduate civil engineer and officer in the USMC. David is also a civil engineer major, graduating in May 2005 and concurrently receiving his commission as an Air Force officer.