FACTORS CAUSING VARIATION BETWEEN THE LEED PILOT AND FINAL CHECKLISTS IN GREEN HEALTH-CARE PROJECTS

A Thesis

by

PRIYANKA TYAGI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2005

Major Subject: Construction Management

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Approved by:

Chair of Committee,	Charles W. Graham
Committee Members,	Richard Burt
	Stuart D. Anderson
Head of Department,	James W. Craig

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ABSTRACT

Factors Causing Variation Between the LEED Pilot and Final Checklists in Green Health-care Projects. (August 2005)

Priyanka Tyagi, B.Tech., Nagpur University, Maharastha, India

Chair of Advisory Committee: Dr. Charles W. Graham

Among most of the LEED registered and LEED certified health-care facilities, there is a credit variation between the LEED pilot checklist and the final checklist. The credit variation between the LEED pilot and final checklists implies failure in achieving the pre-defined green objectives. Most of the credits were given up due to financial reasons. Although most of the credits in the LEED credit list emerge as design issues, accomplishing a LEED rating is primarily the owner's responsibility. In order to minimize the variation between the LEED pilot checklist and LEED approved checklist, the owner needs to conduct significant project planning.

The owner should integrate the LEED objectives early in the project and should include the cost of the LEED process in the capital budget. Since there are limited LEED certified health-care projects, adoption of the systems approach for planning and developing a green health-care facility using the IDEF0 method is recommended. The IDEF0 method can produce an outcome array which represents the matrix of all possible circumstances. This will give the owner and the project team the ability to better forecast cost and schedule decisions, even when there is a lack of historical data relating to green health-care projects. The approach will be beneficial in analyzing the various outcomes, cost, and feasibility of projects in terms of integrating LEED objectives early on. This could minimize the credit variation, as well as cost and schedule overruns during the project execution stage. Adequately defining the full development process upfront is vital to the overall success of any project, especially for green buildings, since they are a developing trend in the construction industry.

DEDICATION

To

My Husband….Vikas

“The first time we met, you said…Let’s grow old together and I knew we would.”

&

My Parents…

"No matter where I am going to be, the world will always see a reflection of you in me."

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Special thanks to my wonderful parents, my twin sister, Swati, and my brother, Gaurav, for never giving up on me, even when I gave up, and for their unconditional love and support. Most of all, I would like to thank my husband, Vikas, who is always by my side through the ups and downs and makes me feel so loved. For all your love, and support, I thank you for being such special a part of my life.

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INTRODUCTION

“Whenever you are asked if you can do a job, tell 'em, 'Certainly I can!' Then get busy and find out how to do it.”

Theodore Roosevelt
26th President of the United States

Background

Even though sustainability occupies center stage in the worldwide debate about the future of the world, it can often be difficult to determine what it means to integrate environmentally responsible design and materials into a building framework. Mainstream concepts of sustainability are broadly adopted by the construction industry; however, they are not widely implemented in the health-care industry. Currently, less than a dozen hospitals have applied for the Leadership in Energy and Environmental Design (LEED) certification (Vittori 2005). The health-care industry should be driven by the concern for public health, the desire to reduce operating costs, and the sense of social responsibility. In order to determine the reasons for hindrances in integrating the LEED objectives in the health-care sector it is important to analyze the challenges and the problems faced by current LEED certified/registered health-care projects. There is a no one-size fits-all approach for integrating LEED in the health-care project, all projects are unique and should be assessed for feasibility in cost and energy paybacks before aiming for LEED certification. Benchmarking with an existing project or other comparable projects could be informative and used as a guide, but does not ensure the same result.

This thesis follows the style of the *Journal of Construction Engineering and Management.*

Health-care Facilities

According to the survey and research conducted within the health-care construction industry, hospitals spent $18 million on capital improvement projects throughout the U.S. which is a 12.5 percent increase over the spending in year 2002 (Whalen 2004). The substantial increase in hospital construction is expected to reach $3.1 trillion by the year 2012 (Cassidy 2005). According to Cassidy (2005), overall health-care spending, including medical offices, specialty centers, and support facilities, went up to $1.54 billion in the year 2002.

Health-care facilities have unique programming criteria that guide design decisions, material, and product and equipment specifications. Understanding the complex human health implications of these decisions is critical. According to a research conducted by the Academy of Architecture and Health, providing natural lighting, indoor landscaping, rooftop gardens, solariums, and small atria have healthy impact on hospital staff. It is recommended to maximize views of nature and landscaping from all patient environments, and increase the use of skylights, interior transom windows, and natural light since it improves the feeling of well being and medical outcomes in patients (Vittori 2000).

Due to constant and ever increasing technological innovation in medical science, the health-care buildings undergo a high rate of change. The interior spaces are constantly reconfigured, remodeled and outfitted with new furnishings and equipment reflecting changes in management and delivery systems (Vittori 2005). The result is an enormous amount of waste. The United States health-care industry contributes to a substantial share of annual design and construction activities averaging from 70 to 75 million square feet of construction per year (Vittori 2005). Therefore, the health-care sector is well-positioned to highlight the potential that buildings have to reverse environmental decline and to create environments for people that enhance health, patient outcomes, and workplace performance (Vittori 2005). According to Vittori (2005), recognizing this collective responsibility among designers, manufacturers, building owners, facility managers and public policymakers should set an agenda that will yield important outcomes. Apart from the allied building professionals who are directed to implement green and healthy buildings, manufacturers should also be increasingly encouraged to shift their practices in response to a growing demand for sustainable products and services.

Similarly, it is appropriate and timely to establish partnerships between the regulating agencies and the regulated communities. Existing guidelines and regulations overseeing the design and construction within the health-care sector should be evaluated based on their impacts on environmental quality and human health and revised so that they reflect these as priority considerations (Vittori 2005, 1).

Indoor environmental quality has a significant impact on the well-being of the occupants. In effect, the U.S. Environmental Protection Agency (EPA) and its Science Advisory Board (SAB) stated that indoor air pollution is one of the top five environmental risks to public. According to the American Institute of Architects' (AIA) guidelines for design and construction of health-care facilities, buildings should be designed within a protocol that distinguishes the crucial duty of the health-care sector, including "doing no harm," and reflects on the larger perspective of improved patient environment, employee effectiveness, and resource stewardship health (Vittori 2005, 1).

For people confined in a hospital due to illness, one of the rising concerns is nosocomial infection, which is caused by the spread of disease between patients in hospitals. Hospitals and clinics are visited by the people who are sick with the expectation to get better. Unfortunately, there is a risk that clients may become infected because of their visits to these places. Often nosocomial infections become apparent while the patient is still in the hospital, but in some cases symptoms may not show up until after the affected patient is discharged. About one patient in ten acquires an infection as a direct result of being hospitalized (Tilton 2003).

Acknowledging such concerns, some health-care organizations, including Kaiser Permanente, one of the largest non-profit health-care providers in the U.S., are seeking better and more responsible methods to build future hospitals. Likewise, the EPA and the American Hospital Association have joined in a partnership known as Hospitals for a

Healthy Environment (H2E) with the main goals of reducing the environmental impact of constructing and operating the health-care facilities, and also to improve the quality and environment for the inhabitant (Greenwall Foundation 2004).

In December 2003, the Boulder Community Foothills Hospital in Boulder, Colorado became the first health-care facility in the nation to earn a U.S. Green Building Council certification, known as a Leadership in Energy and Environmental Design (LEED) rating. The LEED rating system serves as a national standard for high-performance, sustainable buildings. Health-care is one industry that would immediately gravitate toward green buildings. But it is surprising that there are really no focused efforts on the greening of health-care facilities (Vittori 2005).

Health-care facilities are multifaceted building types, encompassing a wide range of services and functions. There are diagnostic and treatment functions, hospitality functions and fundamental functions to provide care and well-being to the patients. Moreover, health-care is driven by the fastest growing technologies including highly complicated medical, mechanical, electrical, and telecommunications systems. This multiplicity is replicated in the span of regulations, codes, and oversight that govern hospital construction and operations.

The health-care sector constitutes a variety of multi-functional facilities. Within every facility, they are numerous other functions that require focused knowledge and expertise. The functional units within the hospital can have challenging requirements and precedence. Realistically, no individual can have complete functional knowledge of an entire facility, which is why specialized consultants play a critical role in health-care planning and designing. Idealized development and strongly-held individual inclinations, such as green objectives, must be balanced against compulsory requirements, actual functional needs, and the financial status of the organization. The health-care sector provides for and sustains many diverse users and stakeholders. Preferably, the design process integrates direct input from the owner and from key hospital staff early on. The designer also has to be an advocate for the patients, visitors, support staff, volunteers, and suppliers who do not generally have direct input into the design. Good hospital design integrates functional requirements with the human needs of its varied users. Therefore, incorporating LEED objectives into an already complex project with multiple participants is a challenging situation in itself.

Leadership in Energy and Environmental Design

The Leadership in Energy and Environmental Design (LEED) rating system is used to evaluate green objectives and efforts put into building construction projects. The LEED rating system was developed by the members of the U.S. Green Building Council (USGBC) as a voluntary, consensus-based set of national standards for developing high-performance sustainable buildings (USGBC 2002). The LEED rating system was developed to establish common standards of evaluation for classifying "green buildings." There were additional objectives behind developing the LEED rating system, such as promoting integrated design and construction process, stimulating a green agenda in the building construction industry, and spreading awareness among consumers relating to green building benefits.

The LEED rating and reference system provides a framework for evaluating building performance and meeting sustainability objectives. The LEED rating and reference system is categorized in 6 categories which are then further sub-divided into 7 prerequisites and 69 elective credits (Appendix C). The primary five categories in the LEED rating system are:

- Sustainable sites development
- Water savings
- Energy efficiency
- Material selection
- Indoor air quality

Apart from assessing a project's performance based on the credit score in the above categories, the USGBC also recognizes and promotes green objectives by offering project certification, profession accreditation, training and practical resources (USGBC 2002).

The LEED reference guide provides the necessary green intents, requirements, and documentation submittals required to achieve the prerequisite credits and the intended project credits. In order to qualify for LEED certification, all prerequisite credits must be achieved. The other intended credits could vary from project to project; any project can go above or below the intended credits. However, a minimum of twenty-six credit points should be achieved in order to earn the LEED certification. If a project fails either to earn twenty-six points or to achieve the prerequisite credits then the LEED certification will not be awarded to the project. On the other hand, if any project exceeds the minimum twenty-six credit requirement including the prerequisite credit then it may achieve a silver, gold or platinum level based on the total credits. The level of certification is divided on the following basis:

- Certified 26-32 points
- Silver 33-38 points
- Gold 39-51 points
- Platinum 52-69 points

The LEED reference guide provides a short explanation of capabilities and the strategies for each credit to provide a guiding protocol to the user. The first step to earning a LEED certification for the project is to register the project with the USGBC by submitting an application along with registration fees (Table 1). The registration form should contain the information regarding the project team, general project details, project program data and the pilot LEED check list. The information provided at this stage is used for tracking and assisting the project through the LEED certification process. In addition, project case studies are prepared based on the certification so that it can act as an historical database in expanding the knowledge base on the green building cost and strategies for the other projects.

Table 1. Charges for registering the project for LEED certification

	Less than 75,000 Square Feet	75,000-300,000 Square Feet	More than 3000,000 Square Feet
Charges	Fixed rate	Based on Square foot	Fixed rate
Registration			
Members	$750.00	$0.01 per Square foot	$3,000.00
Non- members	$950.00	$0.0125 per Square foot	$3,750.00
Certification			
Members	$1,500.00	$0.02 per Square foot	$6,000.00
Non-members	$1,875.00	$0.025 per Square foot	$7,500.00
Fees subject to change. No refunds.			

(Source: USGBC 2000)

Application of green building concepts can yield savings during the construction process. Measures that are relatively easy to implement can result in the following areas:

- Lower energy costs by monitoring use, installing energy-efficient lamps and fixtures, and using occupancy sensors to control lighting fixtures;
- Lower water costs, by monitoring consumption and reusing storm water and/or construction wastewater where possible;
- Lower site-clearing costs, by minimizing site disruption and movement of earth and installation of artificial systems;
- Lower landfill dumping fees and associated hauling charges, through reuse and recycling of construction and demolition debris;
- Lower materials costs, with more careful purchase and reuse of resources and materials;
- Possible earnings from sales of reusable items removed during building demolition; and,
- Fewer employee health problems resulting from poor indoor air quality.

List of Definitions

LEED: The LEED (Leadership in Energy and Environmental Design) Green Building Rating System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings developed by the U.S. Green Building Council (USGBC).

LEED registered projects: Project registration is the first step towards earning LEED certification for any building project. Registration allows the project team to establish contact with the USGBC and provide access to their database. For registration the project contacts are required to submit the details on project team, project information, project program data, and LEED credit checklist along with the registration fee.

LEED certified projects: A project obtains LEED certification if it meets all the prerequisites in the LEED rating list and achieve a minimum of 26 points in the LEED rating system.

LEED pilot list: LEED pilot list is the checklist that is submitted while registering the project for LEED certification. LEED pilot list contains the proposed LEED credits for the project. A pilot list is made during the start of a project.

LEED current list: LEED current list is the next stage for LEED pilot list. LEED current checklist is the list that is applicable to the projects which are in construction execution phase and are not in 100 percent completion stage.

LEED final list: LEED current list is the subsequent stage for LEED current list. LEED final checklist is the list that is applicable to the projects which are 100 percent complete. This list contains all the final credits which were incorporated in the projects.

Credit variation: The LEED credits that were in the LEED pilot checklist but were not in either the LEED current list or the LEED final list. These credits were proposed during the registration phase but for some reasons were dropped from the list during the later stages of the projects.

Validity: Validity, in qualitative research, relates to whether the findings of the study are true and certain. "True" means the findings accurately reflect the real situation. "Certain" means the findings are backed by evidence and that there are no good grounds for doubting the results; that is, the weight of evidence supports your conclusions (Guion 2002).

Triangulation: Triangulation is a method used by qualitative researchers to check and establish validity in their studies (Guion 2002).

Within-method triangulation: Within-method triangulation involves gaining insight from different points of view but all within the sphere of single data set. According to Denzin and Lincoln (2000), examining multiple scales in one survey could be considered a within-method approach.

Between-method triangulation: Between-method triangulation can address issues related to external validity and provide evidence of cross validation. Between-method triangulation involves gaining insight from different points of view using different sources of data/information (Guion 2002).

Grounded theory: A grounded theory study uses a prescribed set of procedures for analyzing data and constructing a theoretical model from the collected data (Appendix D). The term “grounded” refers to the idea that the theory that emerges from the study is derived from and grounded in the data that have been collected in the field rather than taken from the research literature (Leedy and Ormrod 2001).

Systems theory: Systems theory is a broad and basic theoretical approach which subsumes a number of other theoretical developments, such as set theory, graph theory, net theory, cybernetics, theory of automata, information theory, game theory, and decision theory. Systems theory is not a scientific theory, although it forms the theoretical background for most of the specialized theories within applied systems research, such as systems engineering, operation research, linear and non-linear programming (Olsson and Sjostedt 2004, 11). Systems theory asserts that any activity can be described as a system if it constitutes parts which have to be unified to achieve an objective. Either removal or change in one of the part will lead to change in the whole system. Therefore, the systems theory proposes to identify the behavior of the whole, not simply in terms of behavior of the parts. Systems theory advocates looking at the whole situation in a broad sense, instead of looking in detail at individual aspects.

Chaos theory: Chaos theory proposes that when systems in nature become complex, they become more volatile or susceptible to catastrophic events and must expend more energy to maintain the increased complexity. Additional structure is required to maintain stability within the systems or the system may fall apart entirely, due to increased volatility (McNamara 1999).

IDEF0: Integration Definition for Function Modeling (IDEF0) is one of the methods that allow process modeling to be performed by the use of cell modeling. This method involves functions being represented by cells, with each cell having inputs, outputs, and feedbacks. The behavior within each cell is determined by controls and mechanisms. IDEF0 method is based on the structured graphical representations of a system. IDEF0 models provide an outline of functions and their interfaces that must be carried out in order to make decisions based on systems engineering approach. The IDEF0 model reflects how system functions interrelate and operate, in order for the system to perform or fit together (IDEF0 1993).

Problem Statement

There are 62 LEED version 1 certified projects and 198 LEED version 2 certified projects (USGBC 2005). Out of total 260 LEED certified projects there are only 2 projects that belong to the health-care sector. Health-care facilities are designed and constructed by specialized firms in a regulation and code constrained atmosphere. Adding LEED objectives as another factor competing with programmatic need has been difficult for the design team and the owner to get comfortable with (Cassidy 2005). Health-care is among specialty construction and the LEED rating system was developed for general commercial construction. The current LEED rating system might not be compatible with the health-care construction. Traditional project planning and project delivery approaches might be a hindrance in meeting the desired LEED objectives. Currently there are 20 health-care facilities out of which 2 are already certified and remaining 18 are registered for certification (USGBC 2005). These projects are the "first movers for the others to follow," within the health-care sector. It is important to examine these projects to understand the lag within the health-care sector in terms of integrating LEED objectives with health-care projects. Moreover, it is important to identify whether these projects are able to achieve their respective green objectives or if there is a variation between the defined and the achieved green objectives. The variation could be identified by comparing the credits on the LEED pilot checklist and the final checklist.

Sub-problems

To resolve the main problem of the study, the following sub-problems should be addressed:

- Identify both the LEED certified and the LEED registered projects in the health-care sector.
- Identify the variations between the pilot checklist and the certified checklist, if variations exist.

- Identify the causes and the effect for variations between the pilot checklist and the certified checklist.

Assumptions

The following assumptions provide the primary foundation for the research:

1. The overall research and data analysis approach adopted for the study is assumed to be adequate to analyze whether there is any variation between the LEED pre-construction pilot checklist and the LEED post construction final checklist.
2. In order to keep the project consistent with LEED regulations it is important to understand the reasons and factors that cause any variation between the targeted and the achieved objectives.
3. The owner, the project managers, the architects, and the general contractors play an important role in meeting the targeted LEED rating.

Purpose of Study

The construction industry is a complex, dynamic system (Griffin 1996). The health-care construction industry is already among the most code regulated industries. According to the chaos theory, any complex system becomes volatile and susceptible to chaos with additional stipulations. Based on the theoretical fundamentals of chaos theory it is a valid assumption that adding additional stipulation in terms of LEED objectives in an already complex system, that is, in health-care construction, could create chaos. Within the perspective of the research chaos is considered as failure to meet the project green objectives that could be measured by comparing the credit variation between the LEED pilot checklist and final check list. The purposes of this research are first, to identify the credit variation, second, to identify the cause and effect of credit variation and at last, to propose recommendations for an effective approach for the project team in order to keep the project compatible with the LEED requirements for health-care facilities.

LITERATURE REVIEW

The literature review is divided into two sections. The review of the first section is on the theoretical background of the research and consists of brief discussions on chaos theory, systems theory, and concepts of project's front end development and its role in achieving project objectives. The second section of the literature review is on the analytical techniques used in the analysis of research data, that is, the grounded theory approach, triangulation, and the Integrated Definition for Function Modeling (IDEF0).

Theoretical Background

Construction can be described as a process with multiple phases and numerous participants unifying to accomplish an overall goal. There is a lack of any specific theoretical basis of the construction process. There are many existing theories prevailing within research paradigms, but due to the dynamics involved in the construction process, there could be multiple theories that could be implemented in the research paradigms related to the construction process (Seymour, Crook and Rooke 1996). The following research is based on the theoretical background of the systems theory, the chaos theory, and the principles of front end development of the projects.

Systems Theory

Systems theory asserts that any activity can be described as a system if it constitutes parts which have to be unified to achieve an objective. Moreover, removal of one part will lead to the change in the system. For example, a bunch of grapes is not a system, because if one removes a grape the rest still remain as a bunch of grapes. Nevertheless, if the hard-drive is removed from an operating computer, it will no longer work and hence the change in function will cause a change in the system.

A system is perceived as a function or anthology of functions that have inputs, processes, outputs, and outcomes; moreover, a system shares feedback among all four of these phases. Systems theory helps in providing a broader perspective within a process or an organization so as to understand the operations and the functions (McNamara 1999).

Approaching the construction process from the perspective of systems theory, the inputs will include resources such as money, people, materials, technologies, and capabilities, which will go through different processes of planning and development to deliver an output. The output would be the desired quality, facility, and other desired objectives for the project. All the phases of the project life cycle are dependent on each other, and so there will be inevitable interaction, feedback, and iteration within all the phases. There will be regular feedback from the external environment, too, such as government policies and rules. Systems theory could provide a valid theoretical basis to conduct research in the construction industry. The construction process could be broken into the phases of inputs, processes, outputs and outcomes to analyze the operation within each phase and their relationship with other phases to see how well all the phases have to synchronize for the system to work effectively.

Chaos Theory

Classical science has described most of the functions under the model of Newton theory: every function is regular, predictable, controllable, knowable, passive, directionless, and incapable of unexpectedly producing order (Griffin 1996). Under the Newtonian paradigm, even increasingly complex systems fit into linear models that attempt to make a system predictable; however, complex non-linear systems do not fit a Newtonian model. Therefore, a philosophy of “chaos” was introduced, which asserts that physical and lawful does not mean predictable, controlled, or completely knowable (Griffin 1996). Chaos theory, or non-linear theory, does not imply that all systems are random and unpredictable. Instead, it suggests that when systems in nature become complex, they become more volatile or susceptible to catastrophic events and must expend more energy to maintain the increased complexity. As the system expands, and the more energy it requires, more structure is required to maintain stability. This trend continues until the system splits, combines with another complex system, or falls apart entirely (McNamara 1999).

If the fundamentals of chaos theory are applied within the construction context, then it could be explained as: with time, the construction industry and its process have evolved to be much more complex then they were initially. As chaotic and random as the construction industry seems today, and if the scope of the project broadens, then the project becomes more complex, and hence, extra energy or resources are required to maintain the increased complexity. To maintain this complexity the system has to be either spilt into other complex systems, such as planning, design, programming and so on, or else the whole project could lead to failure.

Front End Development of Projects

The project life cycle is a process through which a project is implemented from cradle to grave (Hendrickson and Tung 1998). The process is separated into three core stages: planning, execution, and operation as illustrated in the Fig. 1, with project planning being a critical part of the project life cycle.

The solutions at various stages are then incorporated to attain the ultimate product. Although each stage requires different expertise, it usually includes both technical and managerial activities in the knowledge domain of the specialist. The owner may choose to decompose the entire process into more or less stages based on the size and nature of the project, and thus obtain the most efficient result in implementation (Hendrickson and Tung 1998).

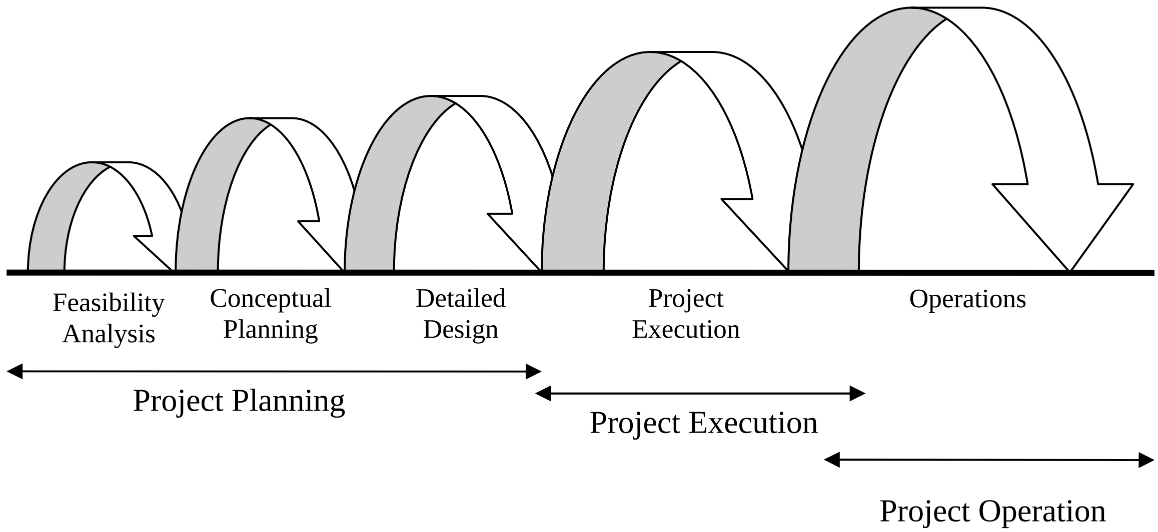

Fig. 1. Project life cycle diagram
(Source: Hendrickson and Tung 1998*)*

The first phase in a project is the business planning phase where a business opportunity or problem is identified (Anderson 2004). Depending on the business opportunity or the business problem, a business case is defined to provide various solutions. A feasibility analysis is conducted on each solution and based on the analysis report a final solution is recommended. Business planning includes a detailed definition of problems or opportunities, and an analysis of the potential options and solutions available. Every option or solution is assessed based on the potential benefits, costs, risks, and problems related with it. A business case is developed based on the recommended solution. A formal feasibility study may be conducted at this stage to investigate whether the forecast costs and benefits are reasonable. A project is formed after the final solution is approved by the key stake holders and funds are allocated to proceed further. The next step in the business planning is then to define the vision, objectives, scope, and deliverables for the project. The business plan should also provide the organization structure including roles and responsibilities, as well as a summarized plan of project activities, resources, and funds required for the project including any known risks, assumptions, and constrains associated with the project. Once the project objectives, deliverables and scope are defined based on the corporate objectives, the project can advance in the project planning phase (Anderson 2004).

The project plan is shaped by the business plan of the organization. The business plan is in turn being governed by market demands and capital constrains. Project planning has a considerable force on the outcome of the construction of any capital facility. The construction process is time and cost driven development. In order to gain time, often the owners and the project team sacrifice detailed project planning and proceed on the project with insufficient definition of the project scope. Invariably, changes occur during the later stages of the project; an indefinite project scope will lead to increases in construction costs and conflicts. Project development requires thoughtful definition of project goals and needs, not to mention that the project goals should be interwoven with the corporate goals (Hendrickson and Tung 1998).

A well developed project plan leads to less unpredictability in terms of project cost, scheduling, and operating characteristics. Moreover, it can increase the chance of meeting project specific objectives such as environmental or social goals. Most companies do have a project planning phase; their approaches might be different, but the fundamental procedure is similar.

There might be dissimilarities between the planning procedures of different companies. Some might have a one-step authorization process, while others might have a three-step authorization process. Few companies have a formalized written procedure, whereas others may have multidisciplinary team-based approaches. The critical issue is not the approach to the planning process, but the deliverables and the efforts that make a major contribution towards the success of the project.

Research conducted by the Construction Institute Industry Pre-project Planning Research Team indicates that well performed project planning can reduce project cost by as much as 20 percent on average, versus poorly planned projects (CII 1995). According to CII (1995), pre-project planning can be defined as the process of developing sufficient strategic information for owners to address risk and decide to commit resources to maximize the chances for a successful project. Pre-project planning is a process that contributes to the front-end planning for capital projects (CII 1995).

The pre-project planning stage of a project should be implemented even before the design phase of any project. As shown in Fig. 2 the primary intent of the pre-project planning phase is to put together a well defined scope of definition for the project. The decisions made during the early stages of the project have maximum influence on the overall life cycle of the project (CII 1995). Reinforcing the scope definition package of any project, in general, involves assessing project alternatives at a very early stage, analyzing project risks and their mitigation factors, project economic payoffs, and development of financial, organization, and control plans. All these factors contribute to making an informed decision as to whether to continue with the project or not. A poorly defined scope of definition leads to project cost and schedule overruns. A well defined project scope allows all the participants to understand the project objectives better (Hendrickson and Tung 1998).

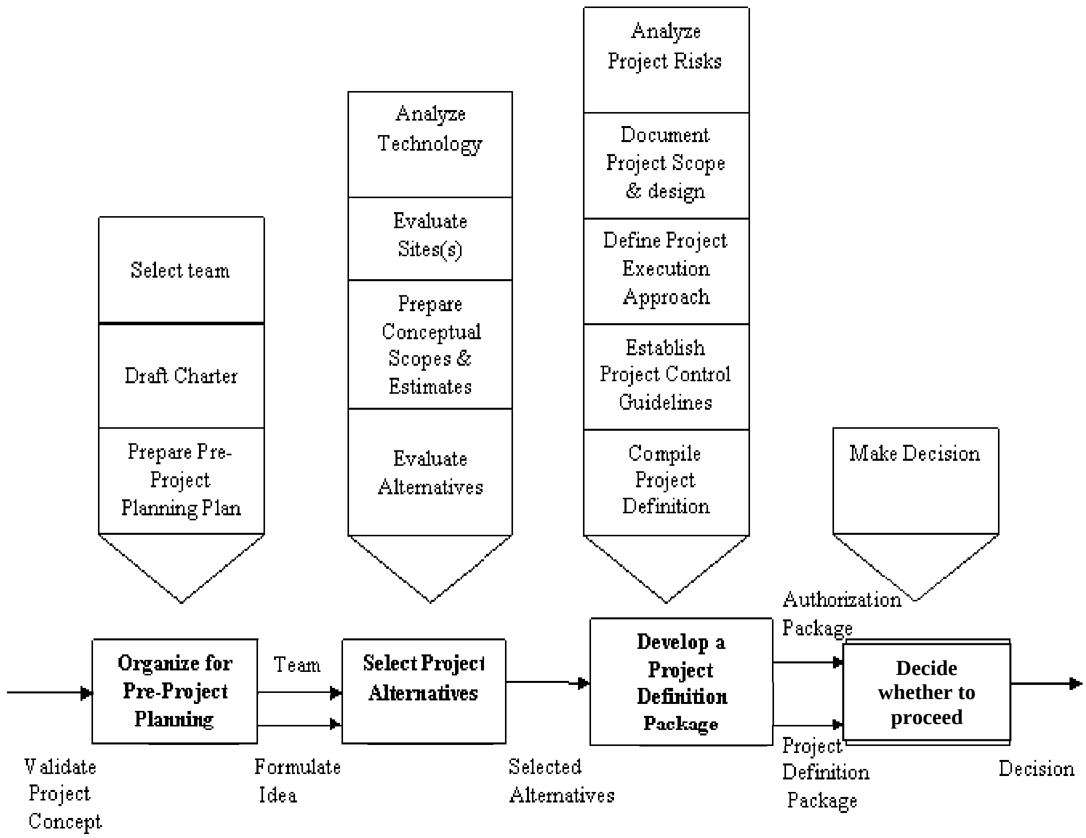

Fig. 2. Pre-project planning diagram
(Source: CII 1995)

Pre-project planning is primarily divided into four phases as shown in Fig. 2. The first phase requires organizing for pre-project planning. This phase requires identification of the project competencies and categorizing them into core or non-core competencies. The core and non-core are categorized based on the criterion of how important the competency is in order to achieve the project objectives. The project team is selected based on these competencies and on the decision as to whether the owner has in-house resources to execute these competencies or if there is a need to hire consultants.

After developing the organizational breakdown structure based on the project objectives and competencies, the project charter is drafted based on corporate and project objectives. The second stage of the pre-project planning includes the selection and evaluation of project alternatives in terms of technology or process. The evaluation includes consideration of cost, risk and any other benefits or factors associated with the alternatives. The third phase comprises the development of a project definition package which further encompasses analysis of project risks, documentation of project scope and design, definition of project execution and control strategy, and compilation of the project definition package. The last stage of pre-project planning is to make a decision on whether to go ahead with the project or to abort the project (CII 1995).

The owner has the maximum potential to influence the construction costs of a project. All the decisions made during the early phase of a project life cycle have higher influence than those made at later stages, as shown schematically in Fig. 3. Moreover, design and construction decisions will influence the continuing operating costs and, in many cases, the revenues over the facility lifetime (Hendrickson and Tung 1998). Therefore, an owner should acquire the proficiency of performing adequate project planning.

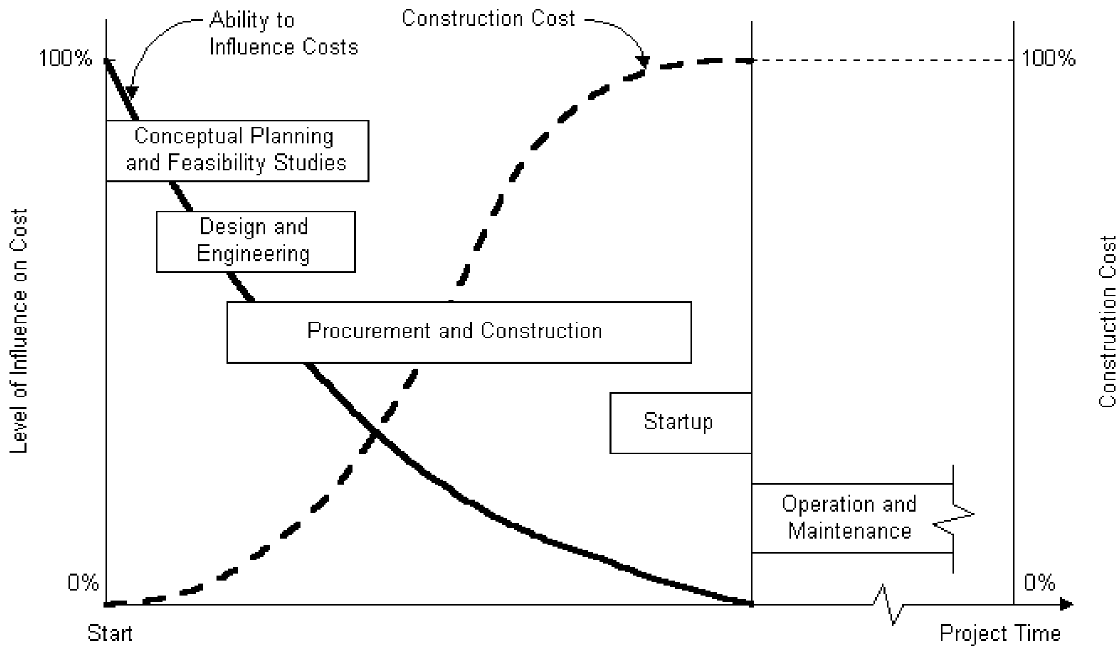

Fig. 3. Ability to influence construction cost over time
(Source: Hendrickson and Tung 1998)

Analytical Methods

Grounded Theory

Grounded theory was originated over thirty years ago by Barney Glaser and Anselm Strauss (Leedy and Ormrod 2001). Grounded theory has its root in sociology but is now successfully employed for diverse topics in a variety of interdisciplinary purposes. Glaser and Strauss do not regard the procedures of grounded theory as discipline specific, and encourage researchers to use their own disciplinary purposes (Leedy and Ormrod 2001). There are several examples where grounded theory has been applied as a basis of research in the construction industry. Loosemore (1999) examined crisis management in the context of building projects procured through design-bid-build.

Data collection in grounded theory is field-based, flexible, and likely to change over the course of the study (Leedy and Ormrod 2001). Interviews play a vital part in data collection; therefore, they must include the perspectives and views of the people being interviewed for the study (Corbin and Strauss 1990). Data analysis should begin with developing categories to classify data. According to Haig (1995), grounded theory is best regarded as a general theory of scientific method concerned with identification and explanation of phenomena. Grounded theory could be perceived as a problem-oriented endeavor in which theories are generated from robust data patterns.

The investigator employed the usual methods suggested in the interview and field work literature to assure credibility of respondents and to avoid biasing their responses and observations. The data for a grounded theory can come from various sources. The data collection procedures involve interviews and observations as well as such other sources as government documents, video tapes, newspapers, letters, and books – anything that may shed light on questions under study. Data collection and analysis are interrelated processes. In grounded theory, the analysis begins as soon as the first bit of data is collected. Data analysis is necessary from the start because it is used to direct the next interview and observations. The carrying out of procedures for data collection and analysis systematically and sequentially enables the research process to capture all potentially relevant aspects of the topic as soon as they are perceived (Glaser and Holton 2004).

The categories are generated through the same analytical process of making comparisons to highlight similarities and differences that is used to produce lower level concepts. Every concept brought into the study or discovered in the research process is at first considered provisional. Each concept earns its way into the theory by repeatedly being present in interviews, documents, and observations in one form or another or by being significantly absent. To maintain consistency in data collection, the investigator should watch for indications of all important concepts in every observation (Glaser and Holton 2004).

As the theoretical basis is developed, the gaps and holes in the theories are filled by conducting theoretical sampling specific to the issues, in order to get more precise information. Theoretical sampling is used to develop the emerging categories and refining the concepts. It helps in identifying conceptual boundaries and specifying phenomena in terms of conditions that give rise to them. It is by theoretical sampling that true representation and consistency are achieved (Denzin and Lincoln 2000, 519). In grounded theory, process has several meanings. Process analysis can mean breaking a phenomenon down into stages, phases, or steps.

Grounded theory is comprised of three basic elements: concepts, categories, and propositions. Concepts are the fundamental elements of examination since the theory is evolved from the conceptualization of data rather than the actual data itself. As Corbin and Strauss (1990, 7) state, “Theories can't be built with actual incidents or activities as observed or reported; that is, from ‘raw data.’ The incidents, events, happenings are taken as, or analyzed as, potential indicators of phenomena, which are thereby given conceptual labels. If a respondent says to the researcher, “each day someone on the team had to spend hours organizing the documents,” then the researcher might label this phenomenon as ‘documentation.’ As the researcher encounters other incidents, and when after comparison to the first, they appear to resemble the same phenomena, then these, too, can be labeled as ‘documentation.’ Only by comparing incidents and naming like phenomena with the same term can the theorist accumulate the basic units for theory.”

Categories are the second element of the grounded theory. Categories are superior and more abstract than concepts and are generated by applying the analytical process of comparing similarities and differences. This approach is similar to the process used to produce lower level concepts. The theory is integrated by grouping the concepts and forming categories. Continuing with the example presented above, in addition to the concept “documentation” the researcher might generate the concepts of “administrative burden,” “paper-trails,” and “additional employment.” While coding, the researcher may observe that, although the concepts are different, they all represent activities directed towards similar process, such as, the keeping the paper-work organized for LEED certification submission. This could further be grouped under a more abstract heading, such as, “Issues related to incorporating LEED in projects” (Corbin and Strauss 1990, 7)

The third element of the grounded theory is termed as ‘propositions,’ which depicts the conceptual relationship in comparison to the measured relationship depicted by the ‘hypothesis.’ Since the grounded theory approach produces conceptual relationships, the former term is preferred. However, there has been a constant debate on the inductive discovery of theory grounded in systematically analyzed data versus the prevalent hypothetical-deductive practice of testing. The former advocate that the proposition should be discovered, developed, and conditionally confirmed through methodical data collection and analysis of data pertaining to that phenomenon. Therefore, data collection, analysis, and theory should stand in a mutual relationship with each other. In other words one does not begin with a theory, and then prove it. Rather, the theory begins with an area of study and emerges as the relevant concepts and categories come out. On the other hand, the latter support the concept that since theories are constructed to explain and predict phenomena, not data, and theories should be taken as grounded in phenomena, rather than in data. In simple terms, the argument is on whether to start the study with a proposition or to start with a concept and evolve the proposition for the analysis of the data. Proposition testing versus emergence are methodological notions that are usually faced by grounded theorists. Concepts and relationships that emerge by comparing several incidents in a certain area are usually probability statements (Haig 1995).

Although grounded theory was developed by both Barney Glaser and Anselm Strauss, there was a clash of ideas and methodology between the originators, so grounded theory was divided into Corbin and Strauss’s method, and Glaser’s orthodox method. Despite the fact that Glaser and Strauss disagree about the procedures and the conclusions of grounded theory, they still share consensus on conducting constant analysis, theoretical sampling, and theoretical memo-making to contribute to the objectivity of the research (Rennie 1998).

The goal of grounded theory is to discover the participant’s concerns and views pertaining to an incident. The main idea of grounded theory is to generate concepts and perceptions to explain a phenomenon irrespective of time and place. The descriptive part of grounded theory is only to illustrate the concept. A concept is the overall element which includes categories and sub-categories, all integrating together to form a core variable that explains most of the views relating to an incident (Pandit 1996).

One of the fundamental properties of grounded theory is the “all is data” approach, which means that everything that the researcher comes across while analyzing a certain incident is considered as data, such as interviews, lectures, seminars, group meetings, newspaper articles, internet mail lists and even television shows. Coding and comparing forms are integral parts of grounded theory, since they help in generating the concepts (Glaser and Holton 2004).

Open coding is the first step of analysis. The written data acquired from either field observations and/or interviews is transcribed in order to find out about the problem and how it is being resolved. The researcher goes back and forth while comparing data, constantly modifying and grinding the growing concept, and following the build-up schedule of grounded theory. Open coding is followed by selective coding when the core variable or the tentative core variable has been identified. After selecting the core variable the data is selectively coded and sub-coded with the core variable guiding the coding process. The new data is sampled in parallel with the core as the driving channel; this is called theoretical sampling which is a deductive part of grounded theory. Selective coding is considered to delimit the study and makes it move fast, which is not a concern since grounded theory is not about achieving accuracy in data as much as generating the concepts leading to a particular incident (Glaser and Holton 2004).

One of the core stages of grounded theory methodology is making memos. According to Glaser and Holton (2004), memos are the speculation of ideas about codes and their theoretical relationships that emerge during coding, collecting, and analyzing data. Memos are made during the early phases of grounded theory since making memos helps in conceptualizing the incidents under observation. Theoretical memos can either be written or be drawn in constant comparison. Memos are crucial in refining and following the trial of ideas and concepts that develop on comparisons within the data analysis.

The next step after making memos is sorting the memos to formulate the theory for presentation. As stated by Glaser and Holton (2004), sorting puts fractured data together and goes back and forth within the data to discover that everything fits somewhere in either the concepts or the codes. New ideas might emerge during sorting which begets new memos producing memo-on-memo phenomenon. While adopting grounded theory, it is recommended not to conduct a pre-research literature review. The researcher might acquire preconceptions about the phenomena before entering the field, and this may block out the real concepts. It is recommended to read literature during the memo-sorting stage which helps in providing more data to compare with the generated codes and concepts (Glaser and Holton 2004).

Triangulation

Triangulation is the function and combination of several research methodologies in the study of the same phenomenon. Triangulation was originally used in social sciences and has now spread to various disciplines (Denzin and Lincoln 2000). Triangulation can be incorporated in both quantitative and qualitative research. It is a method-appropriate approach of identifying the credibility or the validity of qualitative analyses. By combining multiple observers, theories, methods, and empirical materials, sociologists can hope to overcome the weakness or intrinsic biases and problems that come from single-method, single-observer, and single-theory studies. Often the purpose of triangulation in specific contexts is to obtain confirmation of findings through convergence of different perspectives. The point at which the perspectives converge is seen to represent reality (Denzin and Lincoln 2000).

There are four basic types of triangulation:

1. Data triangulation, involving time, space, and persons;
2. Investigator triangulation, which consists of the use of multiple, rather than single observers; theory triangulation, which consists of using more than one theoretical scheme in the interpretation of the phenomenon;

3. Methodological triangulation, which involves using more than one method and may consist of within-method or between-method strategies; and
4. Multiple triangulation, when the researcher combines in one investigation multiple observers, theoretical perspectives, sources of data, and methodologies.

Integrated Definition for Function Modeling (IDEF0)

The purpose of functional design for a projected facility is to approach the process as a composite structure of interconnected tasks. These tasks are organized systematically according to the functions to be performed within these tasks so as to provide a compilation of requirements. The arrangement of these tasks can be viewed as an iterative design process to find suitable functions to facilitate effective implementation of the intended operation. Process modeling is the use of graphical methods to describe the flow of information and activities through an organization. Process modeling diagrams provide a visual portrayal of how a process works. An organization can analyze, streamline, and formalize the procedures by graphically representing the activities within the process with their predecessor and dependent activities. The IDEF0 is one of the methods that allow process modeling to be performed by the use of cell modeling. The National Institute of Standards and Technology has adopted the Integration Definition for Function Modeling (IDEF0) as a Federal Information Processing Standard (IDEF0 1993).

The IDEF0 allows process modeling by the use of cell modeling. This method involves functions being represented by cells, with each cell having inputs and outputs. The behavior within each cell is determined by controls and mechanisms. In IDEF0 modeling cells can be segregated into subcomponents, hence, they depict a process at various levels of detail. One of the greatest benefits of process modeling is that it formalizes the procedures involved within the process modeled. Once a process model has been developed and the operation is streamlined, deviation or modification can be easily determined and eliminated or incorporated into future practice (Anderson and Fisher 1997a). An IDEF0 model is a depiction of a set of components of a system or subject area. The model is developed for understanding, analysis, and improvement or replacement of the system. Systems constitute co-dependent parts that work together to perform a useful function. System parts can be any combination of things, including people, information, software, processes, equipment, products, or raw materials. The model describes what a system does, what controls it, what things it works on, what means it uses to perform its functions, and what it produces (IDEF0 1993).

The IDEF0 is a modeling procedure based on combined graphics and text that are presented in an organized and systematic way to gain understanding, support analysis, provide logic for potential changes, specify requirements, or support systems level design and integration activities. An IDEF0 model constitutes a hierarchical series of diagrams that progressively exhibit levels of detail relating to functions and their interfaces within the context of a system. There are three types of diagrams: graphic, text, and glossary. Graphic diagrams define functions and functional relationships via box and arrow syntax and semantics. Text and glossary diagrams provide additional information in support of graphic diagrams (IDEF0 1993).

IDEF0 is an engineering technique for performing and managing needs analysis, benefits analysis, requirements definition, functional analysis, systems design, maintenance, and baselines for continuous improvement (IDEF0 1993). The IDEF0 model replicates how functions within a process interrelate and operate just as the blueprint of a product reflects how the different pieces of a product fit together. When used in a systematic way, IDEF0 provides a systems engineering approach to:

- Execute systems analysis and design at all levels;
- Construct reference documents associated with evolution to serve as a basis for integrating innovation or improvement in the existing systems;
- Keep up a correspondence among team participants;
- Allow coalition team consensus to be achieved by shared understanding;
- Manage large and complex projects using qualitative measures of progress; and
- Provide reference architecture for enterprise analysis, information engineering and resource management.

As IDEF0 supports function modeling, the box name will be a verb or verb phrase, such as “Perform Analysis”, that is descriptive of the function that the box represents. The example "Perform Analysis" function transforms unanalyzed parts into analyzed parts (IDEF0 1993). The next step after the phrase-naming of the box is the integration of arrows (matching the orientation of the box sides) that complement and complete the expressive power (as distinguished from the representational aspect) of the IDEF0 box (IDEF0 1993). In order to describe the functions in the IDEF0 model, normal vocabulary should be used to make sure that everyone understands the model accurately. While the names of each box unit are descriptive with verbs or verb phrases, the arrow labels are labeled with nouns or noun phrases. Arrow labels are regulatory and constrain the meaning solely to the particular data or function. Arrows are further disintegrated into forks and branches to join syntax (Anderson and Fisher 1997a).

Each side of the function box represents a standard meaning in terms of bow-arrow relationship. Arrows entering the box from the left side are the inputs which are required to perform the function and to generate outputs. Each function is guided by control arrows entering from the top. The control arrows indicate the mandatory requirements for generating the correct outputs. Output arrows are shown on the right side of the box with a forward moving arrow. The output of one function could act either as a restraint or as an input for other functions. Output arrows are basically the required data or the desired object produced by the function. The arrows connected to the bottom side of the function box represent the mechanism required to carry out the functions (IDEF0 1993).

Anderson and Fisher (1997b) developed a constructability review process for transportation facilities using the IDEF0 function modeling technique. IDEF0 models provide a "blueprint" of functions and their interfaces that must be captured and understood in order to make systems engineering decisions that are logical, affordable and could be integrated and achieved.

RESEARCH PROPOSITION, LIMITATIONS, AND DELIMITATIONS

Research Questions

The health-care sector is among the most code regulated industries and adding LEED objectives will influence the projects even further. The research is based on the following research questions:

- Is there a credit variation between LEED pilot list and LEED final list?
- If there is a variation, then
    - What are the causes of variation?
    - What are the effects of variation?
    - How can variation be minimized?

The basic principle is that integrating LEED objectives in health-care projects is a relatively new process. Both, the LEED rating system and the project planning strategies of respective organizations are well developed within their own realm. However, based on the theoretical concepts discussed in the literature review of the study, it is a valid assumption that if there is a variation, then it might be occurring due to the inadequacies in integrating these two together during the front end development of project planning. Based on this assumption the study was based on following propositions.

Propositions

More than optimizing either the LEED rating system or the project-planning strategies, the formula for delivering a LEED project with minimum variation lies in the integration of business objectives with the LEED objectives during the early phase of project planning. The process of greening health-care settings is to be understood by owners and providers. The following propositions will be used in the study:

1. Potential variations between the pilot checklist and the final checklist could be pre-determined during the early phases of the project.

2. LEED objectives should be integrated during the project planning stage instead of the design phase in order to ensure minimum variation in the checklist.
3. Managing the variations between the pilot checklist and the final checklist will further enhance the certification level of health-care projects.

Limitations/Delimitations

Constructing hospitals is a large scale process with multiple development and construction phases involved. The research will focus only on the LEED credit variations and the cause and the mitigation theory for these variations. The research will be bound by the following limitations:

1. The study will focus on the variation that occurred during the construction and execution phase of the project, instead of the credits that were dropped during the project planning phase.
2. The result will recommend the theory applicable for the project-planning and definition stage only.
3. The results will be limited and applicable to the case studies used in the study.
4. The results of the research will be applicable primarily to the health-care sector.
5. The study will not assess any other aspects of projects other than the variations between the pilot checklist and the certified checklist, and the causes of the variations.
6. The findings will be limited only to the view-points of owners, project managers, architects, and general managers.

RESEARCH METHODOLOGY

Research Design

The research utilizes two types of methodology approaches for two separate parts of the study. The first part is to identifying the problem using grounded theory approach based on the data analysis procedure depicted in Fig. 4 (Leedy and Ormrod 2001). The second part is to graphically present the recommended approach on the IDEF0. This research follows a similar methodology that was adopted by Pandit (1995), using grounded theory as a data collection approach and ATLAS.ti as a data analysis tool to propose a theory. However, the aim of the researcher was not to put forth a theory, but to make a recommendation based on systems approach. The recommended approach has been presented using the IDEF0 method, which is a graphical tool to represent the systems approach.

Research Method

The research is a qualitative inquiry using a grounded theory approach to investigate factors that lead to variation between the LEED pilot and final checklist. So far there has been no research conducted on whether there is a variation between the LEED pilot list and the final list. According to Yin (1994), the choice of research strategy depends upon the type of research question posed. The goal of grounded theory is to discover the participant’s views pertaining to an incident. The driving question in grounded theory is: “what is happening,” “what is going on” or “what are the problems and how to solve them?” Although grounded theory has its roots in sociology, the fathers of the theory, Glaser and Strauss, do not regard the procedures of grounded theory as discipline specific and encourage researchers to use their own disciplinary purposes (Loosemore 1999). There are several examples where grounded theory has been applied as a basis of research in the construction industry. Loosemore (1999) examined crisis management in the context of building projects procured through the design-bid-build approach.

Interviews play a vital part in data collection and must include the perspectives and views of the people being interviewed for the study (Corbin and Strauss 1990). Grounded theory research is implemented by focusing on an area of study and assembling related data from a variety of sources. The term “grounded” refers to the concept that the theory that emerges from the research is originated from and “grounded” in the data (Leedy 2001).

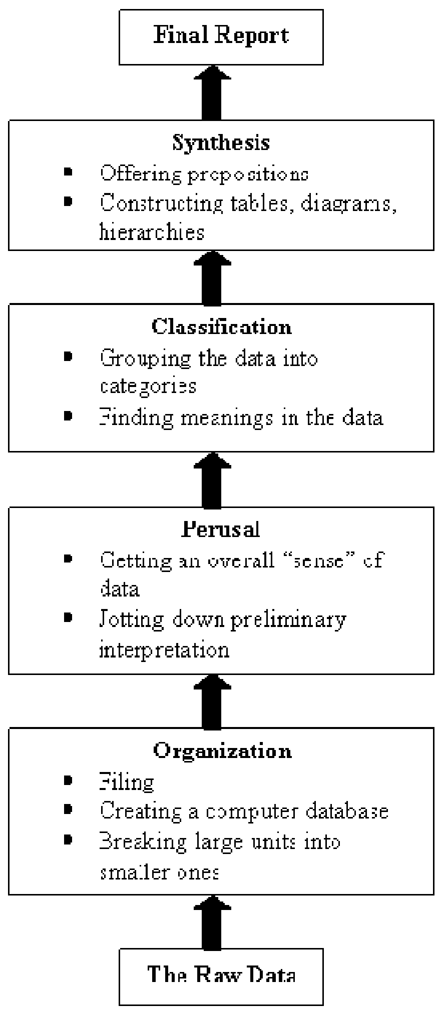

Fig. 4. Procedure for data analysis based on Creswell 1998
(Source: Leedy and Ormrod 2001)

Collective Case Study

The researcher has adopted the collective case study approach where less intrinsic interest is given in one particular case instead; a number of cases are investigated jointly in order to analyze a general condition or an occurrence. Individual cases in collective study may or may not show apparent characteristics in advance. The cases may be similar or dissimilar, they are chosen on the basis of the understanding that analyzing them will lead to better understanding or speculation about a still larger collection of cases or processes (Denzin and Lincoln 2000).

Sample, Location, and Setting

The case studies were chosen based on the quota sampling method by identifying the stratum and the proportions in the population, that is, by identifying LEED certified projects and then selecting LEED certified health-care projects from the project list. A list of twenty hospitals was selected from the world-wide-web (USGBC 2005). All the twenty hospitals are either certified or are registered for the LEED certification with the common objective to acquire LEED certification. The project spanned from the east coast to the west coast in the United States, and represented a mix of public and private investments. The common string binding these projects is the judgment of success in terms of LEED certification.

Data Collection

The data was solicited from the owners, the general contractors, the project managers, the architects and the construction managers of the selected case studies. Foremost, the pilot LEED list, current LEED list and, the final LEED list of the selected case studies are acquired using emails to commence response. After comparing the LEED list of the projects, the major participants and the decision makers, such as the owners, the project managers, the architects and the general contractors of the project were contacted. Semistructured interviews have been used to get a better understanding on the reasons for the credit variation.

Two to three project team members were selected from each facility based on their involvement and role in implementing LEED regulations during the construction phase. The time for the telephone interview was selected on the basis of interest and availability of the people. The participants were asked 15 to 16 open ended questions focusing on the LEED aspect of the projects (Appendix B). The questions were designed to inquire not only the reasons for the credit variation in the LEED list but also other aspects of working on a LEED project, such as current practices, hindrances and the best practices to incorporate the LEED objectives in the project.

Data Coding and Analysis

The basic strategies for data analysis used in the Grounded theory method was open coding, selective coding, and seeking conceptual patterns using constant comparison method. The procedure was implemented using computer-assisted analysis with the ATLAS.ti software package. The ATLAS.ti computer program has been developed by the Grounded Theory Institute explicitly designed to assist in grounded theory analysis (Muhr and Susanne 2004).

Data Analysis

The data was coded using ATLAS.ti, a tool developed for qualitative analysis, particularly of larger bodies of textual data (Muhr and Susanne 2004). The ATLAS.ti is programmed to place emphasis on qualitative, rather than quantitative analysis, that is, determining the elements that comprise the primary data material and interpreting their meaning. A related term would be “knowledge management,” which emphasizes the transformation of data into useful knowledge. There are two principal modes of working with ATLAS.ti, the textual level and the conceptual level. The *textual level* includes activities like segmentation of data files; coding text, image, audio, and video passages; and writing memos. The *conceptual level* focuses on model-building activities such as linking codes to networks (Muhr and Susanne 2004). The use of ATLAS.ti was limited to the textual-level for this particular research. The conceptual level was built using the IDEF0 modeling process due to the constrain advantages offered in the IDEF0 process. Textual-level research activities include segmenting primary data into codes and categories to help facilitate the identification of patterns as shown in Fig. 5. The act of comparing noteworthy segments leads to a creative conceptualization phase that involves higher-level interpretive work and theory-building. ATLAS.ti was used in assisting the researcher in all of these tasks and provides a comprehensive overview of the collected data as well as rapid search, retrieval, and browsing functions. Within ATLAS.ti, initial ideas often find expression through their assignment to a code or memo, to which similar ideas or text selections also become assigned. ATLAS.ti provides the researcher with a highly effective means for quickly retrieving all data selections and notes relevant to one idea (Muhr and Susanne 2004).

Structured interviews were used as survey instrument to obtain the viewpoint of the project team on integrating LEED objectives in health-care project. The data obtained from the interview was categorized into four different categories: viewpoint of the owners, viewpoint of project managers, viewpoint of architects, and the viewpoint of contractors. The viewpoint of respective participants was further divided by the issues they faced and their suggestions to improve the process of integrating LEED objectives within health-care facilities.

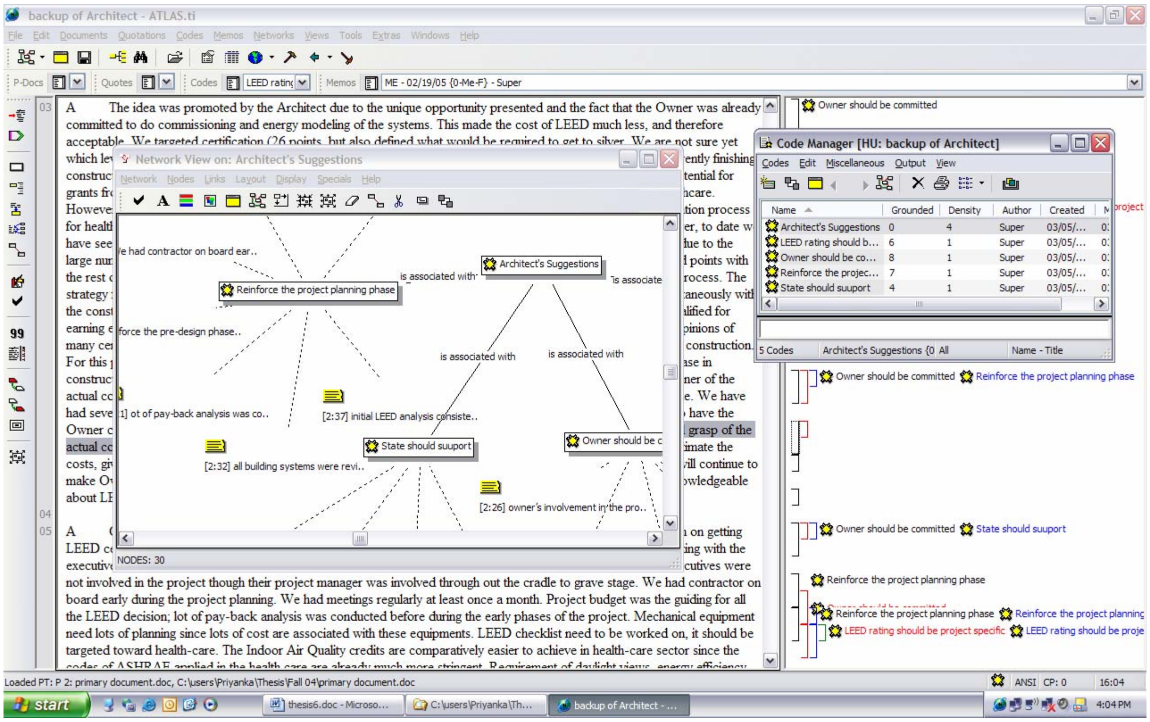

Fig. 5. Forming codes and categories within architect's viewpoint

Triangulation

Triangulation can occur inside a single method, which addresses internal consistency and reliability issues using a latent variable approach with multiple indicators. For example, examining multiple scales in one survey could be considered a within-method approach. On the other hand, between-method triangulation can address issues related to external validity and provide evidence of cross validation. In this case, both an interview and a survey can be used to provide convergent validity information, which contributes to construct validity (Denzin and Lincoln 2000). In order to achieve the validity data will be triangulated based on the data source, that is, the project participants.

Process Modeling

Based on the literature review, the interview responses, and the project participant's suggestions, an approach to minimize the variation is presented using the IDEF0 modeling techniques. A similar but more comprehensive research was conducted by the Transportation Research Board, where a preliminary constructability review model was proposed based on the literature review, survey result, and the IDEF0 modeling techniques (Anderson and Fisher 1997a).

CASE STUDIES

Overview

Twenty case studies were selected from the website of the USGBC council. Ten out of twenty projects were located on the east coast, five projects on the west coast, and five in the central US. Out of twenty projects, five reported credit variation between the pilot LEED and the current list (Table 2). Four projects abandoned the LEED objectives and another one was on hold. Out of the remaining ten, eight were in progress; there was no information available on the case study T, except that the project is no longer registered for LEED certification, and case study M was on hold due to programming and feasibility issues (Table 3). Largely, the credits were dropped out due to financial issues and the cost associated in achieving the credits. The credits that had low or no design and construction cost associated with them had the least variation. However, the credits with cost associated with them were the ones which had maximum variation, such as energy optimization, water efficiency, additional commissioning, and storm water run-off /treatment.

Table 2. Detailed summary of the case studies

	Completed	On-going	Total
Number of case studies with variation	3	2	5
Number of projects that abandoned LEED (100 % variation)	1	3	4
Number of projects with no variation reported	0	9	9
Total case studies	4	14	18

Note: Case studies M & T were dropped from the list due to the reason stated in Table 2.

Table 3. Overview of the case studies

	Case study	Pilot	Current	Variation
1	A	36	33	-3
2	B	33	27	-6
3	C	36	33	-3
4	D	31	0	-31
5	E	35	33	-2
6	F	29	0	-29
7	G	29	-	-
8	H	35	-	-35
9	I	31	-	-
10	J	38	30	-8
11	K	41	-	-
12	L	37	-	-
13	M	On hold due to programming issues		
14	N	-	-	-
15	O	30	-	-
16	P	31	-	-
17	Q	50	-	-
18	R	31	32	+2 -1
19	S	29	-	
20	T	No information		

Case Studies with Variation

Case Study A

Description: This $75 million facility with 220,000 square feet of area was in the operable stage. The project followed a traditional design-bid-build project delivery approach. The project team involved owner, architect, energy architect, and general contractor. The green objectives were initiated by the owner at the very beginning of the project. The LEED rating system was merely used as a tool for the measuring the project performance. As stated by the project manager “there is nothing in the building that we did just to get a LEED point, a lot of things that were done would have been done regardless of going for LEED certification or not.” The project team conducted feasibility and payback analysis beforehand during the pre-construction phase that facilitated laying out a well-defined plan along with a budget for the project. Credits such as daylight and views were filtered since they are difficult to achieve in a health-care facility due to regulatory constrains.

The energy architect acted as the LEED consultant for the project and took care of the documentation and the paper trail. Project budget was the guiding factor for all the LEED decisions; therefore, all the strategies for acquiring the LEED intents were well developed during the pre-construction phase in order to give the owner a fixed project budget. The scope of work included the commissioning and documentation cost as well.

Variations: The intended credit score for the project was 36 credits; however, the team lost 3 credits and got the final score of 33 credits. Credits that were excluded from the pilot list are (Appendix C):

1. Credit 3.1 - Water efficiency
2. Credit 1.2 - Energy and atmosphere.

Causes of variation: The project team intended to use waterless urinal and water saving bathroom fixtures to achieve the credit on 20 percent water-use reduction. However, health-care guidelines have specific requirements towards the sanitary fittings to be used in a hospital, which limit the use of such water-saving fittings to the public toilets only. Given the total space difference between the public toilets for the visitors and the personnel toilets for the patients, the final calculation could not sum up to a 20 percent saving, as required by LEED and therefore the credit was dropped from the list. The team lost another 2 points on credit 1.2 of the energy and atmosphere category. The variation occurred due to a mismatch in the energy calculations submitted by the project team and the calculation conducted by the USGBC.

Case Study B

Description: This was a $6 million project with an area of 28,300 square feet. The project team followed the traditional design-bid-build project. The project was a government project and the state government had the state regulation of competitive bid process for the government project. As stated by the project manager, the traditional project approach did not allow the early involvement of the general contractor, complicating the process. In addition, there were communication problems in making the repeated case for green materials particularly while securing subcontractors and suppliers.

During the project-planning phase the project team consisted of the owner, the architect, and the architect's consultants. Most of the contractors and sub-contractors in the area were unfamiliar with both the LEED process and the intensive paperwork or procurement strategies associated with it. As a result, the owner and the architect had to settle for the comparatively higher bids. Neither the contractor nor the architect had much experience in green construction practices at the beginning of the project, and, as stated by both the parties, it was their first LEED project. According to the architect, "given the opportunity to restart the project with fresh insight, the project team would approach several key issues, such as renewable energy, differently and would look to frame problems and details in a fully integrated perspective and in the future, we would look to reinforce the pre-design phase and bid phase of negotiations with contractors so that the sustainability initiative, including performance metrics, would require less steadfast procurement."

Variation: The project team aimed for 33 credits instead registered for 28 credits. The team further lost one more and the final score came out to be 27 credits. The following credits were dropped by the team (Appendix C):

1. Credit 7.2 – Sustainable sites
2. Credit 8 - Sustainable sites
3. Credit 1 – Energy and atmosphere
4. Credit 3.1 – Indoor environmental quality
5. Credit 3.2 - Indoor environmental quality
6. Credit 1.3 - Innovation and design

Causes of variation: Credit 7.2 and credit 8 of the sustainable site category were dropped due to cost issues. Credit 8 of the sustainable sites was dropped because of some misunderstanding with the civil consultant. According to the civil consultant, the architect and the owner were planning to change the light fixtures that were originally mentioned in the project specifications. However, the new fixtures were costlier than the original ones, which led to the payment issues; that is, whether the owner should pay or the civil consultant should pay the extra cost. At last, the civil consultant went ahead with the original fixture; therefore, the project team could not attain credit 8.

Credit 1 of energy and atmosphere was not achieved due to the mismatch in the energy calculation submitted by the project team and the calculation conducted by the USGBC. Credit 3.1 of the indoor environmental quality was dropped because the contractor refused to incur the cost of implementing the indoor air quality plan during the construction stage. Credit 3.2 of the indoor environmental quality category was dropped for the same reasons, the contractor refusing to pay for the cost of changing the air filters before the occupancy. According to the contractor, the cost of both, changing the air filters before occupancy and implementing the air quality plan during the construction, was not mentioned in the project scope of work as the contractor's liability. On the other hand, the owner and the architect assumed that the since achieving credits in material and resource categories was mainly the contractors' liability, the contractor would ensure that all the specified credits were achieved. Credit 1.3 of the innovation and design was dropped because of the extra cost of installing mercury free medical equipments.

Case Study C

Description: This was a 182,740 square feet facility with the total project value of $40 million. The project followed the traditional project delivery approach with construction manager. The project included extensive demolition, renovation, and rebuilding; however, the credit on building and resource reuse were not considered. According to the project team, "the technology in health-care is fast changing and most of the stripped material was useless and could not be either re-used or recycled."

Variation: The team aimed for total 36 credits in the pilot LEED list but dropped the following (Appendix C):

1. Credit 1.1 – Material and resources
2. Credit 3.1 – Material and resources
3. Credit 5.1 – Material and resources

Causes of variation: Credit 1.1 of the material and resources category was dropped due to the incompatibility between the required latest medical technology and programming/technological limitation of the old building and its equipments. Credit 3.1 of the material and resources category was dropped because the team found it challenging to recycle content from old hospital building. Moreover, there is limited information about recycling the materials that are specific of health-care in the LEED guidelines for recycling. Credit 5.1 of the material and resources was dropped because of the lack of availability of the specified material within the 500 miles of construction site.

Case Study D

Description: This project was a 50,000 square feet health facility. The project was registered for the LEED certification and the team incorporated a number of sustainable design features. However, the project team and the owner abandoned the idea of filing for the LEED certification.

Variation: The pilot list had credit intent of a total of 28 points. The project team incorporated the following features in the building:

- Natural day lighting
- Geothermal ground source heat pump and Heating, Ventilation, and Air Conditioning HVAC system
- Active solar hot water heating for pool water
- High indoor air quality
- Electrical lighting controls with daylight and occupancy sensor controls
- Long lasting durable natural materials
- Materials with recycled content or from rapidly renewable sources
- Low VOC finishes and products
- High performance insulation and glazing systems

However, the owner decided not to file for the LEED certification.

Causes of variation: The owner and the project team stated the cost of both commissioning and documentation as the main factor for abandoning LEED certification. The project team required an additional amount of approximately $75,000 to $80,000 for the commissioning, documenting, and submitting process for LEED certification. The facility was a public facility owned and run by a non-profit organization, and, according to the team and the owner, “we found it bit difficult to make people understand the extra hike in the project budget just to get a certificate, after all it is public money and we are answerable to them.”

Case Study E

Description: This project consisted of a 143,500 square feet hospital and a 6,500 square feet medical office building. The approximate project budget was $37 million and is scheduled to open in November 2006. The project was in 100 percent design completion and in 15 to 20 percent construction stage. The project team was targeting for a total of 35 credits and a LEED silver level certification. The project followed the construction manager project delivery approach. The architect initiated the idea of LEED certification which, added an additional half million dollars over the specified capital budget. The revised budget was approved, since the owner supported the green concept. The core project team consisted of the owner, the architects, the project manager and the contractor. Regular weekly meetings were conducted and extra time was spent during the early planning stages to develop all required strategies and project control techniques for achieving the project green objectives.

Variation*:* The project team had already dropped the following credits (Appendix C):

1. Credit 6.1 – Sustainable sites
2. Credit 7.1 – Sustainable sites

Causes of variation: Credit 6.1 and credit 7.1 of the sustainable sites were dropped because given the area of the project both the credits were adding extra cost. The team intended to use pervious paving and shade reflective surface to achieve the respective credits.

Case Study F

Description: The facility was a $130 million expansion project scheduled to be open in 2007. The project was being developed in multi-phased stages encompassing both infrastructure and patient care requirements. At the time this study was conducted, the facility was at the 10 percent project completion stage. The project followed the construction manager project delivery approach. The project team consisted of the owner, the architect, and the general contractor; however, none of the team members were LEED certified. The team did incorporate LEED objectives in the design phase and early construction phase, though at this writing, the project is moving ahead without the intentions of obtaining LEED certification. The original pilot LEED consisted of 30 credits with the intention of acquiring the certification level.

Variation: The project team took the joint decision for the design team to discontinue the LEED certification.

Causes of variation: According to the project team, the LEED process required an extra 2 to 4 percent on the project, which was not a major concern but the owner was skeptical about spending 2-4 percent on the process, whose result was unpredictable. In addition the design team found it difficult to synthesize LEED objectives in health-care. The team faced problems with the categories such as: water saving, energy saving, and daylight/views which are not health-care specific. One major concern was the uncertainties and ambiguities associated with the procedure to acquire the credits. According to the architect, “we do not want to spend extra time and cost on planning and preparing for some process whose outcome we cannot predict.” As stated by the project manager, hiring a LEED consultant at the current stage when 10 percent construction and 100 percent design is already finished did not seem to be a practical or cost effective solution.

Case Study H

Description: This project was the first health-care facility in the region to go for the LEED certification. The project was on hold while still in initial design phase. Even though the architect-engineers had seven LEED registered projects under them, the project team gave the LEED objectives for this particular project.

Variation: The idea of obtaining LEED certification was aborted in the design phase itself.

Causes of variation: According to the architect the idea was abandoned due to two reasons. First, there were inconsistencies between the LEED rating system and health-care regulations. For example, in comparison to a commercial building, a health-care facility is operable for extended hours. Therefore, water and energy consumption rates for health-care facilities are much more than the consumption rates for commercial buildings. Similarly, it is easier for a general commercial building to install water saving fixtures such as, waterless urinals and other low flow fixtures, but the health-care facilities have specific fixture requirements. There is also the dichotomy between what LEED considers a typical work place environment and the hospital environment. Many rooms in health-care facilities do not work well with operable windows. Besides providing patients with control over their own heating and ventilating is in contrary to patient management requirements. The second reason stated for canceling LEED objectives was that incorporating the LEED objectives in the project was inflating the budget beyond the pre-defined capital budget.

Case Study N

Description: This proposed 309,000 square-feet facility involves construction of a seven-level tower plus a basement and a mechanical penthouse. The project team started with the intent of acquiring LEED certification and carried the LEED objectives ahead until the completion of design and documentation phase. The LEED goals for project N were in total flux, and the project team refused to give any comparable information. Nonetheless, the project manager did share his opinion on integrating LEED and health-care, expressing that incorporating LEED in health-care projects is crucial and should become an everyday activity when such capital investments are initially planned.

The project was on hold due to the design and budget difficulties arising due to the incompatibility between the requirement of health-care projects and the LEED objectives. According to the project manager, the process needed to become more focused for the unique design and construction criteria of health-care projects. The project team recommended spearheading a single comprehensive approach to measuring sustainability in health-care projects, as opposed to having two separate and competing systems; that is, the American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) requirements and the LEED requirements.

Case Study R

Description: This project was a 50,000 square feet addition and a 52,000 square feet renovation development. The architect put forth the proposal of acquiring LEED-certification, aware that the owner was very receptive and supportive of sustainable buildings. The project was using the traditional design-bid-build project delivery approach.

Variation: The project team dropped one credit and added two which depicts both negative and positive variation (Appendix C):

Credit dropped:

1. Credit 6.1- Sustainable site

Credits added:

1. Credit 6.2 – Sustainable sites
2. Credit 7.2 – Sustainable sites

Causes of variation: The project team dropped the credit 6.1 of sustainable site category, although the project site was in the water shed of a lake. The civil engineer assigned to develop the strategy to achieve this credit was unfamiliar with the LEED process and achieving the credit turned out to be harder than expected. Therefore the team decided to abandon attempts to get 6.1, since it would have caused the budget overrun. Instead, the owner decided to install porous paving and achieved credit 6.2.

The project was 50 percent new construction and 50 percent renovation, so it was originally assumed that it would be virtually impossible to model for energy efficiency, considering that the original equipment was obsolete. Consequently, the energy modeling credit points were not considered. Later the project team discovered that the existing mechanical equipment had a serious performance problem and replacing would be more cost effective than repairing the existing plant. The second problem was that the existing roof was almost at the end of its life and the cost of renovating the old roofing was quite high. Therefore, the owner decided to replace the old roofing with black Ethylene Propylene Diene Terpolymer (EPDM) energy star reflective roofing and added insulation in the roof too and hence achieved credit 7.2. The owner filed an application for grant money from the state to offset the $100,000 cost of commissioning required energy modeling. At this writing, the project team is moving ahead with 32 credits in the pilot LEED list.

Summary of Case Studies

The credit variations that occurred in the chosen sample were mainly due to financial reasons (Tables 4 and 5). There were other factors that led to variations, such as lack of communication, inadequacies in project planning, cost-schedule overrun, and unawareness of LEED concepts among the project participants (Table 4).

Out of twenty case studies, one was put on hold due to programming issues and no information could be gathered on the other one. Within the remaining eighteen case studies, five reported variation (Table 4), while four gave up the LEED objectives (Table 5). Giving up the LEED objectives was considered 100 percent variation since the project team abandoned all the intended credits. Although the remaining nine projects did not report any variations (Appendix A), the researcher still interviewed the project participants to understand the problems they were facing in integrating LEED objectives in health-care projects.

Lack of variation does not imply that the remaining nine were moving ahead with complete efficiency. All the remaining nine case studies were still within the 5-25 percent of project phases, so the variation was not very apparent, but the project team did talk about the problems they were facing in integrating LEED objectives within the health-care projects (Appendix A). After identifying the reason for variation within the

Table 4. Summary of case studies with variations

Case studies	Category	Credits dropped	Causes	Effects
A				
	WE	Credit 3.1	Regulatory requirement of health-care	Time and resources lost in planning
	EA	Credit 1.2	Mismatch in energy calculation	Financial loss
B				
	SS	Credit 7.2	Cost issues	Time and resources lost in planning
	SS	Credit 8	Misunderstanding with civil consultant	Impaired the potential for future alliance
	EA	Credit 1	Mismatch in energy calculation	Financial loss
	MR	Credit 3.1 and 3.2	Problems with the contractor	Impaired the potential for future alliance
	ID	Credit 1.3	Cost issues	Time and resources lost in planning
C				
	MR	Credit 1.1	Incompatibility between technological requirements	Time and resources lost in planning
	MR	Credit 3.1	Difficulty in recycle content from old building	Time and resources lost in planning
	MR	Credit 5.1	Lack of availability of the specified material	Time and resources lost in planning
E				
	SS	Credit 6.1	Cost issues	Time and resources lost in planning
	SS	Credit 7.1	Cost issues	Time and resources lost in planning
R				
	SS	Credit 6.1	Civil consultant was unaware of the procedures	Time and resources lost in planning

Table 5. Reasons stated for abandoning the LEED goal

Case studies	LEED status	Reasons
Case study D	Abandoned	Prerequisite 1 of Energy and atmosphere-could not afford the cost of documentation and commissioning
Case study F	Abandoned	Did not want to raise the capital cost to 4 percent and found LEED and health-care requirement inconsistent
Case study H	Abandoned	Inconsistent with the health-care requirement and was inflating the capital budget
Case study N	Abandoned	Inflated the capital cost

nine case studies, the researcher further analyzed the data to find the underlying factors that were leading to the variation. It was necessary to identify the problems being faced by the project team in order to attain a deeper insight into the factor causing the variations. The study had two objectives; first, to identify the variations and the reasons for the variations in the LEED lists of LEED certified/registered health-care projects. Secondly, to recommend an approach, which if implemented, could minimize the variation. To put forth an approach it was important to understand the current issues and bottlenecks associated with integrating LEED in health-care projects. Therefore, the questions asked during the telephone interview encompassed a wide array of issues relating to the implementation of LEED objectives in health-care, including the reasons for variation between the LEED lists, the participant's opinion towards LEED, and their suggestion on minimizing the variation (Appendix B).

Data was organized by grouping like with like and data bits with data bits that is, grouping the perspectives of owner with owner, project manager with project manager, architect with architect, and contractor with contractor. The researcher then compared observations within each group, looking for similarities or differences within the data.

The data was analyzed using the constant comparison method; the data was categorized into different groups; that is, viewpoints of the owners, the project managers, the architects, and the contractors. Categorization forms a crucial element in the process of analysis. Content analysis, or analyzing the content of interviews, is the process of identifying, coding, and categorizing the primary patterns in the data. Fig. 6 shows the data coding of the category specific to the architect's viewpoint. The data was analyzed in phases by going back and forth trying to find issues within one category at a time. For example, Fig. 7 shows all the issues and suggestions related to one specific category, that is, the viewpoint of the contractors.

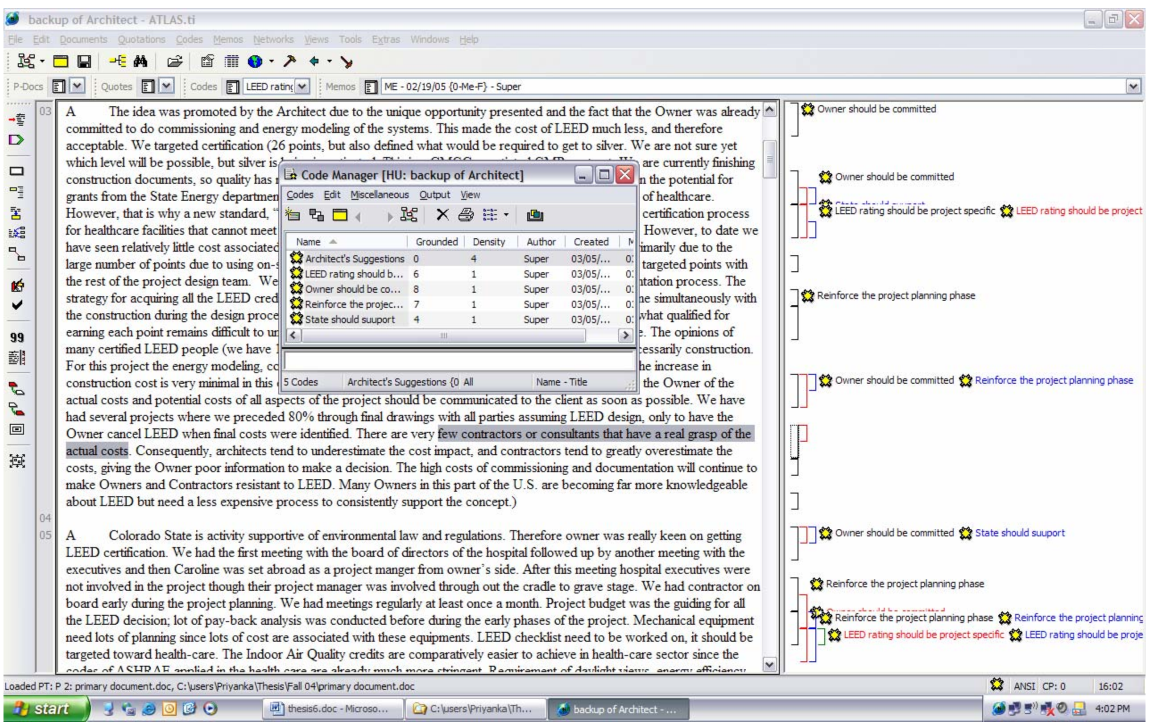

Fig. 6. Data analysis using ATLAS.ti

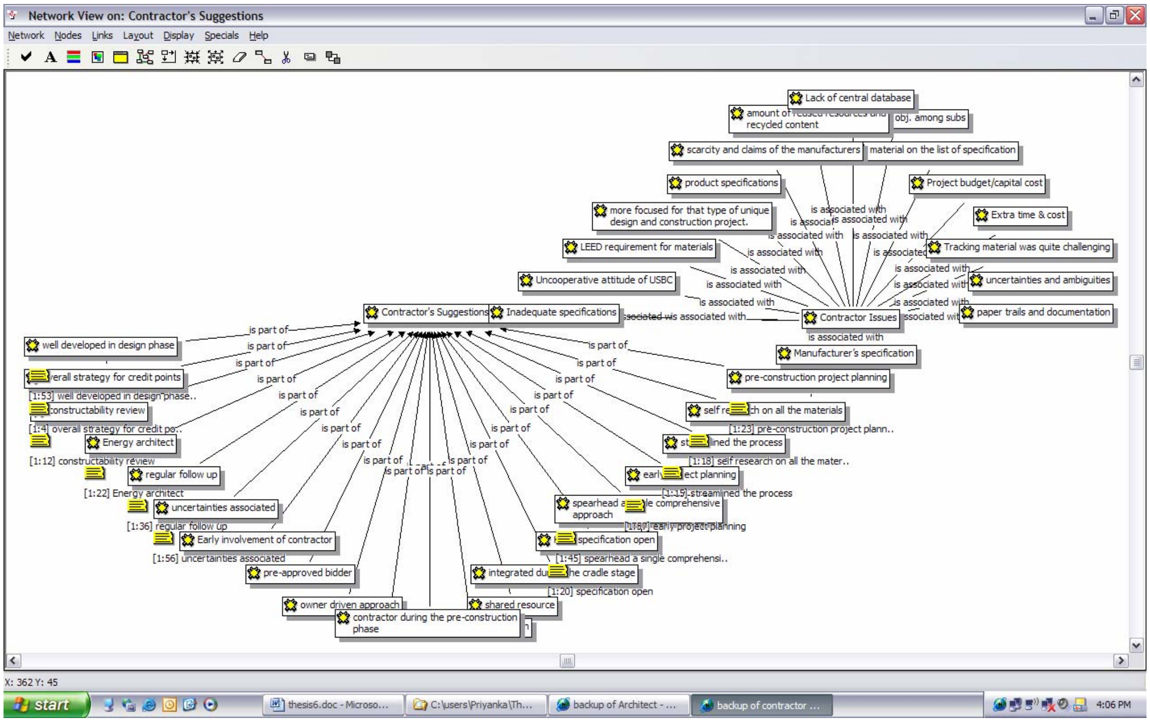

Fig. 7. Network view of the contractor's viewpoint before triangulation

There were number of categories associated with the viewpoints of the owners, the project managers, the architects, and the contractors. Fig. 7 illustrates the network view of all the issues and the suggestions related to the contractor's viewpoint before conducting triangulation. As depicted in Fig. 8, the issues and suggestions were based on the codes (grey colored nodes) which were derived from the quotations from the project participant's statements (yellow colored squares). Within-method triangulation was used to achieve the validity within the viewpoint of the project team. The issues and the suggestions were sorted out after conducting data triangulation as shown in Table 6.

Table 6. Data analysis using triangulation method

Source 1	**Source 2**	**Source 3**
Contractor 1	Contractor 2	Contractor 3
“LEED process requires extensive paperwork and documentation therefore, we have to hire extra administrative staff that we wouldn’t require on a regular project”	“One of the challenging parts of working on the LEED project is to manage the paper trail and the documentation. Everything has to be documented even if it is associated with a trivial issue”	“Ensuring that all the product specifications and sub-contractors work are fully documented and are in accordance to the requirement was a major problem”
Interpretation: “The documentation and the paper trail associated with the LEED process is a concern for the contractors.”		

For example, any concerns and suggestions that were stated by three or more contractors were identified as valid concerns and suggestions among the general contractors (Table 6). Similar procedure was adopted for obtaining the valid concerns and suggestions of the owners, the project managers, and the architects. Instead of using the data triangulation chart, the researcher used the ATLAS.ti software to triangulate the issues and the suggestions of the project team. Fig. 8 represents the suggestions of the contractors that were generated after triangulating the data for suggestion within the category of the contractors using the ATLAS.ti.

Concerns and Suggestions of Project teams

While conducting the interviews, the researcher asked the project teams their views and experiences related to the problems they faced and their strategies for dealing with those

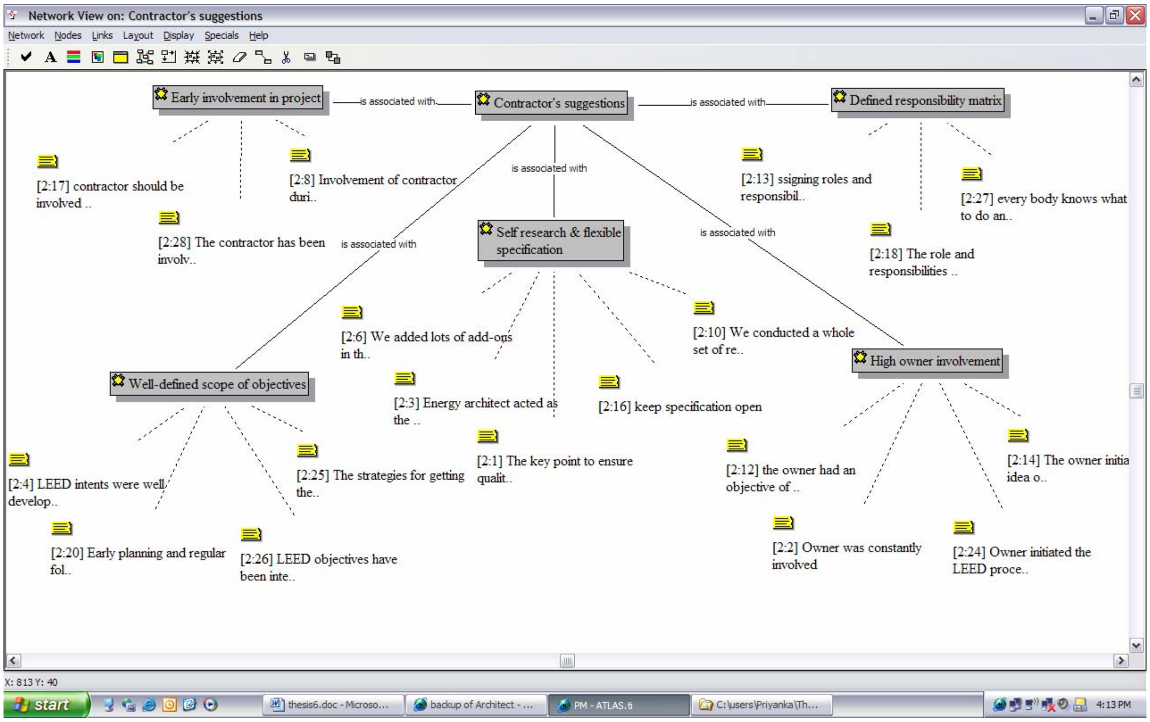

Fig. 8. Network view of contractor's suggestion after conducting triangulation

problems (Appendix B). The data collected through the interviews was categorized according to both, the issues and the suggestions related to the owners, the project managers, the architects and the contractors. The issues were helpful in identifying the root cause of the variations. Alternatively, the suggestions outlined the underlying foundation of the recommended approach in order to maintain the objectivity in the approach. The data was coded, analyzed, and triangulated using ATLAS.ti, an analytical tool developed by the Grounded Theory Institute.

Concerns and Suggestions of Owners

The significance of owners' roles in incorporating LEED objectives in the project is undeniable. The owners are at the very core of the project; a dedicated owner can make the difference to the project being "a hit or a miss" in terms of meeting green objectives. From the project design, commissioning, engineering, construction, procurement, acquisition to the operation and maintenance, it is the owner who pays every dollar for the project to be comprehended.

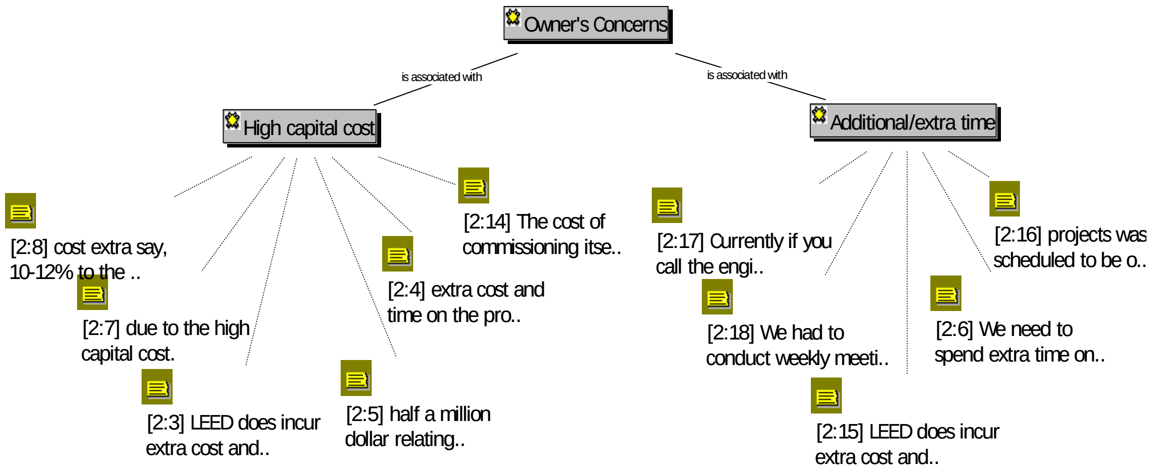

Fig. 9. Network view on owner's issues generated in ATLAS.ti

The two major concerns shared by the owners were, the high capital cost associated with the LEED process, and the extra time required in documentation and planning (Fig. 9). One of the reasons that the owners were reluctant in accepting LEED is due to the high capital cost. Most of them admitted that they were unaware of the process and the benefits associated with the "green approach." Initially some of the owners were skeptical about the LEED concept. Later, they were convinced about the approach and now want to implement green objectives in their future projects, as well. The second concern shared by the owners was about the additional time associated with the LEED process relating either to the planning or to the documentation process. Compared to a project without the goal of achieving LEED certification, a LEED registered project takes up to 12-24 months of extra time due to planning, documentation, and certification. However, the owners agreed that the process takes extra time due to the fact that the industry is still at the learning curve of green objectives. Therefore, it takes time in trying to figure out the approach and to conduct research even on the basic things such as selecting materials.

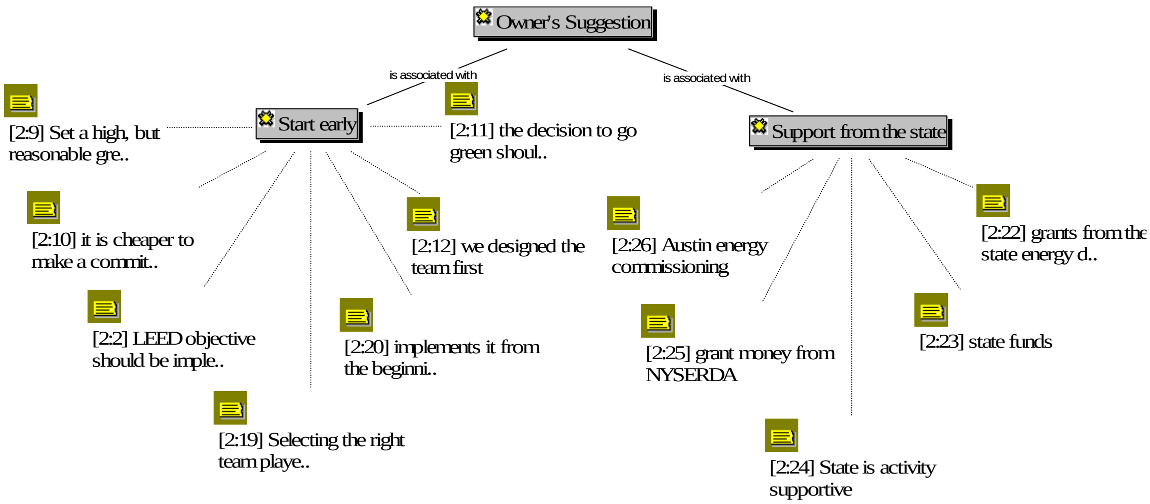

Fig. 10. Network view on owner's suggestion generated in ATLAS.ti

In order to mitigate the owners' apprehension of high capital cost associated with the LEED process, most of the owners recommend that the local government or state should provide some sort of financial support (Fig. 10). It will not only encourage the owners to adopt the LEED objectives but will also pr some financial stability especially for the public projects.

According to the project participants, few cities, especially on the East and the West coast, have energy grants or research innovation funds available for projects with environmental objectives. Another suggestion made by the owners in an attempt to minimize both the extra cost and the extra time on the LEED project is to implement the LEED objectives early in the project. Early planning and development of LEED intents helps in identifying the true cost of the project. An owner can obtain a better representation and could make informed decision regarding the LEED strategies if associated cost is known early. Early planning also helps in developing cost and time control plans, hence mitigating any last minutes disclosures and expenses. The owners highly recommend the early introduction of LEED objectives in the project in order to improve the project success in terms of green objectives.

Concerns and Suggestions of the Project Managers

There are some similarities among the issues and suggestion made by the architects, the owners, and the project mangers. The project managers on all the projects were either from the owner's side or from the architect's side. There were individuals who were both, the architect and the project manager for a particular project. Therefore, if their viewpoints were included in the architect's section then they were not included in the project manager's section. This helped in preserving the validity of the study and avoided the redundancy in the analysis. In addition, triangulating the viewpoint of a person in two different sections, that is, in project manager's viewpoint and again in architect's viewpoint would have added bias by giving a false higher triangulation rate.

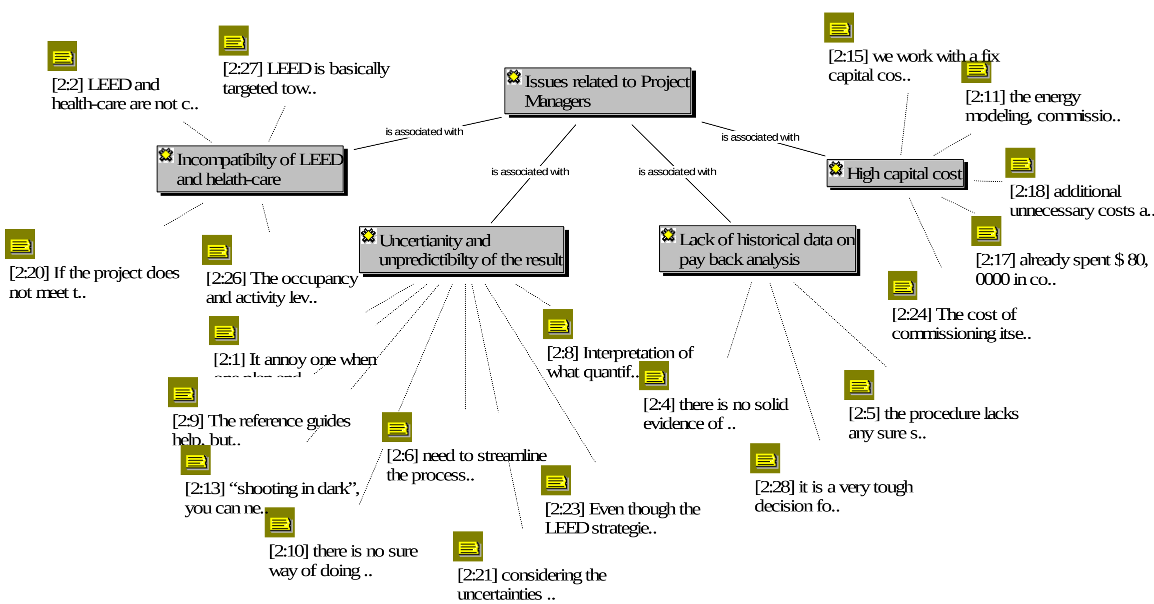

Fig. 11. Network view on project manager's issues generated in ATLAS.ti

As shown in Fig. 11, the following patterns were apparent after conducting the data triangulation:

- Incompatibility of LEED rating system and health-care regulation
- Uncertainty and unpredictability associated with the LEED process
- Lack of historical data, particularly on pay back analysis
- High capital cost

Project mangers also shared concerns over incompatibility of LEED rating system and specialized requirements of health-care projects. The activity and the occupancy level of a hospital are different from that of an office building including energy and water demand. The LEED objectives are more focused towards offices and the general construction sector. Additionally, integrating LEED in a project that is already being governed by dozen of other standards and regulations seems intimidating to the project team.

Another concern is the uncertainties and the unpredictability associated with the end result of the LEED process. Interpretation of what quantified for earning points remain difficult to understand and to verify. According to the project managers, even after going through comparatively high capital cost and documentation it is not definite that the project will get the credits that are being filed. The project managers find the construction industry is still on the learning curve of the LEED process which complicates the situation further. Making decisions on spending four times the cost of ordinary equipment on energy saving equipment based on concepts rather than proven fact of payback is a difficult decision. The project team have a fixed capital cost to work with, and there is a lack of historical data base or case studies where there are proven results of pay back savings. This fact causes hesitation in the minds of the project managers on whether to go ahead with the extra investment or to cling on to the old “tried and tested” route.

An additional issue that was apparent among the project managers is the high capital cost. The cost of commissioning, energy modeling, and documentation were the most talked about factors which inflate front end cost. According to the project managers it is crucial to develop the strategies and identify the hard and the soft cost associated with the LEED process early during the project planning stage. The cost of achieving LEED certification should be included in the project capital budget. If the cost of implementing LEED has the potential to substantially drive up the project budget, the chances are that the owner will not go ahead with the LEED certification.

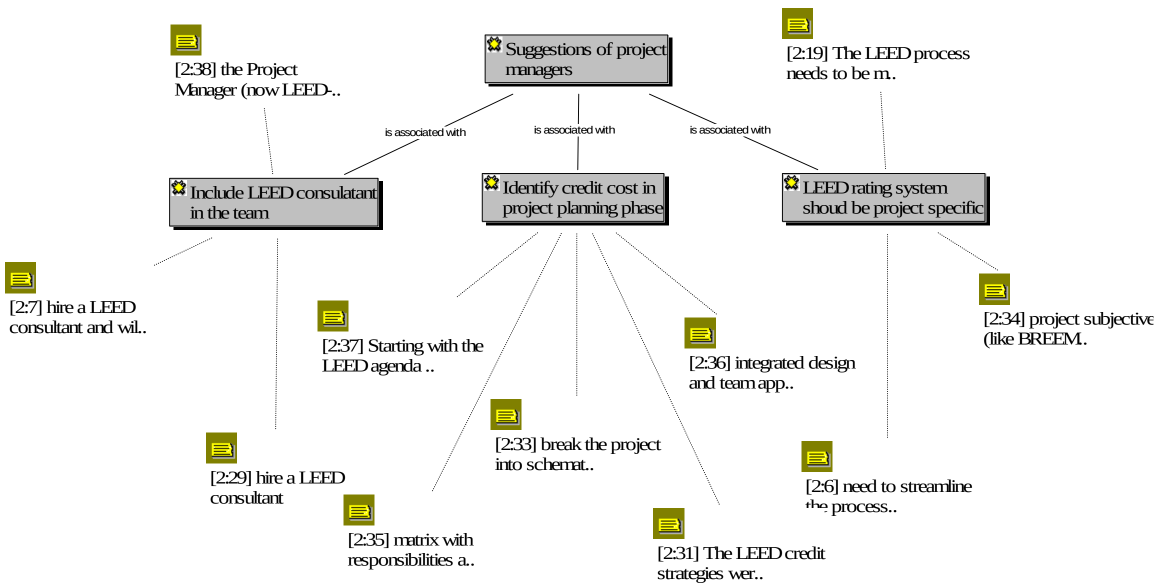

Fig. 12. Network view on project manager's suggestions generated in ATLAS.ti

The project managers made few suggestions which, if implemented have the potential to minimize the variation in the LEED credit lists (Fig. 12).

- Including a LEED certified team member,
- The USGBC council should rate on project subjectivity
- Well-developed LEED credit strategies with associated cost during early phases of project.

According to the project managers, including LEED certified personnel who have an experience working on similar projects, it will be extremely beneficial in achieving the pre-defined LEED credits. Although LEED does have a reference guide but it is helpful in getting an idea about the strategies but is not definitive about any approach. Therefore, it was suggested to include an experienced LEED certified person on the team rather than trying to figure out things on one's own and losing valuable project time.

Another good suggestion made by the project managers was that the USGBC should either develop a rating system or should judge on project subjectivity like the British green rating system, BREEM, does. In other words, instead of asking the project team to build the project according to the guidelines given in LEED the project team should be allowed to submit the documentation of all the green efforts and should be given a rating according to their efforts. There are projects that submitted the documentation for LEED certification but still can not get the certification due to credit calculation or documentation mismatch between the USGBC personnel and the project team. This makes others hesitant about going ahead with the LEED certification process.

As stated by the project manager, the credits that incur extra cost were not pursued. Therefore, it is crucial to define well-developed LEED credit strategies along with associated cost early during the planning stage of the project. This will help in providing "firm grounds" to the owner in order to make a final decision.

Concerns and Suggestions of the Architects

In most of the case studies, architects are the guiding force behind the LEED certification process. Nevertheless, architects also faced difficulties in incorporating LEED objectives in health-care projects. The following concerns were evident among the architects (Fig. 13):

- Inefficiency of contractors
- Incompatibility of LEED with existing health-care regulations
- Convincing the owners to register the project for LEED certification

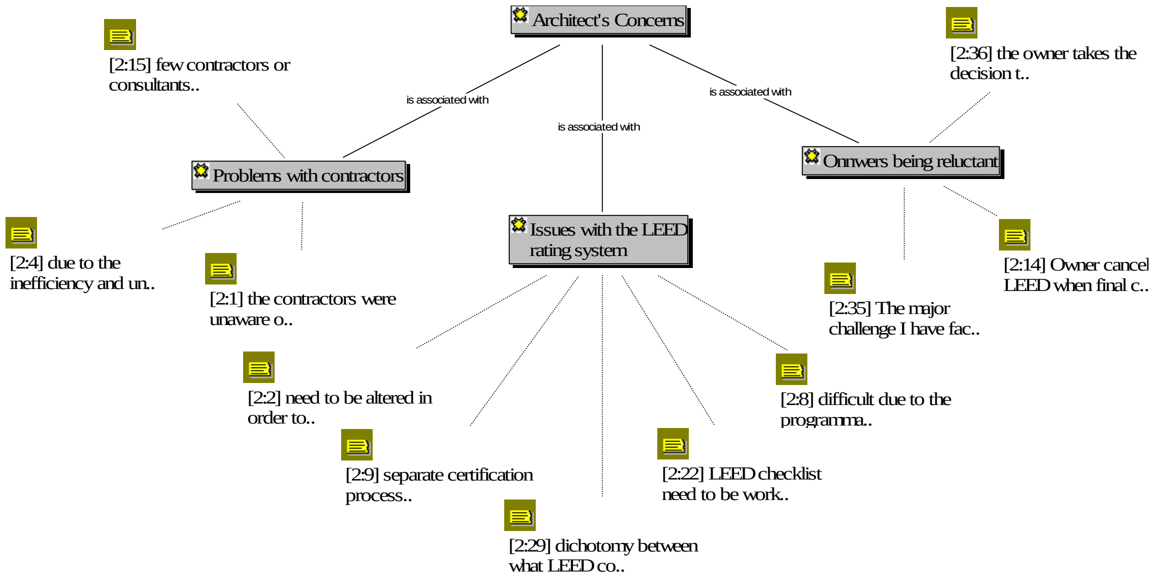

Fig. 13. Network view on architect's issues generated in ATLAS.ti

The architects shared unanimous concern over incompatibility between the current LEED rating system and the specific code requirements of a health-care facility. The current LEED checklist covers the basic concepts of the buildings. Health-care institutes have specific design and operational requirement. Present credits, such as daylight/views and optimizing energy performance are best suited toward the office building but need to be altered in order to implement them in health-care. Water and electricity loads for a health-care facility are much more compared to an office building.

Achieving credits for energy and water efficiency is a challenge considering the size and requirement of a health-care facility. It is not practical from the design point of view to provide 95 percent, or even 70 percent, of daylight in the overall hospital due to the special requirement for x-rays, operating, laboratory, radiology, and other specialized rooms. The LEED reference guide places a lot of emphasis on ASHRAE standards for ventilation where as health-care regulations place prominence on limiting indoor air contamination caused by ventilation. The LEED credits on providing controllability of systems and thermal control are therefore contrary to patient management regulations.

Apart from facing difficulties in merging LEED objectives within the existing codes and regulations of a health-care facility, architects showed concern relating to aligning the green objectives among the contractors and the consultants. According to the architect, finding contractors and suppliers with LEED experience or awareness is comparatively challenging. The contractors are not widely aware of the LEED rating system. Therefore, the owner has to settle for comparatively higher bids since the contractors perceive LEED as an additional requirement. This further makes the owners hesitant towards registering the projects for LEED certification.

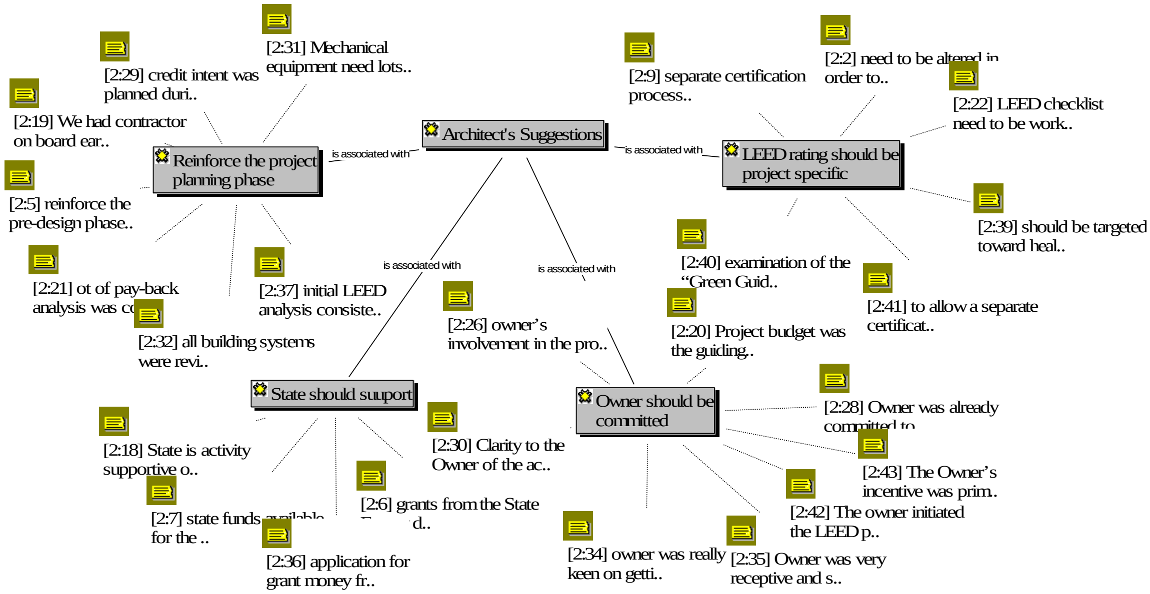

Fig. 14. ATLAS.ti-Network view on architect's suggestion generated in ATLAS.ti

To streamline the process of incorporating LEED objectives in a health-care project and to minimize variation the architects put forth the following suggestions (Fig. 14):

- The state government or the local city government should promote and support the LEED campaign. This will encourage the owner to register for LEED certification.

- The owners should have strong commitment for green building approaches.
- The USGBC needs to modify the LEED rating system in order to meet the specific requirements of health-care sector.
- For successful implementation of LEED objective strong emphasizes should be given on the project planning phase.

There were number of case studies where the state was providing, or has provided, financial support to the owners in terms of grants and research incentives. Additional finances from the state proved to be encouraging for the owners and definitely helped in covering the cost of commissioning and documentation. Getting encouragement from the state helps in reinforcing the owner's commitment to "green objectives." On the whole, the architects believe that including LEED objectives in a project is mainly an owner driven process. An owner with strong commitment toward LEED can make big difference on the final outcome of the project since the owner is the key decision maker.

Nearly all the architects expressed concerns relating to the incompatibility between the current LEED rating system and the specific requirement for health-care projects. In addition, the architects recommended organizing a single comprehensive approach to measuring sustainability in health-care projects, as opposed to having two separate and competing systems, that is ASHRAE standards and LEED requirements.

The approach should be tailored or more specific towards the health-care requirements and standards. Another suggestion that was evident from interviews with the architects was to enhance the progression of educating and training the contractors, the engineers, vendors, and other service-providers with the practices and principles of sustainability. The success of the project in terms of meeting its green objectives lay in the hands of the project team; therefore, it is crucial that all participants irrespective of what phase they get involved in the project have an understanding of the underlying objectives.

Concerns and Suggestions of the Contractors

Contractors make substantial contributions to the success of a LEED project. The contractors can give maximum contribution in the following credits (Appendix C): Erosion and sedimentation control requirements - prerequisite one in sustainable site category; construction indoor environmental quality management - credit 1.3 and 3.2 in indoor environmental quality; coordination with the commissioning agent – prerequisite one in energy and atmosphere; management of performance based materials credits, materials selection – credits form material and resources and indoor environmental quality, and data tracking since all these are on-site issues.

There were number of issues as well as suggestion from the contractor's standpoint. After triangulation, the following problems faced by the contractors were evident (Fig. 15):

- Limitation on the material choice and selection
- Paper trail and documentation
- Unclear project objectives

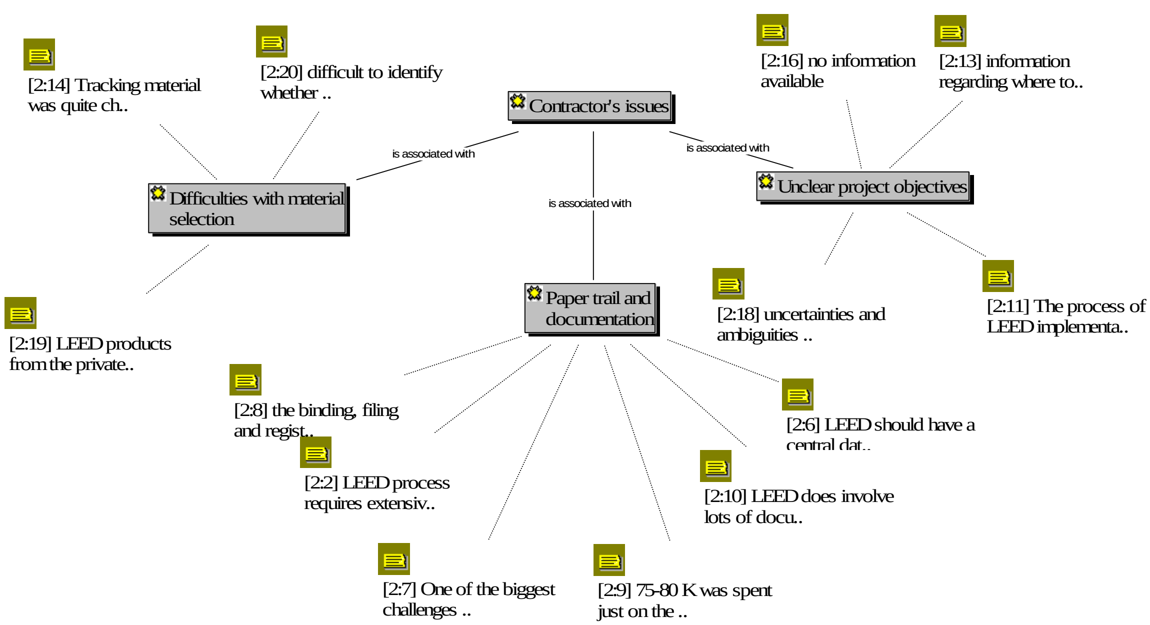

Fig. 15. ATLAS.ti-Network view on contractor's issues generated in ATLAS.ti

Contractors in the building construction industry typically work with preferred groups of vendors and sub-contractors because of past work experience and reduce liability and risk. Abiding to a new set of LEED objectives and aligning them further among the sub-contractor and suppliers is an endeavor for them. Both, forming new alliances or training the old partners, requires extra time and cost. Additionally, the USGBC does not formally certify any green materials as LEED certified. This further increases the contractor's responsibility to conduct market research, to select the green materials, and to get it approved by the project manager. To file for the LEED certification the project team is required to submit the project documents o the USGBC council. As a result there is an evident amount of paper-trail and documentation involved with a LEED project. Most of the contractors in the case studies hired separate administrative people just to manage the documentation and the paper-trail. All these hidden costs came from the contractor's pocket and were not defined in the scope of definition that leads to the problems within the project team. The contractors raised issues related to understanding what is expected especially in terms of responsibilities and associated cost. Some followed the project leader or the LEED accredited personnel direction where else other conducted extensive self-research.

In general, the contractors favored the LEED principles and their application in the construction industry. According to them, incorporating the following suggestion (Fig. 16) would help in improving the project quality in terms of achieving the targeted LEED certification level.

- Early involvement of contractors
- Well-defined scope of work
- Flexible specifications
- Defined project requirements and responsibility matrix
- High owner's involvement

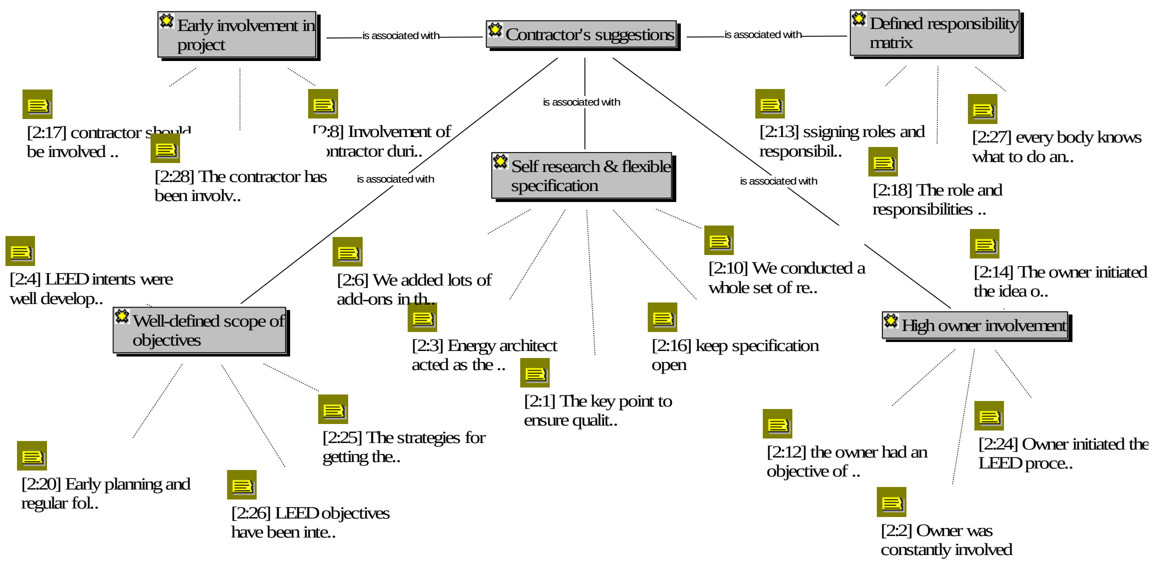

Fig. 16. Network view on contractor's suggestions generated in ATLAS.ti

The contractors considered integrating LEED within the health-care projects as a good practice. From the contractors' perspective early involvement of contractor will be beneficial in understanding the LEED objectives early. It will be helpful to figure out what is expected in terms of green objectives and how to deliver them, early during the project. It will be functional in saving the time later in the project and in better alignment of LEED objectives among the sub-contractors and the vendors. According to the contractors, a well-defined scope of work is crucial since it minimize the possibility of misunderstanding, especially relating to cost and responsibilities of carrying out work items that were not well defined in the scope definition package. In order to further diminish such factors, the contractors recommend the development of a responsibility matrix along with the cost associated with the required items during the pre-construction phase of the project. It would also be helpful in identifying the hard and the soft cost associated with the process and therefore will minimize the surprise factor of hidden cost.

Summary of Results

Factors Causing Variations

The results falls into two major categories: factors causing variation at the micro level and factors causing variation at the macro level. The factors at the micro level are the one which could be amended by the owner and the project team. On the other hand, the factors on the macro level are more of the policy issues that would be difficult to assign to any specific team to resolve.

Factors at the micro level:

- Additional time required for planning, documenting, and certifying a green facility;
- Difficulties in procuring green materials in terms of cost and time,
- Ambiguity in defining project's green objectives;
- Problems within the project team, such as unawareness of LEED process, unclear scope of work, and communication problems.
- Paper trail and documentation required for LEED certification.
- High capital cost of LEED projects.

Factors at the macro level:

- Owners being reluctant towards registering their projects for LEED certification.
- Unpredictability of results in terms of final credits being approved by the USGBC.
- Lack of historical data on green health-care projects for forecasting cost and schedule decision.
- Difficulties in integrating LEED objectives with existing health-care regulations.

Summary of the Suggestions of Project Teams to Minimize Variation

In order to answer the last research question on how to minimize the variation, it was important to obtain the suggestions of the project team on how they dealt with the problems they faced while integrating LEED objectives in health-care projects.

Moreover, it helped in maintaining the objectivity in the study since the recommended approach is build on the suggestions and the issues of the project teams.

Owners

- Integrate LEED objectives in the projects as early as possible.
- Financial support from either the local government or the state government will help in minimize the high capital and commissioning cost.

Project managers

- Identify both; soft cost and hard cost early during the project will minimize the probability of variation occurring due to the financial reasons during the later phases of the project.
- Include a LEED certified person on the project team will be helpful in achieving the pre-defined LEED credits.

Architects

- Financial support from the government will encourage the owner to register for LEED certification.
- Emphasize project planning to define all the strategies associated with intended LEED credits.
- Stronger commitment from the owners will enhance the quality of the projects in terms of meeting its green objectives.

Contractors

- Well-defined scope of work to put across precise project objectives.
- Early involvement of the general contractors minimizes the problems that occurred due to communication issues.
- Responsibility matrix of proposed LEED credits including strategies and associated cost will be beneficial in defining roles and tasks within the team.
- Flexible specifications that allow contractors to conduct self-research in green materials and other available environmentally friendly options.
- High owner involvement to keep the contractor motivated and on-track.

Based on the factors at both, micro and macro level and the suggestion of the project team, the conclusion focus on five areas:

LEED certification is an owner driven process: Integrating LEED and green objective in the health-care project is comparatively a new process. All the case studies, except case study O, were the first green health-care project for the project teams. In general, the owners look for the potential for reducing the project cost and time. Integrating additional green objectives in the project will face resistance, especially when the process is new and the project team has no or limited experience. The apprehension of unfamiliar process can lead to addition of contingencies and risk factors by the architects and the contractors which inflate the project cost for the owner.

If a credit is lost due to the contractor's inefficiency, it does not imply that the contractors are hindrances in implementation of LEED objectives within health-care construction sector. Though there is some resistance from contractors, but as stated by most of them, it is due to the extra cost of liability imposed on them because of work which they have little or no experience in. For example, in case study B, the stated reason for dropping credit was the un-cooperation from the contractors. The contractors expressed the concern that the project scope of work did not state that the cost of implementing the mentioned credit was to be paid form the contractor's pocket. If the project objectives are not clearly stated or are ambiguous in the scope of work then the reason of variation is not the contractor's inefficiency; instead, it is the inefficiency in the project development and planning.

In most of the case studies the owner hired an architectural and engineering firm after the decision to build a new facility was finalized and the concept of achieving LEED was initiated by the architects. LEED objectives should be a major concern during the scope development stage. Implementing LEED objectives requires meticulous planning plus most important a strong commitment from the owner. Introducing a new objective at the design phase when the owner has already the fixed capital budget lead to dropping of credits during the later stages. The credits were sought out totally on the financial basis, if they fit the capital budget they are in or else out irrespective of the fact whether they actually do contribute toward the environmental aspect of the project.

Project performance, in terms of achieving the desired LEED rating, is mainly an owner-driven effort. Assigning and aligning the project LEED objectives among the project-participants should remain the responsibilities of the owner. In term of LEED benefits, such as, improved indoor environment and energy pay-back associated with the implementation of LEED in the health-care facilities, the owners are the ultimate customer and will benefit from its success or its failure.

Integrate LEED objectives early to project ensure better quality and cost control: The occurrence of variation within the LEED objectives does not imply that the projects are successful or not. In case study B, the project team chased the LEED certification process irrespective of the fact that it led to budget and the schedule overruns, but the project did received the certification as well as plenty of national coverage. On the other hand, project F aborted the idea of acquiring the LEED certification while the project was in 100 percent design and 10 percent construction phase. The team realized that incorporating the green objectives according to the LEED rating system will very likely inflate the project budget and schedule. Between both the projects, one can not assert that one was successful and the other was not.

According to Kerzner (2003), abandoning a project early, under right conditions, can be viewed as successful especially, when resources initially dedicated to that project are reassigned to more profitable activities or the technology needed for that project does not exist and cannot be made cost-effective within a reasonable time period. The project success depends on how well the project team was able to achieve the project objectives. Therefore, if the green objectives or getting the LEED certification was not among the project objectives then the project team does not regard either dropping the LEED certification or the LEED credits as objective slippage. Like any other construction project, a LEED registered project requires careful planning and effort, maybe a bit extra compared to the normal project. In a nutshell, the green objectives and the intention of attaining the LEED certification should be set early in a project and the owner should develop the green objectives rather than the project team.

It is recommended to invest efforts and time during the soft-cost phase of the project rather than making decision during the later stages of the project. As proved by the research conducted by the Construction Industry Institute, all the decisions made at the emergent stage of a project life cycle have a higher influence on cost compared to the decisions that are made at the later stages of the project.

An integrated approach with the project team works best: Achieving excellence in integrating LEED objectives can be achieved depending on the speed with which the health-care industry adopts a change in the current project methodology. The objective of implementing LEED within health-care facilities is to create high-performance building. To achieve this goal, it is important to apply the integrated design approach to the project during the planning and programming phases. Irrespective of the project approach being followed it is important to involve all the potential team player early during the project planning. It ensures better and early alignment of project green objectives within the project team. However, it is recommended to adopt alternate project delivery approaches, such as, design build, construction manager, fast track or construction manager at risk. The advantage is the early involvement of project participant which is beneficial to both by aligning the project objectives and minimizing the communication gap among the participants.

Energy architects on board reduce the probability of mismatch in energy calculations: Out of three complete case studies, two reported variation within energy and atmosphere credits while the third case study is also anticipating mismatch in calculation credit. On the general energy and atmosphere had maximum issues related to it. First of all, the owners showed concerns regarding both, the high cost of commissioning and the cost of energy saving equipments versus the cost of standard ones. Secondly, there is high cost associated with optimizing energy performance and renewable energy including green power. In most of the case studies, the project team did not even opt for the credits from energy and atmosphere category due to the high cost and the uncertainties and unpredictability of the result. One of the common concerns was the lack of a specific procedure recommended by the USGBC in order to attain the energy credits therefore; the project teams developed their own techniques to optimize energy. However, it is frustrating not being able to get the intended and planned credits because of an “it was not the right way to do it” statement from the USGBC.

For example, in case study B, the project team saved up to 40 percent of energy through decreasing the plug load of the facility. In health-care facilities plug load leads to substantial energy load due to the intense usage of medial equipments and machines. The team calculated up to 25 percent of energy savings, however, in LEED reference guide there is nothing mentioned on reducing the plug load of a facility, therefore the team could not get the anticipated credits. It is necessary to have LEED certified energy architects on the project. The energy and atmosphere category has high front cost associated with it; on the other hand, the energy credits have maximum energy cost pay-back benefits too. Failure to achieve the intended credits leads to frustration and generate future resistance for the LEED rating system, not to mention the financial and resource loss. Conversely, not opting for the credits in energy and atmosphere category deprive the owner cost pay backs associated with the energy bills during the operation phase of the facilities.

Define roles, responsibilities, and LEED strategies early in the project development phase: The current LEED rating system is divided into six categories, sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality, and innovation and design process. The LEED reference guide gives broad strategies for achieving the credits within these categories but there is no specific information on the role and responsibilities associated with achieving the credit. The overall rating list consists of credits which are applicable either only to the owner or credits which could be achieved only with the assistance from the project team. For instance, the first four points of the LEED list that is, site selection, development density, brown field development and access to public transportation in the sustainable site category were rarely chosen by the project team. By the time the project team came on board the owner already had a site to develop. Therefore these credits fall under the jurisdiction of the owner. Whereas, the credits such as prerequisite on storage and collection of recyclables, implementing indoor air quality plan both, during construction and before occupancy, falls under the responsibility of the contractor. Credits such as providing daylights and views, specifying the local regional materials, ventilation effectiveness, are design issues and fall under the domain of design team. Achieving credits on LEED rating system is a team effort and not defining the roles, the responsibilities, and the cost associated with the intended credits led to problems within the team during the later phases of the project.

Validating the Results Using Between-method Triangulation

There is no publicly accessible research or literature available on credit variations between LEED pilot list and LEED final list in green health-care. It was important to validate the research findings using the in between-method triangulation. Between-method triangulation is used to obtain multiple perceptions to clarify meaning, and verify the repeated occurrence of an observation (Denzin and Lincoln 2000, p.443). Therefore, in order to validate the research finding the researcher attended the web-forum on “greening the health-care” held on 25th February 2005 (Cassidy 2005). The researcher was able to find a published report on managing the cost of green buildings, published by KEMA, an abbreviation of the company’s full Dutch name, *NV tot Keuring van Elektrotechnische Materialen*, through partnership with the State of California’s sustainable Building task force, the California state and consumer services agency and the Alameda county waste management authority (Syphers et al. 2003). As depicted in Fig. 17, the findings of the case studies, the strategies emphasized by the professional to implement LEED in health-care sector including the existing bottleneck in integrating LEED in health-care, and the approaches recommended in the report by KEMA to manage the budget of a green buildings, all points towards the following factors:

- Integrating LEED in a project is mainly an owner driven process
- Starting early ensure quality and better cost control

- Integrated approach works best by aligning the project objective early and effectively
- Energy architects on board
- To maintain the quality it is important to define role, responsibilities, and the strategies early

Fig. 17. Validating the research findings using data triangulation

RECOMMENDATIONS FOR THE PROJECT TEAMS

A Structured Approach to Project Planning and Cost Analysis

Based on the result of the case studies, it is a valid statement that both, implementing LEED within the project and maintaining the project quality in terms of meeting the pre-defined green objectives are primarily owner-driven efforts. In most of the case studies, the owners had substantial experience in building and operating health-care facilities; therefore, they estimated the capital cost based on the portfolio approach. Portfolio based approach works best when the project objectives of the new project are similar to the previous or existing projects. However, if the project has new or additional objectives then the project team, especially the owner, needs to follow a structured approach to project planning and cost analysis.

A structured approach to project planning is based on systems theory which advocates the holistic overview of a process. A system can be defined as a complex set of interactive elements with constant feedback among the elements (Olsson and Sjostedt 2004, 8). A feedback mechanism among the elements within the system is responsible for keeping a system on the previous track in spite of changes in the initial conditions. Broadly there are two types of systems, closed system and open system. The final condition in a closed system is entirely determined by the initial conditions, since a closed system is completely sealed off from its environment. On the other hand, in an open system the final condition cannot be completely determined by the initial conditions. In an open system there is a continuous inflow and outflow of components between the system and its environment (Olsson and Sjostedt 2004, 10). This exchange of component in an open system decreases the predictability of the final outcome. The construction industry is an example of open system since there will be inevitable interaction, feedback, and iteration within all the phases of a project.

The system changes because people within the system are inspired to do new things and vice versa (Olsson and Sjostedt 2004). Integrating LEED objectives in health-care projects is a recent development, and there are limited data available, not to mention only two certified projects completed to date. Within these constraints, it is recommended the project team use the structured approach to the project planning of a LEED intended health-care project. The reason is that the systems approach is applied to understand “emergence,” that is, the emergent behavior or the emergent effect of the interaction between the various agents or components of a system (Olsson and Sjostedt 2004, 9).

Within the viewpoint of the study, the interacting agents within the LEED registered health-care projects are the LEED objectives and the prevalent managerial system of the health-care projects (Fig. 18). There is a lack of historical data on LEED registered health-care projects for the owner and the project team for forecasting or extrapolating the cost and schedule impacts. The structured approach could be helpful in deriving the rationale for decisions at various stages by analyzing the emergent effects of interrelating LEED objectives within the various project planning phases. The systems approach aids in enhancing the planning and decision making and hence presents a detailed matrix of all the functions and their interrelationships required to achieve the final objectives (Olsson and Sjostedt 2004, 165). Therefore, it would be extremely beneficial for the project team, especially the owner, to make an informed decision and diminish the uncertainty related with the forecasting cost and schedule decisions.

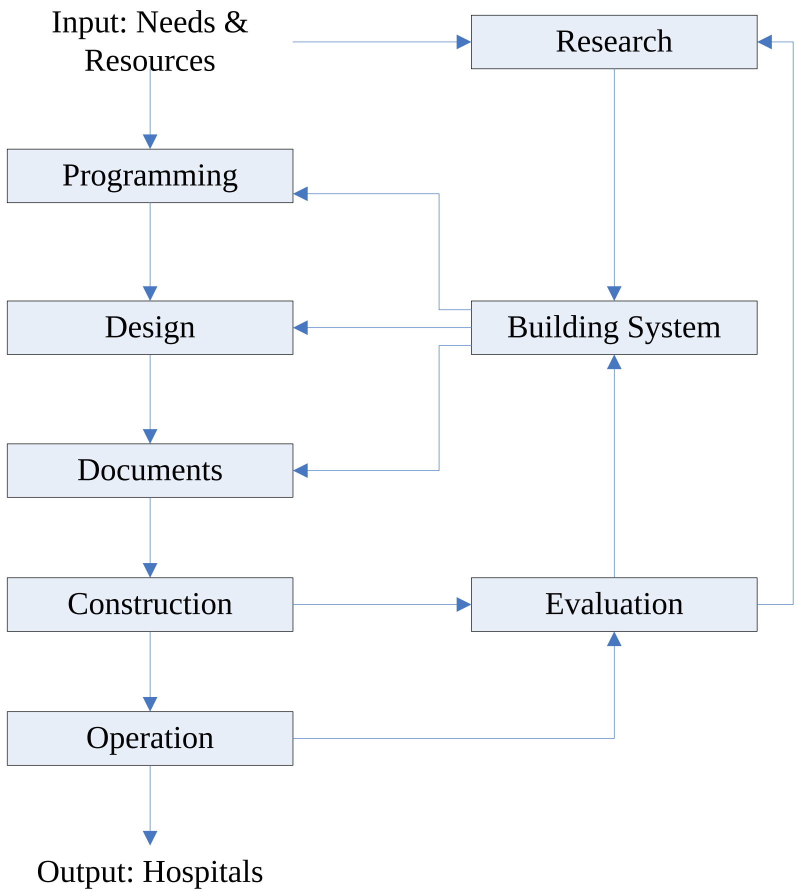

Fig. 18: Total managerial system for the health-care facilities.
(Adapted from: Development study- Veteran Administration Hospital Building System-Research Study Report)

Use of Integrated Definition for Function Modeling (IDEF0)

In structured approach, the focus is kept on identifying critical data and setting out the tasks that must be carried out in order to achieve the main project objectives. This design technique is known as Structured Analysis and Design Technique (SADT) which requires the user to design and create a hierarchy of tasks that are implemented by free functions. However, it is important to have feedback among all the free functions, as the feedback mechanism among the elements within the system is responsible for keeping the system on the pre-defined track in spite of changes in the initial conditions, in accordance with systems theory.

The Integrated Definition for Function Modeling (IDEF0) model is a functional modeling tool and is a subset of SADT, which is used in the research to graphically represent the hierarchy of the tasks and the feedbacks among the various functions (IDEF0 1993). In a study conducted by the Transportation Research Board, a preliminary constructability review process model was developed using the IDEF0 modeling technique (Anderson and Fisher 1997a). The structured approach exemplified in the study recommends functions and required feedback among the functions. The recommended approach could potentially reduce the variations and enhance the project quality in terms of meeting the pre-defined green objectives. The fundamental concept behind SADT is to develop a method to improve the quality of the systems and the productivity of system work (Karhu 2000).

The remaining information has been gathered by conducting a comprehensive literature review. The levels within the business planning are based on the theoretical understanding of business planning process taught in a graduate course offered in the Department of Civil Engineering at Texas A&M University (Anderson 2004). The breakdown of project planning levels is based on the pre-project planning guidelines developed by the Construction Industry Institute (CII 1995). The overall concepts of project management are derived from literature on systems approach to planning, scheduling, and controlling (Kerzner 2003). However, few functions and activities are customized in order to incorporate the actions required for a LEED project.

An IDEF0 model is built from the viewpoint of the user. Incorporating LEED objectives in health-care projects is mainly an owner-driven process; therefore, the recommended approach is built from the viewpoint of the owners. The owner is the investor and should be aware of the process, as sometimes the project team might not keep the owner's best interest as a primary objective. For example, one of the major advantages of the LEED approach is that it minimizes the operation cost of the facility, due to the pay-back associated with the energy cost.

The architect involved in case study O already worked on similar green health-care project. Therefore the architect was aware of the difficulties associated with achieving the credit on the energy and atmosphere category and decided not to pursue the energy credits. The team might be able to deliver a LEED certified project in the end, but if the owner cannot benefit from the pay-back associated with the energy cost then, from the owner's perspective, is it worth to go for the LEED certification?

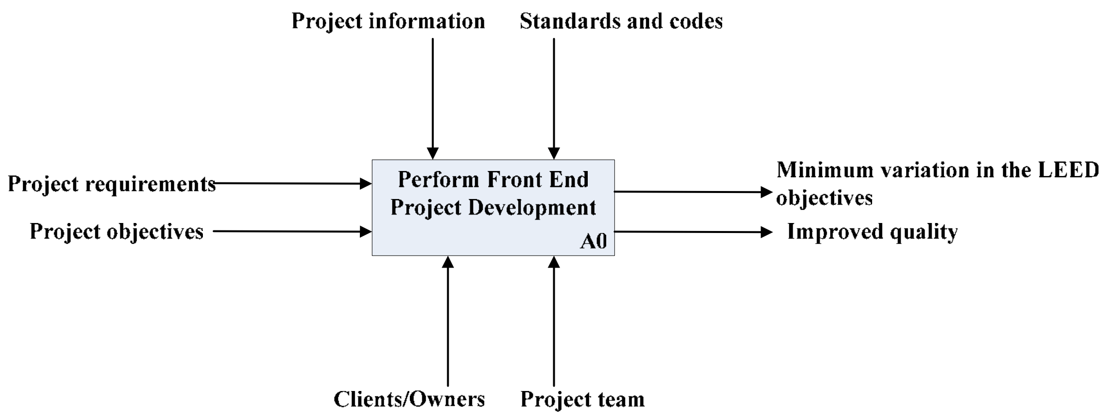

Fig. 19. A-0 IDEF0 diagram – Perform front end project development

It is recommended that the owner should be highly involved and should conduct the maximum ground work by performing front end project development (Fig. 19). The approach recommended in the study could be helpful for the owner and the project team to make an informed decision. Though the variation occurred in execution phases of the project but it was due to the inadequacies in project planning and development phases. Therefore, the recommendation focuses on the early phases of project that is business planning and project planning (Fig. 20).

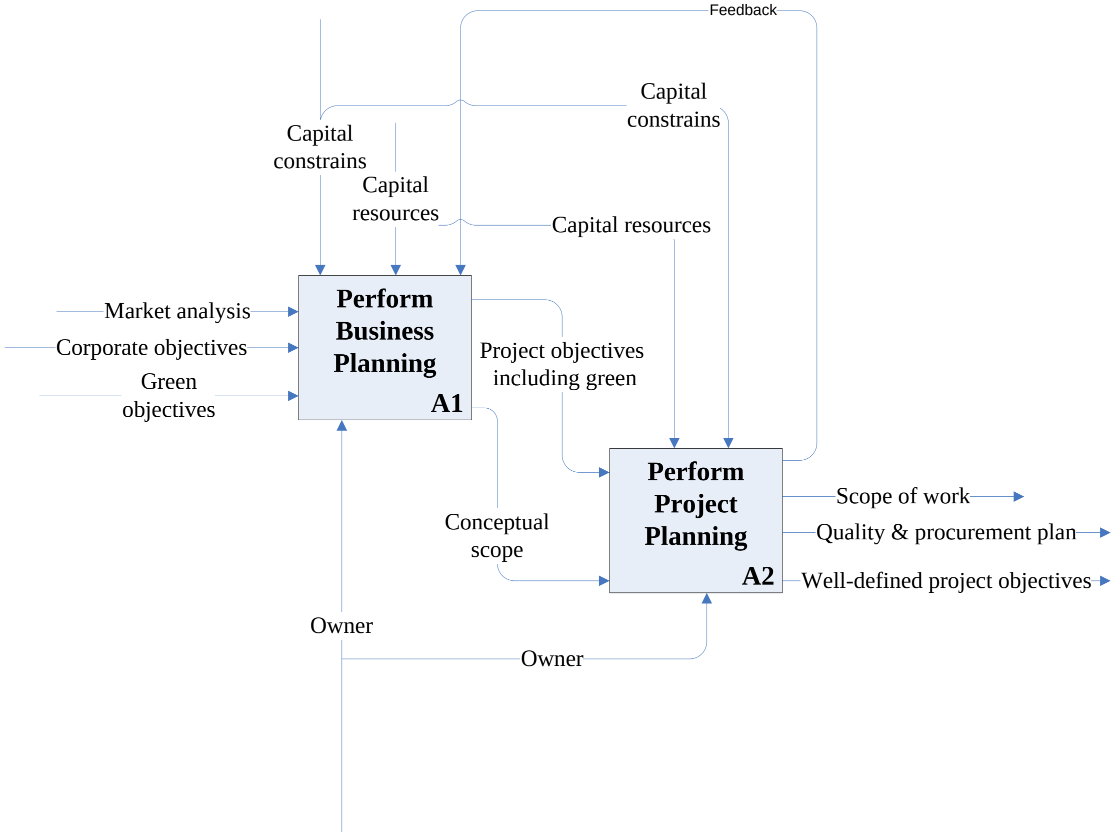

Fig. 20. A-0 IDEF0 diagram – Perform business planning and project planning

Business Planning (Level A-1)

To embark on a health-care project with the intent to acquire LEED certification, the crucial factor for the owner is to be committed to the green objective. Apart from the benefits, such as the pay-backs and the improved indoor air quality factors, the owners should also realize the importance of building a green health-care facility. As illustrated in level A1 in Fig. 20, the green objective for the project should be integrated in the owner's business objectives. On the whole, market leadership and future growth are the two objectives which are on the corporate objective of most of the companies. These companies view change in the market as an opportunity to grow by providing significant services, products, and solutions in order to expand into new areas, produce innovative products, and generate profit by providing services to satisfy emerging customer needs and increasing their profits in the process. Incorporating LEED into the business objectives, and later into the project objectives, can easily be aligned with the corporate objectives. The benefit of incorporating LEED during the very start of the project is that while conducting the various phases within the business planning, such as building project team, objectives, schedule, developing conceptual site plan, capital cost estimate, conducting economic, market, and risk analysis, the project team can include the LEED cost and time factor as well. The final recommendation includes the project conceptual cost and schedule inclusive of the time and cost associated with incorporating the LEED objectives in the project. Hence, the corporate committee can make better informed decision based on the recommendation and if approved, the capital budget will include the cost of LEED certification process.

The business plan for a project can be divided into following basic segments: organize for business plan-A11, develop business plan-A12, and analyze business plan-A13 (Fig. 21). All three phases could be disintegrated further into sub-phases as shown in Figs. 22, 23, and 24, respectively.

After validating a business idea, the first step is to organize the team within the owner's organization; building a strong team is crucial for the project success (Fig. 22). Care should be taken while choosing the team participants, especially in regard to the participant's views, ideas, and experience on LEED projects. Even if they lack experience, the participants should have a positive approach towards green objectives. A

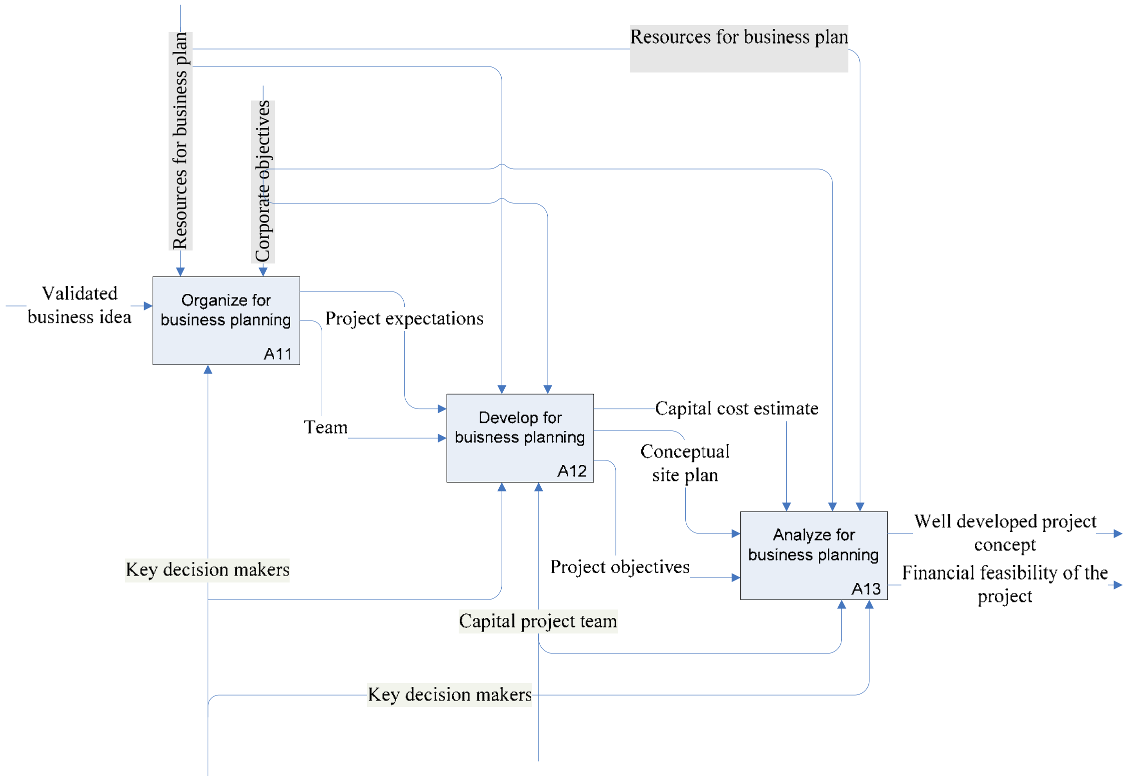

Fig. 21. A-1 IDEF0 diagram – Conduct business planning

proactive member of the team could make major contributions to the success of the project with respect to its green goals. For example, on the Southern York county library project in Pennsylvania, neither the owner nor the architect had much experience with the LEED process, though the team did hire a LEED consultant. The major contribution came form the lowest bidder on a low-bid format: the contractor. As stated by the team, the project went out to bid without appropriate LEED documentation, but the proactive contractor was very motivated to implement green objectives into the building, and hence put extra efforts and made all the difference (Syphers et al. 2003).

It is necessary to build a good project team with proactive participants who understand the green objectives and have the capabilities to manage and direct the LEED process from the planning phase to the execution stage. The owner should provide the team with additional training by either attending seminars or by reviewing case studies and their respective LEED strategies, level A112 in Fig. 22.

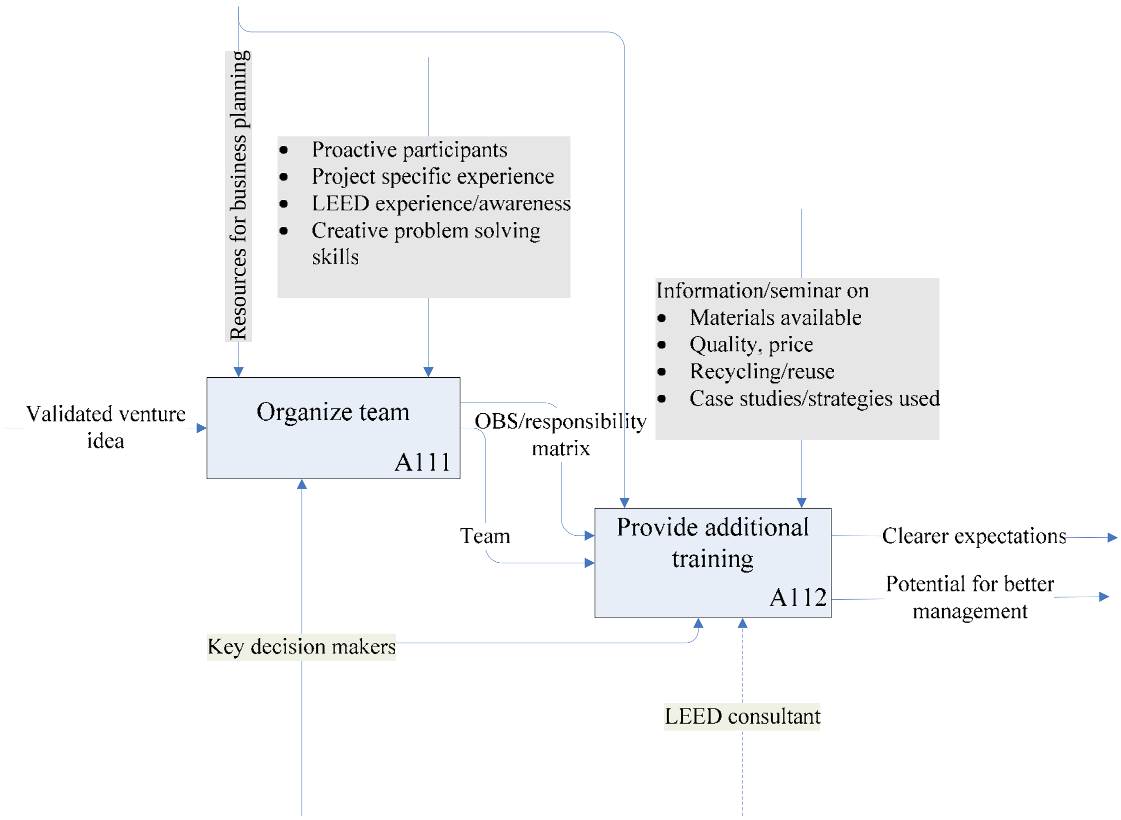

Fig. 22. A-11 IDEF0 diagram – Organize for business planning

Hiring LEED consulting personnel at this stage could prove beneficial, especially if there is no LEED certified person on board. The LEED consultant could be hired either to provide training specific to the project objectives or to supervise all the LEED related objectives for the overall project, depending on the owner's budget. After the team is selected the project team should be provided addition knowledge relating to the

LEED materials, their availability, rates, life cycle analysis, recycling, and reusing (Fig. 22).

As represented by Level A12 in Fig. 21, after organizing the capital team the next step constitutes developing the project objectives based on the corporate, business, and green objectives. If no one in the capital project team has hands-on experience with the LEED process, it is recommended to involve a LEED consultant at this stage (Fig. 23).

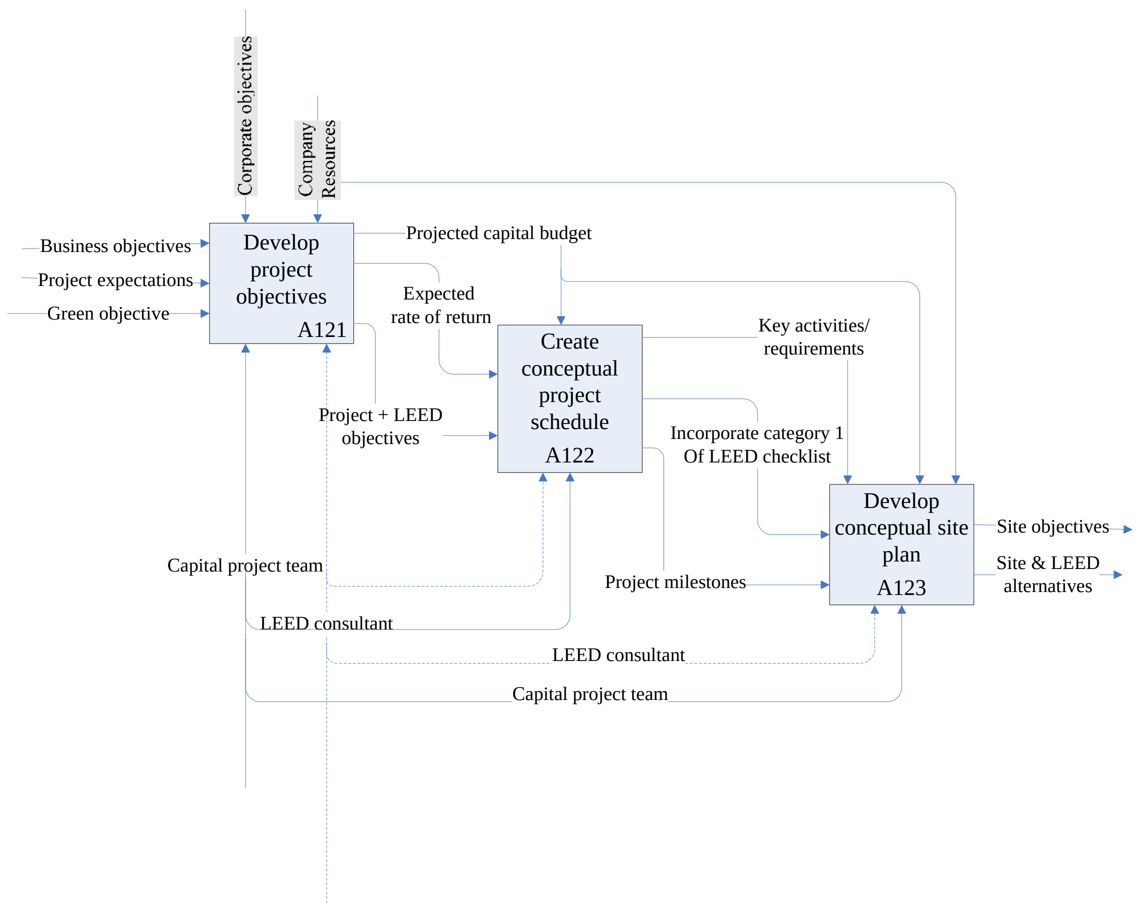

Fig. 23. A-12 IDEF0 diagram- Develop business plan

Care should be taken while choosing the LEED certified consultant. The current certification exam could be excelled on the basis of the theoretical knowledge with no practical experience in the process, since the exam is based on the LEED reference guide and some ASHRAE codes. The potential LEED consultant should have experience in working on at least one project of similar scope.

The LEED certification requirement should be developed and should be integrated within the project objectives itself. After developing the project objectives (Level A121), the conceptual project schedule should be developed (Level A122), based on the project objectives, expected rate of return and by keeping the tentative capital budget in focus (Fig. 23). Once the project objective and the project conceptual schedule have been developed, the conceptual site plan should be developed (Level A123), encompassing the “green” project requirement, such as brown field development or proximity to the public transportation system. At this stage, category one of the LEED rating system could be analyzed, since most of the credits in category one relate to site issues, such as site selection, density development, brown field development, and proximity to public transportation system (Fig. 23).

The final step in developing the business plan is to conduct the feasibility analysis for the project in terms of economic, technical, and environmental viability, level A13 in Fig. 21. The first sub-phase within this segment is to perform the market analysis based on the project need basis as depicted by level A131 in Fig. 24. The important factor that guides the construction of a health-care facility in a community is totally on the need basis. The project team could evaluate the alternatives such as available brown field for development, city policies on environmental policies, and any potential state grants available. If the state government or the local government has any financial grants or support programs for green development, then the owner can file for the grant application and could make the amendment in the capital cost estimate, accordingly.

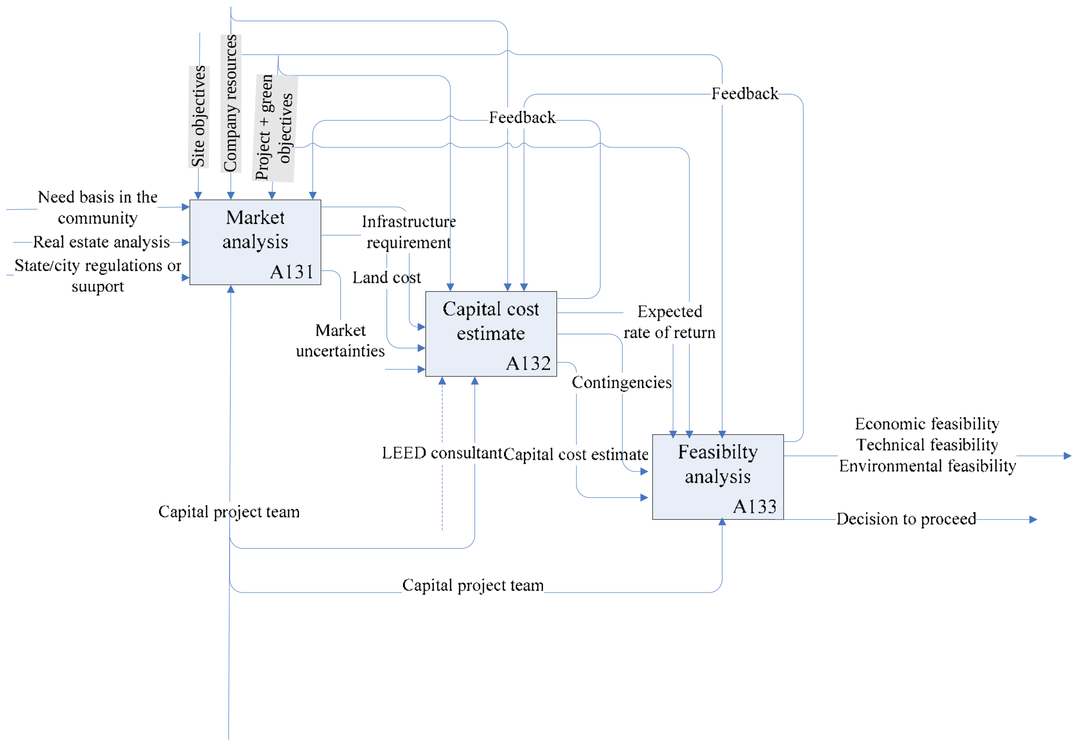

Fig. 24. A-13 IDEF0 diagram – Analyze business plan

Level A132, the capital cost estimate, should be developed after conducting market analysis (Fig. 24). The LEED consultant could be valuable in providing a conceptual estimate of the cost involved in incorporation of LEED objectives in the project based on his/her prior experience. The last level, A133, that is feasibility analysis, should be conducted both with and without the LEED objectives to see whether adding LEED to the project is justified or not (Fig. 24). Feasibility analysis should be conducted on the basis of economic feasibility, technical feasibility, and environmental feasibility, so that the owner could make an knowledgeable decision on whether to go ahead with the project or to rework either the project objectives or the capital budget, based on the feasibility analysis.

Project Planning (Level A-2)

After conducting the business plan the next stage is project planning as shown in Fig. 20. Fig. 25 represents the different phases within project planning. The project plan, A21, is an underlying foundation of a project; therefore, it should include the description of the key green objectives undertaken to achieve the LEED certification.

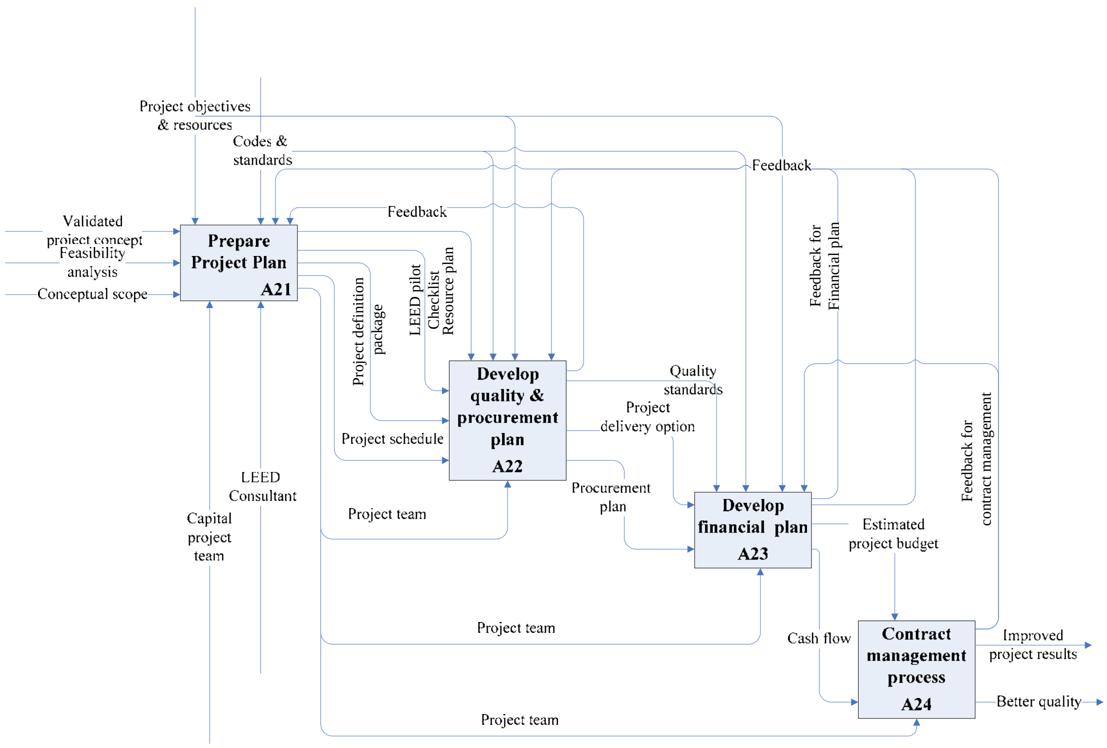

Fig. 25. A-2 IDEF0 diagram – Conduct project planning

The next function should be to develop a quality and procurement plan, level A22 in Fig. 25. The quality and procurement plan should be based on the project outputs of the project plan so as to obtain the comprehensive representation of the project objectives. The procurement plan should include the selection of the project delivery method according to the project requirements. At this stage, it is recommended to start the selection process for the design team to match the project requirement. It is essential for the project managers to communicate the green objectives among the potential bidders during selection of the design team.

A detailed financial plan, level A23, Fig. 25, should be derived after the quality and procurement plan. A detailed financial plan should be prepared based on the total cost of labor, equipment, materials, and the intended credits on the LEED pilot list. The contract management phase should follow after developing the financial plan as represented by level A24 in Fig. 25.

As illustrated by Level A211 in Fig. 26, it is recommended to organize a design team which should include architects, mechanical/electrical engineers, civil engineers, and, if no one either on the capital team or on the design team is LEED experienced, a LEED consultant as well.

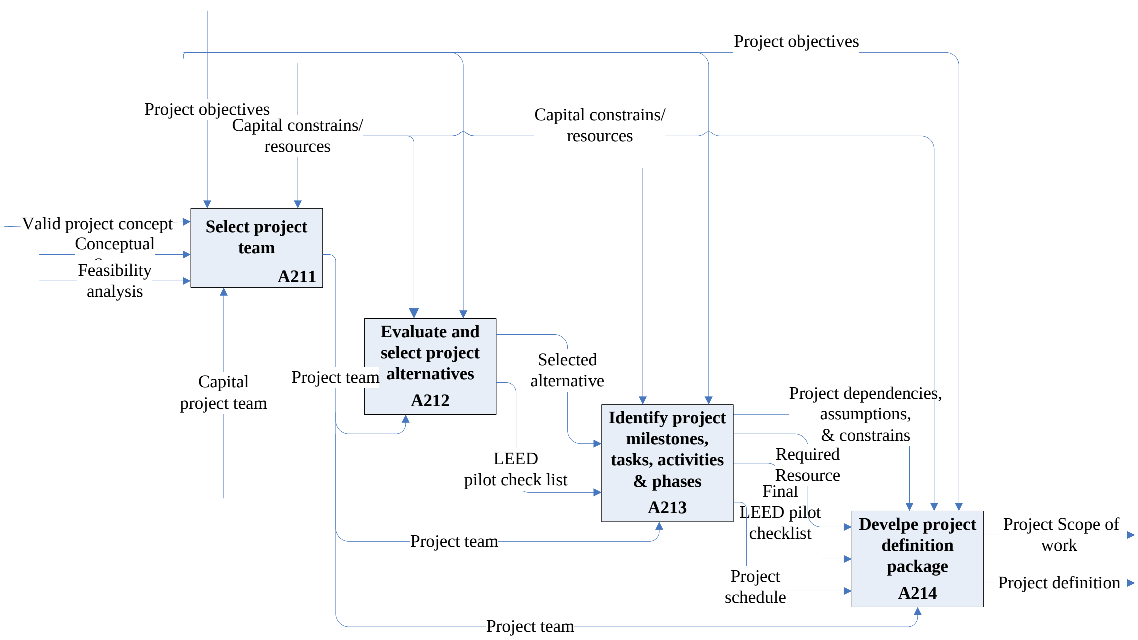

Fig. 26. A-21 IDEF0 diagram – Prepare project plan

It is important to provide training pertaining to the LEED objectives and ASHRAE codes to the design team so that everyone understands the green objectives. It is entirely an owner's decision whether to hire different consultants or one firm with all the above competencies. After selecting the project team (level A211), project alternatives should be identified and evaluated, level A212 in Fig. 26. It is recommended that the owners follow the pre-project planning steps for evaluating the process and technology for their projects. The owners could evaluate the process and technology requirement based on the pre-project module, developed by the Construction Industry Institute (CII 1995). However, the owner should evaluate the environmental aspect of the project based on the procedure illustrated in Fig. 27, based on the life cycle analysis approach.

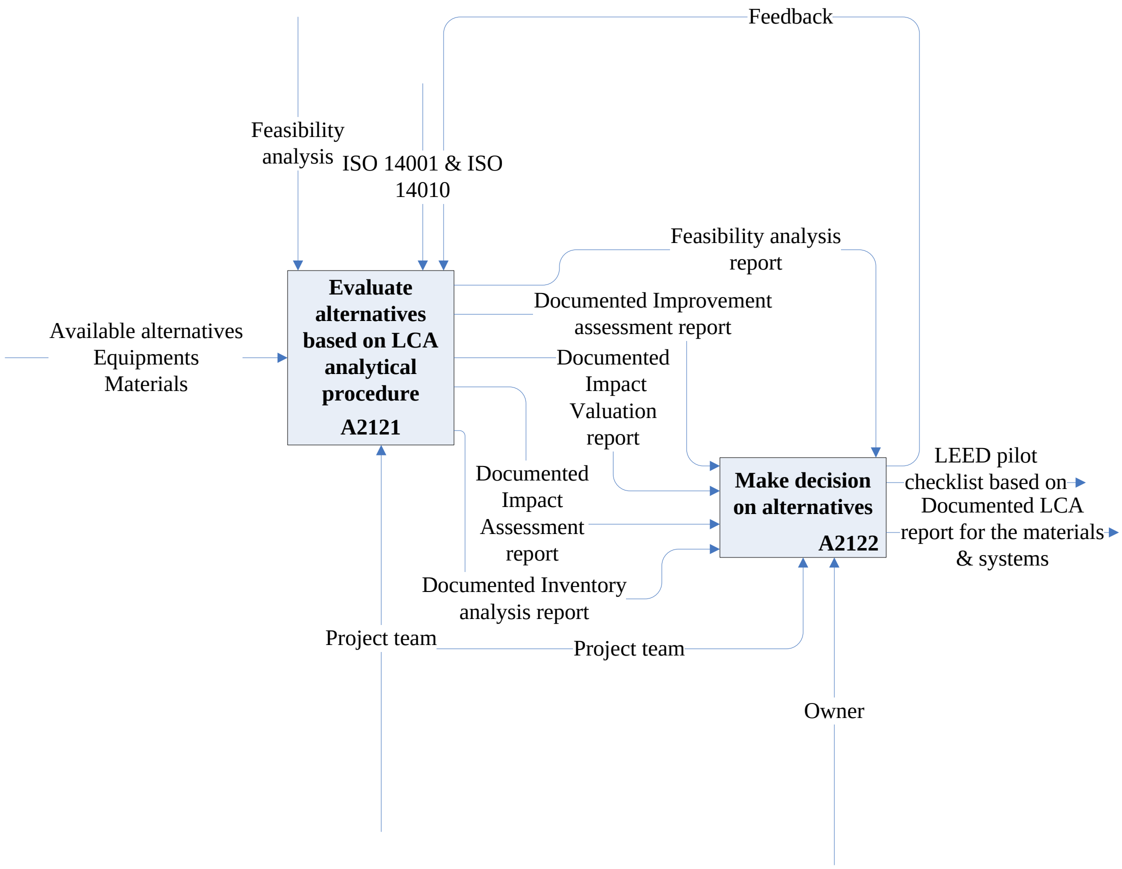

Fig. 27. A-212 IDEF0 diagram – Select project and LEED alternatives

Currently, there are two primary approaches of assessing environmental attributes that relate to buildings, eco-labeling and Life Cycle Assessment (LCA). The eco-labeling procedure has been derived from the LCA procedure, but they have different formats of reporting (Scheuer and Keoleian 2002). Between the two approaches, it is recommended to use the life cycle assessment (LCA) while evaluating the project alternatives. Eco-labeling procedure is preferred by manufactures since it gives them the flexibility of transmitting the environmental qualities of the product without revealing proprietary information.

One of the fractions of life cycle assessment is a comprehensive material evaluation methodology whereby all the material, resources, and energy flow of a project are quantified and evaluated (Scheuer and Keoleian 2002). The International Standard Organization (ISO) is functioning on creating guidelines and principles for the use of life cycle concepts and purpose. These standards are numbered ISO 14041 through 14044. Much of the work to date is based on the existing practice of inventory assessment. The areas of impact analysis and interpretation still need much work and review before consensus can be reached at an international level (Scheuer and Keoleian 2002).

The project definition package should be based on the selected project alternatives and intended LEED credits, level A214 (Fig. 26). The project definition package should be derived after identifying project milestones, phases, and major activities along with the resource plan and responsibility matrix, level A213 in Fig. 26.

Level A22 – Develop Quality and Procurement Plan

Once the project definition package is fully developed, it is advisable to build a quality and procurement plan based on the resource and objective requirement of the project (Fig. 25). Developing the procurement plan is important in identifying the factors, such as project delivery approach, design team, identifying the environmentally-preferred materials, and potential suppliers. The quality and procurement plan is divided further into three main levels as illustrated in Fig. 28.

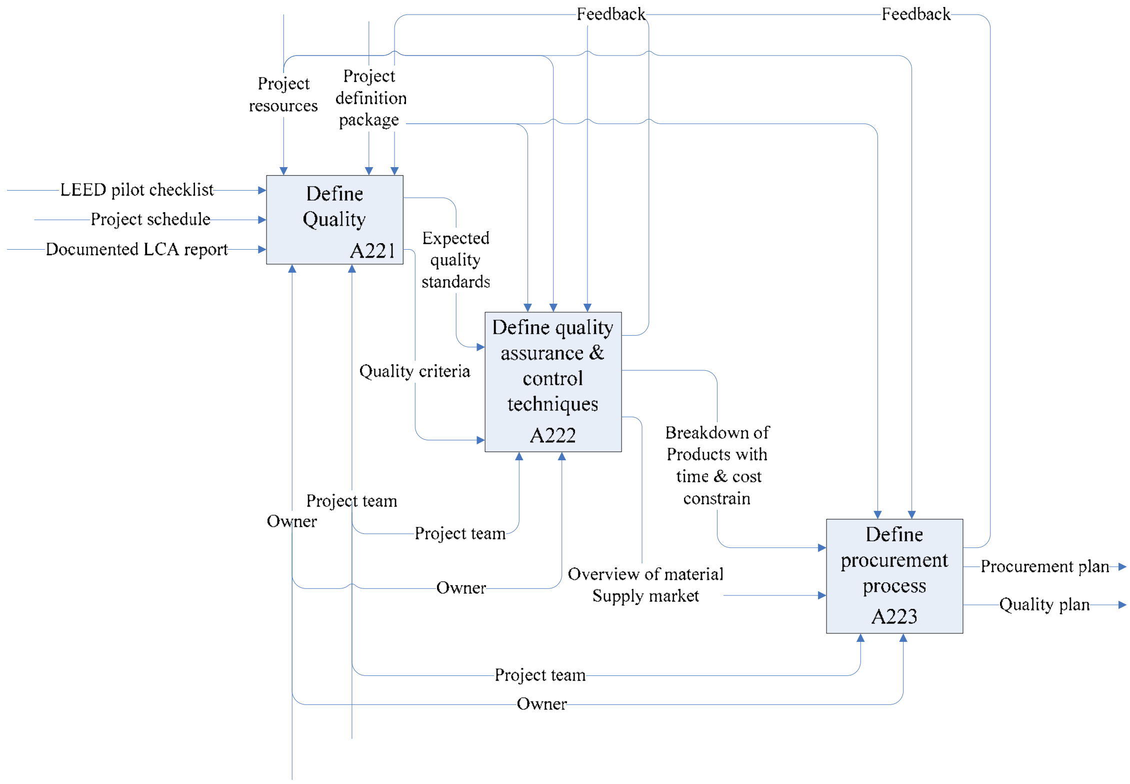

Fig. 28. A-22 IDEF0 diagram – Develop quality and procurement plan

First and foremost is to define quality before proceeding further on to Level A222 for defining quality control techniques (Fig. 28). For example, in case study B, the specification mentioned the use of a specific "environmental friendly" carpet backing sheet. Both the sheet and the glue for the sheet had a limitation to be applied only to the sub-floors with the moisture content between 2 to 4 percent. It was a concrete sub floor on which both the materials were to be applied and regular moisture content for the regular concrete floor is round about 7 to 8 percent. Therefore, the owner had to buy a high priced sealer in bulk which had the potential to lower the moisture content up to 4 percent. The team went ahead and applied the new sealant and the specified glue and the backing, at present, the entire flooring is coming off with bubbles forming all over the surface. According to the contractor, although the vendors claimed that the material could be applied on the surface with up to 4 percent moisture content, they never tested the material themselves at 4 percent moisture level. This led to extra expenditure and time, not to mention the inferior quality of work.

LEED objectives are not very prevalent objectives; therefore, there are limited suppliers and sub-contractors who are familiar with the LEED process. For the general contractor this usually leads either to find new suppliers and sub-contractors or to educate the existing ones. In addition, there are no LEED certified materials, although there are many vendors who claim to deliver environmentally-preferred materials.

Instead of hiring suppliers and vendors for a one-time job, it is preferred to form partnering, especially if the green objectives are incorporated in the corporate and the business objectives. Forming a sustainable, collaborative long-term relationship with the suppliers could provide potential for the improving the project quality. After defining quality in terms of "green," develop a quality assurance and control techniques, level A222 in Fig. 28. The quality assurance and control plan should consist of all the available options in terms of green suppliers, materials, and application. The team, especially the owner, should not have to spend either extra time or extra money on last minute alternatives.

The next level should be to define the procurement process, level A223, (Fig. 28), based on partnering and the ability of the supplier and subcontractors to deliver, replicate, or exceed the project requirements. Since the basic aim of partnering is to share the success in terms of value that is added by the project team for the owner. In the traditional design approach, budgets and schedules are imposed upon the design and construction teams. On the whole, owners, designers and contractors do not get together early in the process. In many cases, LEED certification criterion is introduced to the team during the phase of construction documentation. The results were lost project time and frustration, not to mention the higher professional fees. In addition, the team had to request the owner to revise the capital budget in order to incorporate the cost of implementing the LEED strategies. Having a glimpse of what to expect allows time for development of new procedures and, if needed, allows time for training and education of team members, thus reducing uncertainty and unnecessary contingencies.

A24 Contract Management

Based on the documented report based life cycle and the project definition package derived after going through the various levels of project planning, the contract management process should be developed, level A24 in Fig. 25. The project team needs to write the Request for Information (RFI) and solicit information from the bidders. The RFI should specify the bidders to declare their experience related to the green buildings and LEED experience. Developing RFI would be helpful for the project team to pre-qualify the suppliers and service provider based on the project objectives.

The next step should be to develop the request for proposal (RFP) based on detailed scope of work and project requirement. The scope of work should clearly define specific LEED credit intents, implantation, and documentation requirements, so that the bidding contractors and the suppliers are aware of the project requirements. The project team needs to be very apparent about the LEED intended credits and their strategies while developing the construction documentation, especially the specifications. The project specifications are crucial in terms of meeting the desired objectives and quality. A LEED project requires specialized and well-written specification customizing off-the-shelf specifications may lead to potential problems during the execution stage.

In conclusion of the chapter, reinforcing the business planning and project planning based on a structured approach is an effective way to minimize the credit variation and to meet the pre-defined green objectives, because it helps in approaching the green objectives as one of the project objectives, rather than the project upgrades. The project scope should be well-developed and should clearly state the green objectives; most of the case studies developed a separate project plan and LEED plan. Ideally, both plans should be incorporated into one that gives better information and representation to the owner in order to make an informed decision.

CONCLUSIONS AND RECOMMENDATION FOR FUTURE STUDY

Conclusions of the Research

This study attempts to answer the following research questions:

- Is there a credit variation between the LEED pilot list and the LEED final list?
- If there is a variation, then
    - What are the causes of variation?
    - What are the effects of variation?
    - How can variation be minimized?

The first research question was based on the theoretical basis of chaos theory which states: any complex system becomes volatile and susceptible with additional stipulations. A system can then be called at the "edge of chaos." Construction is a non-liner process; it is a complex adaptive system (Griffin 1996). The health-care construction industry is already among the most code regulated industries. Apart from following the local or state building codes depending of the existing three regional model codes, health-care facilities are required to abide to federal codes, as well. Additionally, in order to be accredited, the health-care facilities must meet the standards of the Joint Commission on the Accreditation of Health-care Organizations (JCAHO), including the National Fire Protection Association (NFPA) model fire codes, NEPA 99 and NEPA 101, both specifying the standards and the safety codes respectively for health-care facilities. Further, the Americans with Disabilities Act (ADA), the Uniform Accessibility Standards (UFAS), and the regulations of Occupational Safety and Health Administration (OSHA) must be followed. Therefore, incorporating additional LEED objectives in the existing complex system of health-care can cause chaos (Carr 2005).

Causes of Variations

Study of eighteen case studies showed that implementing the decision to pursue LEED certification midway through the project design or documentation phase leads to variation in the credits during the later stages. Analysis of the case studies found the following factors caused the credit variations:

- Additional time required for planning, documenting, and certifying a green facility;
- Difficulties in procuring green materials in terms of cost and time;
- Ambiguity in defining project's green objectives;
- Problems within the project team, such as unawareness of LEED process, unclear scope of work, and communication problems;
- Paper trail and documentation required for LEED certification;
- High capital cost of LEED projects;
- Owner reluctance towards registering their projects for LEED certification;
- Unpredictability of results in terms of final credits being approved by the USGBC;
- Lack of historical data on green health-care projects for forecasting cost and schedule decision; and,
- Difficulties in integrating LEED objectives with existing health-care regulations.

Variations in the LEED credits occurred whenever LEED objectives were considered as an upgrade or an add-on in the project rather than as project objectives. Generally, the intention of acquiring LEED certification was introduced after the capital budget was finalized by the owner, and the credits that had cost associated in achieving them were dropped. The credits that have low or no design and construction cost associated with them had the least variation. The credits were dropped out due to financial issues and the cost associated in achieving the credits.

Effects of Variations

Why was it necessary to identify variation and how does it matter if there is variation? Failure to achieve the pre-defined credits is comparable to failure to achieve project objectives. The owners spend the resources, such as employees, their salaries, time, and cost to plan and develop for the intended credits. Therefore by failing to achieve the pre-defined green objectives, owners lose project time, cost, and frustration, not to mention the higher professional fees, especially for the energy credits. The credits in energy and atmosphere category have high cost associated with them in terms of purchasing energy saving equipments at higher cost, compared to the regular equipments. Almost all the case studies were pioneers in terms of constructing green health-care projects within their respective regions and were "first movers for the others to follow." Consequently, failure in terms of meeting the green objectives discourages others to register their projects for LEED certification.

How Can Variation be Minimized?

The purpose of incorporating the chaos theory or complex non-linear theory in the construction industry is to identify the behavior of the whole, not simply in terms of behavior of the parts but to look in a broad way at the whole situation, instead of looking in detail at individual aspects (Griffin 1996). The last research question was how to minimize the variations. Presence of chaos or increase in chaos within an existing complex system does not imply that the system will fail or collapse. As per chaos theory, while the system expands it requires more energy and more structure to maintain stability. This trend continues until an additional system is introduced to maintain the stability of the structure and prevent failure. Therefore, while planning and developing a green health-care project a structured approach is recommended as a supplementary system to maintain the stability and structure within the existing complex system.

The recommendation is based on the fundamental concept of the systems theory and is presented using the function modeling tool called IDEF0. Functional modeling is a structured and graphical representation of the functions, activities or process within a system. A system is defined as a function or compilation of functions that have inputs, processes, and outputs; moreover, a system shares feedback among all four components of a system.

Hence based on the study, it is recommended that the LEED objectives should be developed by the owner instead of the project team. The project team should facilitate meeting the owner’s objectives and should be able to provide complete information based on the cost, time, and pay-back associated with the process. Introducing LEED objectives in a health-care project without detailed planning caused credit variation during the later stages of projects. This leads to dissatisfaction between the owner and the project team.

The recommended approach might help the owner to develop and to meet the targeted LEED objectives. As discussed in the report, inclusion of detailed project planning can potentially minimize the credit variation in the project. Early development of project plan, quality standards, procurement plan, financial plan, and incorporating contract management can help to recognize cost and time associated in achieving the LEED certificate during the early phases of the project. The Project sponsor should ensure that a detailed project plan is developed and is approved by all the team members. The Project sponsor must be satisfied that the project plan represents a viable and realistic plan for implementing the project and achieving its objectives.

For green buildings, an integrated approach ought to begin at the conception of the project. It is recommended to use alternative project delivery approaches, such as design build, fast track, and construction manager at risk. The advantage of adopting these project delivery approaches is that the contractors get the opportunity to be involved during the early phases of the project. In the case studies there were factors, such as communication gap within the project team, poorly defined scope of work, and reluctance among the project team members that led to the variation in the project. Therefore, adopting project delivery approaches, such as, design build, fast track, and construction manager at risk have the potential to diminish such factors by enabling the team to integrate during the early phases.

Theoretical Conclusions

To justify the proposition, twenty LEED certified/registered health-care facilities were selected to analyze whether the additional LEED objective increased the chaos within the existing complex project. Out of twenty case studies, two were excluded since one was on hold due to the programming issues and no information could be gathered on the other one. Out of the remaining eighteen, nine reported variations and remaining nine stated problems in terms of integrating LEED objectives within health-care projects.

Within the perspective and realm of the study, failure to achieve the intended LEED objectives and the presence of variation within the LEED credits is considered as the edge of chaos within the green health-care projects. Moreover, the problem with integrating both the LEED requirements and the health-care specific regulations also pertains towards bringing the project to the "edge of chaos." Hence, the chaos theory stays unaffected, since the research findings concur with the theoretical basis of the chaos theory.

The researcher put forth the following propositions based on the literature review and theoretical background:

Potential variations between the pilot checklist and the final checklist could be pre-determined during the early phases of the project. As per chaos theory, an additional system must be introduced when new conditions arise within an existing complex system. If an additional system is not introduced, the increasing chaos or randomness due to the new conditions could lead the existing system to failure. Consequently, when new objectives, that is, the LEED objectives, were added without an additional planning or development phase, it led to chaos within the projects in terms of credit variations and failure to achieve pre-defined green objectives.

LEED objectives should be integrated during the project planning stage instead of the design phase in order to ensure minimum variation in the checklist. Adding new conditions within an existing complex system increased the randomness within the system. As the project moved further into the advanced project stages, the randomness and chaos within the project increased due to the changes in the inflow and outflow of activities, people, and resources. The case studies where the project team integrated the LEED objectives early during the planning stages reported less variations and problems compared to case studies where the LEED objectives where introduced during the late design phases. It is advisable to introduce the additional conditions, that is, LEED objectives, when the project is in earlier stages, resulting in less randomness than in later stages. The research conducted by the Construction Industry Institute proves that all the decisions made at the emergent stage of a project life cycle has high influence on the cost, compared to the decisions that are made at the later stages of the projects (Anderson 2004). Adding LEED objectives early during the planning stage of the projects will ensure minimum credit variation and maximize the project quality in terms of meeting green objectives.

Managing the variations between the pilot checklist and the final checklist will further enhance the certification level of health-care projects. As mentioned earlier, all the case studies were the "first movers for the others to follow" in the health-care sector. Achievements for the pioneers will motivate and encourage the others within the health-care sector to opt for LEED certification, and hence will enhance the certification level within health-care projects. Furthermore, meeting the pre-defined credits will encourage the existing project participants to incorporate LEED objectives within prospective projects.

Benefits of the Research Findings

The research findings will benefit in the development of green health-care facilities by providing these contributions:

To the Owner and the Project Building Team

Planning a green health-care project on the basis of systems approach will allow owners to determine the potential costs associated with LEED intended credits early in the planning phase. The systems approach to project planning benefits the owners by clearly spelling out the project objectives and by analyzing the project feasibility in terms of whether or not to pursue LEED certification before significant costs are incurred.

To the Health-care Sector

Identifying the existing bottlenecks and recommending a project planning approach for the owners and the project team is a small step at the micro level to encourage the health-care sector to build environmentally responsible buildings. Integrating LEED objectives within health-care design and construction will benefit the health-care industry in recognizing the interdependence of the natural and built environments. This will allow health-care facilities to minimize the use of energy, water, and other natural resources, while providing healthy and productive indoor environments for the health-care workers and their patients.

Recommendations for Future Study

The researcher further recommends the following studies:

1. Develop detailed IDEF0 representation of comprehensive integration of health-care project and LEED objectives based on project planning strategies developed by the Construction Industry Institute. The systems approach could be used to develop the whole project life cycle phases for a green health-care project, with the help of the IDEF0 modeling technique. This will help in developing a common protocol for the potential project team and will be helpful in removing the uncertainty factor from the LEED projects.
2. Identify differences and causes of differences between the energy calculation submitted by the project team of LEED registered projects and the calculations approved by the USGBC council. This study would be beneficial in developing standard procedures of energy optimization, since the current strategies mentioned in the LEED reference guide are considered ambiguous.

3. Quantify the factors identified in this study and conduct the quantitative analysis, this may help in building a model to plan and develop a more effective approach for LEED registered projects.
4. Conduct a study on whether the choice of any particular project delivery approach enhances the process of integrating the LEED objectives in the health-care projects.

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APPENDIX A

CASE STUDIES

Case Study G

Description: The $502 million project was a 937,000 square feet facility scheduled to be opened in 2007. As a replacement for a 30-year-old facility, the project is in 10 to 15 percent completion phase with the design and construction documentation 100 percent complete. The project was on a fast track project delivery approach, with the owner being involved with the trade contractors. The owner found the LEED objectives to be a flexible and practical approach to improve the environmental issues associated with the building and construction industry. As stated by the architect, integrating LEED objectives from the beginning of the project and careful planning helped in controlling the project budget. The strategies for the LEED intents were well developed in the design phase and later the project team conducted value engineering. The credits that were adding extra cost to the project were filtered out, such as energy optimizing credits and storm water treatment/run off credits. On the whole, the project team started with a fixed project budget and then picked LEED credits that could be implemented in the project without escalating the budget. The project team developed and defined definitive strategies for the credits and even conducted value engineering to ensure the validity of the approach.

Variation: The project is in 15 percent construction stage and so far the project team has not reported any variation.

Case Study I

Description: The facility was a 110,000 square feet expansion project with a capital budget of $45,000,000. The second phase, scheduled for 2008, was planned to include the expansion of the emergency and diagnostic imaging departments, and the third phase, seismic upgrades, was scheduled to be completed in 2009. At the time of this writing, the project was in early stages with design stage being 100 percent complete and documentation of contract and specification near completion. The project delivery approach of the project was construction manager as general contractor with negotiated guaranteed maximum price contract. The owner's incentive was primarily financial given the potential for grants from the State Energy department.

Variation: Since the project was not yet in the construction phase, no variation was reported. However, the project team was finding it challenging to incorporate the LEED objectives in health-care project due to the programmatic requirements of health-care.

According to the project manager, the points that would add significant cost would probably be deleted. The project team started with the objective to get the certification but is assessing the idea of going for silver rating instead. The reason for this was, "to date we have seen relatively little cost associated with the points that may get the project to the silver level." This was primarily because of the large number of points due to using on-site geothermal energy. At the time of this writing, the team was also assessing the idea of involving a LEED consultant in the required documentation process. All building systems were reviewed extensively and no variation was evident on the project.

Case Study J

Description: The proposed facility was a $91,000,000 new construction project and was one of the first green health-care projects in the region. The project was in 5 percent construction completion phase but was on hold due to the extreme weather conditions. The project was on tradition design-bid-build project delivery approach.

Variation: The construction had barely caught momentum and the construction stage was limited to erection of steel frame structure due to weather conditions, and hence, there was no evident variation. Nonetheless, the project team was initially aiming for the LEED silver rating with the total 38 credits in the pilot list, but finally targeted for certification with just 30 credits. According to the project manager, the team was going ahead for the "sure shot" credits. Therefore, the project team abandoned the energy optimization credit since the result for this particular credit is unpredictable.

Case Study K

Description: The 300 million dollar state-of-the-art project was scheduled to be completed in 2011 and was being developed in multi-stages. The project was in 10 percent completion stage and was on construction manger at risk project delivery approach. The project involved preservation, renovation, and new development on a large scale with the total development area of 911,000 building gross square feet. The project was a under direction of the state government and energy efficiency and optimization was a state requirement in the region.

Variation: The project team had included a total of 41 credits in the pilot list, out of which 26 were confirmed and 15 were probable points. The meaning probable implies that in case of budget over-run the team might filter a few credits out of these 15 credits. Therefore the project may end up at any level form certification to gold. At the time of this writing, no variation had been reported except that the project team was facing an issue relating to the fundamental commissioning credit, one of the prerequisite credits of energy and atmosphere. The project team wanted to acquire commissioning credit for the overall project. However, the USGBC council was not accepting the previous commissioning report for the renovated portion of the building and was demanding re-commissioning on the renovated wing which was approximately around 80,000 square feet. The project team perceived this as an unpractical demand since at the commissioning rate of $1 to $2 per square feet, the project would have to incur the additional cost of $80,000 to $90,000 for a procedure which had already been carried out and received the same result.

The project was a public project, and both the project team and the USGBC council were adamant on their perspectives. Since the credit was a prerequisite, the team had to achieve it in order to get the LEED certification. Apart from this dilemma no other credit had been dropped, though because of the LEED paper trail and documentation involved, the schedule date of completion was postponed for one more year.

Case Study L

<u>Description:</u> The $22,000,000 project was an expansion project with a 76,000 square feet central plant replacement facility. It was to be followed by $15.4 million surgery development plan with the total area of 300,000 square feet. The project was in 25 percent completion stage with fast-track project delivery approach with high owner involvement. The facility was one of the first health-care plants in the country to deploy rotator flywheel technology for uninterrupted power, an innovative, green, battery-free power source for the entire hospital campus. For the optimum design integration, specification, costing, installation, and commissioning of systems and equipments, the project team consisted of owner, architect-engineer, electrical engineering consultant, system suppliers and manufactures.

In order to enable long-term energy efficiencies and maximize the “green performance” of the facility, the owner designed the project team first. During the early planning phase of the project the owner realized that to facilitate integrate green objective the traditional electrical distribution systems would not get them to where they needed to be in order to improve energy optimization of the facility. The project manager, who was from the owner’s side, envisioned electrical distribution for the hospital of the future and got backing from the board of trustees, hospital president, and chief financial officer to redesign the system in a completely innovative method.

According to the project manager, “this is an existing team with which to work. I have been fortunate to be able to pick the best, from design, engineering, commissioning, and cost estimating.” Architect-engineers assisted in developing flexible plan to make smart green choices. As stated by the architects, selecting the right team players for the job is critical, even the contractors and vendor were brought aboard during design phase as team players. The project team even included the hospital staff into the design process to make decisions based on their equipment familiarity, training and specialties. A LEED certified professional was working with contractors to ensure all LEED requirements are upheld and documented during the process.

<u>Variation:</u> The project team reported no variation so far in the project.

Case Study M

Description: This project was registered for the LEED certification; however, the project was on hold due to feasibility and requirement issues related to the project and its development within the community. There was a strong possibility that the project would be unable to take off at all. Hence the LEED credit variation was not applicable to this particular project.

Case Study O

Description: This proposed facility with 204,000 square feet of area and project worth of approximately $55.5 million was in 5 percent completion stage and was scheduled to be opened in 2006. The project delivery approach was traditional design-bid-build. The design and construction documentation had been 70 percent developed and the steel frame had been erected on site. The architects had already worked on another LEED certified health-care project and this was their second project with similar scope of work. Therefore, the project team was already aware of the roles and responsibilities associated with LEED.

The strategies for getting the LEED credit were already well developed in design phase. Since the architect was already aware of the potential bottlenecks of LEED credits, they had decided not to go for the energy efficiency point which, according to them, was the most unpredictable part of the rating list.

Variation: The project was in emergent stage and no variation had been reported by the project team. The project team was aiming for certification level with pilot list containing 30 credits in total.

Case Study P

Description: This 917,379 square feet replacement project was in pre-construction phase with design phase being 100 percent complete. The design phase of the project was developed in a fast track model basis with construction manager and multiple contractors. The project was following the traditional design-bid-build project delivery approach.

Variation: Due to the incipient stage of the project the variation in the LEED credit lists was not applicable to the project.

Case Study Q

Description: This project was a 470,000 square feet facility with approximate project cost of $200 million. The project was in 5 percent completion stage and was scheduled to be open in 2007. The project was on construction manager at risk project approach. The project team consisted of owner, project manager, architectural-engineering company, and general contractor. The team spent 24 months on project planning during the pre-construction phase, and the role and responsibilities were well laid out. The document development was on multiple stages of fast track development. The documents related to LEED were developed into three sections:

- Utilities
- Building shell
- Electrical, mechanical, and plumbing including building interiors

Variation: The stated goal for the project was platinum with 50 credits and no variation had been reported by the project team. According to the project team, early planning and regular follow up thorough meeting is very important in order to make sure every body is on board.

Case Study S

Description: Project S was likely to become the first psychiatric facility in the United States recognized for its energy efficiency and environmental design. The construction was 30 percent complete. The project team spent 12 months in project LEED process planning.

According to the owner, incorporating LEED objectives will save 20 percent on energy cost during the operation phase of the facility. The project was a renovation and new construction project, with the team focusing on resource reuse and recycling with a total of 29 credits in the LEED pilot list. Most of the debris generated by construction would be recycled into the base for sidewalks and roads, while ceiling tiles would be removed for reuse in the new facilities. The objective to improve energy efficiency was integrated in the design phase and thus lots of emphasis was placed on providing natural sunlight.

Variation: The project team did not report any variation. As stated, all the strategies for LEED credits were well laid out and all the participants were onboard early on the project so every thing has been well defined and planned out.

Case Study T

Description: This project was the first health-care project in the region to even register for the LEED certification. However, the project was no longer going ahead with the certification process. No other information could be gathered about the project except that the team withdrew the LEED objectives.

APPENDIX B

SCRIPT FOR TELEPHONE INTERVIEW

The information obtained from this study will help identify the variation between the LEED pilot checklist and the LEED final certified checklist. The study will further analyze the causes of variation and ways to manage these factors. Your assistance in reaching these goals will be appreciated and may directly benefit you and your practice. A summary of the results of this study will be immediately made available upon your request. ALL information supplied in this questionnaire will remain confidential.

INSTRUCTIONS:

- Who should answer the questionnaire? The owners, the general contractors, the project managers and the executive construction manager in the organization those who were involved in making or implementing any decision relating to LEED regulations in the project.

Please respond as accurately as you can. If you personally do not feel qualified to respond, please forward the name and contact number of the appropriate person in your organization.

1. Which project-delivery and compensation strategy was adopted for the given project?
2. Do you think that the choice of project delivery and contracting strategy could contribute to better success in terms of meeting the green objectives?
3. What do you think about incorporating LEED in health car construction? Do you favor it or not? Explain.
4. Are there any potential problems you can oversee in getting LEED certification on a project such as, acquiring LEED certified materials or extra cost or time?
5. What was the original LEED credit intent for the project?

6. Did the credits identified during the LEED pilot and final certified checklists were consistent or did they change during the construction phase?
7. What were the reasons for dropping these credits?
8. Did the variation within LEED pilot checklist and the final checklist had any impact on your project schedule, cost or planning?
9. How did you ensure that the project was moving in consistent with LEED requirements?
10. Did you develop any specific project execution strategies focusing on implementing LEED regulations?
11. Did you aligned the LEED project objectives among all the parties involved in the process, were there any advantages and disadvantages of doing so?
12. How did you evaluated and selected materials in accordance to LEED criteria?
13. Which LEED credits were/are the most difficult to achieve?
14. Who made all the decisions relating to the different categories?
15. Do you think a choice of different project delivery system could have enhanced the overall LEED procedure?
16. Were you satisfied with the overall result achieved in terms of final credits? Explain.
17. Would you like to be involved in another LEED certified project?

APPENDIX C

LEED RATING CHECKLIST – VERSION 2.1

LEED — LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN — U.S. GREEN BUILDING COUNCIL

Version 2.1 Registered Project Checklist

Project Name
City, State

Yes	?	No			
			Sustainable Sites		**14** Points
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Development Density**	1
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation**, Alternative Fuel Vehicles	1
			Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling	1
			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
			Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
			Credit 6.1	**Storm water Management**, Rate and Quantity	1
			Credit 6.2	**Storm water Management**, Treatment	1
			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
			Water Efficiency		**5** Points
			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1
			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
			Energy & Atmosphere		**17** Points
Y			Prereq 1	**Fundamental Building Systems Commissioning**	Required

Yes	?	No			
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**	Required
			Credit 1	**Optimize Energy Performance**	1 to 10
			Credit 2.1	**Renewable Energy**, 5%	1
			Credit 2.2	**Renewable Energy**, 10%	1
			Credit 2.3	**Renewable Energy**, 20%	1
			Credit 3	**Additional Commissioning**	1
			Credit 4	**Ozone Depletion**	1
			Credit 5	**Measurement & Verification**	1
			Credit 6	**Green Power**	1

Yes ? No

Materials & Resources — 13 Points

Yes	?	No			
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1
			Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
			Credit 2.1	**Construction Waste Management**, Divert 50%	1
			Credit 2.2	**Construction Waste Management**, Divert 75%	1
			Credit 3.1	**Resource Reuse**, Specify 5%	1
			Credit 3.2	**Resource Reuse**, Specify 10%	1
			Credit 4.1	**Recycled Content**, Specify 5% (post-consumer + ½ post-industrial)	1
			Credit 4.2	**Recycled Content**, Specify 10% (post-consumer + ½ post-industrial)	1
			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
			Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes ? No

Indoor Environmental Quality — 15 Points

Yes	?	No			
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
			Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1
			Credit 2	**Ventilation Effectiveness**	1
			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1

Yes	?	No	Credit	Description	Points
			Credit 4.2	**Low-Emitting Materials**, Paints	1
			Credit 4.3	**Low-Emitting Materials**, Carpet	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Perimeter	1
			Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
			Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
			Innovation & Design Process		**5** Points
			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
			Credit 2	**LEED™ Accredited Professional**	1

Yes	?	No		
			Project Totals **(pre-certification estimates)**	**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

APPENDIX D

THE PROCESS OF BUILDING GROUNDED THEORY

PHASE		ACTIVITY	RATIONALE
RESEARCH DESIGN PHASE			
Step 1	Review of technical literature	Definition of research question *Definition of a priori constructs*	Focuses efforts *Constrains irrelevant variation and sharpens external validity*
Step 2	Selecting cases	Theoretical, not random, sampling	Focuses efforts on theoretically useful cases (e.g., those that test and/or extend theory)
DATA COLLECTION PHASE			
Step 3	Develop rigorous data collection protocol	Create case study database *Employ multiple data collection methods* *Qualitative and quantitative data*	Increases reliability Increases construct validity *Strengthens grounding of theory by triangulation of evidence. Enhances internal validity* *Synergistic view of evidence*
Step 4	Entering the field	Overlap data collection and analysis *Flexible and opportunistic data collection methods*	Speeds analysis and reveals helpful adjustments to data collection *Allows investigators to take advantage of emergent themes and unique case features*
DATA ORDERING PHASE			
Step 5	Data ordering	Arraying events chronologically	Facilitates easier data analysis. Allows examination of processes
DATA ANALYSIS PHASE			
Step 6	Analyzing data relating to the first case	Use open coding ***Use axial coding , Use selective coding***	Develop concepts, categories and properties ***Develop connections between a category and its sub-categories, Integrate categories to build theoretical framework , All forms of coding enhance internal validity***
Step 7	Theoretical sampling	Literal and theoretical replication across cases (go to step 2 until theoretical saturation)	Confirms, extends, and sharpens theoretical framework
Step 8	Reaching closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small
PHASE		ACTIVITY	RATIONALE
LITERATURE COMPARISON PHASE			
Step 9	Compare emergent theory with extant literature	Comparisons with conflicting frameworks ***Comparisons with similar frameworks***	Improves construct definitions, and therefore internal validity ***Also improves external validity by establishing the domain to which the study's findings can be generalized***

(Source: Pandit 1996)

APPENDIX E

IRB APPROVAL

VPR
Office of the Vice President for Research
Texas A&M University

Date 12/09/2004

MEMORANDUM

TO: Privanka Tyagi
Department of Construction Science
MS 3137

FROM: Dr. E. Murl Bailey, CIP, Advisor
Institutional Review Board
MS 1112

SUBJECT: IRB Protocol Review

Title: GREEN HEALTH CARE: Analyzing the Variations between the LEED Pilot Checklist and the LEED Final Checklist for Existing LEED Registered-Certified Hospitals Using IDEFO Model

Protocol Number: 2004-0618
Review Category: Exempt from Full Review
Approval Date: December 9, 2004 **to** December 8, 2005

The approval determination was based on the following Code of Federal Regulations http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm

______ **46.101(b)(1)**	______ **46.101(b)(4)**
✓ **46.101(b)(2)**	______ **46.101(b)(5)**
______ **46.101(b)(3)**	______ **46.101(b)(6)**

Remarks: Request of waived signed consent has been approved.

After specific review, it has been determined that approval for waiver of the requirement to obtain signed informed consent may be granted under 45 CFR 46.117(c). However, a study information sheet with all elements of consent must be provided to study participants.

The Institutional Review Board – Human Subjects in Research, Texas A&M University has reviewed and approved the above referenced protocol. Your study has been approved for one year. As the principal investigator of this study, you assume the following responsibilities:

***Renewal*:** Your protocol must be re-approved each year in order to continue the research. You must also complete the proper renewal forms in order to continue the study after the initial approval period.

***Adverse events*:** Any adverse events or reactions must be reported to the IRB immediately.

***Amendments*:** Any changes to the protocol, such as procedures, consent/assent forms, addition of subjects, or study design must be reported to and approved by the IRB.

***Informed Consent/Assent*:** All subjects should be given a copy of the consent document approved by the IRB for use in your study.

***Completion*:** When the study is complete, you must notify the IRB office and complete the required forms.

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Academy for Advanced Telecommunication and Learning Technologies
Center for Information Assurance and Security
Comparative Medicine Program
Institute for Scientific Computation
Institute for Telecommunications and Information Technology
Integrative Center for Homeland Security
Microscopy Imaging Center
Office of Business Administration
Office of Distance Education
Office of Graduate Studies
Office of Organizational Development and Diversity
Office of Proposal Development
Office of Research Compliance
Office of Sponsored Projects
Professional Development Group
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VITA

PRIYANKA TYAGI — 3634 144TH PL NE APT N14
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EDUCATION

Master of Science in Construction Management — August 2005
Texas A&M University, College Station, TX
Bachelor of Design (B.Tech.) — April 1998
Nagpur University, India

WORK EXPERIENCE

Research Assistant — Aug 2003-Jan 2005
For Dr. S. Grider at Department of Anthropology
Project Designer — Nov 1998-Feb 2002
For a Design-build Firm
Intern — June 1997-Nov 1997
For Commercial Developers

COMPUTER SKILLS

Construction Applications	Primavera Project Planner (P3), MS Project, AutoCAD 2004
Office Applications	MS Office Professional 2003, MS Visio
Statistical Application	SPSS, ATLAS.ti, AIØ WIN for IDEF Function Modeling Method
Graphics/ Web Applications	AutodeskViz 4, 3DStudioMax 5, Photoshop 7, Illustrator

SCHOLARSHIPS/AWARDS

- Letter of Appreciation from the President of the Texas A&M University 2005
- AUF Scholarship 2005
- AUF Scholarship 2004

ORGANIZATIONS

- Member of student chapter of Construction Management Association (CMA) • Organized undergraduate college annual meetings