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Computer Model to Select Leed Certification for Building Projects

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COMPUTER MODEL TO SELECT LEED CERTIFICATION FOR BUILDING PROJECTS

by

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According to the US Green Building Council (USGBC) residential and commercial buildings in the United State consume huge amounts of natural resources; pollute the environment, and generate large amounts of waste, all of which affect the environment, economy, public health, and productivity. As a result, USGBC committees developed the Leadership in Energy and Environmental Design (LEED) rating system to help professionals improve the quality of buildings and lessen their impact on the environment.

The (LEED) Green Building Rating System is a point-based system for certifying the level of a building's sustainability. There are four LEED certification categories: (1) Certified, (2) Silver, (3) Gold, and (4) Platinum, which reflect amounts of qualified credits. In order for the applicant to apply for a specific level of certification he has to meet certain prerequisites and achieve a specific number of credits, or points. This common practice is time consuming and a complex process for users; therefore, this thesis incorporates the development of a computer model that automates the process of identifying the required number of points that must be accumulated based on selected LEED certification categories. Furthermore, the proposed model provides a general idea of the cost of this specific certification.

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GLOSSARY

ASTM	American Society for Testing and Materials
BREEAM	Building Research Establishment's Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CFC	Chlorofluorocarbon
CIWMB	California Integrated West Management Board
CIR	Credit Interpretation Request
EA	Energy and Atmosphere
EB	Existing Buildings
EPA	Environmental Protection Agency
GB	Green Building
GSA	Services Administration
HCFC	Hydrochlorofluorocarbon
HVAC	Heat Ventilation and Air Conditioning
IAQ	Indoor Air Quality
ICF's	Insulated Concrete Form Systems
ID	Innovative Design
IEQ	Indoor Environmental Quality
IRR	Internal Rate of Return
IUOM	Innovation Upgrade Operating and Maintenance

LEED	Leadership in Energy and Environmental Design
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
Low-e	Low-emitting
LRV	Light Reflectance Value
MIS	Management Information System
MR	Material and Resources
NC	New Construction
NEMC	Northbridge Environmental Management Consultants
NIST	National Institute of Standard and Technology
NPV	Net Present Value
PCB	Polychlorinated Biphenyl 1
SIPS	Structural Insulated Panel Systems
SQL	Structured Query Language
SS	Sustainable Site
USGBC	U.S. Green Building Council
VOCs	Volatile Organic Compounds
WE	Water Efficiency

CHAPTER ONE

INTRODUCTION

1.1 Overview

The construction industry is now converting to environmentally friendly buildings due to concern about environment factors, such as the impact of human beings on natural resources and the atmosphere. There are different terminologies for environmentally friendly buildings, such as (a) green buildings, (b) environmental buildings, (c) sustainable buildings, (d) green development, (e) sustainable development, and (f) sustainable design. Though there are many expressions for and varying definitions of green buildings, the basic principles, concepts, and goals remain the same: a balanced economy, a safer environment, and social accountability that would improve the current and future quality of life (EPA, 2006a).

In order to effectively pursue these goals, there is a need for a standard to evaluate whether a building's design and construction qualifies as green or not. Five separate green building rating systems exist to address this need: (1) Building Research Establishment's Environmental Assessment Method (BREEAM), (2) Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), (3) Green Building Challenge/Green Building Assessment Tool (GB Tool), (4) Green Globes US, and (5) Leadership in Energy and Environmental Design (LEED).

This thesis focuses on the LEED Rating system because it is well-established and the most popular of the systems listed above. Furthermore, the General Services Administration (GSA), which operates as the federal government's landlord, finds that "LEED rating system continues to be the most appropriate and credible system available for evaluation of GSA projects (USGBC, 2006b)."

LEED was created by a non-profit organization, the U.S. Green Building Council (USGBC) which is "a community of more than 6,400 organizations from every sector of the building industry united by a common purpose: to transform the building marketplace in terms of sustainability (USGBC, 2006a)."

There are six products of LEED: 1) LEED for new construction, 2) LEED for existing buildings, 3) LEED for commercial interiors, 4) LEED for core and shell, 5) LEED for home, and 5) LEED for neighborhood development. This thesis focuses on the most common two: 1) LEED-NC which is concerned with new construction and major renovation, and 2) LEED-EB, which deals with the maintenance of existing buildings (more explanations regarding this will be provided in Chapter Two). There are 403 certified projects, and 3,113 registered projects in the United States. Figure (1-1) shows the top ten states that implement LEED-NC, based on statistics from October of 2005. It reveals a huge increase in registered and certified projects from the previous year. The horizontal axis represents the states and number of projects in each one, and the vertical axis represents the project's gross square feet (USGBC, 2005).

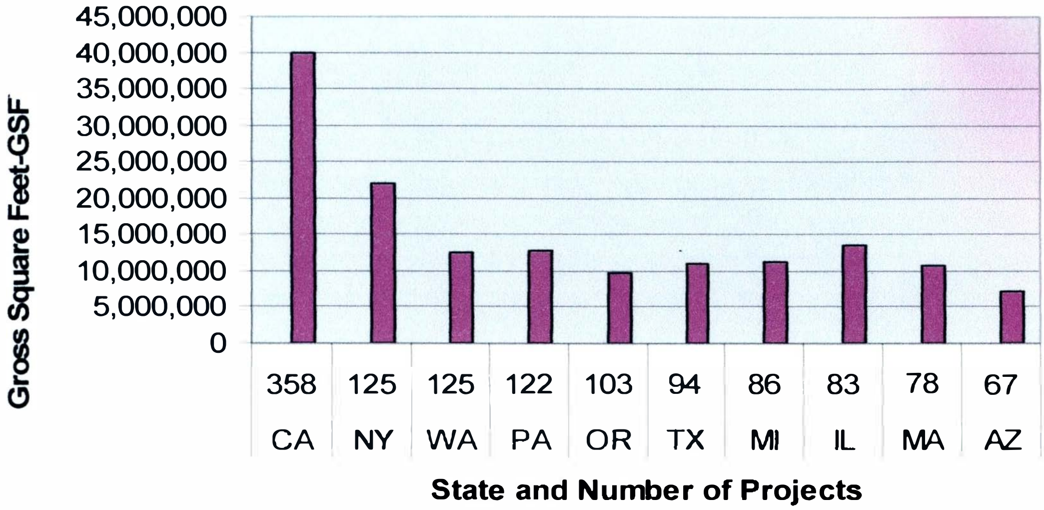


Figure 1-1. Registered LEED-NC Projects by State - Top 10 (USGBC, 2005)

1.2 Research Objectives

Although USGBC has LEED Green Building Rating System available online with summaries of the documentation requirements, accessible training workshops and most of the documentation information are available on the USGBC web site, LEED documentation still is one of the biggest barriers to pursuing LEED certification because it is time-consuming, costly and requires a lot of effort. The objectives of this thesis are listed as follows:

- Automate the process of recognizing the required number of points that must be accumulated based on the selected LEED certification category.
- Estimate the cost of certification based on the selected type.
- Minimize user input and eliminate confusion arising during the selection procedure.

1.3 Research Methodology

In order to attain the research objectives the following steps will be fulfilled:

- Conduct a comprehensive literature review of green and sustainable buildings.
- Collect data from the literature and the industry.
- Develop a work plan to implement the proposed model.
- Implement the proposed model by using Microsoft Access as a management information system.
- Validate the model through an actual case study.

1.4 Thesis Organization

Chapter Two introduces a summary of the literature review. This includes green building definitions, strategies, technologies, and economics.

Chapter Three introduces and explains the LEED products, rating system, and the current practice of LEED certification. Moreover, it outlines the application of the management information system.

Chapter Four explains the methodology followed in developing the proposed model, the model structure, components, and data flow.

Chapter Five discusses the implementation of the system. It also illustrates the system's databases and their modules, and the required input and expected output. It concludes by examining the system performance through an actual project.

Chapter Six is the thesis conclusion, contributions and recommendations for future extensions.

CHAPTER TWO

GREEN BUILDING

2.1 Introduction

The United State Green Building Council (USGBC) found that in the United States there are significant impacts on our natural environment, economy, resources, public health, and productivity from the design, construction, and maintenance of buildings. Buildings are a main pollution source; they consume many resources and generate large amounts of waste. The (USGBC) statistic shows that commercial and residential buildings use (a) 36 percent of total energy consumption, (b) 65 percent of electricity consumption, (c) 30 percent of greenhouse gas emissions, (d) 40 percent of raw materials (3 billion tons annually), (e) 30 percent of waste output/136 million tons annually, and (f) 12 percent of potable water consumption (USGBC, 2006c).

Furthermore, buildings produce about 35 percent of the carbon dioxide emissions, which contribute to climate change, in addition to 49 percent of sulfur dioxide emissions, 25 percent of nitrous oxide emissions, and 10 percent of particulate emissions, all of which cause urban air quality problems (Smart Communities Network, 2006).

This chapter presents a review of green building ideas and concepts, including advantages, disadvantages, strategies, and technologies, as well as briefly discussing green building economics. It also introduces the different types of LEED certifications and standards, focusing on two commonly used: (a) LEED for new construction and major renovation, and (b) LEED for existing buildings. Outlines, processes, point distributions, and the associated costs of the certifications are also discussed. Furthermore, it provides a general overview of the Management Information System (MIS) and its application in the construction.

2.2 Green Building Definitions

Other names of green building/design include “sustainable buildings/ design”, and “high performance buildings”. The Environmental Protection Agency (EPA) defines green buildings as “structures that incorporate the principles of sustainable design in which the impact of buildings on the environment will be minimal over their lifetime.” Moreover, green buildings create healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition. Research and experience increasingly demonstrate that when buildings are designed and operated with their lifecycle impacts in mind, they can provide great environmental, economic, and social benefits. Elements of green building include the following: (a) energy efficiency and renewable energy, (b) water stewardship, (c) environmentally preferable building materials and specifications, (d) waste reduction toxics, (e) indoor environment, and (f) smart growth and sustainable development. The EPA has different programs to implement and develop sustainable design (EPA, 2006b).

The USGBC defines sustainable design as “A design and construction practice that significantly reduces or eliminates the negative impact of buildings on the environment and occupants in five key areas: 1) Sustainable site design, 2)

Safeguarding water and water efficiency, 3) Energy efficiency and renewable energy, 4) Indoor environmental quality, and 5) Conservation of materials and resources" (USGBC, 2005).

2.2.1 Sustainable Site (SS)

The main objective of this element is to minimize needless destruction of valuable land and environments by supporting higher-density urban development to preserve valuable green space. Although there is no priority for the five key elements, sustainable design is not the first category by chance. Focusing on green building and choosing the appropriate site will make it easier and more economical to collect more points from this and other categories. Listed below are some key features for sustainable design (Zeigler, 2003):

1. Reuse existing buildings and sites to avoid clearing of green field sites.
2. Durability.
3. Flexibility to change buildings to adapt to user needs.
4. Optimize the use of passive solar and natural ventilation.
5. Minimize building footprint.
6. Use alternative storm water management technologies that help to recharge ground water.
7. Minimize the overall impervious area by selecting the right location for building, parking, and driveway
8. Protect and preserve wetlands and other features that are key elements to existing eco-systems.

9. Use hardy and drought-resistant indigenous plants, trees, and turf.
10. Minimize urban heat island (roads, sidewalks, brick buildings, and asphalt roofs intensify summer heat by locking the sun's energy and remaining warm long after the sun set) effect by using light-colored roofs and paving.

2.2.2 Water Efficiency (WE)

The idea behind water efficiency, also known as water conservation and quality, is to minimize the inefficient and redundant use of potable water on the site and to maximize the recycling and reuse of water, including harvested rainwater, storm water, and gray water. Below is sample of water conservation and quality practices at Pennsylvania State as pointed out in the Governor's Green Government Council GGGC, (GGGC, 2006):

- Design buildings to follow the natural contours of the land instead of carving the land to suit the building, because this is the most economical, least time consuming, and most environmentally preferable design for site and storm water management.
- Preserve and emulate natural hydrological features of the site (i.e., natural storm water retention, ground water infiltration, and recharge systems).
- Minimize site improvements and construction area cut, fill and compaction of top soil.
- Design and locate buildings and site improvements to maximize the use of alterative low-impact methods of storm water management such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, and

living/vegetate roofs. These methods support ground water recharge and on-site retention or evapo-transpiration, in other word they protect the natural water cycle.

- Implement designs that minimize the use of potable water and establish a water budget for the building. Design improvements include water-efficient plumbing fixtures, toilets, and waterless urinals. Also use on-site treatment systems that enable use of rain water for site irrigation and gray water for toilet flushing.
- Conserve water and preserve site and ground water quality by using only indigenous, drought-resistant, and hardy trees, shrubs, plants and turf that require no irrigation, fertilizers, pesticides, or herbicides.

2.2.3 Energy and Atmosphere (EA)

Energy and Atmosphere, also known as energy conservation and renewal energy, is used to maximize the application of renewable energy and other low-impact energy sources such as wind turbine, which will minimize adverse impacts on the environment. However, traditional energy consumption, such as nuclear and gas turbine plants play big roles in environmental pollution by sending great amounts of toxic waste to the ozone. Effective energy conservation, using highly efficient materials and systems, will reduce the cost for renewable energy. Below are some criteria for energy conservation and renewable energy (GGGC, 2006):

- Good passive solar design, design building in order to maximize desirable solar gain during the cold seasons and to minimize undesirable solar gains during the hot seasons, is the fundamental building block of any high-performance building.

- Aggressive use of natural daylighting is the key to reducing building lighting loads, which in turn reduces cooling loads and cooling equipment size and cost.
- High performance low-emittance (Low-e) thermally broken windows (a glass coating that keeps heat inside in winter and out in summer) and frames are the single most effective energy conservation technology.
- Design a thermally broken high performance envelope. Consider advanced performance envelope building systems such as structural insulated panel systems (SIPS) and insulated concrete form systems (ICFs) because they offer the highest energy performance.
- Use energy efficient T-8 and T-5 bulbs, high-efficiency electronic ballasts, and lighting controls.
- Use only high-efficiency HVAC, plumbing, lighting, and electrical equipment and controls, including the use of Energy Star certified energy-efficient appliances.
- In addition to air temperature, control humidity, mean radiant temperature, and air velocity year-round for maximum occupant comfort and highest energy efficiency.

California Integrated Waste Management Board (CIWMB) adds to the previous strategies another one, suggesting the use of computer model to optimize the design of electrical and mechanical system (CIWMB, 2006).

2.2.4 Indoor Environmental Quality (IEQ)

The indoor air quality, natural daylighting and ventilation, in addition to thermal comfort, can reduce the rate of respiratory disease, asthma, and allergy, sick building symptoms, and enhance worker performance. Zeigler (2003) stated some IEQ techniques:

- Maximize use of natural daylighting.
- Use operable windows to maximize use of natural ventilation – design HVAC systems for mixed mode operation.
- Provide dedicated engineered ventilation system that operates independently from heating and cooling systems and controls.
- Minimize sources of indoor pollutants. Use only materials, adhesives, finishes, paint, and furnishings, which do not contain Volatile Organic Compounds (VOCs) that can cause irritations.
- Provide a smoke free environment.
- Design to control space humidity, mean radiant temperature, air velocity and air temperature year round instead of only controlling air temperature. Provide user accessible zone controls when possible.
- Protect and seal HVAC equipment and ductwork during construction.

2.2.5 Materials and Resources (MR)

The key principle is to minimize the use of non-renewable construction materials and resources such energy and water, and to maximize the use of recycled content materials, modern resource-efficient engineered materials, and resource-efficient composite type structural systems wherever possible. Some of the materials and resource reduction techniques (Zeigler, 2003) are:

- Identify ways to reduce and optimize the amount of material used in each building system through efficient design and the use of modern materials. Use resource-efficient engineered materials and systems, such as trusses, composite design, and stress skin structural panels, etc.
- Use bio-based and recycled content materials wherever possible.
- Require the use of certified lumber from managed forests.
- Evaluate all materials for ability to be recycled at end of useful life.
- Reduce transportation of materials by placing emphasis on using regionally harvested and manufactured building materials.
- Avoid use of Chlorofluorocarbon (CFC) or Hydrochlorofluorocarbon (HCFC) based materials, insulation, or refrigerants.
- Implement an aggressive construction waste management plan. For most projects, 80 to 90 percent of construction debris is recyclable.

2.3 Advantages of Green Building

Green building may increase the capital cost, but it reduces the operating and maintenance cost over the life cycle of the building. The maximum environmental, economic and health benefits of green building can be gained when the use of available resources such as rainwater, wind turbine, or solar power is increased, and when recycled materials are used in an efficient manner without affecting the overall environment. Environmental, economical, health, and community benefits are considered the main advantages of green building. There are explained in the subsections below.

2.3.1 Environmental Benefits

This is the most important benefit type that distinguishes green buildings from traditional buildings, and it is the main target of green technologies. The USGBC lists the major environmental benefits (USGBC, 2005) as:

- Enhance and protect the complex of a community of organisms and its environment. Sustainable design preserves valuable green-field, and minimizes site disturbance. Also it minimized adverse impact on the environment, by maximizing the used of low impact energy source.
- Enhance and protect the biological diversity in an environment. Green design minimized destruction of valuable land, habitat and green space.
- Improve air and water quality, by using the high performance materials and systems.
- Minimize solid waste, because green building encourage the used of recycle and reuse materials.
- Minimize the impacts of natural resource consumption.

2.3.2 Economic Benefits

Money is the biggest concern and it has to be optimized whether it is cost or profit. Furthermore, environmental and health benefits are converted to cost benefit. The USGBC lists the economic benefits of green buildings (USGBC, 2005) as:

- Reduce operation and maintenance costs, by using high efficiency energy and water systems and equipments.
- Enhance asset value and profits. Green buildings improve real estate value, which is helpful when securing loans or building resale. Also green buildings sell or lease faster.
- Improve employee productivity and satisfaction, as a result of providing a healthy and comfortable indoor environment.
- Optimize life-cycle economic performance. The use of sustainable materials and systems will reduce the energy cost.
- Integrated design allows high benefit at low cost, because it ensures the right selection of the design, materials, and systems from the beginning, as well as reduces the change orders.
- Significantly lower utility costs, by using passive solar design, natural ventilation, and high performance envelop systems.
- Increase the value of a building.
- Quantify financial benefit in terms of Return on Investment (ROI) instead of payback period.

- Marketing advantages by decreased vacancy and improved retention. Green buildings normally sell or lease faster, and attract occupants better because they comfort with lower occupancy costs.
- Improve risk management by reduced liability. A healthy indoor environment can reduce the possibility of insurance claims and lawsuits.

2.3.3 Health and Community Benefits

Sustainable buildings provide clean, quality, and healthy environment that help to improve people health and productivity. The USGBC lists the major health and community benefits (USGBC, 2005):

- Improved air, thermal and acoustic environments.
- Enhanced occupant comfort and health.
- Minimized strain on local infrastructure. Green design decreases transportation development and maintenance, and increased economic performance of mass transit systems. Moreover, green building uses fewer resources which reduce the demand on power plants, drinking water supplies and sewers.
- Improved quality of life. Green buildings provide healthy and comfortable indoor environment.
- Improved occupant performance. Reduced absenteeism and turnover and improved employee satisfaction from providing a healthier workplace.

2.4 Green Building for Less Strategies

Some strategies can reduce the cost of green buildings. Targeting sustainable buildings and organizing all construction parties from the beginning would eliminate cost overrun as a result of claims and change orders. Zeigler (2003) confirmed some green buildings for less strategies:

- *Going Green Early Costs Less* – Establishing early environmental goals before even selecting the site will reduce early project costs. Design with intent to benefit from passive solar and day lighting principles and other green features.
- *Avoid Over-design and Over-sizing* – Time spent calculating project requirements such as HVAC systems, lighting, and electrical systems will avoid over-sizing design.
- *Fully Integrated Design Process* – The key to achieving effective cost savings is in the integration of all major systems, elements, and materials in the building design. For example, a minor increase in the paint Light Reflectance Value (LRV) will eliminate the lights in classrooms and open office spaces in addition to reducing the lighting heat. These reduce the first cost of the lighting and electrical system, besides reducing the lighting energy use for the life of the building.
- *Optimization of all Systems and Materials* – Balancing building performance and initial construction cost is challenging. This optimization is best done

through the use of modern computer-based energy, lighting and daylighting modeling and simulation software.

- *Use Computer Modeling to Validate Optimization* – Modeling and simulation software can be used to help evaluate and compare the benefits and cost effectiveness of various energy saving green technologies.
- *Apply Less is More* – Keep the building as simple as possible and focus on increasing the performance with minimum components.
- *No Line by Line "Value Engineering"* – Considering interrelationships between different building systems when using value engineering is a key that leads to the actual cost saving.
- *Apply "Cost Trade Off" Principle* – Savings in some of green technologies such as sustainable site design, alternative storm water management or daylighting can be used to help pay for newer and costly green technologies like low-VOC paints, alternative materials, indoor air quality monitoring, fuel cells, solar, and renewable energy. That will result in no net increase in overall green project cost.
- *Design and Construction Professionals Selection* – Hire professionals (A/E, Specialty Consultants, Contractor & CM) who have good experience with high performance buildings, green materials, green technologies, and the use of a fully integrated design process. It is possible to recover higher design fees from integrated design processes with lower construction costs.

- *Environmental Performance Contracting* – Make written environmental goals for all five key elements (site, water, energy, materials, and IEQ) to be contractually binding throughout all aspects of the project and use the preliminary LEED target score as a point of reference.

2.5 Green Building for Less Technologies

There are some technologies that optimize the benefits of green buildings without maximizing the project cost. These technologies are brought out by Zeigler (2003).

- *Sustainable Site Design* – Preserve the natural and hydrological features that can be used as elements of design. Instead of carving the land to suit the building form the building to the natural contour of the land.
- *Sustainable Storm Water Management* – Use technologies such as rain gardens, previous paving, and pervious walkways. That allow site to retain and infiltrate the storm water in order to recharge local ground water.
- *Pervious Bituminous Paving* – This type of paving is porous because it does not contain fine gravel, which allows rain water to pass through the paving and enter to the ground water. The cost for this paving is almost same as the traditional paving.
- *Sustainable Landscaping* – Using of site integrated sustainable storm water strategies such as rainwater gardens, sub-surface irrigation systems, on-site ground water recharge, and infiltration beds to support sustainable

landscaping, in addition to the use of less costly native, hardy, drought-resistant landscaping and turf.

- *Climate Responsive Design* – Maximizing the use of passive solar massing and orientation, passive solar heating and cooling techniques, sun-tempering of windows, natural shading, natural ventilation, and natural day-lighting will reduce the lighting/electrical and heating/cooling loads, equipment size, and costs by as much as 30 percent to 60 percent or more. Furthermore there is little or no additional cost added to the project.
- *Daylighting* – Improving daylighting of interior spaces, thereby reducing the cooling load and mechanical daylighting, has been shown to enhance employee productivity, improve child performance and learning in schools, and increase retail sales. To improve daylighting of interior spaces, building orientation and massing, location, sizing and window design, and effective use of light wells is very important. Effective use of daylighting leads to cost savings because in some cases it requires fewer light fixtures, which produces less heat, reducing HVAC system requirements and costs.
- *Lighting System Optimization and Light Colored Paints* – Computer modeling tools such as lighting simulation programs can be used to optimize lighting system design and light color paints. Proper lighting design and color selection reduces both lighting and HVAC system size and first costs, helping to offset the cost of better quality daylighting and more energy efficient light fixtures. In addition it reduces long-term lighting and HVAC operational costs.

- *High Performance Lighting* – Energy savings can be achieved by using high performance light fixtures with polished specular reflectors, energy-efficient T-8 and T-5 bulbs, high-efficiency electronic ballasts, and compact fluorescents. Moreover, using this high performance lighting can reduce the overall cost of the building.
- *High Performance Glazing* – Use of high performance low-emittance glazing and thermally broken window frames can reduce the size of building heating and cooling equipment, and can result in net project savings that can be twice as much as the added cost of the upgrading.
- *Insulated Concrete Form Systems (ICFs)* – Insulating foam blocks are filled with steel-reinforced concrete to form "high mass", earth coupled, and thermally broken super-energy efficient walls. ICFs eliminate the time and cost associated with set-up and tear-off of formwork for traditional concrete wall systems. Furthermore, they reduce the size of building heating and cooling systems.
- *Ground-source Heat Pumps* – They require about 30 percent to 40 percent less energy to operate, and the first cost for these systems was less than other traditional HVAC systems. Because it uses a small central boiler, chiller and cooling tower, and associated water treatment system. Besides the heat-pump system uses a two pipe system vs. a four pipe system in the traditional one.
- *Waterless Urinals* – Waterless urinals have a special patented design that eliminates the need for the use of water for flushing. The trap in the waterless

urinal contains a special fluid that is lighter urine. This fluid remains in the urinal while the urine passes to the drain; therefore, water supply lines and flush valves are not needed.

- *Shallow Frost Protected Foundations (SFPF)* – SFPFs use horizontal and/or vertical insulation to protect the building footing from frost. Insulation helps to raise the depth of building footing by raising the frost depth around the building. This saves both time and money because less excavation, concrete, and masonry are used in the shallow foundation walls. The US Department of Housing and Urban Development recently published manual guidelines to help builders in design and material selection of the SFPF insulations.
- *Construction Waste Reduction* – More efficient site and building design and detailing, and implementation of a few construction waste reduction strategies can save a lot of money. Construction waste can be reduced by the following key areas of the project:
  a. Site Design: Building, roadway and parking configuration Landscape and Architecture: Design and detailing
  b. Construction Management: Resource management
- *Construction Waste Recycling* – The implementation of an aggressive construction waste management plan, especially the urban areas where landfill costs are moderate to high, can result in 20 percent to 40 percent savings in construction waste hauling and disposal costs due to the elimination of costly landfill tipping fees.

2.6 The Economics of Green Buildings

Green economics is the economics of the whole world of individual needs, the earth's materials, and how they connect together harmoniously. It is mainly about use-value not exchange-value or money; quality not quantity; regeneration of individuals, communities, and environment. It is not about increasing, of either money or material.

In the 1980s American Society for Testing and Materials (ASTM) set a series of standards for building economics: (a) Life-Cycle Cost Analysis (LCCA), (b) Benefit to Cost Ratio, (c) Internal Rate of Return (IRR), and (d) Net Benefits and Payback Period. The mainly effective and commonly used one is LCCA. The most building main direct costs come from the design, construction, renovation, operation, and any related infrastructure, which can be measured by Life-Cycle Cost (LCC). This direct cost result considers running cost expenses from buildings, related occupant health and productivity, waste generations, air and water pollutions, and environmental destruction. Life-Cycle Cost Assessments (LCA) represents the running cost. Traditional buildings consider only the direct building cost, but in the sustainable buildings the running cost, actually benefit, are also included in the building economic analysis (Gottfried, 1996).

California State is number one state that applies LEED. It conducted a green building savings study and found (a) 30 percent energy reduction, (b) 30 percent to 50 percent water use savings, (c) and 50 percent to 79 percent waste use savings. The economic analysis from the 40 California certified projects is 2 Platinum, 9 Gold, 21 Silver, and 8 Certified buildings that were studied by Capital E, capital E is a premier provider of strategic consulting, technology assessment and deployment, and advisory services to firms and investors in the clean energy industry, member in term of Net Present Value (NPV), for 20 years in 2003 reflect the gains from energy consumption reduction, emissions reductions, water consumption savings, reduced waste, operations and maintenance cost savings, improved productivity and health gains that increase with increasing green feature or certification level, and green cost premium are shown in table (2-1) (Kats et al , 2003).

Table 2-1. Economics Benefits of Green Buildings (Kats et al, 2003)

Category	20-year NPV/ft^2
Energy Value	$5.79
Emission Value	$1.18
Water Value	$0.51
Waste value – (construction only)	$0.03
Commissioning Operation & Maintenance Value	$8.47
Productivity and health value (Certified and Silver)	$36.89
Productivity and health value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-years NPV (Certified and Silver)	$48.87
Total 20-years NPV (Gold and Platinum)	$67.31

2.6.1 Life –Cycle Cost (LCC)

LCC is used to measure the economic performance of buildings. It provides an analytical tool that can establish the interaction between planning, design, construction, operation, and maintenance costs. It also gives the sum of an investment over its life in terms of present value or annual value. Gottfried (1996) stated in Sustainable Building Technical Manual a definition for Life-Cycle Cost Analysis LCCA as "an increasingly accepted analytical method that calculates costs over the useful or anticipated life of an asset".

2.6.2 Life-Cycle Cost Assessment (LCA)

LCA measured the environmental impact generated from the life of materials, including raw materials extraction and processing, materials manufacture, installation, operation, maintenance, waste, and recycling management.

In a study of environmental and economically balanced building materials conducted by Lippiatt and Norris (1996), it was concluded that the methodology of LCA begins with goal scoping and identification in order to define the boundaries, followed by the analytic procedure consisting of the following four steps

1. Inventory analysis step: this step identifies and quantifies the environmental inputs and outputs.
2. Impact assessment step: this step characterizes the inputs and outputs for the previous step.
3. Impact evaluation step: this step synthesizes the environmental impact of the inputs and output

4. Improvement assessment step: this step identifies and evaluates opportunities for changes made by the inputs and outputs in the product life cycle. The last step is not necessary if the goal is to select the most environmentally preferable material.

2.6.3 Balance LCC & LCA

National Institute of Standards and Technology (NIST) with the support of Environmentally Preferable Purchasing part of the Environmental Protection agency (EPA) Program developed a decision–support software to implement the methodology of balancing economic and environmental performances. This software with the database of environmental and economic data is known as BEES (Building for Environmental and Economic Sustainability). BEES displays the environmental and economic offered by decisions alternative; Figure (2-1) below displays an example of balancing LCC and LCA for one material. For instance, Alternatives D and E are eliminated because they perform worse than Alternative B with respect to both the environmental and economics performances. Alternative A is the best environmental performance but it costs the most. Alternative C offers the best economic performance although it gives the worst environmental performance. Alternative B improves environmental performance at little increase in cost (Lippiatt & Norris, 1996).

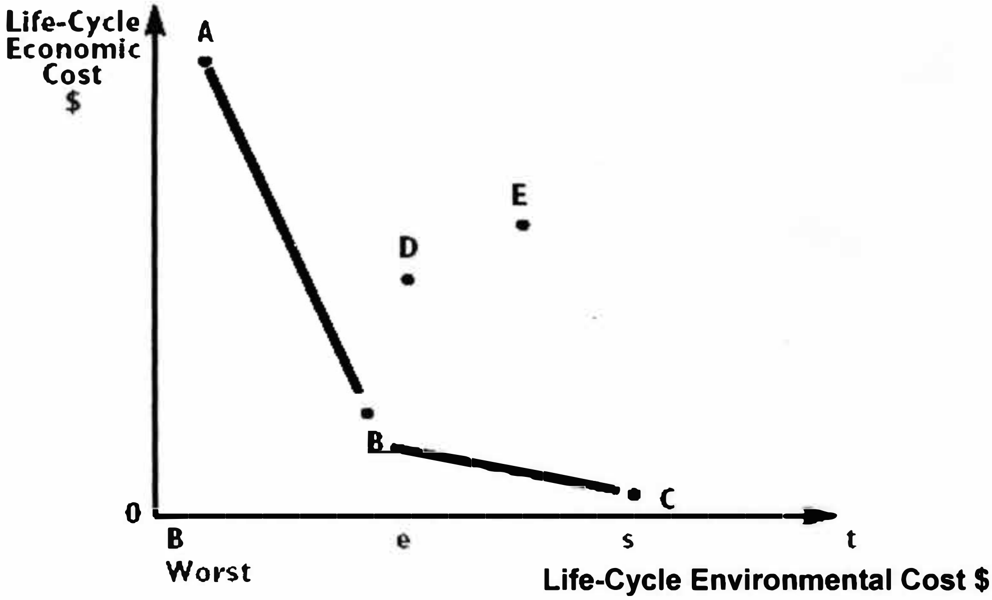


Figure 2-1. Balancing Environmental & Economic Performance
(Lippiatt & Norris, 1996)

2.7 Summary

This chapter gave an overview about green building definition, brief description of the five key elements of sustainable design: 1) Sustainable site, 2) Water efficiency, 3) Energy and atmosphere, 4) Indoor environmental quality, and 5) Materials and resources. General information about green building advantages, strategies, technologies, and economics. Then the following chapter will concentrate on Leadership in energy and environmental design as evaluation method for green buildings.

CHAPTER THREE

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

3.1 Introduction

The Leadership in Energy and Environmental Design (LEED) is identified as a standard-rating system for green buildings in the United States. LEED is developed by USGBC and is defined as "a leading-edge system for designing, constructing, operating and certifying the world's greenest buildings" (USBGC, 2005).

The purpose of the LEED rating system from the USGBC point of view (USGBC, 2005) is to:

- Facilitate positive results for the environment, occupant health, and financial return.
- Define "green" by providing a standard for measurement.
- Prevent "greenwashing" (false or exaggerated claims).
- Promote whole-building, integrated design processes.
- Educate building industry and establish design guidelines for what constitutes sustainable design practices in the U.S.
- Recognize leaders.
- Stimulate green competition.
- Establish market value with recognizable national "brand".
- Raise consumer awareness.

- Transform the marketplace.

3.2 LEED Economic

LEED takes into account not only financial outcomes but also social and environmental factors. Davis Langdon Company, a cost consulting firm, studied and evaluated the cost per square foot of 138 buildings, out of which 93 buildings are non-LEED and 45 are LEED seeking as shown in Figure (3-1). To ensure consistency they normalized the cost for time and location using the t-distribution statistical test method. They used t-distribution because the population (population is a statistical term used to refer to a set of values, including not only cases actually observed but those that are likely observable) standard deviation is unknown and has to be estimated from the LEED seeking and non-LEED seeking data. Moreover, the sample size (61 projects) is small compared to the number of construction projects. Another reason for using t-distribution is that the standard deviation is not the main goal; rather than examining the difference between LEED mean (average) and non-LEED Population mean (average), they concluded that there was no statistically significant difference between LEED population mean and non-LEED population mean. This means that any variation from any random sample from the whole population will be within the expected range, despite that the estimated standard deviation for each category is high due to the wide variation in building cost (Matthiessen & Morris, 2004).

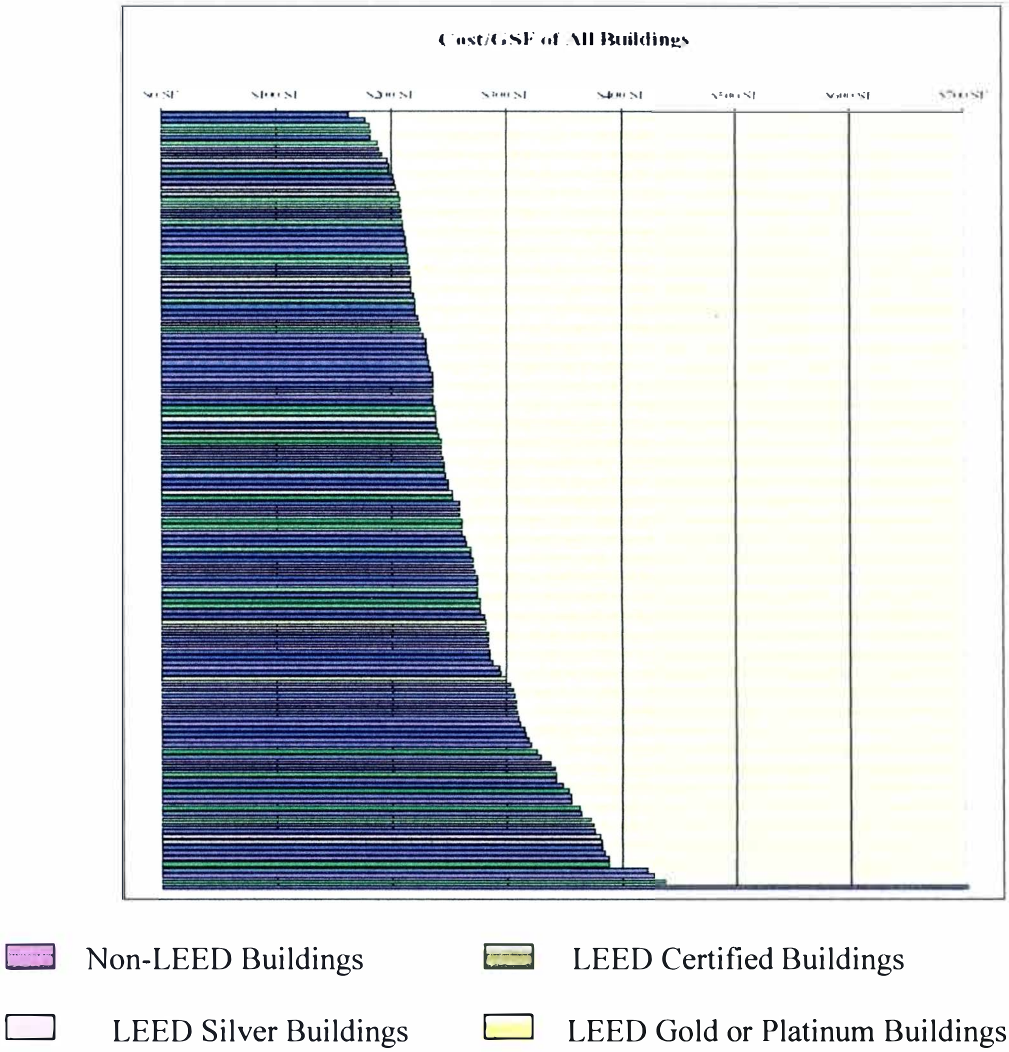


Figure 3-1. Cost Per Gross Square Foot of Non-LEED & LEED Buildings
(Matthiessen & Morris, 2004)

3.3 LEED Rating System

Green Building Rating System is a nationally accepted benchmark for the design, construction, and operation of high performance green buildings. LEED gives tools for owners and operators to have an immediate and measurable impact on their buildings' performance. For different types of buildings there are different LEED products as shown in Figure (3-2).

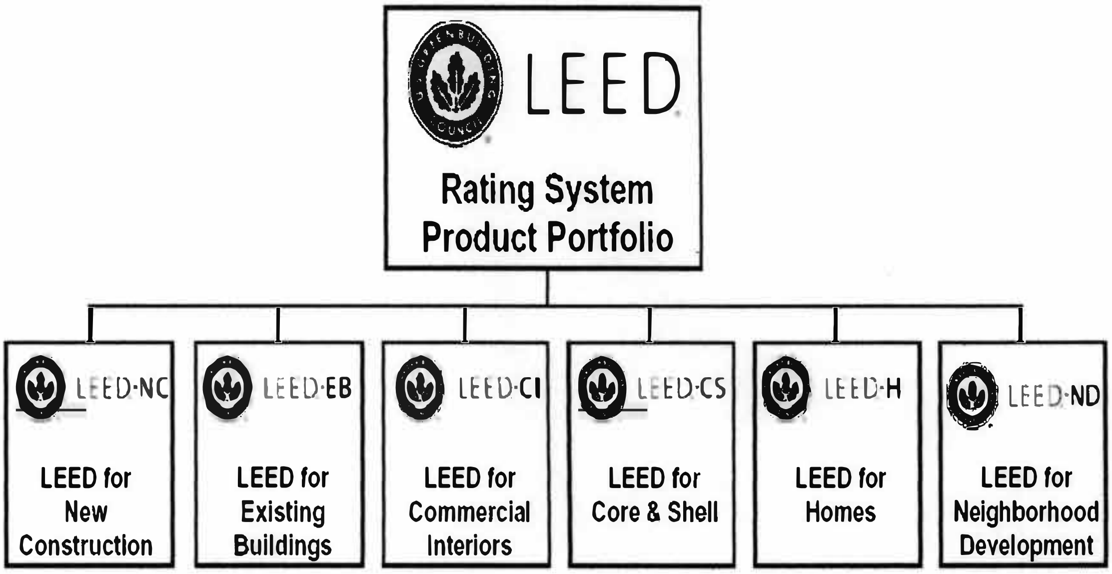


Figure 3-2. LEED Products (USGBC, 2006d)

LEED promotes a whole-building approach to sustainability by recognizing performance in the following five environmental key elements: (1) sustainable site development, (2) water savings, (3) energy efficiency, (4) materials selection, and (5) indoor environmental quality. These five keys are divided into credits. The LEED rating system identifies three sections for each credit to be achieved and each credit has one or more points.

These sections are:

1. Intent: the objective of each prerequisite or credit
2. Requirements: what must be done to earn each prerequisite or credit.
3. Technologies or strategies: Ways to achieve each prerequisite or credit

There is a fourth section for LEED-EB:

4. Submissions: it describes what must be submitted to document achievement of each Prerequisite or Credit.

The total points achieved by the project will qualify the project for a certain level of certification under its categories. There are four levels of certification: (1) Certified, (2) Silver, (3) Gold, and (4) Platinum. For the purpose of this thesis there are further details later on LEED-NC and LEED-EB.

3.4 LEED Process

The LEED process consists of three steps: (1) project registration, (2) technical support, and (3) building certification. Only buildings certified by USGBC under the LEED Green Building Rating System may refer to themselves as LEED buildings. The LEED project certification can be an asset, by receiving third party (USGBC) confirmation of achieving green principles, and by qualifying for a growing collection of local government and state enterprises. The certification process involves the following three steps: (1) project registration, (2) technical support, and (3) building certification.

3.4.1 Project Registration

The first step in the LEED process is to register the project with USGBC and receive orientation materials. Registration during the pre-design phase is highly recommended. Helpful resources are available for users such as LEED Letter Templates, Credit Interpretation Request (CIR) access, and on-line project registration as seen in Figure (3-3).

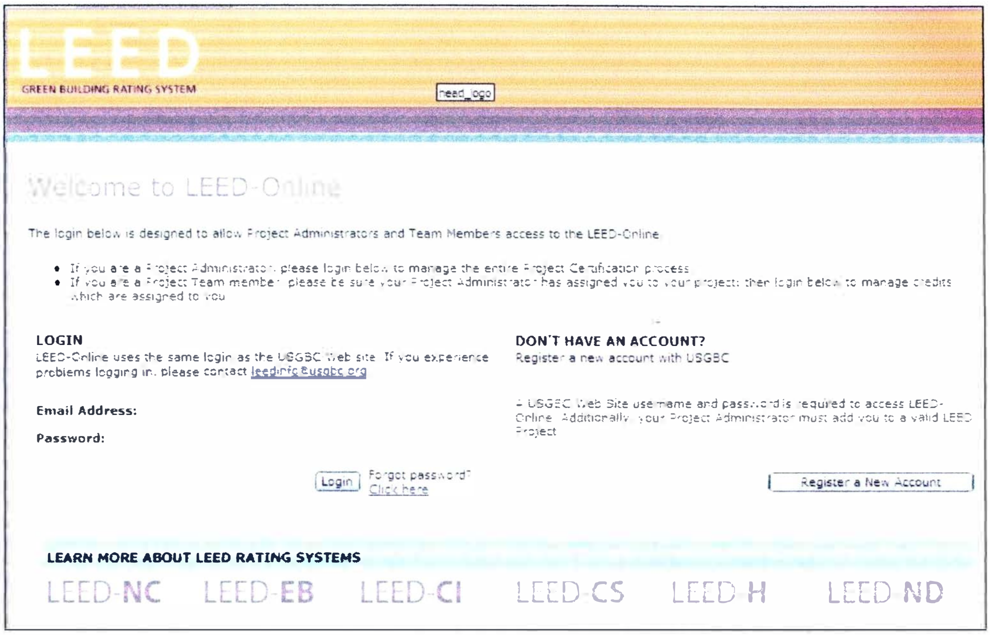


Figure 3-3. LEED On-Line (USGBC, 2006e)

3.4.2 Technical Support

The second step comes in the form of a Reference Guide and Credit Rulings. In some cases, the design team may encounter questions about the application of a LEED prerequisite or credit to the specific project. The project contact should first thoroughly consult the Reference Guide. All this support is available through the credit rulings page on the USGBC web site. If there are further questions the contact should use the following credit interpretation process:

- The project associates evaluate the intent of the credit or prerequisite in question to self-evaluate whether their project meets this intent.
- The project associates review the LEED Credit Rulings Page for a previously logged Credit Interpretation Request (CIR) that may give a hand to answer their exacting question. All LEED project contacts have access to this page.

- The project contact may suggest an on-line CIR to the USGBC, if no similar or relevant credit interpretation has been logged.

The USGBC Credit Ruling Committee posts its decision on the Credit Rulings Page within two to five weeks.

3.4.3 Building Certification

The third step is to give the building the attainable certificate; in order to ensure qualification for the specific certificate the application review must be done. This review can take anywhere from six weeks to several months. There are several opportunities for response and request throughout the review stages (administrative, preliminary technical, and final technical reviews).

3.5 LEED Certification

LEED certification is presented and verified by trained professionals, and it has an understandable and updated system; as a result it is the most commonly used rating system in the U.S., even though like any other system there are some benefits and barriers for the LEED certification.

3.5.1 Advantages of LEED Certification

Using LEED ensures that the building will have a low negative impact and a high positive impact on its occupants and the environment, besides the economic benefit over the life of the building. There are many other benefits (USGBC, 2005) such as:

- Third party confirmation of achievement
- Qualify for growing array of state and local government incentives
- Contribute to increasing knowledge base
- LEED certification sign on building
- Official certificate
- Receive marketing exposure through USGBC web site, case studies, and media announcements
- LEED facilitates integrated design from start to finish; it encourages design teams to use a holistic approach and to measure progress.

3.5.2 Disadvantages of LEED Certification

LEED is a new technology in the construction industry, which leads to unfamiliarity and lack of experience for most parties involved in the construction. Below are some disadvantages and techniques to avoid them:

1. Problems with the LEED documentation process: to overcome this barrier USGBC offer online project registration. This thesis reduced documentation time and procedure for users instead of recording all points they can only choose the specific number of points that achieve the targeted certificate.
2. Lack of education. To overcome this barrier USGBC organizes training workshops in educational institutes and wherever needed.
3. Costs associated with LEED certification. To defeat this weakness some states, such as Oregon, give a tax credit to offset the cost of certification.

In order for a project to become certified, proof of each pre-requisite and credit must be documented and approved by the USGBC. In the current practice, all processes are paper documented, which makes it so complicated due to the fact that it is difficult to make immediate changes, beside that it is time intense and needs more effort. That practice is time consuming and has potential of making errors.

3.6 LEED for New Construction (LEED-NC)

LEED for new construction was the first rating system in the market. The first version was launched in 1998, while the last version, LEED-NC version 2.2 was released in 2005 (USGBC, 2006f). LEED-NC addresses the whole building and building site that covers the design and construction process for new construction and major reconstruction of buildings. LEED–NC is used also for building upgrades, under the condition of less than 50 percent of the building occupants remain in the building during the building upgrade.

Most categories contain prerequisites. All seven prerequisites must be met in order to qualify for any certification level. In addition to the five environmental categories, there is also an "Innovation and Design Process" category. Each category has a certain amount of credits. A credit may have one or more points depending upon the level of specification and the requirements. A detailed checklist for LEED-NC is indicated in appendix (A) and it is also available on the USGBC website (USGBC, 2006g).

3.6.1 Point Distributions

There are 69 possible points for LEED-NC; they are distributed as follows:

- Sustainable Sites: 8 credits, 14 points
- Water Efficiency: 3 credits, 5 points
- Energy and Atmosphere: 6 credits, 17 points
- Materials and Resources: 7 credits, 13 points
- Indoor Environmental Quality: 8 credits, 15 points
- Innovation: I credit, 4 points
- LEED Accredited Professional: I credit, 1 point

As mentioned before, the different level of specification and requirements create a difference between the total number of points and credits in some categories; for example, in Sustainable Sites credit 4, has four sub-credits that lead to a total of four points for one credit as shown in Table (3-1).

Table 3-1. LEED-NC Credit Points Distribution Example

Credit	Sub-Credit	Points
SS Credit 4: Alternative Transportation	4.1 Public Transportation Access	1
	4.2 Bicycle Storage & Changing Rooms	1
	4.3 Low-Emitting and Fuel-Efficient Vehicles	1
	4.4 Parking Capacity	1
TOTAL		4

The four levels of the LEED-NC certification are as follows: (1) Certified Level 26 to 32 points (about 38 percent of total points), (2) Silver Level 33 to 38 points (about 48 percent of total points), (3) Gold Level 39 to 51 points (about 57 percent of total points), and (4) Platinum Level 52+ points (about 75 percent of total points).

The pie in Figure (3-4) below represents LEED categories and percentage of points in each one out of the total possible points. More than one quarter of the points are for energy and atmosphere while 6 percent is for innovative and design process. This means that there is no consistency of the points' distribution because the main idea about green buildings is to be environmental friendly; the energy and atmosphere and indoor environmental quality are about half of the total points.

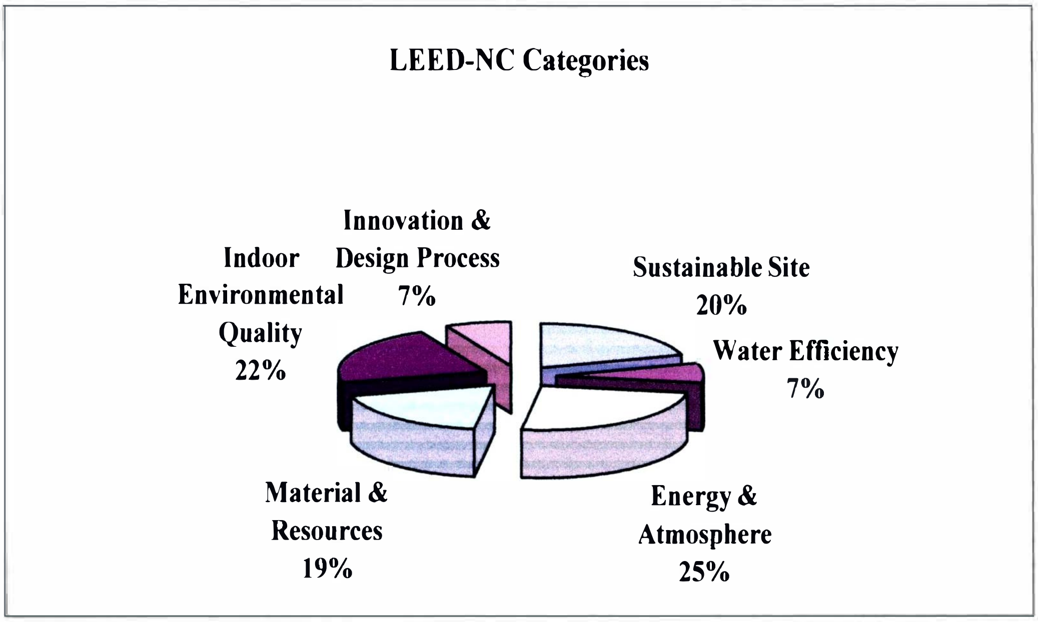


Figure 3-4. LEED for New Construction Categories

3.6.2 LEED-NC Feasibility Study

Matthiessen and Morris (2004) conducted a comprehensive cost database and budget methodology for green buildings. In their study; they analyzed the cost for each point applicable to the selected project and the level of point achievement for 61 LEED seeking projects. The (y) axis represents the percentage of the points that may be achieved by the projects; the (x) axis represents the LEED-NC points. The following eight Figures (3-5a) through (3-10) show the percent of projects out of the 61 projects that they expect to qualify for the LEED-NC points. LEED-NC points would be counted in the project only if it was included in the design and budget of that project.

In the following Figures, green bars represent projects aiming for Certified, silver indicate projects seeking Silver, and Gold bar encompasses both Gold and Platinum certifications.

In the Sustainable Site Figure (3-5a) the first four credits are for Site Selection. It is clear that credit 1.0 Site Selection; credit 4.1 Mass Transit is the most popular; while credit 3.0 is rarely achieved.

The other credit is for Site Design, which is shown in Figure (3-5b); most of these credits being attempts at a minimal cost, and most project attempts credit SS 8.0 Light Pollution.

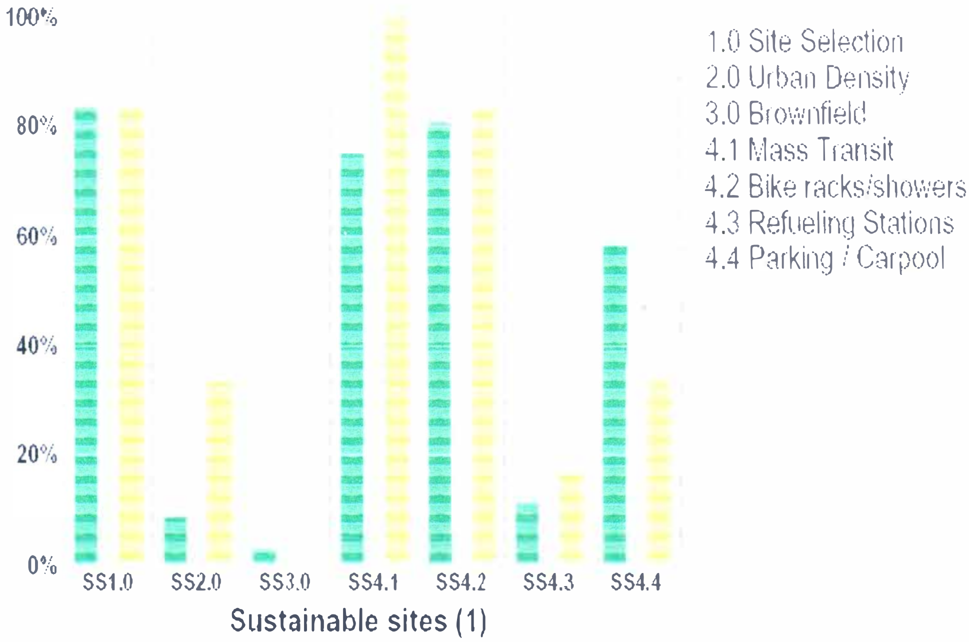


Figure 3-5a. Sustainable Site Selection Points (Matthiesen & Morris 2004)

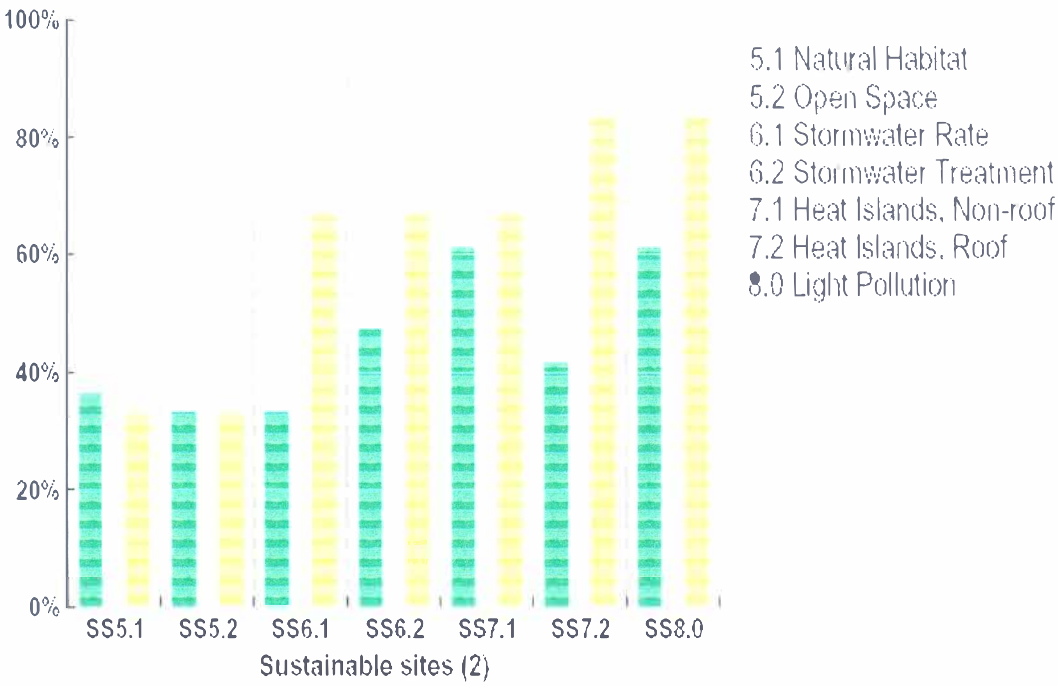


Figure 3-5b. Sustainable Site Design Points (Matthiesen & Morris 2004)

In the water efficiency category, Figure (3-6), point WE 1.1, Reduce Irrigation by 50 Percent, is easy to achieve when landscaping does not include turf grass by designing high-efficiency irrigation system at a minimal cost. On the other hand, the WE 1.2, No Permanent Irrigation, requires stronger commitment.

Generally, Certified and Silver projects tended to achieve WE 1.1, Irrigation, and WE 3.1, Water Used Reduction, at no additional cost using standard technologies, while Gold and Platinum projects tended to achieve all 5 points, at reasonable cost but with significant commitment.

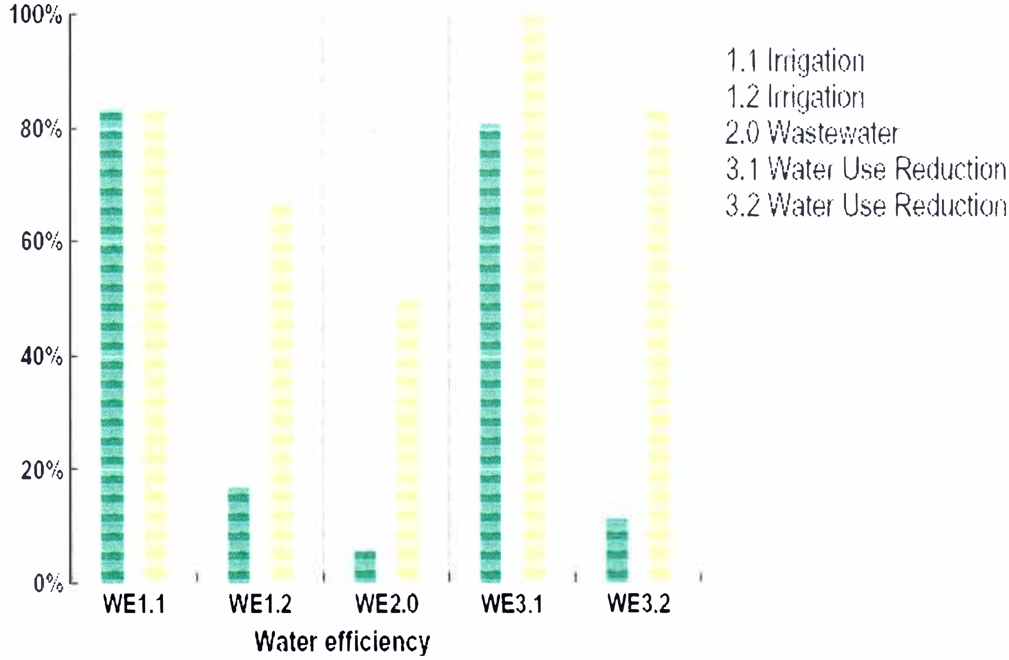


Figure 3-6. Water Efficiency Points (Matthiesen & Morris 2004)

On the energy and atmosphere Figure (3-7) the first two or three energy credits for optimizing energy used reduction points. The minimum energy cost reductions percentage for the first three points are 10.5 percent, 14 percent and 17.5 percent respectively. For new buildings and for renovations the percentages are 3.5 percent, 7 percent and 10.5 percent respectively, which can be achieved by relatively little cost. Also the additional commissioning point (EA 3.0) represents a reasonable added cost but it requires early commitment. The measurement and verification performance point (EA 5.0) mostly targets laboratories and large buildings with strong facility departments because it needs a high monitoring level.

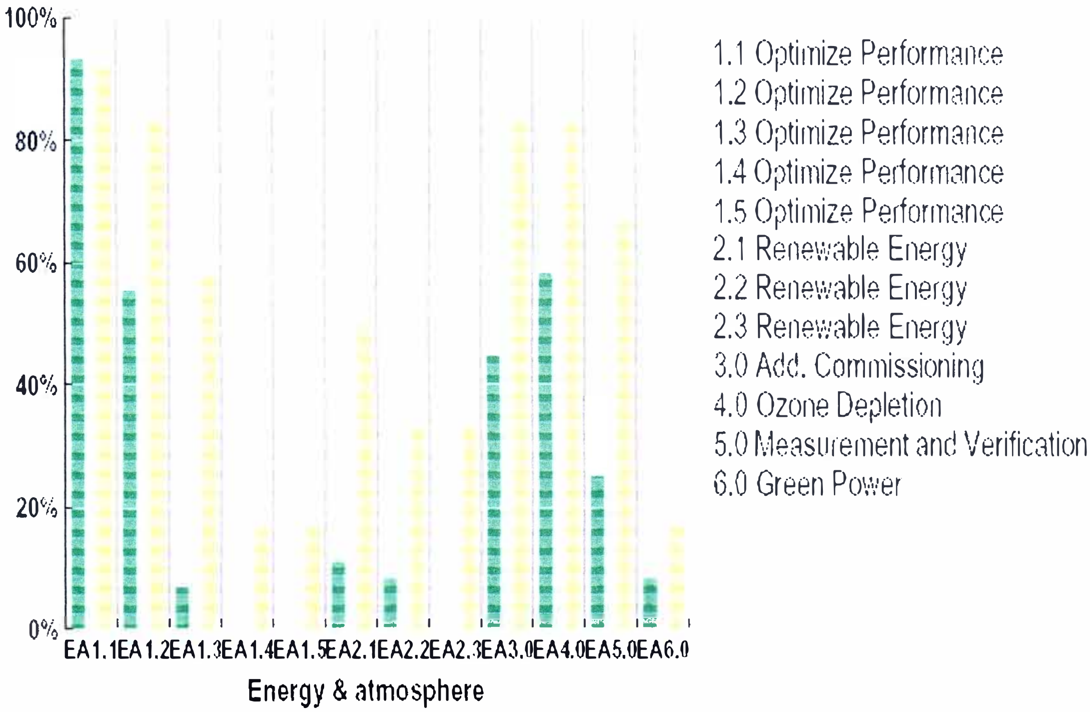


Figure 3-7. Energy and Atmosphere Points (Matthiesen & Morris 2004)

In material and resources category shown in Figure (3-8) Certified and Silver projects tend to achieve 4 out of 13 points, which are MR 2.1&2.2 for waste management, MR4.1 recycled content and MR 5.1 locally manufactured material, because actual specification for this points is neither difficult nor costly for most of the projects. Gold and Platinum achieve 8 or more. Most projects are unable to meet the reused and renewable materials points (MR 3.1&3.2 and MR. 6) because of the percentage of building materials required and the cost.

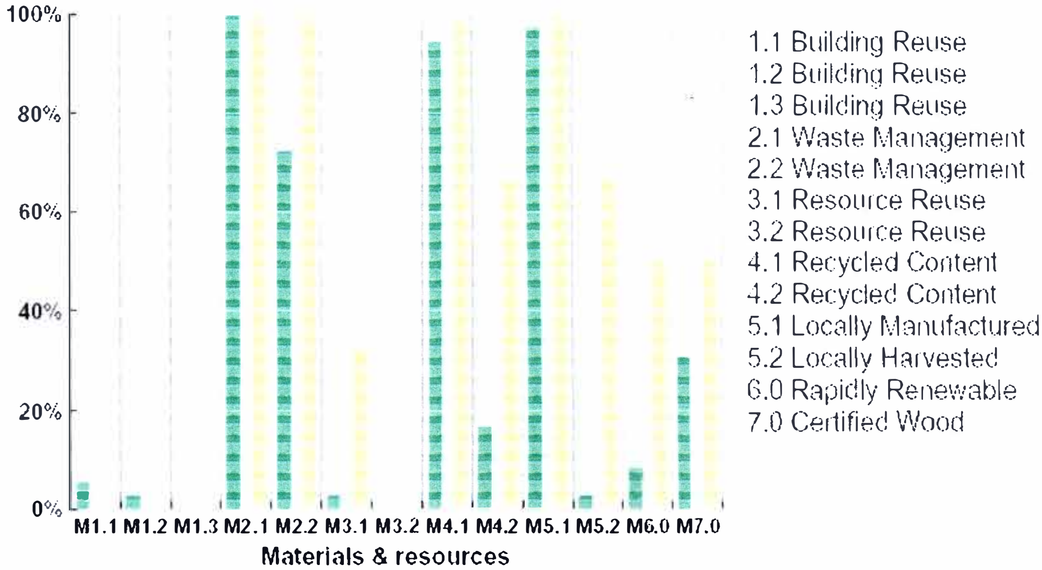


Figure 3-8. Material and Resources Points (Matthiesen & Morris 2004)

The most points sought are the indoor environmental quality category points; because they have no or little cost impact but they need strong commitment. Figure (3-9a) shows the IEQ points that can be met at approximately no cost, while Figure (3-9b) shows the points with small added cost.

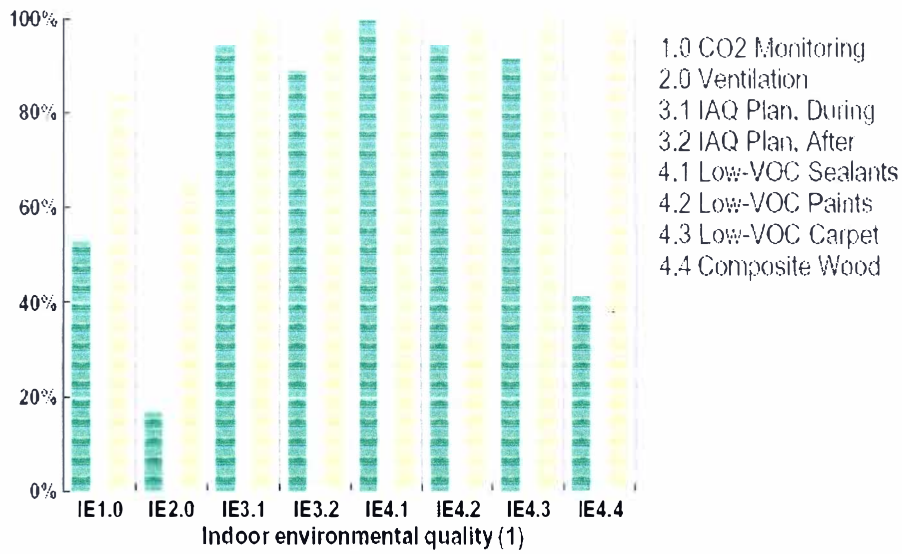


Figure 3-9a. Indoor Environmental Quality Points (Matthiesen & Morris 2004)

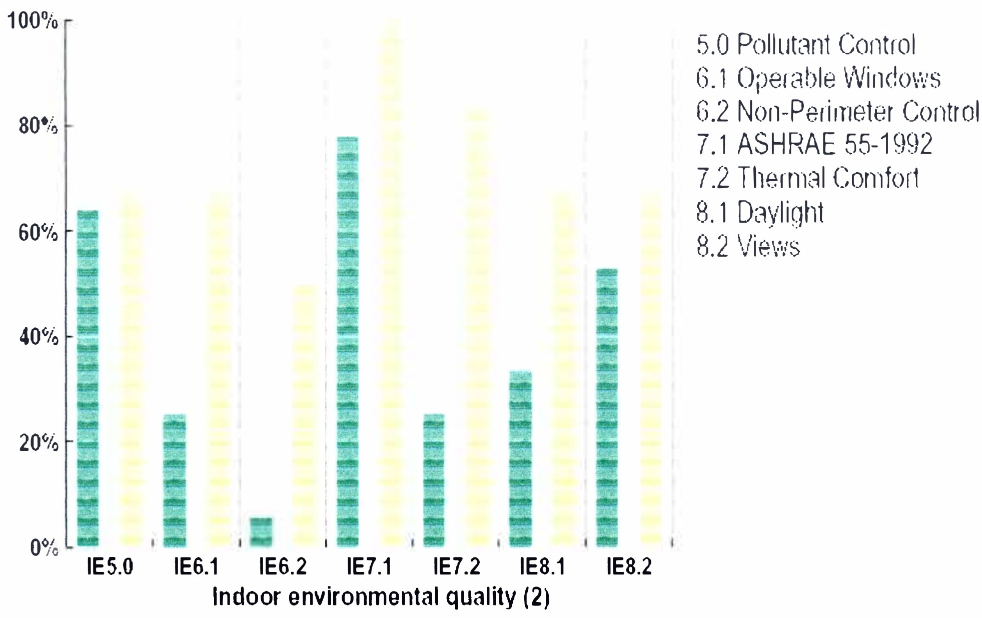


Figure 3-9b. Indoor Environmental Quality Points (Matthiesen & Morris 2004)

The last categories Figure (3-10), innovation and design are designed to allow projects to earn points for other items that are not included in any other design points.

To achieve this point there are two ways, either to incorporate new things not already addressed in the design or to go over the above requirement level for specific points. Almost all projects are achieving ID 2.0 LEED Accredited Professional Point, at no cost.

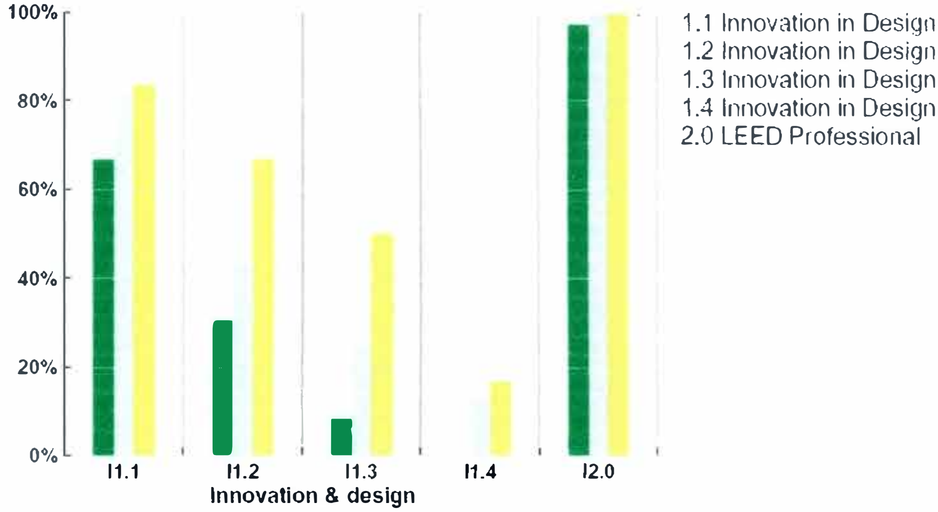


Figure 3-10. Innovation and Design Points (Matthiesen & Morris 2004)

3.7 LEED for Existing Buildings (LEED-EB)

LEED-EB covers re-certification of existing buildings for both buildings originally certified under LEED-NC and buildings originally certified under LEED-EB. LEED-EB minimizes environmental impacts while maximizing operational efficiency.

3.7.1 LEED-EB Rating System

The LEED-EB Rating System is a set of voluntary performance standards for the sustainable upgrades and operation of buildings not undergoing major renovations;

optimizing use of water and energy, purchasing of environmentally preferred products, waste stream management, and ongoing indoor environmental quality (IEQ). In addition, LEED-EB provides sustainable guidelines for whole-building cleaning/maintenance, recycling programs and systems upgrades to improve building energy, water, IEQ and materials use (USGBC, 2006d).

LEED-EB certification is based on actual building operating performance, not design expectations. The LEED-EB certification application must provide building performance data demonstrating that the building operation meets the LEED-EB Prerequisites and credits attempted.

Most categories contain prerequisites. All fourteen prerequisites must be met in order to qualify for any certification level.

In addition to the five environmental categories, there is also an "Innovation Upgrades, Operation and Maintenance" category. Similar to LEED-NC, a credit may have one or more points. A detailed checklist for LEED-EB is provided in appendix (B) and it is also available on the LEED website (USGBC, 2006h).

3.7.2 LEED-EB Point Distribution

The total possible points are 85, and they are distributed as follows:

- Sustainable Sites: 7 credits, 14 points
- Water Efficiency: 3 credits, 5 points
- Energy and Atmosphere: 6 credits, 23 points
- Materials and Resources: 6 credits, 16 points
- Indoor Environmental Quality: 10 credits, 22 points

- Innovation: I credit, 4 points
- LEED Accredited Professional: I credit, 1 point

The four levels of the LEED-EB certification are (1) Certified 32 to 39 points (about 38 percent of the total points), (2) Silver 40 to 47 points (about 47 percent of the total points), (3) Gold 48 to 63 points (about 56 percent of the total points), and (4) Platinum 64 to 85 points (about 75 percent of the total points)

Same as LEED-NC, the difference between the total number of points and credits in some category is the result of the specification's level and the requirements' differences. For example, in IEQ credit 4 has two sub-credits, which lead to a total of two points for one credit as shown in Table (3-2)

Table 3-2. LEED-EB Credit Points Distribution Example

Credit	Sub Credit	Points
IEQ Credit 4: Documenting Productivity Impacts	1.1 Absenteeism & Healthcare Cost Impacts	1
	1.2 Other Productivity Impacts	1
TOTAL		2

The pie, in Figure (3-11) below, represents LEED-EB categories. It shows the percentage of points in each slice out of the total possible points, and the maximum points for each category. Note that the percentage for each category is almost the same as in LEED-NC, though there is a slight increase in indoor environmental quality category according to the decrease of sustainable site selection. This is reasonable because for existing building the site is already being selected.

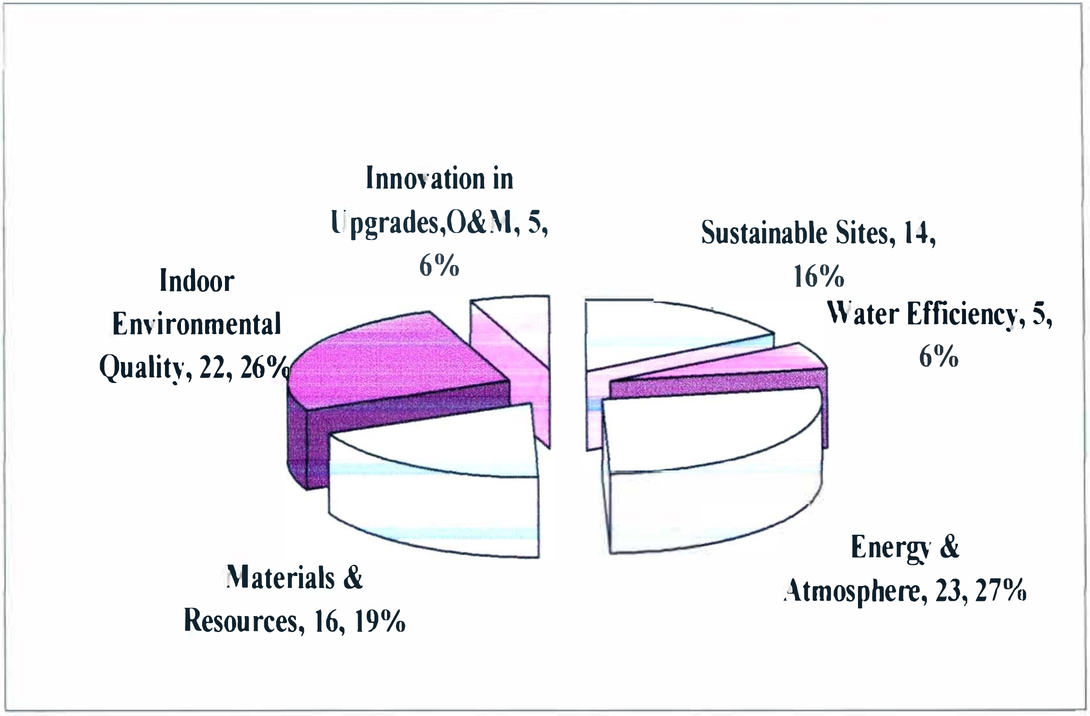


Figure 3-11. LEED for Existing Buildings

3.7.3 Use of LEED-EB

LEED-EB can be used to certify the following types of buildings as in LEED-EB Version 2 (USGBC, 2006d):

- LEED-NC certified buildings seeking ongoing re-certification. Filling applications require performance data for the period between the previous LEED-NC certification and the current application "performance period".
- LEED-EB certified buildings seeking ongoing re-certification. Filling applications require performance data for performance period.

- Non-LEED buildings seeking initial certification and ongoing re-certification. Filling required some credits performance data for the most recent three months of building operations.

A re-certification application needs to be filed at least once every five year to maintain LEED-EB certifications, and it can be filed as often as once per year.

3.8 LEED-NC and LEED-EB Comparison

Despite the differences in the points attained, there are some main characteristics that distinguish LEED-NC from LEED-EB.

LEED-NC is:

- One time event
- Based on capital budgets
- Process ends with design and construction

LEED-EB is:

- Ongoing upgrades, operations, and maintenance
- Based on operating budgets
- Continuous process with re-certification every 1-5 years

3.9 LEED Certification Cost

Costs data are variable depending on the building type, region, size, and any other criteria that may be involved in the project. Northbridge Environmental Management Consultants (NEMC) (2003) determined that LEED adds between 4 percent and 11 percent to construction costs. More than half of these costs are for green design and construction feature; the remaining costs fall outside the range of construction cost known as "soft cost", which is the focus of this thesis. Soft costs include incremental costs for design, commissioning the project, Energy Modeling for the project, documenting compliance with the various criteria selected, and LEED application fees.

3.9.1 Design Cost

Participating in the LEED process adds time and effort to the design and specification phase of a project because the designers or the LEED consultant must assess the project's design and specifications to reflect any additional requirements in order to attain the LEED Certification. R.S. Means, providing costing data for all aspects of the construction industry, estimates that additional design cost for green buildings represents 5 percent of the project construction cost as illustrated in table (3-3). The range for additional green buildings design cost is 0.4 percent to 0.6 percent, estimating the traditional design cost range 8 percent to 12 percent of construction cost (NEMC, 2003).

Table 3-3. Sub-Total Estimated Soft Cost

Type of Cost	Estimated Cost percent*	Purpose
Design Cost	0.5 percent	Estimate required additional design cost for green buildings
Commissioning	1 percent	Basic commissioning required
Documentation	0.7 percent	Extensive documentation required to indicate how each LEED point was met.
Energy Modeling	0.1 percent	Estimated savings beyond national energy code is required.
Total	2.3 percent	

* Estimated cost as a percentage of the construction costs.

3.9.2 Commissioning

Commissioning is a prerequisite for LEED certification. It involves an outside team, not part of the design and construction project team, to ensure the compliance of fundamental building elements and systems with the LEED guidelines. There is an extra point for additional commissioning.

Commissioning costs depend on two main variables, which are complexity and size of the project. A higher cost can be for smaller and more complex buildings such as laboratories. NEMC (2003) found that the commissioning cost is about 1 percent of the total construction cost as shown in table (3-3), for this reason various sources estimate commissioning costs to be in the range of 0.5 percent to 1.5 percent. These sources include:

- R.S. Means estimation between 0.5 percent and 0.75 percent of construction cost.
- The Weidt Group found that commissioning costs ranged between 0.75 percent and 1.5 percent of total construction costs.
- The Oregon Office of Energy stated that a typical range for commissioning was 0.5 percent to 1.5 percent of total design and construction costs.

3.9.3 Energy Modeling

Energy modeling is another prerequisite of LEED process. It is a smaller part of the soft costs. Energy modeling adds about 0.1 percent to the total construction costs as presented in table (3-3) (NEMC, 2003).

3.9.4 Documentation Fees

Documentation is the largest obstacle that project teams have encountered in working with the LEED process. A proper LEED documentation is necessary for certification. The costs for this documentation depend on the experience of the team documenting the LEED process despite of the project size.

After conducting several researches NEMC (2003) identified documentation costs to be between $8,000 and $70,000 per project, which averaged 0.7 percent of construction costs with a range from 0.5 percent to 0.9 percent for typical projects. Table (3-3) present summary of the documentation cost.

3.9.5 Registration and Certification Fees

Project registration is the first step towards earning LEED certification, and provides access to LEED online and credit interpretations. The cost for registration and certification is cheaper for USBGC members. Certification cost depends on the size and building type (i.e., LEED-NC is different than LEED-EB). The details of these fees are provided on table (3-4).

There is also another optional soft cost, which is the green building consultant cost. This cost is applied when contracting a consultant to work throughout the process to secure materials, bid specifications, and document points. This cost is not included in the calculation of the total soft cost, because this is an optional cost. Table (3-4) shows registration and certification costs for LEED-NC and LEED-EB.

Table 3-4. Registration and Certification Cost for LEED-NC and LEED-EB (USGBC, 2006i)

Fees Categories			Fixed Rate		
Registration Fees for LEED-NC & LEED-EB		Member	$450.00		
		Nonmember	$600.00		
Certification Fees			Less than 50,000 Sq.Ft. Fixed Rate	50,000 – 500,000 Sq.Ft. Based on Sq.Ft.	More than 500,000 Sq. Ft. Fixed Rate
LEED-NC	Design Review	Member	$1,250.00	$0.025/Sq. Ft.	$12,500.00
		Nonmember	$1,500.00	$0.03/Sq. Ft.	$15,000.00
	Construction Review	Member	$500.00	$0.01/Sq. Ft.	$5,000.00
		Nonmember	$750.00	$0.015/Sq. Ft.	$7,500.00
LEED-EB	Initial Certification Review	Member	$1,250.00	$0.025/Sq. Ft.	$12,500.00
		Nonmember	$1,500.00	$0.030/Sq. Ft.	$15,000.00

Accordingly, the total soft cost calculation from tables (3-3) and (3-4) for LEED-NC and LEED-EB will be as follows:

- For LEED-NC USGBC member = 2.3 percent of total construction cost + registration fees ($450) + Design review (either $1,250, $0.025/Sq.Ft, or $12,500) + Construction review (either $500, $0.01/Sq.Ft, or $5,000)

- For LEED-NC USGBC non member = 2.3 percent of total construction cost + registration fees ($600) + Design review (either $1,500, $0.03/Sq.Ft, or $15,000) + Construction review (either $750, $0.015/Sq.Ft, or $7,500)
- For LEED-NC USGBC member = 2.3 percent of total construction cost + registration fees ($450) + initial certification review (either $1,250, $0.025/Sq.Ft, or $12,500)
- For LEED-NC USGBC non member = 2.3 percent of total construction cost + registration fees ($600) + Design review (either $1,500, $0.03/Sq.Ft, or $15,000)

3.10 Management Information System (MIS)

Hegazy (1993) defines MIS as "a computer system capable of integrating data from many sources to provide data and information useful to support operations and decision-making." Management Information is normally produced from a shared database that store data from many sources. Elmasri and Navathe (2000) categorize the database management system DBMS into six criteria which are:

1. Data model in which the database management system is based. DBMS will categorize as rational, object, object-rational, hierarchical, network, and other. This thesis will use the rational data base model
2. Number of users supported by the system single-user systems, personal computer, or multi users system.
3. Number of sites – if the data is stored at single computer, the site is identified as a centralized DBMS and can support multiple users; it is named as a

distributed DBMS when is it distributed over many sites connected by computer network.

4. DBMS cost depends on the package cost.
5. Types of access path options for storing files.
6. DBMS purpose; either general or special.

Database design is defined as “designing the structure of database in a given environment of users and applications such that all users ‘data requirements and all applications’ process requirements are ‘best satisfied’” (Batini, et al., 1986).

According to Storey and Golstein (1993) database design is normally divided into four segments as described below:

1. Requirements specification: focuses in the information needed by different groups.
2. Conceptual design: expresses all information requirements and specifications of the processing or use of the information form of DBMS.
3. Logical design: translates the conceptual schema into the logical data model of the selected DBMS.
4. Physical database design: transforms the logical data model design into suitable hardware and DBMS form to help determine the data storage structure and access paths.

Relational databases are commonly used in the construction industry because it is a simple and powerful relational operator and applies simple structures (tables) without having to predefine the data interrelations, it is not costly, and does not consume time. Moreover, it can store and arrange a lot of data.

The data stored in relational databases can be accessed and queried by using a language named Structure Query Language (SQL). SQL is a language that controls user access by specifying security constraints. It allows sophisticated data management processes to be performed on databases that are based upon highly orthogonal yet simple principles (Kibert & Hollister, 1994).

Therefore, this research will employ the database techniques in designing and implementing the required certificate level or points databases. The design processes commence with conceptual-to-physical modeling and end by data mapping and entering. The design and development steps are explained in detail in Chapter Three

3.11 Summary

This chapter gave an overview about LEED rating systems and certification levels focusing on LEED-NC and LEED-EB was provided, as well as the feasibility study for the hard (construction) cost for LEED-NC. Moreover, the total soft cost associated with LEED, which received the most consideration, mainly in smaller projects because it may discourage projects from actually seeking LEED certification. The management information system was also outlined.

To ensure that project goals, and featured levels of certification are met within the project budget, the collaboration and integration among building and design professionals should begin as early as the conceptual phase of the project, as well as the selection of all design construction professionals.

As a conclusion and based on the comprehensive literature review that has been fulfilled in this chapter, it was found that the need of a computer model that automates the process of selecting, identifying certification type, and calculating associated soft cost is needed to facilitated the documentation process.

CHAPTER FOUR

MODEL DEVELOPMENT METHODOLOGY

4.1 Introduction

This chapter illustrates the methodology used in developing the computer model that automatically selects LEED certification for new or existing building projects. The model's database development process is obtained from Elmasri and Navathe (2001), and Alkass and Jrade, (2002). This process is divided into two phases: (1) the conceptual modeling phase and (2) the implementation phase. The conceptual phase consists of data and functional requirements, besides the conceptual schema; while the implementation phase consists of logical and physical design. The different features of the conceptual model phase will be discussed in this chapter, while the implementation phase will be discussed later in Chapter Five.

The data modeling is preceded by model planning and analysis. Planning stands for the advantage of the model. Moreover, it is convenient and informative because it helps the user to easily identify and select the specific credits in order to achieve the particular certification level. Analysis of the model requirement is fulfilled by the literature review.

In order to establish the conceptual design, a model outline and its components are designed. Subsequently, a conceptual schema is developed. The conceptual schema is a brief description of the data requirements of users and includes detailed description of entities, relationships, and attributes (Elmasri and Navathe, 2000). Schema is displayed using a graphical presentation known as Entity- Relationship (ER) diagram. Furthermore, all the modules and calculations for the new and existing buildings that are used in the system will be clarified. At the end, the methodology data flow will be explained.

4.2 Model Outline

In order for users to get the output, they have to do data input and to do some selection constraints or criteria (the user requirement). Accordingly, the model will be able to analyze the data and produce the output. These are described below; additionally the model outline is shown in Figure (4-1).

4.2.1 Input

The input into the model includes information about the project such as: Project Name, Project Address, Owner Name, Total Area, Total Cost, Area per Sq Feet, Architect, Estimator, Date, etc.; however, Total Area and Total Cost are the most important inputs for the proposed model, without which the data analysis cannot take place and the results cannot be generated. Furthermore, the user has to select the credits or points that he wants to achieve in the project from the six LEED categories which are: (1) Sustainable Site, (2) Water Efficiency, (3) Energy Efficiency, (4) Indoor Environmental Quality, (5) Material and Resources, and (6) Innovative.

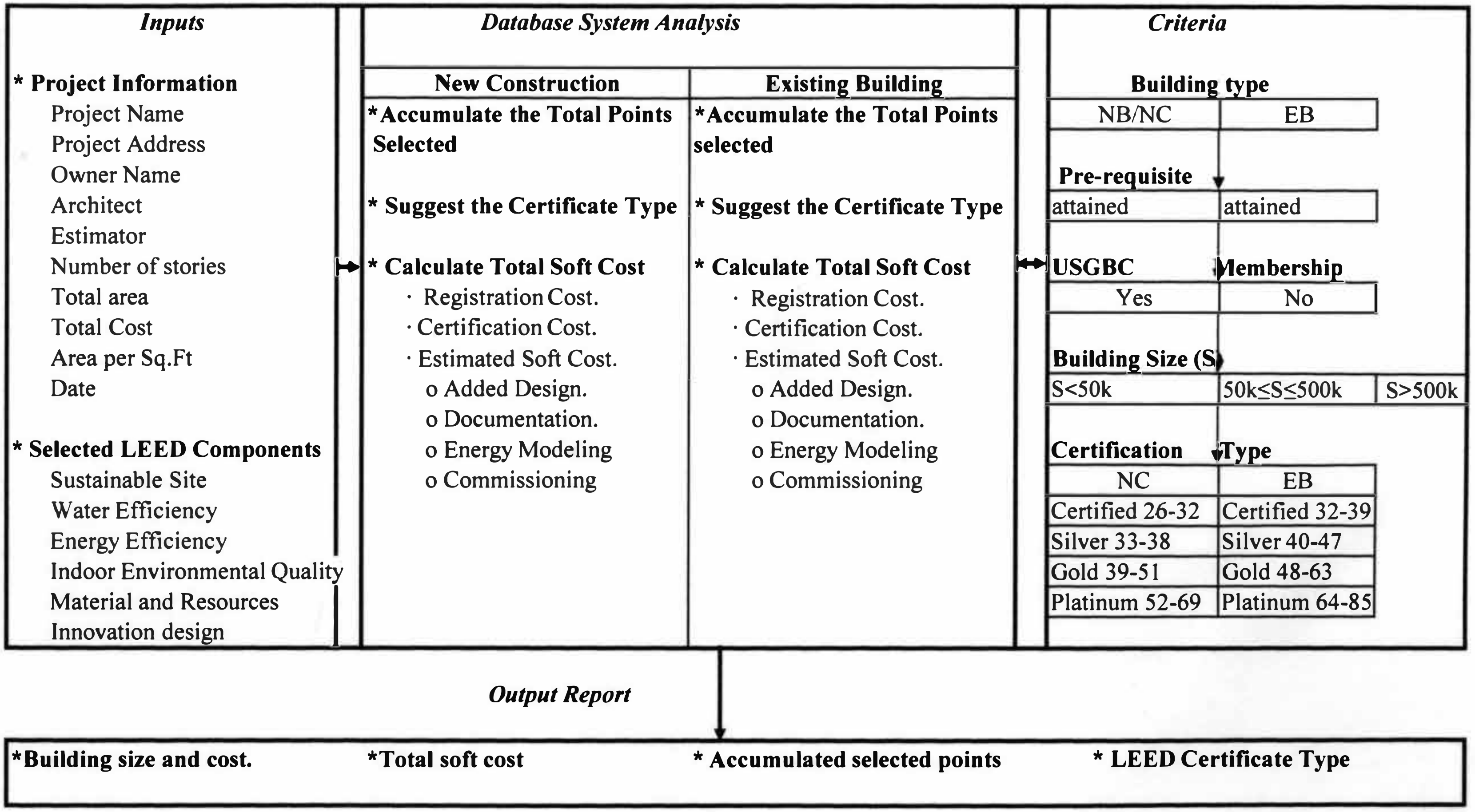


Figure 4-1. Model Outline

4.2.2 Database Analysis and Criteria

The database analysis consists of all calculations required to generate the output. In the proposed model the analysis is further divided into two parts: 1) new construction, and 2) existing building.

The analysis is done separately depending on whether we defined the calculations for new building or existing one. The criteria are also different for these two types of analyses. Criteria are some specific conditions which, when met, certain calculations are executed on specific data, as explained earlier in Chapter Three. The results of these calculations can be an output or an input to a different module in the model.

4.2.2.1 New Construction Criteria and Computation

There are 4 specific criteria for new construction buildings:

1. Prerequisites for the LEED Category: the 7 new building prerequisites that are shown in table (4-1) the code column is written as it appears in the USGBC project checklist (USGBC, 2006g). These prerequisites have to be met before the user will be able to select the LEED components.
2. Building Size: part of the certification cost calculation is based on the building area. There are three size categories for the building; these categories are shown in table (3-4):
    a. Building Area Less than 50,000 Sq. Ft.
    b. Building Area between 50,000 Sq. Ft. and 500,000 Sq.Ft.

c. Building Area More than 500,000 Sq. Ft.

Table 4-1. New Construction Prerequisites

Number	Code	Description
1	SS Prerequisite 1	Construction Activity Pollution Prevention
2	EA Prerequisite 1	Fundamental Commissioning of the Building Energy Systems
3	EA Prerequisite 2	Minimum Energy Performance
4	EA Prerequisite 3	Fundamental Refrigerant Management
5	MR Prerequisite 1	Storage & Collection of Recyclables
6	IEQ Prerequisite 1	Minimum IAQ Performance
7	IEQ Prerequisite 2	Environmental Tobacco Smoke (ETS) Control

3. Number of LEED Components Selected: this will affect the expected type of certification. Each certification type has a minimum and maximum number of points. The total number of points achieved has to be within these ranges as shown below in table (4-2).

Table 4-2. New Construction Certification Level

Type	Minimum	Maximum
Certified	26	32
Silver	33	38
Gold	39	51
Platinum	52	69

4. USGBC Membership: the status of the project owner will affect the calculation of the registration and certification cost; for members cost will be less as shown in table (3-4).

4.2.2.2 Existing Building Criteria and Computation

There are 4 specific criteria for existing buildings:

1. Prerequisites for the LEED category: the prerequisites for LEED Category consist of 14 existing building prerequisites that are shown in table (4-3). These prerequisites have to be met before the user will be able to select the LEED components.
2. Building Size: part of certification cost calculation is based on the building area. There are three size categories for the building, these category as shown in table (3-4) which are:
   a. Building Area Less than 50,000 Sq. Ft.
   b. Building Area between 50,000 Sq. Ft. and 500,000 Sq.Ft.
   c. Building Area More than 500,000 Sq. Ft.
3. Number of LEED Components Selected: this will affect the expected type of certification. Each certification type has a minimum and maximum number of points. The total number of points achieved has to be within these ranges as shown in table (4-4).

Table 4-3. Existing Building Prerequisites

Number	Code	Description
1	SS Prerequisite 1	Erosion & Sedimentation Control
2	SS Prerequisite 2	Age of Building
3	WE Prerequisite 1	Minimum Water Efficiency
4	WE Prerequisite 2	Discharge Water Compliance
5	EA Prerequisite 1	Existing Building Commissioning
6	EA Prerequisite 2	Minimum Energy Performance-Energy Star 60
7	EA Prerequisite 3	Ozone Protection
8	MR Prerequisite 1.1	Source Reduction & Waste Management - Waste Stream Audit
9	MR Prerequisite 1.2	Source Reduction & Waste Management - Storage & Collection
10	MR Prerequisite 2	Toxic Material Source Reduction - Reduced Mercury in Light Bulbs
11	IEQ Prerequisite 1	Outside Air Introduction & Exhaust Systems
12	IEQ Prerequisite 2	Environmental Tobacco Smoke (ETS) Control
13	IEQ Prerequisite 3	Asbestos Removal or Encapsulation
14	IEQ Prerequisite 4	PCB Removal

Table 4-4. Existing Building Certification Level

Type	Minimum	Maximum
Certified	32	39
Silver	40	47
Gold	48	63
Platinum	64	85

4.2.3 Outputs

Outputs are the results of the calculations that are done in the data analysis phase. In the proposed model the outputs are Total Soft Cost and sub category costs, LEED Certification type, and accumulated selected LEED points. The outputs generated can be visualized in the form of report generated by the proposed model. Model's implementation is discussed in Chapter Five.

4.3 The Conceptual Schema

The conceptual schema is displayed using the Entity-Relationship (ER) diagram. The ER diagram is used to graphically represent the data objects because it is simple and easy to understand. The ER model views the project objects in terms of entities, attributes, and relationship association between entities (Elmasri and Navathe, 2000). Figure (4-2) shows the symbols used to construct the schema along with examples that are used in the proposed model, and Figure (4-3) shows the model conceptual schema.

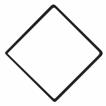
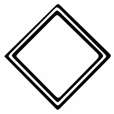
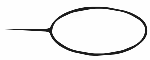
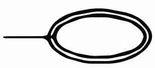
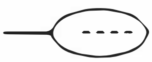
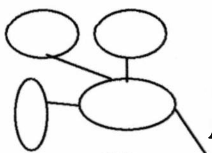
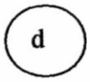
Symbol	Meaning	Model Example
	Entity	Project, Soft_Cost
	Dependent Entity	New_Category
	Relationship	"Certification" Entity has a relation with "Soft_cost" entity
	Identifying Relationship	"New" Entity has a relation with "New_Category" week entity
	Attribute	"Owner" in the "Project" entity
	Key Attribute	"ID" in the "New" Entity
	Multivalued	"Certification" in the "Soft_cost" Entity
	Partial key	"ID" in the "Existing_Category"
	Composite Attribute	Date in the Project Entity
	Disjoint	"New" and "Existing" entities are disjointed from the "Project" entity

Figure 4-2. ER Diagram Symbol and Example

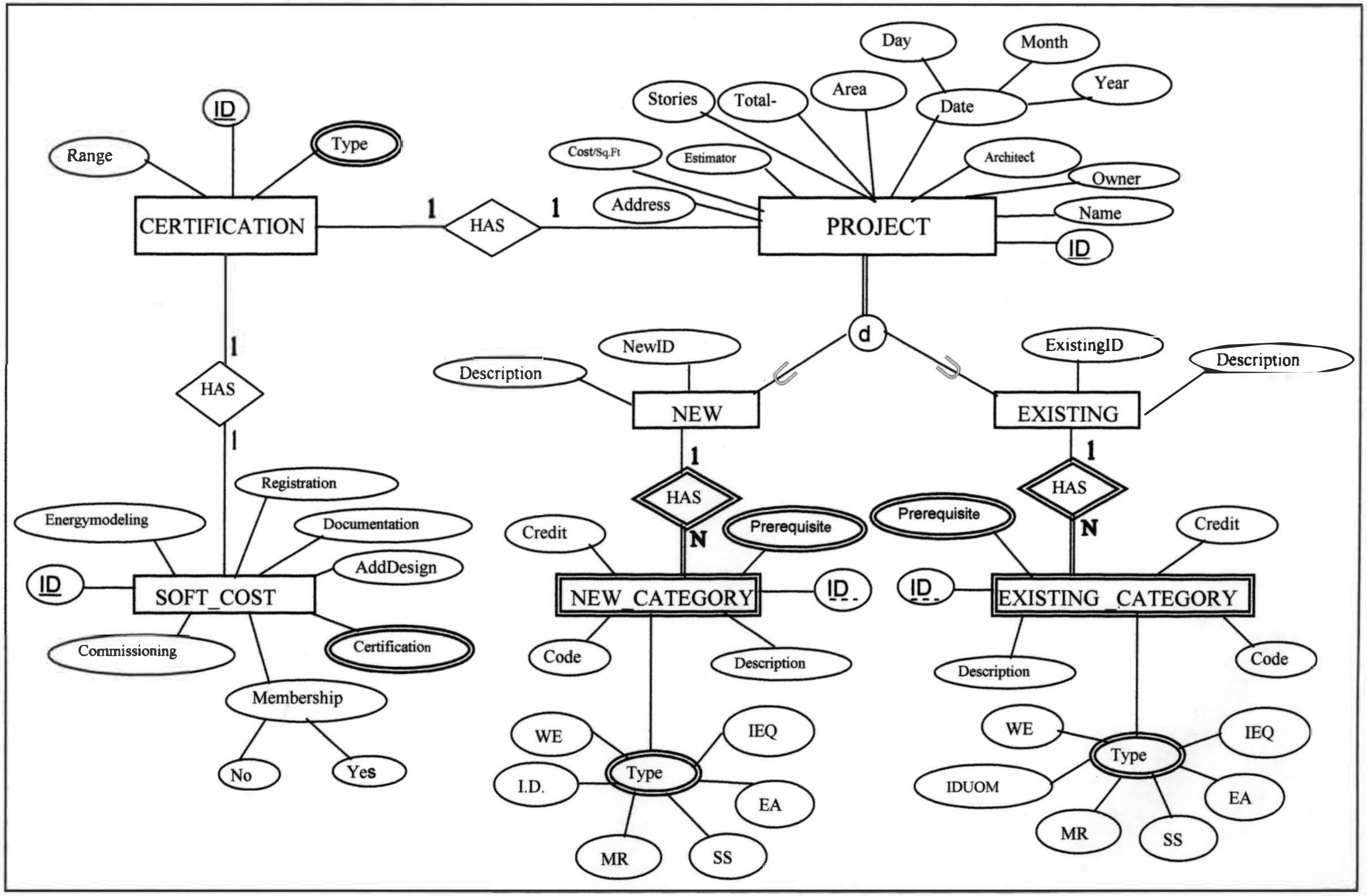


Figure 4-3. ER Conceptual Schema Diagram

4.3.1 Entity

Entities are objects in the real word that contain descriptive information by other objects. They are the principal data objects about which information is to be collected. An entity is corresponding to a table in the relational model. In the proposed model there are 7 entities.

Entities are classified as independent or dependent, below is a brief description for these two classifications.

Independent entity is strong because it does not depend on another entity for identification. This entity is represented by a single line rectangular with the name inside. The primary key for an Independent Entity is indicated in the Entity-Relationship diagram (ER Diagram) by means of underlining a particular attribute with a thick line, which uniquely identifies a record in a relation or a table. Example: Project, Existing, New, Soft_Cost and Certification.

Dependent entity it relies on another entity for identification. This entity is represented by a double line rectangular with the name inside. The primary key for a Dependent Entity is indicated in the Entity-Relationship diagram (ER Diagram) by means of underlining a particular attribute with dotted lines, which uniquely identifies a record in a relation or a table. Example of dependent entity in the conceptual schema Figure (4-3): New_category and Existing_category.

4.3.2 Attributes

Attributes are the objects which define a Relation or an Entity. A key attribute identifies a particular record uniquely in any relation while all the other attributes are called non-key attributes. A primary key attribute uniquely identifies a particular record in a table or a relation.

In the Figure (4-3) we have an Independent Entity called Project; this has 14 attributes, out of which 1 is a key attribute and the other 13 are non-key attributes. The key attributes of this project Entity are ID and the non key attributes are Area, Total Cost Cost/Sq.Ft, Stories, Estimator, Address, Date, Architect, Owner and Name. Date is a Composite Attribute having Day, Month and Year as its sub-attributes. An attribute is called a Composite attribute if it can be further subdivided into sub-attributes that identify it (Elmasri, Navathe 2000).

4.3.3 Relationship

Relationship is an association between one or more entities. Considering Figure (4-3) we have two types of relationships:

- Relationship: this is the regular relationship. It connects two regular entities. As an example the entity "Certification" has a relation with entity "Soft Cost".
- Identifying Relationship: this is not a regular relationship; it connects the weak entities to the main entity as an example the entity "Category" has an identifying relation with weak entity "EA".

Relationships are classified in terms of degree and connectivity. The degree of a relationship is the number of entities associated with the relationship. In the Figure

(4 -3) we have the degree of relationship as 2 since it associates with 2 other entities, which are Project and Soft Cost.

The connectivity of a relationship describes the mapping of associated entity instances in the relationship. It can be classified as "one" or "many". The basic types of connectivity for relations are: one-to-one, one-to-many, and many-to-many.

One-to-One (1:1) relationship is where one instance of an Entity is associated with just one instance of the other. Example One Existing building has only one certificate.

One-to-Many (1:N) relationship is where one instance of entity is associated with one, or many instances of another entity.

Many-to-Many (M:N) relationship is where many instances f an entity is associated with many instances of the other entity.

In Figure (4-3) we have an association of the disjoint entity type, specialization, because the entity "PROJECT" represents different entity type of building either "NEW" entity or "EXISTING" entity, but not both as the same time.

4.4 The Conceptual Methodology

Conceptual methodology is depicted as a data flow diagram as shown in Figure (4-4). This data flow diagram begins with the data entry level which consists of all the data inputs required for the calculations in the data analysis phase. The input consists of all the data related to the Project (e.g., Project Name, Project Address, Owner Name, Architect, Estimator, Number of Stories, Total Area, Total Cost, Area per Sq Feet, and Date). The data entry for this input is done in an input screen.

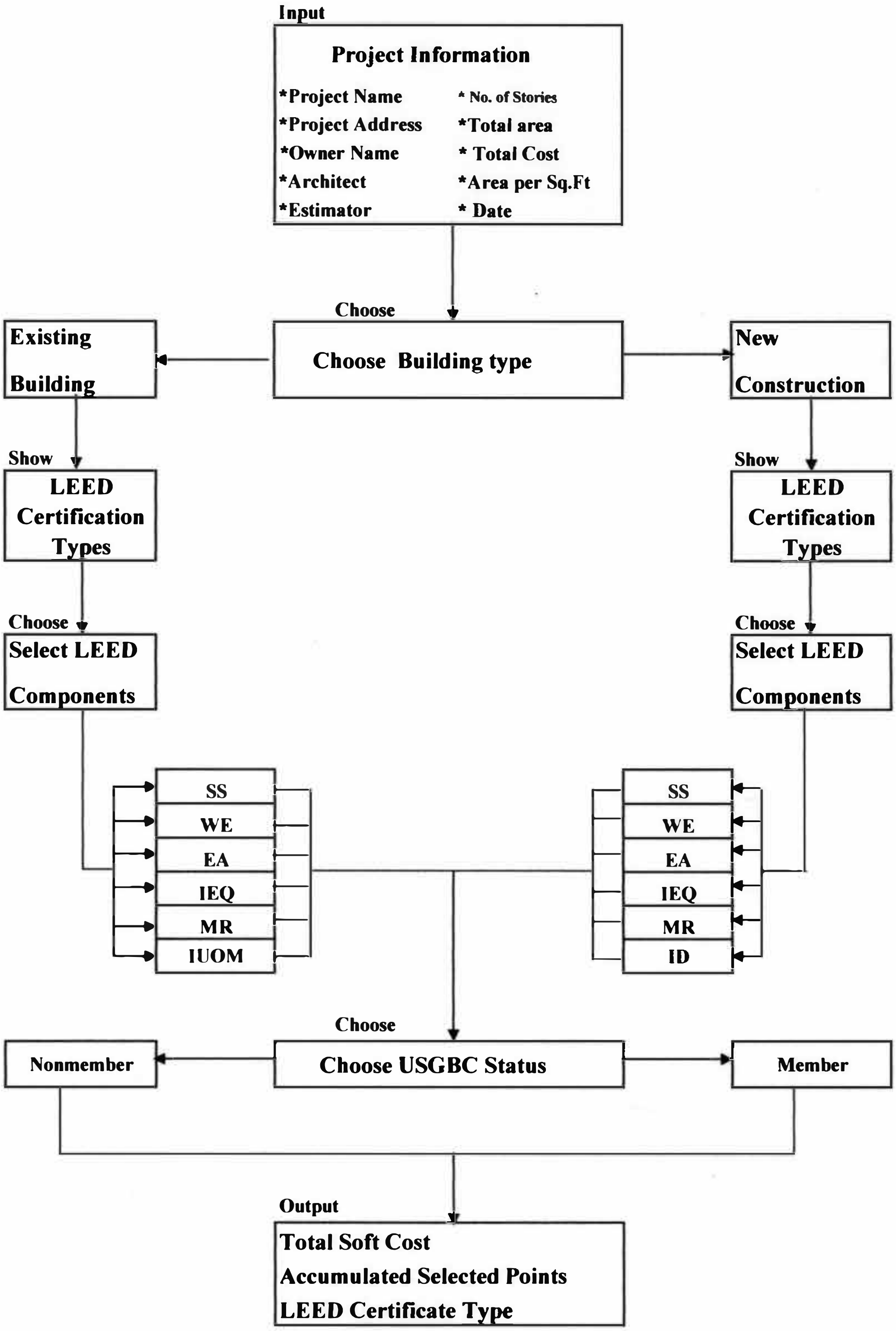


Figure 4-4. Model Data Flow

Once data entry is done, the user is taken to another screen that prompts him to choose the type of building which is either a new building or an existing one. After the user chooses the type of building a new screen will appear started by the LEED certification types. The user than has to select the LEED components for each of the building types (which is either New or Existing) from LEED category EA, IEQ, ID, MR, SS and WE in sequence.

Selecting each of these sub-component categories prompts the user with another screen which consists of credits the user has to choose from. The user may choose zero or more credits depending on his requirement. The user is then guided to select his membership status. For a member of USGBC the soft cost is less when compared with a non-member who has chosen the same number of credits as that of a member of USGBC. This soft cost is a part of the output. The output of the model also consists of the other data which are Accumulated Selected Points and LEED Certificate Type.

4.5 Summary

This Chapter described the database concepts used in the model with the descriptions of certain database terminologies such as entities, attributes, relationships and ER Diagrams and their particulars. We started with the model outline: the input, the criteria that control the system analysis, and the output, passing through the conceptual design and the scheme and ending with the methodology data flow for the model in order to help user finding his way in the model implementation.

CHAPTER FIVE

MODEL IMPLEMENTATION PROCESS

5.1 Introduction

While conducting the literature review in green building we found that there are many applications and software for the life cycle cost analysis, energy modeling and sustainable design such as BEES, Building Energy Analyzer, and Green Building Advisor; however, there is still a big gap in achieving the process and documenting the application. This chapter contains the proposal of creating a computer application to facilitate and manage the documentation process for the user.

Microsoft Access is used as a database management system to store and retrieve the LEED rating system for new construction and existing buildings data in order to develop the model. This chapter shows a step by step procedure for implementing the model, using the Energy and Atmosphere category as a sample for new construction. Furthermore, the model is validated to measure its performance using Michigan Alternative and Renewable Energy Center, Grand Valley State University as a case study.

5.2 Data Model Design

Refer to the database conceptual modeling that is illustrated in Chapter Three in Figure (4-3), ER Relationship Diagram. Accordingly a database design is constructed. In any database application, each of the tables requires means to get data into them and retrieve the data at a later time. The primary way to get data into tables is to use data entry forms. The primary way to display data in tables is to use queries. Every database application design consists of four major steps.

1. Creating the tables.
2. Finding the relationship between the tables.(relationship)
3. Entering data into the tables (forms)
4. Getting data from the tables (queries)

5.2.1 Table

To start, tables are created. A table is a collection of data about a specific topic, and each table has different categories (fields) in order to identify the specific table. In the proposed model, there is one table for project information, six tables for existing categories, and six tables for new construction categories, and estimated sub total soft cost, six tables for the actual cost (registration and certification cost), six tables for the building certification cost, and two tables for the LEED certification categories for a total of 28 tables. Each table has a single field primary key to eliminate duplications and to retrieve the data faster. Figures (5-1) and (5-2) show a sample table created in the database; the first one represents the table design view, while the second one represents the table view.

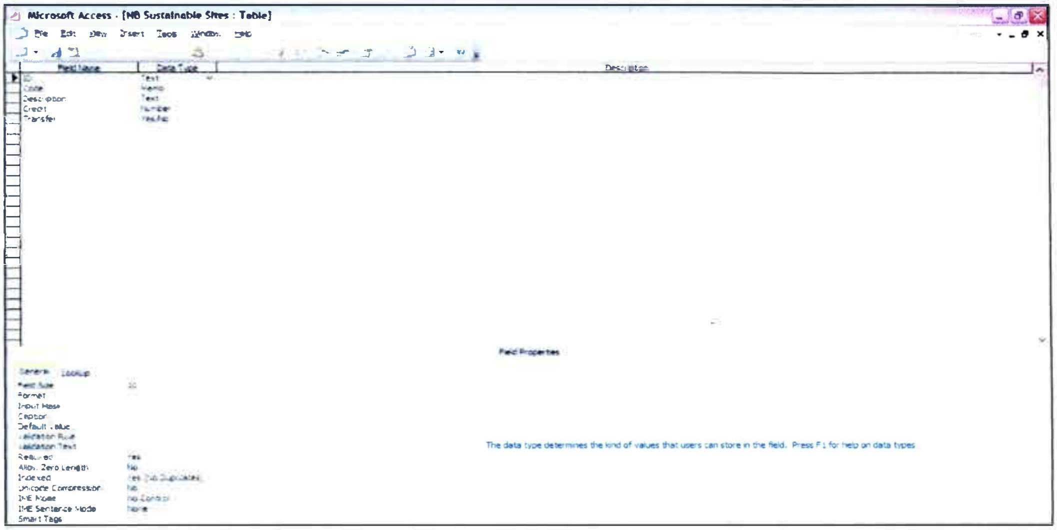


Figure 5-1. Microsoft Access Table Design View

ID	Code	Description	Credit	Transfer
NBSS000002	SS Credit 1	Site Selection	1	Yes
NBSS000003	SS Credit 2	Development Density & Community Connectivity	1	No
NBSS000004	SS Credit 3	Brownfield Redevelopment	1	No
NBSS000005	SS Credit 4.1	Alternative Transportation, Public Transportation Access	1	No
NBSS000006	SS Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	1	No
NBSS000007	SS Credit 4.3	Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles	1	No
NBSS000008	SS Credit 4.4	Alternative Transportation, Parking Capacity	1	No
NBSS000009	SS Credit 5.1	Site Development, Protect of Restore Habitat	1	No
NBSS000010	SS Credit 5.2	Site Development, Maximize Open Space	1	No
NBSS000011	SS Credit 6.1	Stormwater Design, Quantity Control	1	No
NBSS000012	SS Credit 6.2	Stormwater Design, Quality Control	1	No
NBSS000013	SS Credit 7.1	Heat Island Effect, Non-Roof	1	No
NBSS000014	SS Credit 7.2	Heat Island Effect, Roof	1	No
NBSS000015	SS Credit 8	Light Pollution Reduction	1	No

Figure 5-2. Snapshot of the Table

There are different types of coding systems such as numeric and alphanumeric (Aridity et al, 2002). In the proposed model the alphanumeric coding system is used to create the primary keys. It contains ten digits; the first part refers to the category name and type and the second part is a number to keep the place. There are five different types used. A sample of these types is given below:

i. Existing Building: Energy and Atmosphere: prerequisite **3**: Ozone Protection

   Code 4:6

   E B E A 0 0 0 0 0 3

ii. New Building: Indoor Environmental Quality: Credit 8.1: Daylight & Views, Daylight 75 percent of Spaces.

   Code 5:5

   N B I E Q 0 0 0 1 6

   Note: Here although the credit number is 8.1 but it is row number 16 in the table, which is why the last two digits in the coding are 16

iii. Existing Building Certification Fees (for area) Less than **50, 00** sq. ft. construction review member (the first row)

Code 7:3

E B C F L 5 K 0 0 1

Note: here 50,000 indicated as 5K and the number 1 refers to the first row.

iv. Existing Building: Certification Fees Between **50,000** sq. ft and **500,000** sq. ft.

Code 8:2

E B C F B 5 K K 0 1

5.2.2 Table Relationships

The most important feature of relational databases is the fact that all tables are related one to another. Relationships are used to tie the tables together. There are three types of relationships:

- One-to-many, which is the most common type; a record in one table can have many related records in another table but not vice versa. It is created if only one of the related fields is a primary key.
- One-to-one: each table can have only one matching record in the other table. It is some times used to store information that applies only to a subset of the main table. This is the relation that was used in the NC and EB tables. It is created if both of the related fields are primary keys or have unique indexes.
- Many-to-many: this is the most complicated relationship type. In this relation a record in the one table can have many matching records in the other table and vice versa. It is really two one-to-many relationships.

5.2.3 Query

Queries select records from one or more tables in a database in order to be viewed, analyzed, and sorted on a datasheet. The resulting collection of records, called a dynaset (short for dynamic subset), is saved as a database object and can consequently be easily used in the future. Whenever the original tables are updated the query will be updated as well. There are different types of queries:

1. Select queries: it is the most common type of query.
2. Parameter queries
3. Crosstab queries
4. Action queries: an action query is a query that makes changes to or moves many records in just one operation. There are four types of action queries:
   a. Delete queries
   b. Update queries
   c. Append queries
   d. Make-Table queries
5. SQL queries: An SQL query is a query you create by using an SQL statement such as SELECT, UPDATE, or DELETE, and includes clauses such as WHERE and FROM. This type of query is used in this model to retrieve data from one or more tables and display the results in a datasheet where the user will be able to update the records. Moreover, it is used to calculate the accumulated selected LEED points and the certification soft cost.

SQL Select Query selects points from New Building Innovation Design Operation and Maintenance to put it as selected LEED components as in Figure (5-3). Below is sample of Select Query format:

SELECT [Take Off List New Building].ID, [Take Off List New Building].Code, [Take Off List New Building].Description, [Take Off List New Building].Credit

FROM [Take Off List New Building]

*WHERE ((([Take Off List New Building].ID) Like "NBOM******"));*

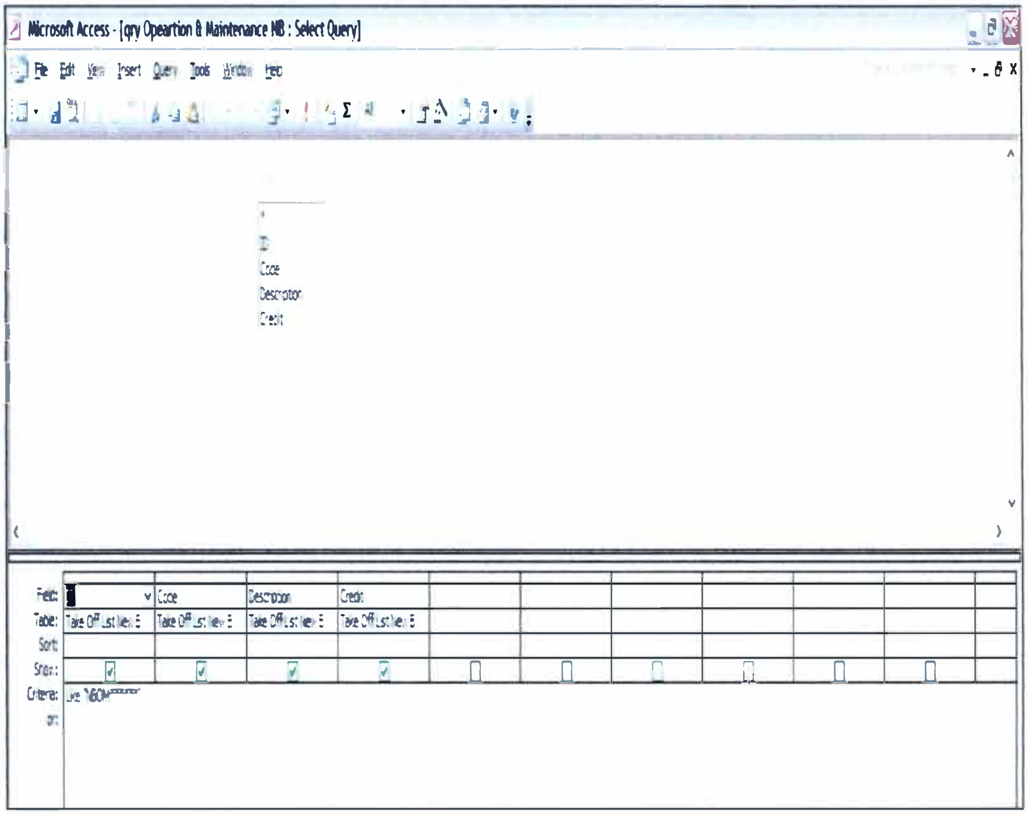


Figure 5-3. Sample Snapshot of Select Query from the Model

Append SQL Query function is to add a group of records from one or more tables to the end of one or more tables. Figure (5-4) shows an example of this query, which is the Takeoff list for existing building. It adds the points selected from all the six categories to the Selected LEED components. The code is shown below:

INSERT INTO [Take Off List Existing Building] (ID, Description, Code, Credit)

SELECT [EB Energy & Atmosphere].ID, [EB Energy & Atmosphere] . Description, [EB Energy & Atmosphere].Code, [EB Energy & Atmosphere].Credit

FROM [EB Energy & Atmosphere]

WHERE ((([EB Energy & Atmosphere].ID)=[Forms]![frm EB Energy and Atmosphere]![ID]) AND (([EB Energy & Atmosphere].Transfer)=True));

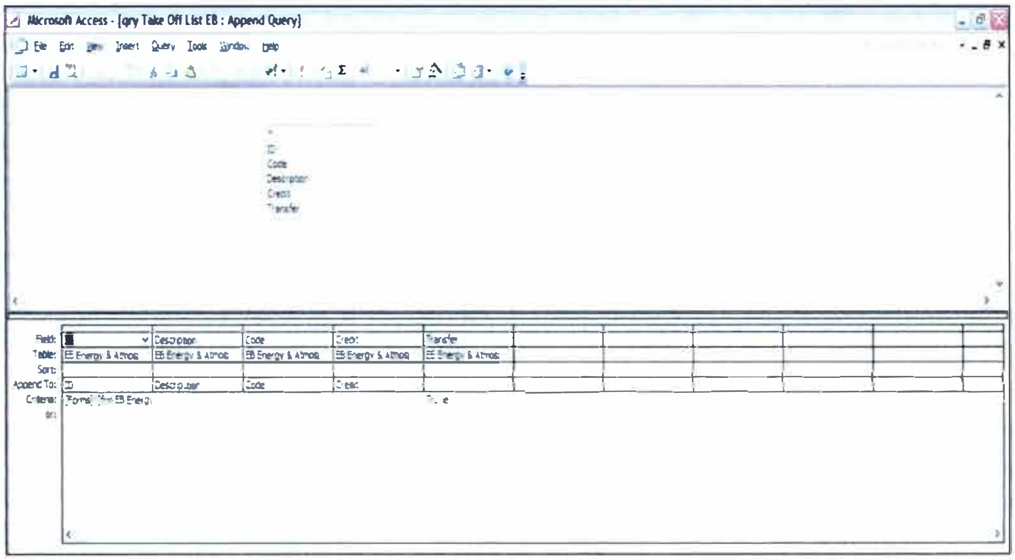


Figure 5-4. Sample Snapshot of Append Query from the Model

Delete Query deletes a group of records from one or more tables. Hence to delete points from The Selected LEED Components delete category is used as in Figure (5-5). An example of Delete Query is shown below:

DELETE [Take Off List Existing Building].

FROM [Take Off List Existing Building];

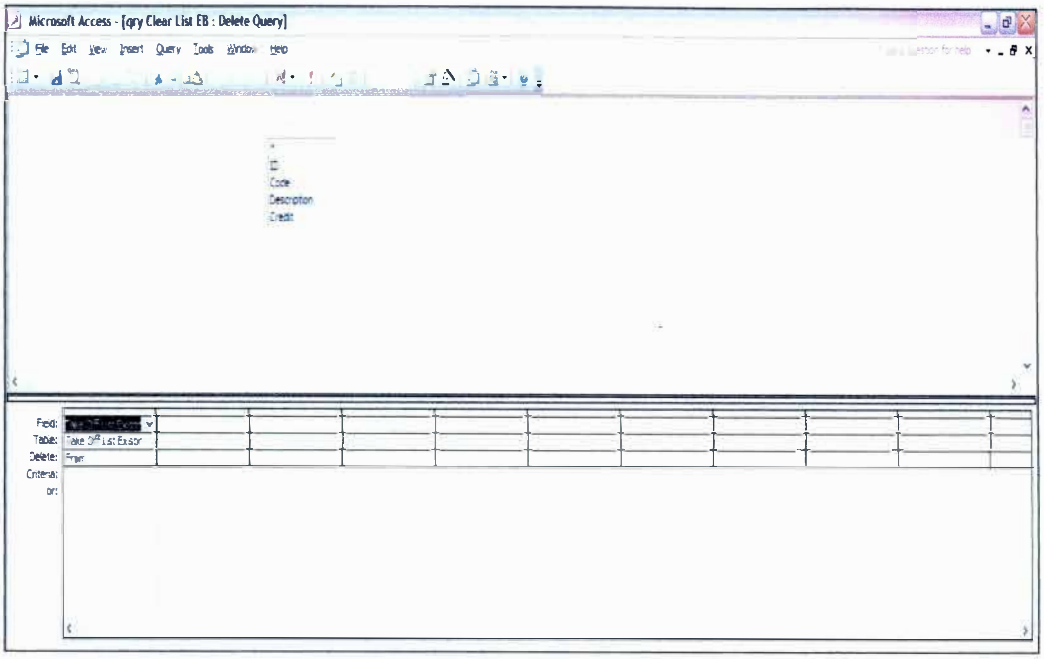


Figure 5-5. Sample Snapshot of Delete Query from the Model

5.2.4 Form

Forms are means of displaying, modifying, and adding data. They are flexible and powerful. A form focuses on one record at a time, and it can display fields from more than one table. It can also display pictures and other objects. A form can contain a button that prints, opens other objects, or otherwise automates tasks, which will be explained in details later in this chapter. There are three ways to create a form:

1. Based on a single table or query by using AutoForm: AutoForm creates a form that displays all fields and records in the underlying table.
2. Based on one or more table or query with a wizard: the wizard asks you detailed questions about the record sources, fields, layout, and format you want and creates a form based on your answers.

3. On your own in Design view: by creating a basic form and customizing it in Design view to suit your requirements. Figure (5-6) represents one of the forms used in the proposed model.

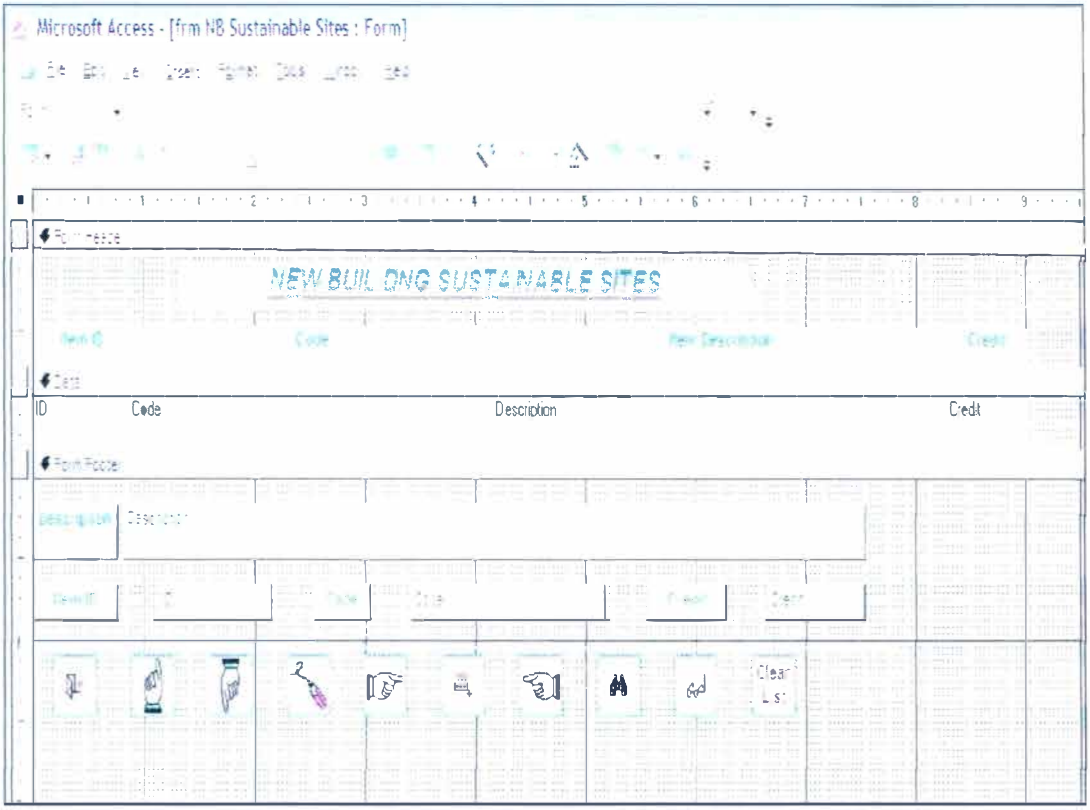


Figure 5-6. Sample Snapshot of Form Design View from the Model

5.3 Model Interface

The first screen in the proposed model is the logo window as shown in Figure (5-7). By clicking the bottom tab "Enter Project Information", user is transferred to the project information screen to input data.

Figure 5-7. Computer Interface Logo

5.3.1 Data Entry

First, project general information is entered as shown in Figure (5-8a): Project Name, Project Address, Owner, Architect, Estimator, Number of Stories, Total Area, and Construction Cost have to be entered. Cost per Square Feet is calculated automatically by the proposed model and the date. The Total Area and the Construction Cost are the most important, because they will be required later in the project to calculate the total soft cost. After entering these two mandatory information fields the “Continue” tab will be activated. After clicking on “Continue” two other tabs will come into view; those are "New Building" and "Existing Building" as shown in Figure (5-8b).

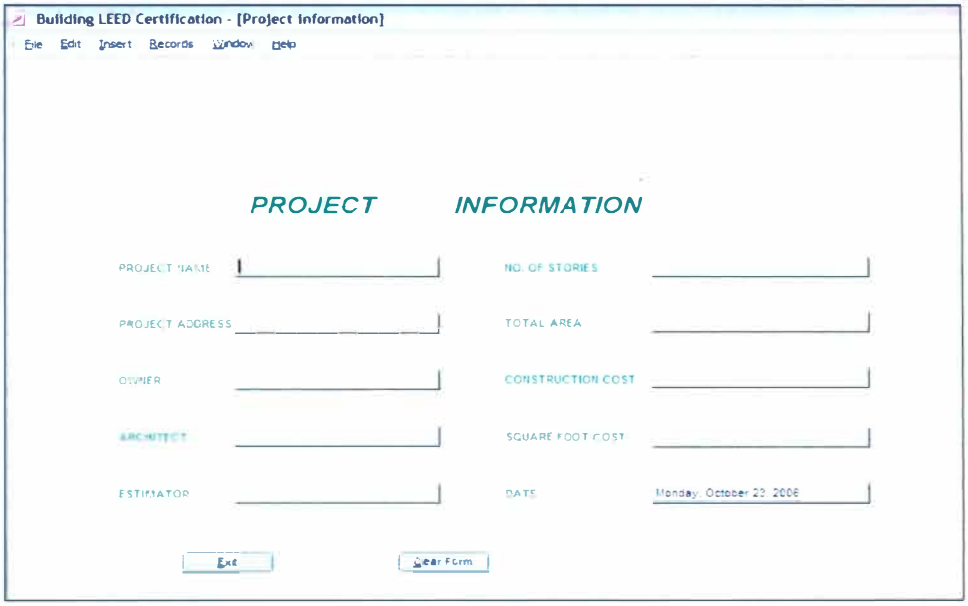


Figure 5-8a. Project Information

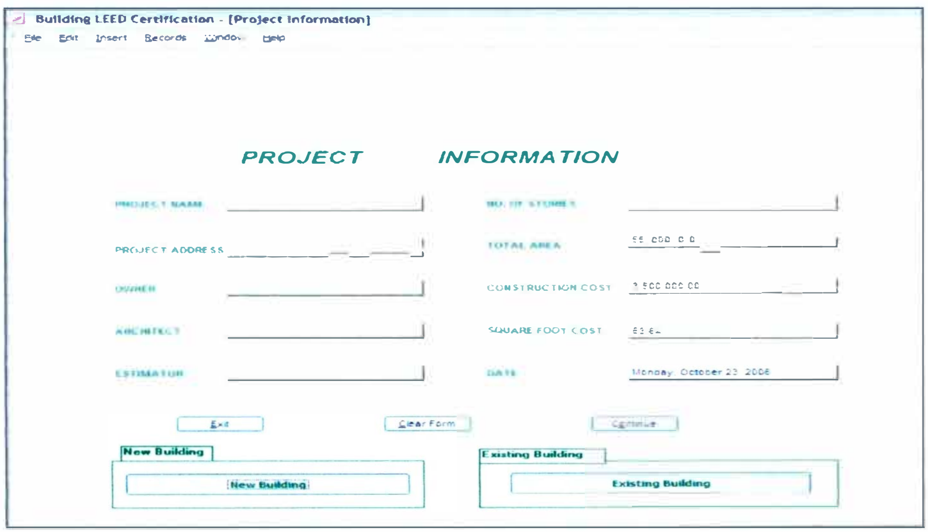


Figure 5-8b. Project Information

By clicking on the “New Building” tab, Figure (5-9a) will appear. It contains nine different choices: LEED certification criteria, six LEED-NC categories, and “Continue” and “Back to Project Information” tabs. When clicking on each of the links a related form will appear. Otherwise, clicking on the “Existing Building” tab Figure (5-9b) will appear.

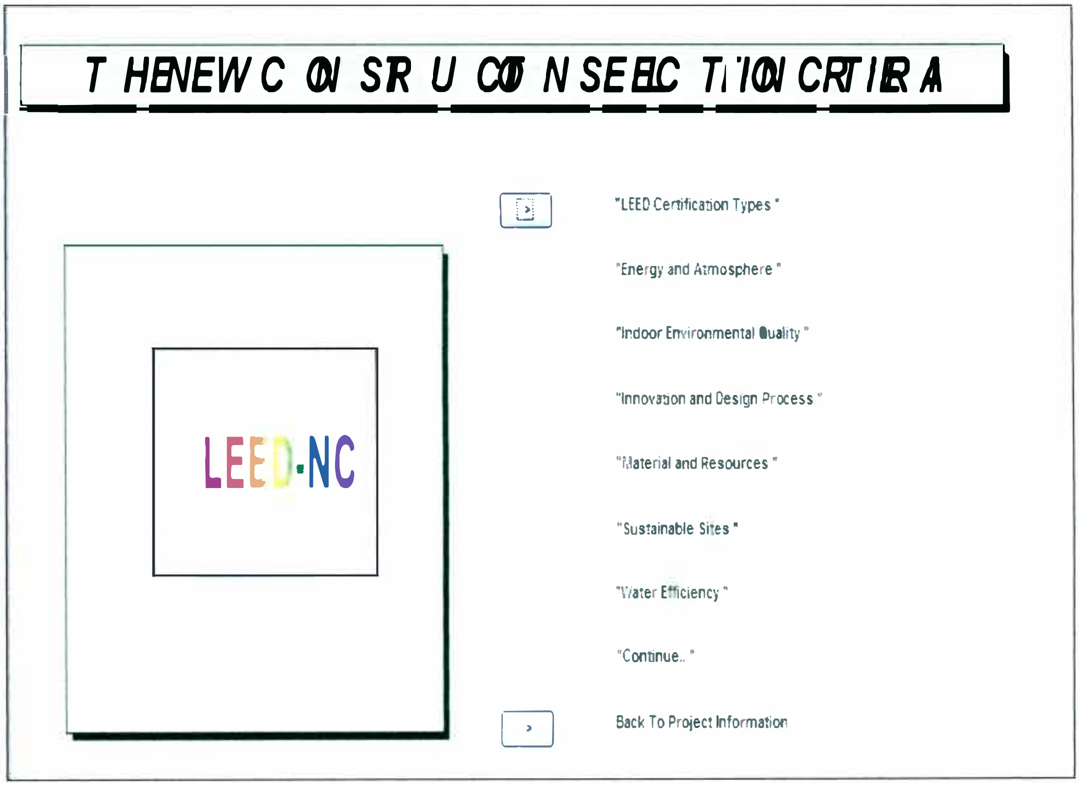


Figure 5-9a. New Construction Selection Criteria

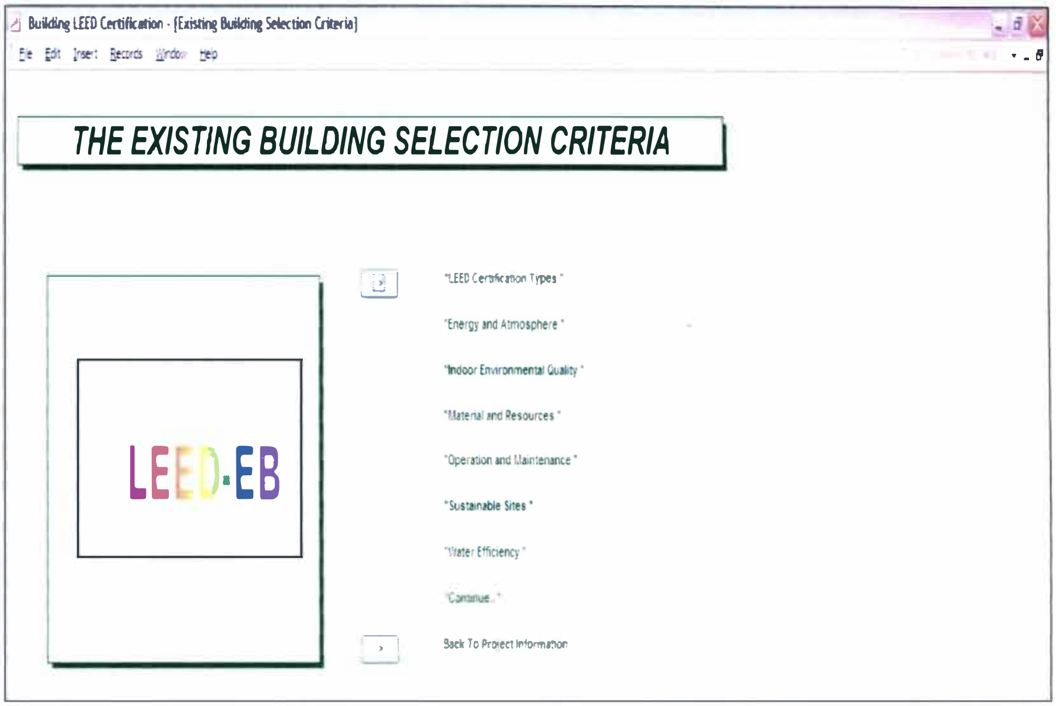


Figure 5-9b. Existing Building Selection Criteria

The first tab on New Construction gives the user the range for the four different certification types and the range of the required points to be attained to qualify for each certification that is shown in Figure (5-10a). For existing buildings the four different types are the same but the range is different for each certification type.

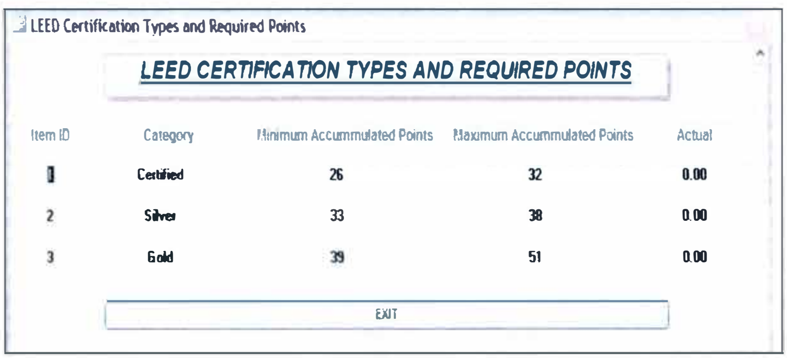


Figure 5-10a. New Construction LEED Certification Types

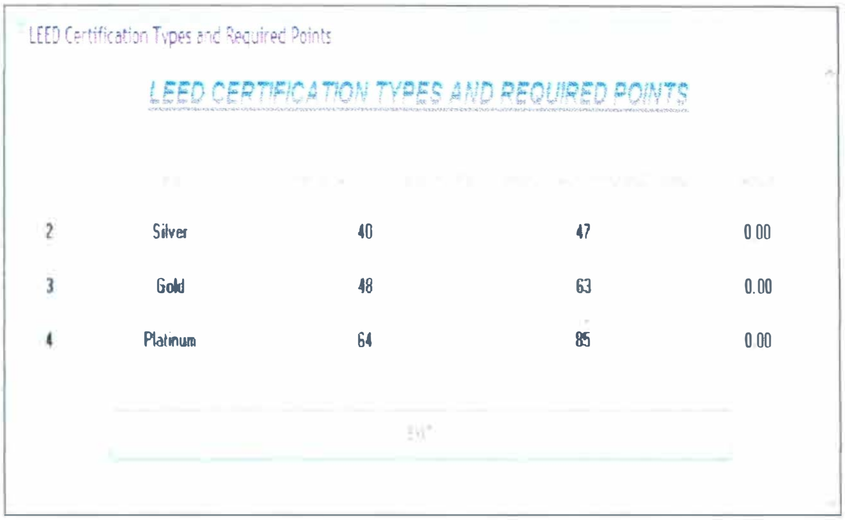


Figure 5-10b. Existing Building LEED Certification Types

The next six tabs after clicking "New Construction" are for LEED-NC credit categories, while the next six tabs after clicking "Existing Building" tab are for LEED-EB categories. When selected each of these tabs opens a pre-requisites memo, if there are required achievements that need to be satisfied. Then the user is guided to the credit details for each category, in order to choose the points required for specific certification. Because the implementation procedures for all six categories are the same for both LEED-NC and LEED-EB, apart from the different credit and point fields; the new construction Energy and Atmosphere category is taken as a sample.

When clicking on the "Energy and Atmosphere" tab, the prerequisites memo will appear as in Figure (5-11). The user then has to ensure that these prerequisites are met before proceeding to select the credits. If these pre-requisites are not fulfilled, the "Close" tab is chosen so as to exit the model instantly.

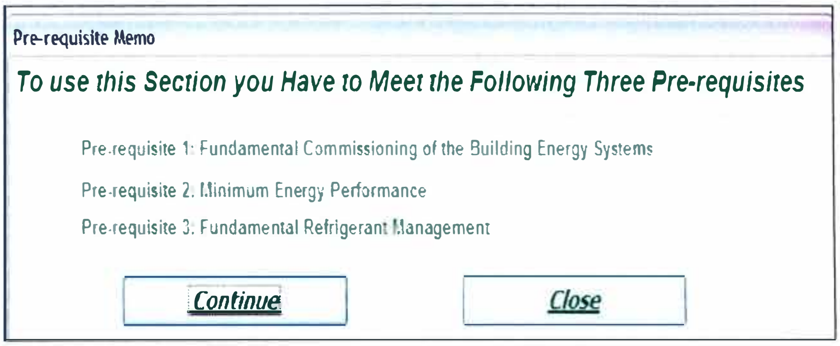


Figure 5-11. New Construction Energy and Atmosphere Prerequisites Memo

Otherwise, if all prerequisites are met then the "Continue" tab is clicked to go to the Energy and Atmosphere credit details screen as shown in Figure (5-12a). This window allows the user to choose the credits he wants to achieve in the project.

The first part of the window in the table consists of 4 columns: (1) Item, (2) ID Code, (3) Item Description, and (4) Credits. The next column is the credit code that is assigned by the USGBC. The third column describes the credit. And the last column is the number of points that each item has.

There are some keys at the bottom of the window for simple navigation as in Figure (5-12b); the function of each key is presented in table (5-1).

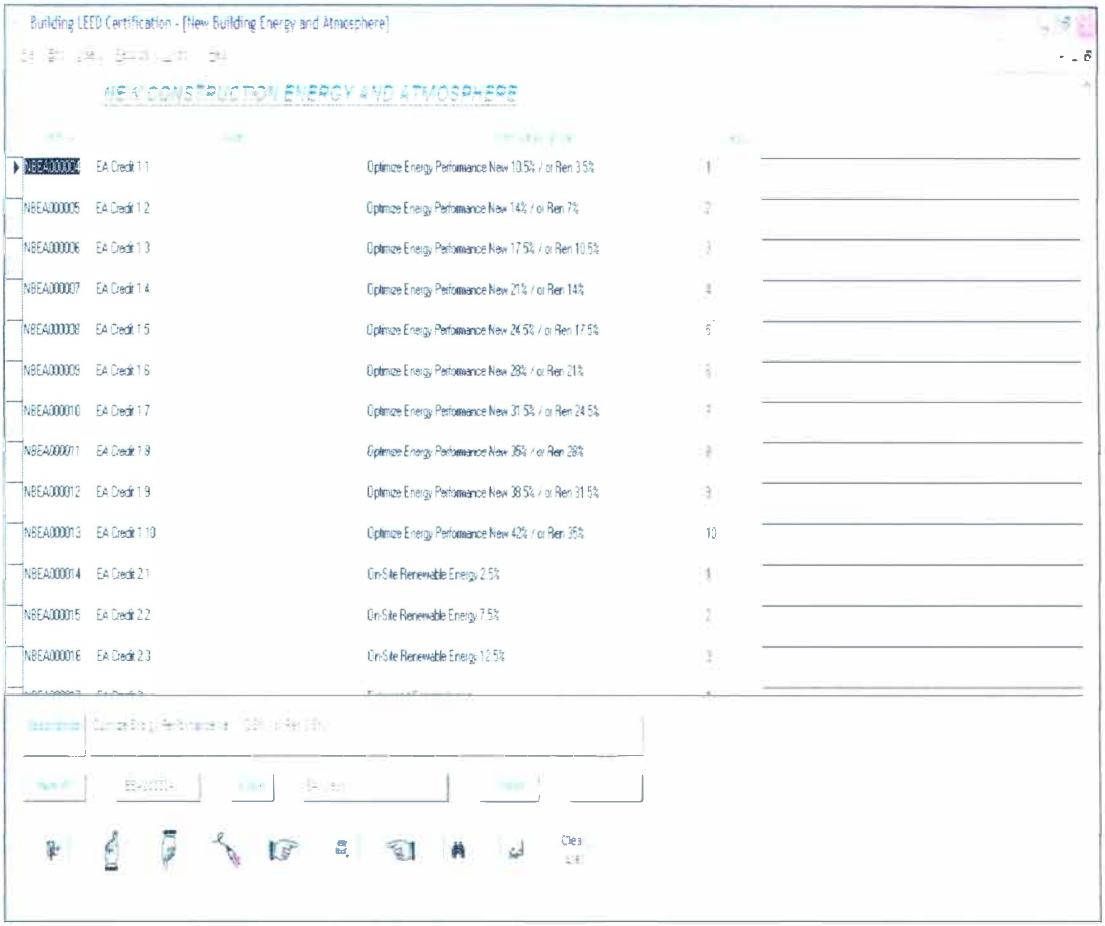


Figure 5-12a. New Construction Energy and Atmosphere Credit Details Window

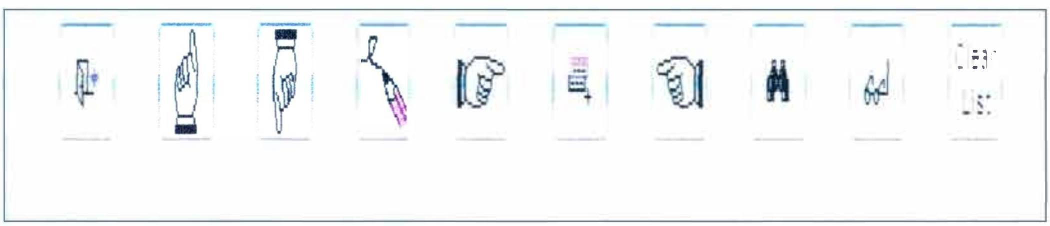


Figure 5-12b. Navigation Keys

Table 5-1. Navigation Keys Function for the LEED Category Credits Window

Icon	Function
	Exit and return to the main menu
	Go to the first record
	Go to the last record
	Add new record
	Go to the next record
	Transfer this record to take off list (select)
	Go to the previous record
	Find a specific record
	View the take off list
	Clear the take off list

5.3.2 Point Selection

The user will be able to select a point by clicking the transferring record key. It is important to be careful when selecting the points, as some items have an upgrade option. When an upper level point field is selected it will include all lower level points under the same credit. For example, if Energy and Atmosphere credit 1-Optimizing Energy Performance is selected it has a different scale depending on the building type (new construction or it is a major renovation buildings as in table (5-2));

Credit 1.7-Optimize Energy Performance for new construction with 31.5 percent cost saving is selected, a total of 7 points will be automatically accrued because it adds all the cost saving points under 31.5 percent. Thus, choosing an EA Credit with a cost saving of less than 31.5 percent along with the highest (in our case EA Credit 1.7) is not allowed in this model, as the credit scores will be replicated.

If "View the Takeoff List" icon is selected the LEED component (credits) screen comes into view, and it includes all the points that are selected from different categories. Figure (5-13) displays the selected LEED window screen, which has two special icons, the purpose of those icons are shown in table (5-3):

Table 5-2. Energy and Atmosphere Credit1: Energy Cost Savings Percentage Breakdown

Code	Description	New construction	Major renovation	Points	Total points
EA Credit 1.1	Optimize Energy Performance	10.5 percent	3.5 percent	1	1
EA Credit 1.2	Optimize Energy Performance	14 percent	7 percent	1	2
EA Credit 1.3	Optimize Energy Performance	17.5 percent	10.5 percent	1	3
EA Credit 1.4	Optimize Energy Performance	21 percent	14 percent	1	4
EA Credit 1.5	Optimize Energy Performance	24.5 percent	17.5 percent	1	5
EA Credit 1.6	Optimize Energy Performance	28 percent	21 percent	1	6
EA Credit 1.7	Optimize Energy Performance	31.5 percent	24.5 percent	1	7
EA Credit 1.8	Optimize Energy Performance	35 percent	28 percent	1	8
EA Credit 1.9	Optimize Energy Performance	38.5 percent	31.5 percent	1	9
EA Credit 1.10	Optimize Energy Performance	42 percent	35 percent	1	10

Figure 5-13. Selected LEED Components

Table 5-3. Navigation Keys Function for the Selected LEED Component Window

Icon	Function
	Delete record
Σ	View your take off list sum

The "Delete Record" icon will delete the selected record, while the "Sum" icon will open another window that shows the number of accumulated select points as seen in Figure (5-14).

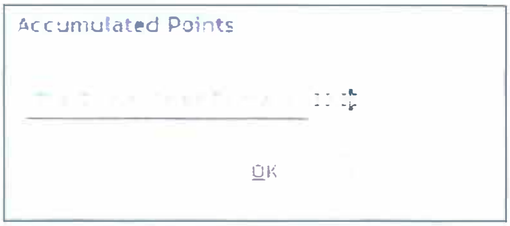


Figure 5-14. Accumulated Point

Click on the "OK" tab to go back to the selected LEED components screen. Click on the "Exit" to go back to the new construction selection criteria window. Next click on the "Continue" tab; this is done to calculate the total soft cost. A small window with a message will appear as in Figure (5-15) to confirm the project area that we entered earlier in the project information screen. This message will prompt the user to select his status (if he is a member at USGBC or not) because that will effect the registration cost. Because one of the tabs has to be selected, a "Yes, I am a member" tab is chosen, to proceed to the "Total Soft Cost for New Construction" screen as in Figure (5-16a)

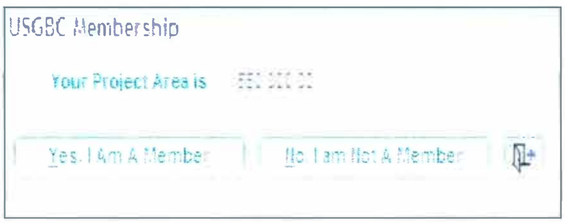


Figure 5-15. USGBC Membership Status

This screen shows us the Project Area and Project Construction Cost that we input as the user. The registration fee is also shown in this screen and this fee is calculated based on the membership status with the USGBC. The certification fees are

are calculated from the project area information provided by the user. The estimated soft cost is calculated according to total construction cost as shown in table (3-4), and then the total soft cost is given by adding registration fee to the certification fees and to the estimated sub total soft cost.

Finally the LEED certification status is stated based on the accumulated select points as shown in Figure (5-14). However, if the total points achieved are less than the minimum points required for certified certification then the LEED certification field would be blank as in Figure (5-16b). This Figure also gives a summary of soft cost. It can be printed by clicking the print icon at the upper left corner.

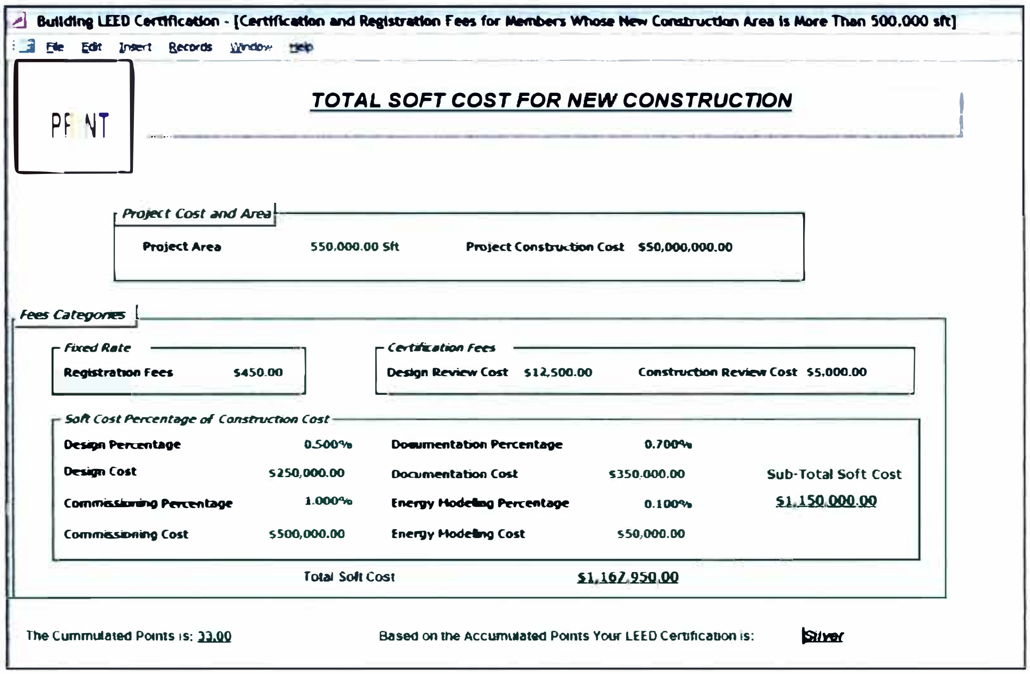


Figure 5-16a. Total Soft Cost for New Construction

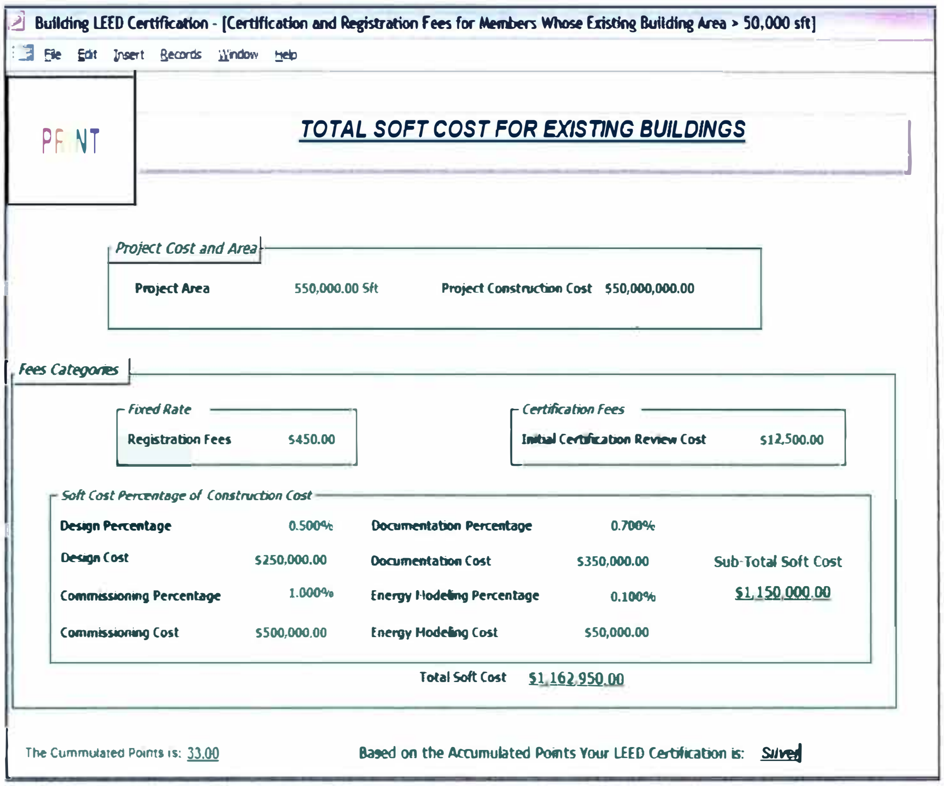


Figure 5-16b. Total Soft Cost for Existing Building

There are small differences in calculating certification cost between Figure (5-16a) "Total Soft Cost for New Construction", and (5-16b) "Total Soft Cost for Existing Building". For LEED-NC certification fees are equal to the design review cost plus construction review cost, while for LEED-EB the certification fees are equal to the initial certification review cost only.

5.4 Model Validation

The Michigan Alternative and Renewable Energy Center (MAREC) at Grand Valley State University (GVSU), owned by the City of Muskegon, has been selected as a construction case study to justify the model. All the information provided about MAREC below is gathered from their website.

5.4.1 Michigan Alternative and Renewable Energy Center (MAREC)

MAREC is owned by City of Muskegon local government. It is located on the Muskegon Lakeshore SmartZone on Muskegon Lake in West Michigan. It is a two story building that offers business space, conference center, energy laboratory, and higher education classroom facilities. MAREC award LEED-NC gold certification from USGBC on 2005 by achieving 46 points out of 69 points, which will be clarified later in this chapter.

5.4.2 General Information

There are some important dates for this facility:

- 1999: the initial spark for the development of MAREC
- 2002: the groundbreaking for the Center
- November 2003: project complete
- 2005: awarded LEED-NC v2 Gold certification form

The MAREC indoor and outdoor spaces are divided as follows:

- Indoor Spaces: Conference (20 percent), Laboratory (15 percent), Classroom (15 percent), Office (15 percent), Circulation (10 percent), Lobby/reception (10 percent), Mechanical systems (10 percent), Restrooms (5 percent)

- Outdoor Spaces: Restored landscape (80 percent), Drives/roadway (20 percent)

5.4.3 Green Criteria

This case study is selected because it is the first fully integrated expression facility that uses alternative and renewable energy technologies for distributed electricity generation in the United States. It is the first commercial project in the world to integrate a fuel cell, heat recovery, photovoltaic, and nickel-hydride battery storage.

Moreover, MAREC employs several green materials and systems that reduce operating costs by producing or saving energy such as daylighting, photovoltaic system, and fuel cell for electromechanical power generation.

Daylighting and sensor-controlled lights, for example, reduce energy costs by ensuring that electric lighting is used only when necessary. The photovoltaic solar roof tiles system saves money by reducing the building's need for peak energy from the local utility. The building is a self-sustaining distributive energy center that features a high-temperature molten carbonate fuel cell for electrochemical power generation. As long as fuel and air are supplied, the fuel cell produces electricity and heat with neither the burning nor the toxin associated with burning fuel.

Furthermore, MAREC is placed to establish West Michigan as a leader in the application of alternative energy technologies that can be used anywhere. MAREC is operated to be an international target point as well as a leader for researchers and businesses developing alternative energy technologies and applications.

Figure (5-17) shows the 46 points attain by MAREC; a summary of these points are as follows and the detailed points are provided in appendix C:

- Sustainable Sites, 11 of 14 possible points
- Indoor Environmental Quality, 9 of 15 possible points
- Water Efficiency, 4 of 5 possible points
- Energy and Atmosphere, 12 of 17 possible points
- Materials and Resources, 5 of 13 possible points
- Innovation and Design Process, 5 of 5 possible points

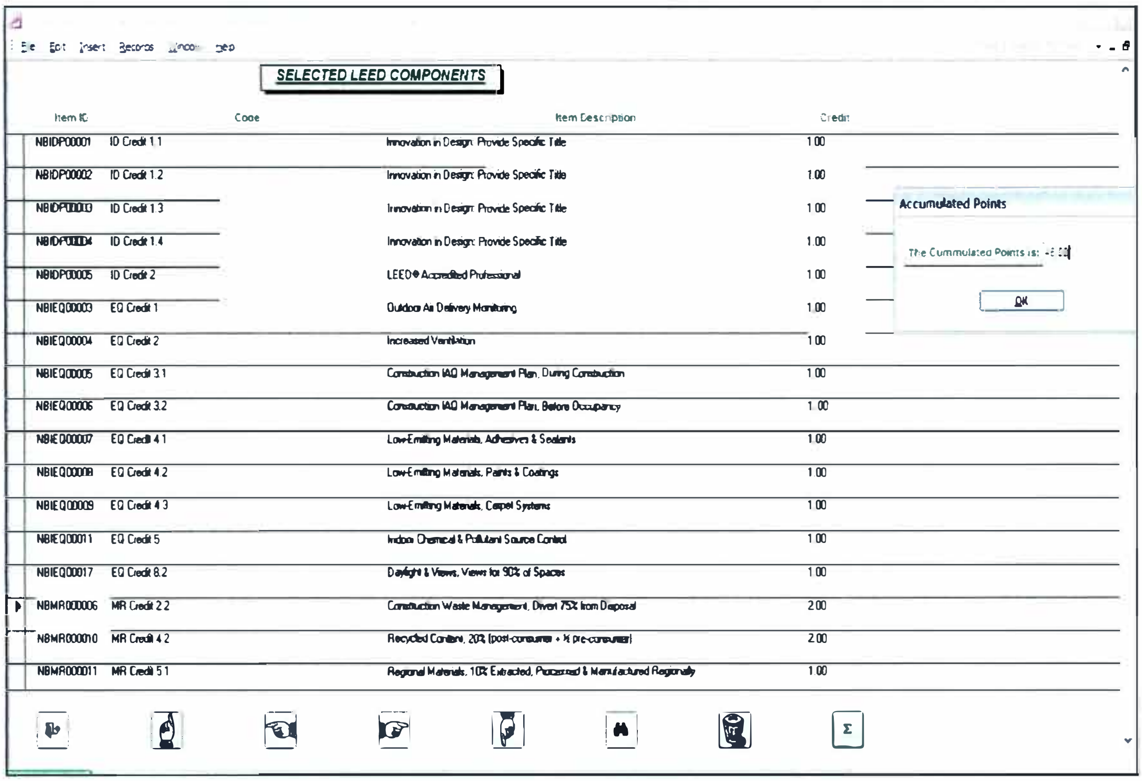


Figure 5-17. Selected LEED Components for MAREC

5.4.4 Finance and Cost

The project was financed via a partnership among the City of Muskegon, Grand Valley State University (GVSU), and the U.S. Department of Defense.

Compared to a traditional facility, MAREC is expected to save GVSU $156,000 in energy and $365,000 in other life cycle costs over 15 years. The building's under floor HVAC, electrical, and voice and data systems alone save upwards of 15 to 20 percent in energy costs compared to conventional design.

5.4.5 Analyzing the Result

Figure (5-18) provides the total soft cost calculated using the model. It shows that the total soft cost for this project is about $138,000 while the life cycle cost saving only during the first 15 years is $521,000 ($ 156,000 + $365,000). That is without including the life cycle assessment benefits, such as increasing productivity, reducing absenteeism, and the well-being for the occupants as well as reducing the impact on the environment. Furthermore it increases the building values. So the soft cost can be negligible comparing to all the benefit gained. Although this study is focused on the soft cost only, Matthiessen and Morris (2004) demonstrated that many projects achieve sustainable design within the same budget of the non-sustainable design.

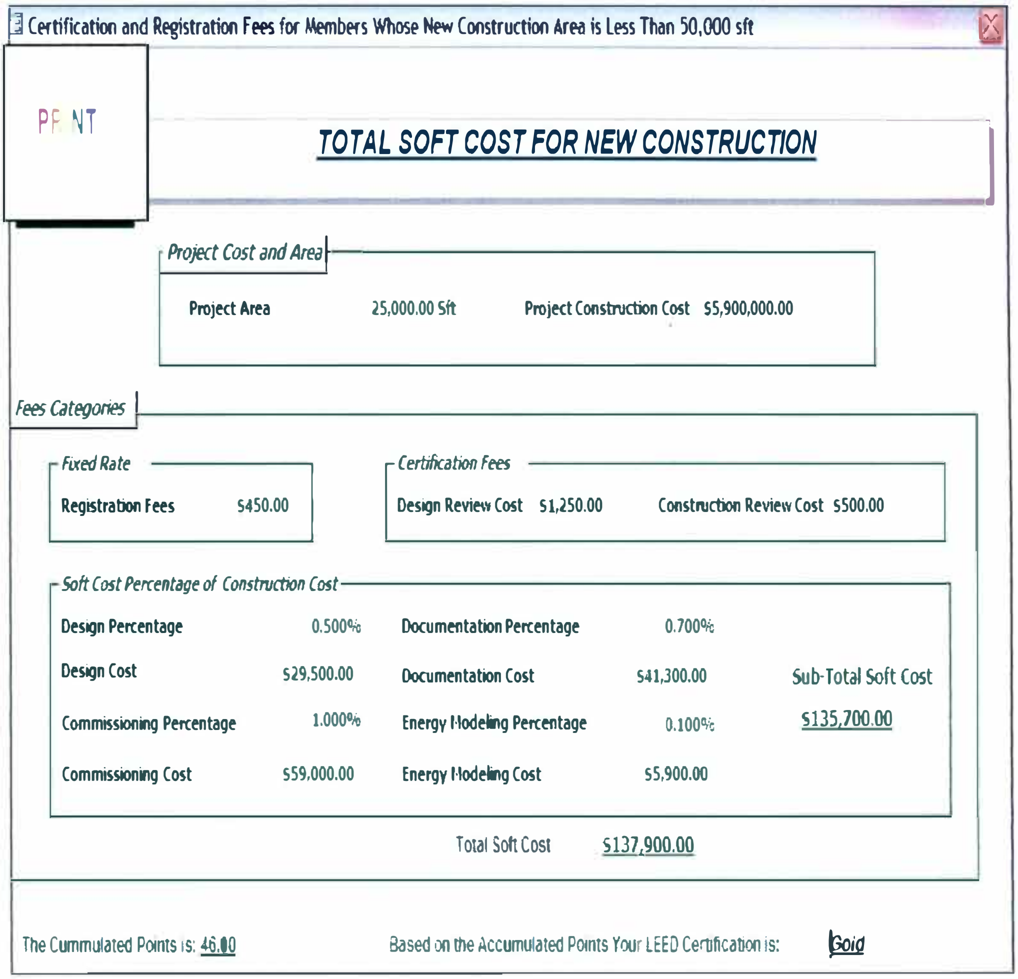


Figure 5-18. Total Soft Cost Report for MAREC

The actual total certification cost was $1,500, while in the model report the total certification cost equal to $1,750 (1250+500) because the model calculates the certification cost depending on the new fees that must be applied for project registered after November 2005, while the MAREC was registered before that.

5.5 Summary

This chapter presented the computer model's implementation steps, along with a detailed description for each screen and its purpose. The chapter ended by using MAREC as a case study to validate the model. As a result we conclude that the model is suitable for any LEED-NC or LEED-Existing building projects to calculate the total points that may achieved by the project, as well as the LEED certification that may be awarded and the total soft cost associated with that project.

CHAPTER SIX

CONCLUSION

6.1 Overview

Since natural resources are limited, the sustainable design is very significant because it considers the future requirements as well as present needs by reducing the impact on the natural environment and resources while improving the built environment.

To optimize financial, environmental, and social benefits of green design, developers and owners have to think about implementing green design in the early stage of project life. Furthermore, early integrated design and collaboration among all building partners lowers the project cost and achieves the project's goals. Green practice should not be considered as a separate (alternative) from the original design, otherwise it will lead to increase the cost not the opposite.

Applying the technologies and strategies that fit project needs and goals will lead to a successful and cost-effective green building project. Some green materials, systems and technologies costs are still expensive depending on the local contractor experience; however, they are changing rapidly and vary from one place to another. In addition, Zeigler (2003) stated that there they are "some green materials and technologies cost the same or less than traditional technologies, and many green technologies result in significant cost savings or cost trade of in other parts of the building."

To save the time and costs associated with LEED, a preliminary implementation of the LEED goals, (e.g., Gold certification level), should be set. Evaluation of the LEED points for project applications and impacts in the schematic design phase is recommended besides integrating the associated design requirements for the LEED points into the contract documents in the contract documentation phase. Most Certified and Silver projects are built with little or no additional cost in reference to the hard or construction cost, some states give tax credit for the soft cost charged on green projects.

This thesis facilitates the documentation process for users, by representing a computer model that automates the process of identifying the required number of points based on selected LEED certification categories, accumulates the total points selected as well as suggests the qualified certification. Furthermore, the developed model estimates for the total soft cost associated with the certification.

6.2 Research Contribution

The developed model in green building practice has the following contribution:

- Reducing one of the biggest barriers for going green by eliminating the documentation process
- The first model that deals with LEED categories, associated certification levels and soft cost estimation
- Saves users' time

- Reduces users' effort
- Simple points selection method
- Easy to use

The reason that it is easy to use is because there is no need for the applicant to document and record all points, just the expected points that he may achieve. Furthermore, the developed model will improve the documentation process. The model concentrates more on the soft cost rather than hard cost; also it does not analyze the cost associated with the different ways (material or system) that can be used to attain each credit or point.

6.3 Research Limitations

The developed model holds a number of limitations that include:

- It does not include all the LEED products; it includes only LEED-NC and LEED-Existing Building.
- It does not test the risk of achieving each point.
- It does not incorporate the cost analysis for each point depending on material and system used besides the project size and cost.
- It does not incorporate the construction (hard) cost.
- It does not include the Life Cycle Cost Analysis for the project.

6.4 Future Research Expansion

Because the green practice is still new to the construction industry, further studies and research efforts are needed. Included below are some suggestions for future expansion of this research.

1. This research focused only on two types of building; there are four more types that can be added in the future. These types are:
   a. LEED for Commercial Interiors LEED-CI
   b. LEED for Core and Shell LEED-CS
   c. LEED for Homes LEED-H
   d. LEED for Neighborhood Developments LEED-NC
2. Analyze each point's hard (construction) cost and its effect upon the total construction cost with respect to the other points, such as giving different weight for each point depending on the system or material used to achieve these points with respect to the benefit-to-cost ratio and life cycle cost analysis.
3. Detailed analysis of the points that are achieved by the already certified project's cost in order to distinguish between points or credits that have higher benefit from the ones that least benefit along with the value for these benefits.
4. Another study may be useful to focus on the risk management for achieving specific certificates with respect to the target credits and points that need to be achieved.

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Appendix A

LEED-NC Version 2.2 Registered Building Checklist

Sustainable Sites 14 Points

SS Prerequisite 1: Construction Activity Pollution Prevention Required

SS Credit 1: Site Selection 1

SS Credit 2: Development Density & Community Connectivity 1

SS Credit 3: Brownfield Redevelopment 1

SS Credit 4.1: Alternative Transportation: Public Transportation Access 1

SS Credit 4.2: Alternative Transportation: Bicycle Storage & Changing Rooms1

SS Credit 4.3: Alternative Transportation: Low Emitting & Fuel Efficient Vehicles 1

SS Credit 4.4: Alternative Transportation: Parking Capacity 1

SS Credit 5.1: Site Development: Protect or Restore Habitat 1

SS Credit 5.2: Site Development: Maximize Open Space 1

SS Credit 6.1: Stormwater Design: Quantity Control 1

SS Credit 6.2: Stormwater Design: Quality Control 1

SS Credit 7.1: Heat Island Effect: Non-Roof 1

SS Credit 7.2: Heat Island Effect: Roof 1

SS Credit 8: Light Pollution Reduction 1

Water Efficiency 5 Points

WE Credit 1.1: Water Efficient Landscaping: Reduce by 50 percent 1

WE Credit 1.2: Water Efficient Landscaping: No Potable Water Use or No Irrigation 1

WE Credit 2: Innovative Wastewater Technologies 1

WE Credit 3.1: Water Use Reduction: 20percent Reduction 1

WE Credit 3.2: Water Use Reduction: 30percent Reduction 1

Energy & Atmosphere 17 Points

EA Prerequisite1: Fundamental Commissioning of the Building Energy Systems Required

EA Prerequisite 2: Minimum Energy Performance Required

EA Prerequisite 3: Fundamental Refrigerant Management Required

EA Credit 1: Optimize Energy Performance 1-10

EA Credit 2: On-Site Renewable Energy 1-3

EA Credit 3: Enhanced Commissioning 1

EA Credit 4: Enhanced Refrigerant Management1

EA Credit 5: Measurement & Verification 1

EA Credit 6: Green Power 1

Materials & Resources 13Points

MR Prerequisite 1: Storage & Collection of Recyclables Required

MR Credit 1.1: Building Reuse: Maintain 75percent of Existing Walls, Floors & Roof1

MR Credit 1.2: Building Reuse-Maintain 95 percent of Existing Walls, Floors & Roof 1

MR Credit 1.3: Building Reuse: Maintain 50 percent of Interior Non-Structural Elements1

MR Credit 2.1: Construction Waste Management: Divert 50 percent from Disposal 1

MR Credit 2.2: Construction Waste Management: Divert 75 percent from Disposal 1

MR Credit 3.1: Materials Reuse: 5 percent 1

MR Credit 3.2: Materials Reuse: 10 percent 1

MR Credit 4.1: Recycled Content: 10 percent (post-consumer + 1/2 pre-consumer) 1

MR Credit 4.2: Recycled Content: 20 percent (post-consumer + 1/2 pre-consumer) 1

MR Credit 5.1: Regional Materials: 10 percent Extracted, Processed & Manufactured Regionally1

MR Credit 5.2: Regional Materials: 20 percent Extracted, Processed & Manufactured Regionally1

MR Credit 6: Rapidly Renewable Materials 1

MR Credit 7: Certified Wood 1

Indoor Environmental Quality 15 Points

EQ Prerequisite 1: Minimum IAQ Performance Required

EQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control Required

EQ Credit 1: Outdoor Air Delivery Monitoring 1

EQ Credit 2: Increased Ventilation 1

EQ Credit 3.1: Construction IAQ Management Plan: During Construction 1

EQ Credit 3.2: Construction IAQ Management Plan: Before Occupancy1

EQ Credit 4.1: Low-Emitting Materials: Adhesives & Sealants 1

EQ Credit 4.2: Low-Emitting Materials: Paints & Coatings 1

EQ Credit 4.3: Low-Emitting Materials: Carpet Systems 1

EQ Credit 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products 1

EQ Credit 5: Indoor Chemical & Pollutant Source Control 1

EQ Credit 6.1: Controllability of Systems: Lighting 1

EQ Credit 6.2: Controllability of Systems: Thermal Comfort1

EQ Credit 7.1: Thermal Comfort: Design 1

EQ Credit 7.2: Thermal Comfort: Verification 1

EQ Credit 8.1: Daylight & Views: Daylight 75percent of Spaces 1

EQ Credit 8.2: Daylight & Views: Views for 90percent of Spaces 1

Innovation & Design Process 5 points

ID Credit 1–1.4: Innovation in Design 1-4

ID Credit 2: LEED Accredited Professional 1

Appendix B

LEED-EB Version 2.0 Registered Building Checklist

Sustainable Sites 14 Points

SS Prerequisite1 Erosion and Sedimentation Control Required

SS Prerequisite 2 Age of Building Required

SS Credit 1 Plan for Green Site and Building Exterior Management 2

SS Credit 2 High Development Density Building and Area 1

SS Credit 3.1 Alternative Transportation: Public Transportation Access 1

SS Credit 3.2 Alternative Transportation: Bicycle Storage & Changing Rooms 1

SS Credit 3.3 Alternative Transportation: Alternative Fuel Vehicles 1

SS Credit 3.4 Alternative Transportation: Car Pooling & Telecommuting 1

SS Credit 4 Reduced Site Disturbance: Protect or Restore Open Space 2

SS Credit 5 Stormwater Management: Rate and Quantity Reduction 2

SS Credit 6.1 Heat Island Reduction: Non-Roof 1

SS Credit 6.2 Heat Island Reduction: Roof 1

SS Credit 7 Light Pollution Reduction 1

Water Efficiency 5 Possible Points

WE Prerequisite 1 Minimum Water Efficiency Required

WE Prerequisite 2 Discharge Water Compliance Required

WE Credit 1 Water Efficient Landscaping: Reduce Water Use 1-2

WE Credit 2 Innovative Wastewater Technologies 1

WE Credit 3 Water Use Reduction 1-2

Energy & Atmosphere 23 Points

EA Prerequisite 1 Existing Building Commissioning Required

EA Prerequisite 2 Minimum Energy Performance Required

EA Prerequisite 3 Ozone Protection Required

EA Credit 1 Optimize Energy Performance 10

EA Credit 2 On-site and Off-site Renewable Energy 4

EA Credit 3.1 Building Operations and Maintenance: Staff Education 1

EA Credit 3.2 Building Operations and Maintenance: Building Systems Maintenance1

EA Credit 3.3 Building Operations and Maintenance: Building Systems Monitoring 1

EA Credit 4 Additional Ozone Protection 1

EA Credit 5.1-5.3 Performance Measurement: Enhanced Metering 3

EA Credit 5.4 Performance Measurement: Emission Reduction Reporting 1

EA Credit 6 Documenting Sustainable Building Cost Impacts 1

Materials & Resources 16 Points

MR Prerequisite 1.1 Source Reductions and Waste Management: Waste Management Policy and Waste Stream Audit Required

MR Prerequisite 1.2 Source Reductions and Waste Management: Storage & Collection of Recyclables Required

MR Prerequisite 2 Toxic Material Source Reductions: Reduced Mercury in Light Bulbs Required

MR Credit 1 Construction, Demolition and Renovation Waste Management 2

MR Credit 2 Optimize Use of Alternative Materials 5

MR Credit 3 Optimize Use of IAQ Compliant Products 2

MR Credit 4 Sustainable Cleaning Products and Materials 3

MR Credit 5 Occupant Recycling 3

MR Credit 6 Additional Toxic Material Source Reduction: Reduced Mercury in Light Bulbs 1

Indoor Environmental Quality 22 Points

EQ Prerequisite 1 Outside Air Introduction and Exhaust Systems Required

EQ Prerequisite 2 Environmental Tobaccos Smoke (ETS) Control Required

EQ Prerequisite 3 Asbestos Removals or Encapsulation Required

EQ Prerequisite 4 PCB Removal Required

EQ Credit 1 Outside Air Delivery Monitoring 1

EQ Credit 2 Increased Ventilation 1

EQ Credit 3 Construction IAQ Management Plan 1

EQ Credit 4.1 Documenting Productivity Impacts: Absenteeism and Healthcare Cost Impacts 1

EQ Credit 4.2 Documenting Productivity Impacts: Other Impacts 1

EQ Credit 5.1 Indoor Chemical and Pollutant Source Control:

Non-Cleaning – Reduce Particulates in Air Distribution 1

EQ Credit 5.2 Indoor Chemical and Pollutant Source Control:

Non-Cleaning –High Volume Copying/Print Rooms/Fax Stations 1

EQ Credit 6.1 Controllability of Systems: Lighting 1

EQ Credit 6.2 Controllability of Systems: Temperature & Ventilation 1

EQ Credit 7.1 Thermal Comfort: Compliance 1

EQ Credit 7.2 Thermal Comfort: Permanent Monitoring System 1

EQ Credit 8.1 Daylighting and Views: Daylighting for 50percent of Spaces 1

EQ Credit 8.2 Daylighting and Views: Daylighting for 75percent of Spaces 1

EQ Credit 8.3 Daylighting and Views: Views for 45percent of Spaces 1

EQ Credit 8.4 Daylighting and Views: Views for 90percent of Spaces 1

EQ Credit 9 Contemporary IAQ Practice 1

EQ Credit 10.1 Green Cleaning: Entryway systems 1

EQ Credit 10.2 Green Cleaning: Isolation of Janitorial Closets 1

EQ Credit 10.3 Green Cleaning: Low Environmental Impact Cleaning Policy 1

EQ Credit 10.4-5 Green Cleaning: Low Environmental Impact Pest Management Policy 2

Credit 10.6 Green Cleaning: Low Environmental Impact Cleaning Equipment Policy1

Innovation in Operation, Upgrades and Maintenance 5 Points

IOUM Credit 1.1-1.4 Innovation in Operation & Upgrades 1-4

IOUM Credit 2 LEED Accredited Professional 1

Appendix C

Case Study: MAREC Detailed Credits Achieved

Source (USGBC, 2006j)

Sustainable Sites		
Prereq 1	**Construction Activity Pollution Prevention**	Required
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**, Low-Emitting and Fuel-Efficient Vehicles	1
Credit 4.4	**Alternative Transportation**, Parking Capacity	1
Credit 5.1	**Site Development,** Protect of Restore Habitat	1
Credit 5.2	**Site Development,** Maximize Open Space	1
Credit 6.1	**Stormwater Design,** Quantity Control	1
Credit 7.1	**Heat Island Effect,** Non-Roof	1
Credit 7.2	**Heat Island Effect,** Roof	1
Credit 8	**Light Pollution Reduction**	1
		11

Water Efficiency		
Credit 1.1	**Water Efficient Landscaping**, Reduce by 50percent	1
Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
Credit 3.1	**Water Use Reduction**, 20percent Reduction	1
Credit 3.2	**Water Use Reduction**, 30percent Reduction	1
		4
Energy & Atmosphere		
Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Prereq 2	**Minimum Energy Performance**	Required
Prereq 3	**Fundamental Refrigerant Management**	Required
Credit 1	**Optimize Energy Performance**	7
Credit 2	**On-Site Renewable Energy**	3
Credit 4	**Enhanced Refrigerant Management**	1
Credit 6	**Green Power**	1
		12

Materials & Resources		
Prereq 1	**Storage & Collection of Recyclables**	Required
Credit 2.1	**Construction Waste Management**, Divert 50percent from Disposal	1
Credit 2.2	**Construction Waste Management**, Divert 75percent from Disposal	1
Credit 4.1	**Recycled Content**, 10percent (post-consumer + ½ pre-consumer)	1
Credit 4.2	**Recycled Content**, 20percent (post-consumer + ½ pre-consumer)	1
Credit 5.1	**Regional Materials**, 10percent Extracted, Processed & Manufactured Regionally	1
		5
Indoor Environmental Quality		
Prereq 1	**Minimum IAQ Performance**	Required
Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
Credit 1	**Outdoor Air Delivery Monitoring**	1
Credit 2	**Increased Ventilation**	1
Credit 3.1	**Construction IAQ Management Plan**, During Construction	1

Indoor Environmental Quality		
Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
Credit 5	**Indoor Chemical & Pollutant Source Control**	1
Credit 8.2	**Daylight & Views**, Views for 90percent of Spaces	1
		9
Innovation & Design Process		
Credit 1.1	**Innovation in Design**: Exemplary Performance: Green Power"	1
Credit 1.2	**Innovation in Design**: Educational Outreach Program	1
Credit 1.3	**Innovation in Design**: Fuel Cell	1
Credit 1.4	**Innovation in Design**: Green Housekeeping	1
Credit 2	**LEED® Accredited Professional**	1
		5
Project Totals (pre-certification estimates)	**Gold**	**46**