RETROFITTING OF EXISTING BUILDING AIMING LEED CERTIFICATION USING BIM

FINAL YEAR PROJECT UG 2014

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This is to certify that the

Final Year Project Titled

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for the undergraduate degree

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ABSTRACT

LEED, or Leadership in Energy and Environmental design, is the most widely used green building rating system within the world available for nearly all buildings, community and residential project types. LEED provides a framework to form healthy, highly efficient and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement. Instead of targeting new buildings this research aims to find the optimal retrofitting solutions for existing building keeping in mind the cost and availability of products in Pakistan. An educational institute in NUST was chosen, and the methodology used involves simple understanding of LEED v4 (BD+C) and involves softwares such as Autodesk REVIT 2017 and manual calculations. The retrofitting solutions proposed in this study can be used to achieve Silver category of LEED certification for case study building.

DEDICATION

We dedicate our thesis to our parents, teachers and everyone who helped us in our project.

ACKNOWLEDGEMENTS

We are thankful to Almighty Allah, Who gave us the courage and strength to complete this research. We would like to pay a debt of gratitude to our advisor, Dr. Khurram Iqbal, for his profound encouragement to complete this research, which was a great support throughout this journey. We sincerely appreciate the valuable time, motivation, and personal support he provided for this research. We are also incredibly grateful to our co-advisor Lecturer Bilal Ayub for his sincere guidance in all regards. The guidance and support from Dr. Abdul Rehman Nasir was vital, above all, for the success of this research. We would also like to pay our earnest and honest gratitude to our parents and friends for their unconditional support, encouragement, prayers. We pay our earnest gratitude with sincere sense of respect to our family members for their unending support, encouragement, prayers and patience.

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KEY TO ABBREVIATIONS

BIM	Building Information Model
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment and Environmental Assessment Methodology
LOD	Level of Development
MEP	Mechanical, Electrical and Plumbing
CAD	Computer Aided Design
ASHRAE	American Society for Heating, Refrigerating and Air Conditioning Engineers
USGBC	United States Green Building Council
CASEN	Center of Advanced Studies in Energy, NUST

CHAPTER 1

INTRODUCTION

1.1 Preamble

The process of emergence, innovation and elevation are the only constants in today's world, and all of this is being done for better performance in general and for better living in particular. Construction industry or construction methods are being modified and improved continuously. Green buildings are one of the major breakthrough that researchers made during a decade or so and top assess the performance of these buildings we have developed different rating tools.

The globally followed rating system to evaluate the performance of the green buildings is LEED (Leadership in energy and environmental design) (Newsham, Mancini, & Birt, 2009). Its nemesis BREEAM, HK-BEAM 96 are also followed in UK and Hong Kong respectively. These buildings standards have encouraged the developers to look for more sustainable approach. These rating systems include different criteria such as indoor air quality, materials and resources and then certify the buildings accordingly i.e. platinum, gold, silver etc. according to the points a building score (Refer Figure 1). The rating systems target buildings differently depending on its type i.e. newly constructed building, major refurbishment of building, retails, hospitals and education institutes. These rating systems subdivide their categories into smaller categories and give them credit points which then all add up to form a cumulative score. The LEED certified buildings play an important role not only in conversion of energy resources, but these also increase comfort of the occupants.

Buildings conforming to these standards have positive impact on the environment and in US you get additional benefits such as increased rent cost, higher occupancy rate and deduction in taxes. However, such laws and regulations have not yet been introduced in Pakistan.

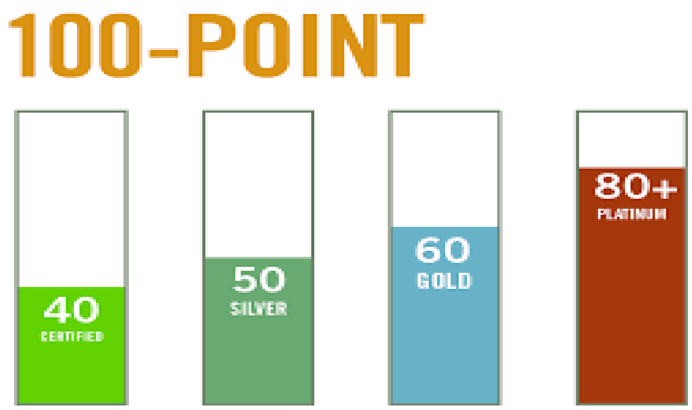

Figure 1: Classification of LEED Certification

1.2 BIM

BIM was introduced earlier in 21st century to enhance the understanding of a building. The most common functions performed by BIM are design, construction quantity take off, facilities management etc. but the actual concept dates back to almost three decades (Eastman et al., 2011).A model in BIM environment not only can perform the above mentioned functions but it is more capable than that for example a user can vary the properties of a material by just a click and it also demonstrates the energy analysis, life cycle and life cycle cost analysis of a building. (Alwan, Greenwood, & Gledson, 2015).This demonstration enables quantities and shared properties of materials to be readily extracted, and scopes of work to be easily isolated and defined. BIM is equally common among architects and for them it is a model based technology that is easily accessible and can be used simultaneously among all the stake holders involved in a project. The information within BIM objects benefits all the design and construction processes. BIM data is now all set to revolutionize the construction industry as it also follows its applications in 2D environment. Implementing BIM in a firm does not only improve the productivity of a firm but also monetary benefits (Wu & Issa, 2014).BIM represents the process of development, and use of a computer simulation emulating the planning, design, construction, and operation of a building facility (Azhar, Carlton, Olsen, & Ahmad, 2011).BIM is a complete package that provides its user with an in-depth understanding of a building. With the rapid technologies in computer and construction industry we are now enable to duplicate the exact site condition on the computer and perform the corresponding analysis.

1.3 Retrofitting

A person usually spends 70-90% of their lifetime in buildings. Energy-efficient or green building retrofitting is a huge contribution to the sustainability of the society. Existing green building standards are also enacted for local environmental benefits. LEED designed buildings, whether retrofitted or new are ones that optimize the energy consumption associated with the typical uses of the building including the heating and cooling energy needs while maintaining the envisaged temperature. Buildings are energy extensive throughout their whole life cycle; therefore preserving the existing structures has more potential to save energy and reduce GHG emissions while incurring less cost than completely relying on new energy efficient or green buildings(Maltese et al., 2017). However, retrofitting can at times be more challenging. There is a plethora of retrofit techniques available. The optimal combination of such techniques can be chosen through cost and energy effective analysis and simulations.

1.4 Background

During the last years many researchers focused on the load and demand management because of the depletion of resources and increasing enthalpy. The total energy used in buildings is 32% of the entire energy consumption in the world; In terms of basic energy consumption buildings account for almost 40% in most IEA (International Energy Agency) countries like England, New Zealand. Secondly to meet the energy performance and load management is a key issue to achieve the EU climate and Energy Objectives as the main objectives are to reduce the greenhouse gases emissions by 20% till the end 2020 as well as 20% of energy savings, so in order LEED is very successful (Ding 2008).

Pakistan is under the development process and its ability to cope with the energy situation now demands that new methods or researches be started so that power consumption can be minimized. It also addresses the current civil engineers to find new ways and new techniques so that in the near future we don’t have to face the same situation. Although new power projects are being started in Pakistan and the power will be added in National Grid System it is still the need of the hour that such ways be found which will decrease the energy consumption.

Construction of buildings in Pakistan is still very traditional, concept of sustainable buildings, and new methods such as LEED or BREEAM are not followed on a large scale. These traditional methods include cost saving techniques, increasing life of structure, using non-renewable resources and buildings not conforming to the standards of OSHA. This can be due to the number of reasons:

1. Initial Cost saved upfront
2. Social Acceptability
3. Awareness
4. Convenience
5. Time
6. Traditional methods of construction still being followed

One of the many applications of BIM is to transfer the actual situations present on site into computers and run different simulations such as energy analysis, replacing different materials, tracking the life cycle of building etc.

1.5 Problem Statement

It's a matter of fact that natural resources are depleting and there are threats of climate change, it's considered that green buildings are one of the valuable factors in sustaining the environment. Awareness is being raised, due to which modern world is now moving towards the construction of green buildings by following the guidelines like LEED, BREEAM etc., however, in order to effectively ensure sustainability of the environment, it is imperative to convert existing buildings to Green Buildings and for that matter it is important to study how retrofitting can be carried out for this purpose. Using BIM for sustainability assessments will help in increasing its incorporation in construction industry which will also benefit all the stakeholders involved in a project.

1.6 Objectives

We aim to achieve the following objectives through this project:

a) To understand the concept and application of LEED criteria.
b) To model a case study building in BIM environment.
c) To evaluate and suggest retrofit solutions based on LEED criteria for certification.

d) To develop a relationship between cost and LEED credit points for building retrofitting.

1.7 Softwares

Following is the list of softwares that are used for this study

e) Autodesk Revit
f) Autodesk AutoCAD
g) Autodesk Insight
h) A360
i) Oracle Primavera
j) Microsoft Excel

The purpose and details of each of the above mentioned softwares will be provided in the section in which they are used.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Study

Due to detrimental effects of traditional buildings researchers are now more willing to improve the sustainability and life cycle implications of the building. To overcome these factors designers, researchers and engineers are focused to combine technical advances in materials and energy systems with newly developed methods (Moussa & Farag, 2017)**).** An example in this case can be of a green roof, vertical farming, and exact orientation of shades and life cycle analysis of building as well as raw materials that will be used during its construction and demolition phases. Although we are moving to new exact methods but still we need to understand the effectiveness of the methods that will be used.

2.1.1 LEED

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), targets different types of buildings differently. LEED for the purpose of its applicability and modification have developed different versions keeping in mind the use, occupants schedule, life cycle implications and its use in a certain environment.

Figure 2 discusses different aspects of the buildings that LEED online rating system targets. It must be kept in mind that these categories are constant however the percentage of these categories vary with the change in building type. As discussed earlier LEED finds its applicability in number of different projects and some of the project are listed below:

- New Construction(BD+C)
  - Institutions
  - Health Care Facilities
  - Retail Centers
- Existing Buildings: Operations & Maintenance(O+M)
  - Datacenters

    - Hospitality
    - Warehouse and Distribution Centers
    - Multifamily
- Interior Design and Construction
    - Commercial Interiors
    - Retails
    - Hospitality

LEED certified buildings mean increased standard of living along with better environment therefore encouraging energy efficient buildings. Certified buildings payback period is also decreased as they decrease utility bills, high lease rate and increased rents. According to a survey conducted by website of USGBC, United States can save more than $29.8 billion by 2018.

2.1.2 LEED Certification Process

One of the main reason for the popularity of LEED is its certification process, after going through many research papers we can conclude that LEED certification process involves third party verification the GBCI verifies the projects compliance with LEED requirements. The certification process for design teams is made up of two consecutive applications: one including design credits, and one including construction credits. Design credits are drafted by architect and engineer and are represented in official construction drawings. Construction credits are the responsibility of the contractor and these requirements are met by the contractor during the construction and commissioning of the building.

2.1.3 LEED Prerequisites and Credit Points

The total credit points for LEED are 110 and they are further divided into categories. The given pie chart shows the division of credit points.

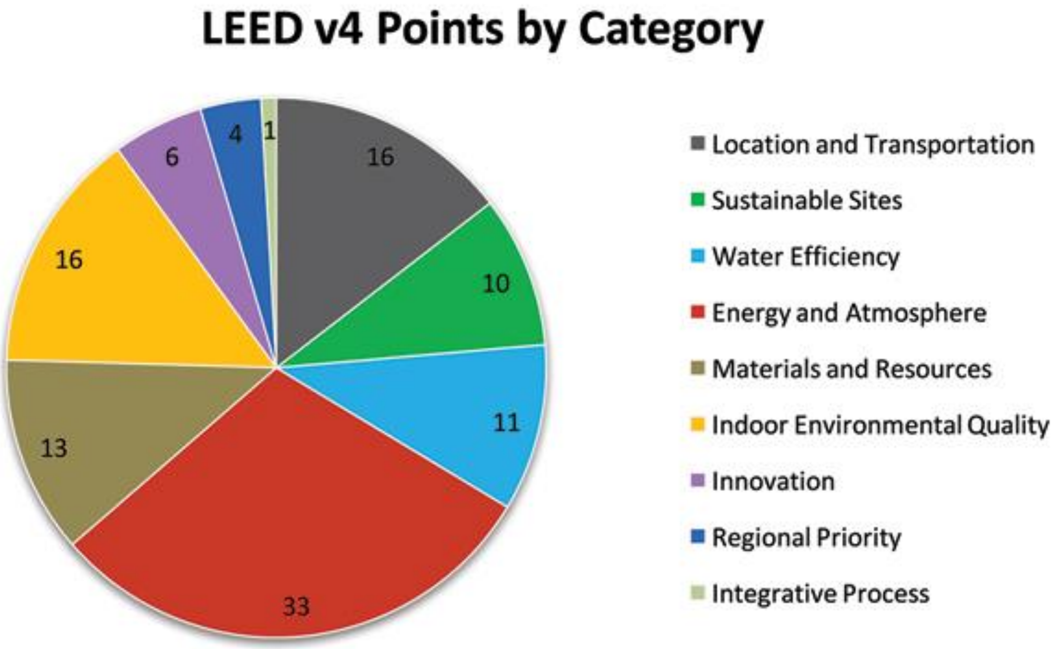

Figure 2: LEED v4 points by category

These categories are further divided into credit categories and prerequisites. Prerequisites are necessary to achieve whereas for credit points there are different options that are chosen based on the basis of convenience. Normally, there are more than two options available. Figure below shows LEED Categories with their constituent sub-categories.

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Project Name:
Date:

Y	?	N			
			Credit	Integrative Process	1
0	0	0	**Location and Transportation**		**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1
0	0	0	**Sustainable Sites**		**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	0	0	**Water Efficiency**		**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1
0	0	0	**Energy and Atmosphere**		**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2
0	0	0	**Materials and Resources**		**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2
0	0	0	**Indoor Environmental Quality**		**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	0	0	**Innovation**		**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0	**TOTALS**	Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Figure 3: LEED detailed points division

2.2 Retrofitting of a building

Retrofitting of a building can be termed as the addition of a component or accessory that was not present earlier during its construction process. Retrofitting although economical process compared to start from the scratch but it has many challenges as well. It will be unwise to apply same retrofitting techniques without keeping in mind the effect of climate change, services change, and impact of these retrofitting solutions. Other challenges associated with retrofitting are financial and time constrains. Retrofitting can increase the standard of living by increased staff productivity and reduced maintenance costs. With the global drive towards retrofitting existing buildings, the optimal solution for retrofitting is a multi-decision criteria. While making this decision one should keep in mind specific building characteristics, total budget available, project cost, building services type and efficiency. The overall process of retrofitting can be divided into five major phases

- Project Survey and Pre-Retrofit Survey
- Energy audit and Performance Assessment
- Identification of Retrofit Options
- Site Implementation and Commissioning
- Validation and Verification

The key elements that increase the success of retrofitting includes regulations for a certain region, retrofit technologies, information related to a building human behavior factors and uncertainty factors. The techniques available in market now vary from installation of efficient energy systems, advanced controls and renewable energy systems to change the consumption requirements. The information related to the building such as location, its utility, energy resources, type utility rate structure, age and occupancy also finds their application in decision making criteria. For a particular project, the optimal retrofit solutions must be determined by keeping in mind building specific information. (Konishi, 2017)

For commercial and institutional buildings, it has been observed that the potential for retrofit is greater when compared to residential buildings. Normally they require repair of refurbishment process after 15-20 years so if these buildings can support retrofitting measures these measures can then increase its efficiency level and the standard. Optimal retrofitting solution for a selected project can increase its sustainability at relatively low cost and high uptakes.(Giddings, Hopwood, & O'brien, 2002)

The retrofit technologies can be divided into three categories

a) Supply Side Management
b) Demand Side management
c) Change of Energy Consumption Patterns

Because of the increasing environmental awareness researchers have contributed to supply management which includes building electrical system retrofits and the use of renewable energy consumption.

Building air tightness techniques, windows shading and strategies to reduce building heating and cooling demand are included in demand side management.

Energy consumption patterns aim comfort requirements, occupancy regimes, management and maintenance, occupant activities and access to controls. (Autodesk, 2005)

2.2.1 Using BIM for Retrofitting of Existing Buildings

BIM offers its user with comprehensive and integrated platforms for construction projects not only in new construction but also in retrofit projects. The condition of the building i.e. type, age, ownership, structure, required level of details are the inputs required in BIM to carry the retrofitting process. The difference in frameworks and the outputs expected from BIM can greatly increase the retrofitting process. (Bernstein, 2007)

Only selected materials, LEED categories or equipment can be targeted in retrofitting while using BIM. Due to current energy situations, energy gained the most momentum under green and sustainable buildings. The results extracted from BIM for energy analysis comes into question when compared with other methods for energy renovation drives. The advancement of energy audit technologies offer more exact and reliable information. For refurbishment of existing buildings, number of soft wares with their simulation can be used to assess the performance of energy retrofit measures. Other literature work describes the prerequisites, credits, and measurement methods required to achieve a certification for a refurbished building while others quantified the financial benefits of improving the environmental performance of existing buildings. BIM can also help its user by providing a solution to achieve a sustainable approach by providing digital model of premises and making the possible options comprehensive for stakeholders and assure them about the quality of retrofit measures. By linking cost information to the models, designers and stakeholders are able to obtain more accurate quantity schedules and cost estimations. Accurate quantity information allows designers to convince homeowners through cost drivers and market trends accompanied by a robust plan of work. By comparing the investment costs and energy savings at the initial stage of a project stakeholders can be reassured over the payback period. The clash detection tools in BIM reduce the errors and thus also construction time. Although capturing sufficient and accurate data can at the moment be time consuming, the technologies are developing fast and considerable improvements in automated capturing are expected in the near future and, in general, BIM applications will improve the predictability and reduce the time of construction in retrofit schemes.

BIM has a collaborative environment, the 3D visualization and coordination, eliminating object clashes and by providing real time analysis of proposed retrofitting for an existing building it is one of many ways to select optimal solution of retrofitting.

To model an existing building in BIM environment one should know what he wants to achieve from the model. Existing site conditions can be shown by 2 D format or 2D CAD files from a prior project or as underlays of architectural information.

2.3 BIM and its Application in LEED Evaluation

BIM (Building information modelling) has been in use worldwide for a decade and it also finds its application in evaluation of sustainability of building. BIM allows for a more reliable data transformation, removing ambiguities and providing a simple platform for working. BIM is considered to be the most innovative process-oriented methodology in construction.(Maltese et al., 2017)

Building Information Modeling (BIM) allows for multi-disciplinary information to be superimposed within one model, it creates an opportunity for sustainability measures and performance analyses to be performed throughout the design process. A model in BIM environment can also help architects in many ways for example they can analyze a buildings conceptual mass and form to optimize envelope and adjust the glazing ratios of a building. Energy demands can also be optimized by engineers by changing different electrical equipment, window shades and materials used for the building. A single BIM model can also be of a great value to the contractor. A contractor can use BIM to analyze site conditions, including wetlands and protected habitats to eliminate potential issues. Moving to the subcontractors, they can use BIM to reduce waste and to reduce GHG emissions and carbon footprints. GSA has made it compulsory now to use BIM on all major products to estimate accurate energy requirements in design process. Implementing BIM in these type of projects can potentially increase budget for a certain project and also plays vital role on final design construction and operating costs.

Many practitioners, academics and policy makers now think that BIM has a great potential to move all the stake holders to better decision making to go for green and sustainable building.

The sustainable design for an existing building can be the byproduct of the standard design process. To put in simple words a sustainable design can be easily extracted by using BIM for your project. (Wong & Fan, 2013)

BIM finds its applications in the conceptual phase of a project which can be really helpful in earlier modifications of the design. Linking the model using different energy analysis tools to evaluate the energy consumption during the early design phase. It could not have been possible while using 2D traditional tools. 2D tools require a separate energy analysis to be performed at the end of a design process, thus increasing the time, cost and iterations for a certain project.

2.4 Energy Optimization, Environmental Impacts and LEED

The building sector consumes 30-40% of energy and 12% potable water globally. In addition reported negative impacts on environment result in 45-65% of solid waste and 40% carbon dioxide emissions. The replacement rate of existing buildings vs. new buildings is about 1-3% per year, resulting in existing buildings being the largest segment of the building sector where energy and water saving opportunities can be identified (Thesis of Smart Buildings, 2012).

A study conducted yielded the following results:

After energy analysis of 100 LEED certified buildings it is concluded that 2 out of 5 buildings use less energy than their counter parts however more than quarter of LEED certified buildings perform poorly than their conventional counter parts. It will be in conclusive to state that LEED certified buildings save energy.

It can be concluded that although the higher the category for LEED it will have more points in energy but it cannot be said that silver category will perform better energy wise when compared to certified building or buildings having gold category would perform worse as compared to platinum category. There were, for example, certified buildings that received more energy credits than Gold/Platinum buildings.

2.5 Expected Outcomes

Following are the expected outcomes of our case study project:

a) Detailed Building Information Model of CASEN building.

b) Recommendations for retrofitting of case study building to achieve LEED certification.

c) A relationship between retrofitting cost and LEED credit points of project.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to explain the methodology that was followed to achieve the objectives of this research study.

3.2 Methodology Flowchart

The following flowchart shows the path which is followed during this research study:

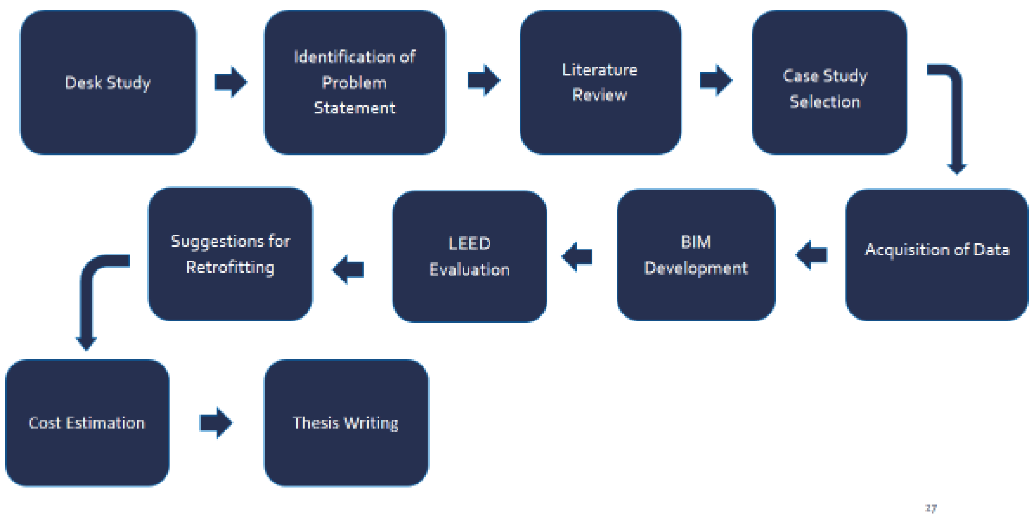

Figure 4: Methodology Flow Chart

3.3 Case Study Selection

For the research to be conducted, a real life building needs to be selected. CASEN (Center for Advanced studies and Energy) located in NUST H-12, is selected as case study building for this research study.

Salient Features of Building are:

a) Total Site Area = 64690 sq.ft
b) Building Footprint Area = 17611 sq.ft
c) Total Floors of Building = 4
d) Total Cost = $5 million
e) Client: USAID
f) Consultant: Kashif Aslam & Associates
g) Contractor: Izhar Group of Companies

Following are the reasons to select this building as our case study:

a) Its drawings and specifications were easily available from NUST PMO.
b) It includes almost all the components on the basis of which LEED evaluates a green building.
c) It also follows the fixed occupancy schedule 12/5.
d) Building is easily accessible as it lies in NICE vicinity.
e) As it is the project of NUST itself, hence in case of any ambiguity we can consult NUST professionals who have worked on this project.

3.4 BIM Model

The building model was modeled using Autodesk Revit using the drawings obtained from PMO.

3.4.1 Structural Model

a) AutoCAD Drawings were linked with our project file.
b) Grids were modeled.
c) Levels were assigned.
d) Structural Columns and Beams were assigned to their reference levels.
e) Structural Slabs for respective grounds were also modelled.

3.4.2 Architectural Model

a) Structural Model was saved and then linked with the architectural model.
b) Grids, Levels and Columns were copied.
c) Different Walls for floor, First floor, Second floor and third floor were placed.

d) Windows and Doors were installed on respective floors.
e) Flooring plans with specific rendering appearance were also modelled.
f) Three staircases were also modelled.

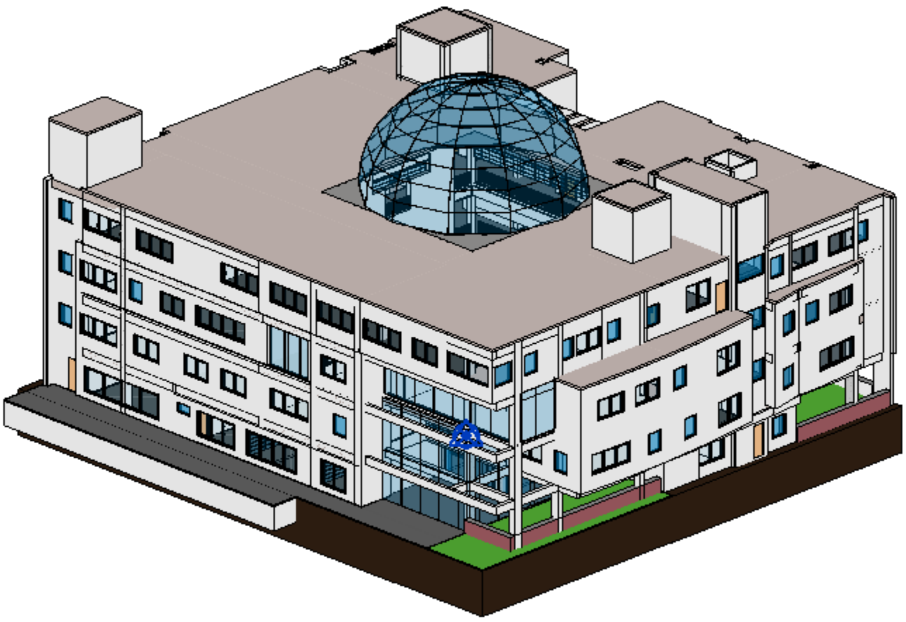

Figure 5: CASEN model

3.4.3 Sections and Walkthroughs

a) For better understanding of building, sections and walkthroughs were also rendered in Revit.
b) Some building elements were also painted.
c) Gypsum plaster board and Vinyl emulsion was applied.

3.4.4 Ceiling plans

a) Ceiling plans for respective floors were also modelled.

3.4.5 Plumbing fixtures

a) Families were downloaded from internet and they were modified accordingly.
b) Plumbing fixtures for bathrooms including urinals, faucets and sinks were installed.

3.5 LEED Evaluation and Criteria

As already mentioned, there are different version of LEED criteria available. For our research we have used LEED v4 of BD+C (Building design and construction). After going through LEED categories, we came to the conclusion that different softwares are also required to be used for evaluating certain credit points along with judgement. These softwares are mentioned in table below:

Table 1: Software used for evaluation of different categories

Category	Software
Energy analysis and performance	Autodesk Revit and Insight 360
Indoor water reduction	Calculator by LEED and MS excel
Area Calculations	Autodesk Revit
Surrounding Density and Diverse Uses	Google Maps

The credit points achieved in our study through BIM are minimal due to following reasons

a) Financial Constraints
b) Out of Scope
c) Time Constraints
d) Specifications and BOQs of Buildings

CHAPTER 4

LEED EVALUATION

4.1 General Introduction

This chapter is focused on LEED evaluation of CASEN Building. LEED v4 is used in this research study which evaluates a building on the basis of following eight categories:

a) Location and Transportation
b) Sustainable Sites
c) Water Efficiency
d) Energy and Atmosphere
e) Materials and Resources
f) Indoor Environmental Quality
g) Innovation
h) Regional Priority

These categories are discussed in this chapter with their constituting sub-categories. Each sub-category is explained with its intent, requirements, required calculations and achieved credit points in that sub-category. Existing case study building doesn't fulfill the requirement of many sub-categories, retrofit solutions are also proposed for such sub-categories to achieve credit points. Some sub-categories are evaluated using softwares and LEED calculators provided by USGBC, results of software analyses and calculators are shown with those sub-categories.

4.2 Location and Transportation (LT)

4.2.1 LT Credit: Sensitive Land Protection

The aim of this credit is to cut back the impact on environment due to the location of a building and prevent the construction on sites which are environmentally sensitive.

As case study building is being retrofitted hence this project fulfills the requirement of first option of this credit which requires to establish the building's footprint on site which is already developed.

Credit Achieved: 1

4.2.2 LT Credit: High Priority Site

The credit aims to promote project sites in locates with development restrictions or constraints and aim to assist in promoting the health of encircling area.

Case Study Building doesn't neither lie in Historic District nor in any other listed category hence this credit can't be achieved.

Credit Achieved: 0

4.2.3 LT Credit: Surrounding Density and Diverse Use

This aim of this category is to boost health of the public by fostering physical activity and protecting land and defending land being used for farming and wildlife's settlements by fostering development on sites with already present infrastructure. To encourage walking, and transportation potency and scale back distance travelled by using vehicles.

Following buildings lie within 800-meters walking distance from the main entrance of CASEN Building:-

1) Educational facility (NICE, NIT, Exam Hall)
2) Bank (HBL)
3) Cafeteria (C2)
4) Place of Worship (Masjid E Rehmat)
5) Office (CIE, Admin Block)
6) Hostels (Rumi 1, 2, 3)

Area marked blue in the figure below shows the area lying within 800 meters starting from the entrance of CASEN Building.

Figure 6: Marked Area lies within 800m radius from CASEN main entrance.

Credits Achieved: 2

4.2.4 LT Credit: Access to Quality Transit

This credit aims to foster construction of buildings in such areas which different modes of transportation available or contrarily minimized motorized vehicles utilization as a result of which reduction in pollution, greenhouse gas emissions and other environmental issues related to motorized vehicles use can be achieved.

Total Students Studying in CASEN = 230

Hostelite Students: 173 (75.2%)

As all hostels lie within 1200 meters distance from the entrance of CASEN building and all hostelites have pedestrian access hence CASEN building achieves 4 points as per option 2.

Credits Achieved: 4

Figure 7: Marked Area lies within 1200m radius from CASEN main entrance.

4.2.5 LT Credit: Bicycle Facilities

This credit aims to scale back distance travelled by public using vehicles and to boost the health of the public by promoting effective physical activity and to promote transportation efficiency and encouraging people to travel distance on bicycle. Requirement for this credit is that a bicycle facility should be provided within one hundred and eighty meters walking distance from the building entrance.

To achieve this credit following retrofits are recommended:-

“Cyqik” stand to be provided within the parking area of CASEN

Construct three washrooms (containing showers and changing facility) in parking area.

After provision of above facilities 1 credit point can be achieved.

Credits Achieved: 1

4.2.6 LT Credit: Reduced Parking Footprint

This aim of this category is to attenuate the impacts on environment related to parking facilities, as well as public dependence on automobile, consumption of land and runoff generated as a result of rainfall.

Current Parking Slots = 40

Total Population of Building = 302

Base Line:

From Table 18-2 Parking and Recommended Parking ratios for ITE codes 021 through 495 (as recommended by LEED)

Type: University/College (Urban)

85th percentile=0.19

302*0.19=57.38≈58

Reducing 40%

Parking Slots after reduction of 40% parking slots = 58*60%=34.78≈35

Total parking slots to be reduced = 40-35 = 5

As Bicycle facility and Washrooms are to be constructed in parking area to achieve Bicycle Facility Credit hence 5 slots will get reduced from the available parking slots.

Credit Achieved: 1

4.2.7 LT Credit: Green Vehicles

The aim of this category is to promote the usage of green vehicles rather than conventionally fueled cars as a result of which pollution can be reduced.
To achieve this credit 5% of the total parking lots designated for the building occupants should be prioritized to be used by green vehicles and installation of Electrical Vehicle Charging Equipment (EVSE) in 2% of total parking lots designated for the building is required.

Total Parking Slots Available = 35

For Green Vehicles
35*5%=2 slots

Electrical vehicle supply equipment (EVSE)
35*2%=0.7≈1 EVSE

Hence to achieve this credit it is recommended to paint 3 parking slots with green paint to show dedicated parking for green vehicles and install one EVSE for charging of green vehicles.

Credit Achieved: 1

4.3 Sustainable Sites (SS)

4.3.1 Prerequisite: Construction Activity Pollution Prevention

This credit aims to prevent erosion, waterway sedimentation and dust in air as a result of which pollution can be reduced.

As retrofitting construction will be executed on already constructed site so erosion and sedimentation chances are negligible hence prerequisite requirement is fulfilled.

4.3.2 SS Credit: Site Assessment

The requirement to be fulfilled to achieve this credit is the assessment of conditions prevailing on site before design to figure out sustainable options related to site design.

To achieve this credit it is recommended to conduct a site survey and document the information obtained related to site conditions, plants, underground water, rainfall, human use and other requirements as mentioned in LEED Criteria. As LEED Accredited Professional will be hired during the retrofitting project, it will be his duty to complete this document.

Credit Achieved: 1

4.3.3 SS Credit: Site Development

The target of this category is to restore damaged sites as a result of which natural habitat can be produced and biodiversity can be promoted and existing natural areas can be protected in this way.

To achieve this credit, option 2 provided by LEED requires that an amount equal to $0.4 per square foot of site area to be donated to any land conservation organization that must be nationally recognized e-g SCOPE in Pakistan.

Total Site Area = 64690 sq.ft

Amount to be provided per sq.ft = $0.4

Total Amount to be provided = $0.4*64690sq.ft = $25876

This credit is not being aimed in this research study.

Credit Achieved: 0

4.3.4 SS Credit: Open Space

This category encourages the interaction of building occupants with the surrounding and promotes socializing and physical activities.

To achieve this credit it is required that at least 30% of site area should be designated for outdoor space out of which 20% should be vegetated.

Total site area = 64690 sq.ft

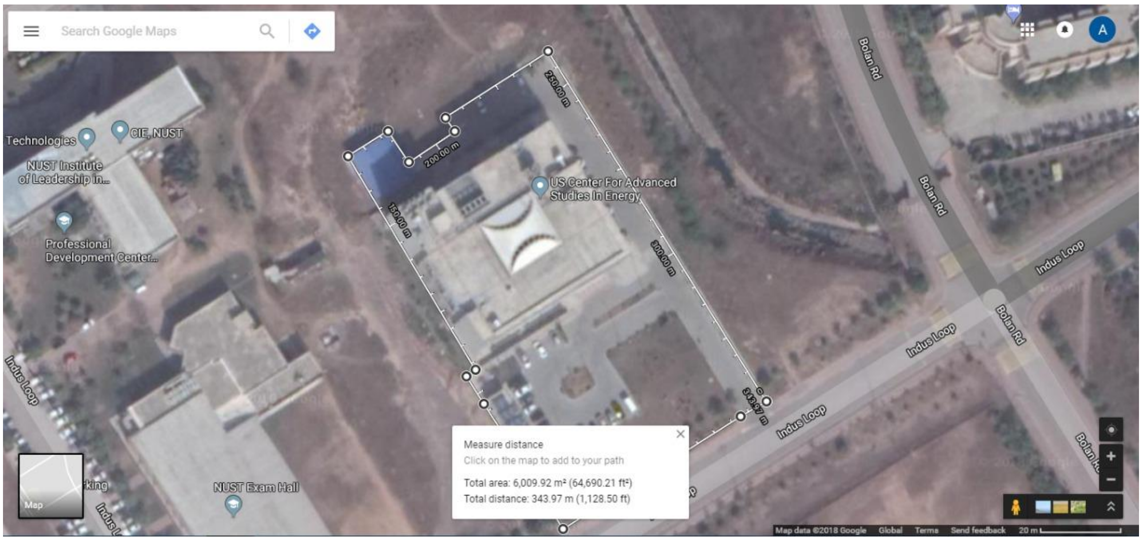

Figure 8: Total site area

Outdoor area = 64690-17611 =47079 sq.ft (greater than 30% of total area i.e. 19407 sq.ft)

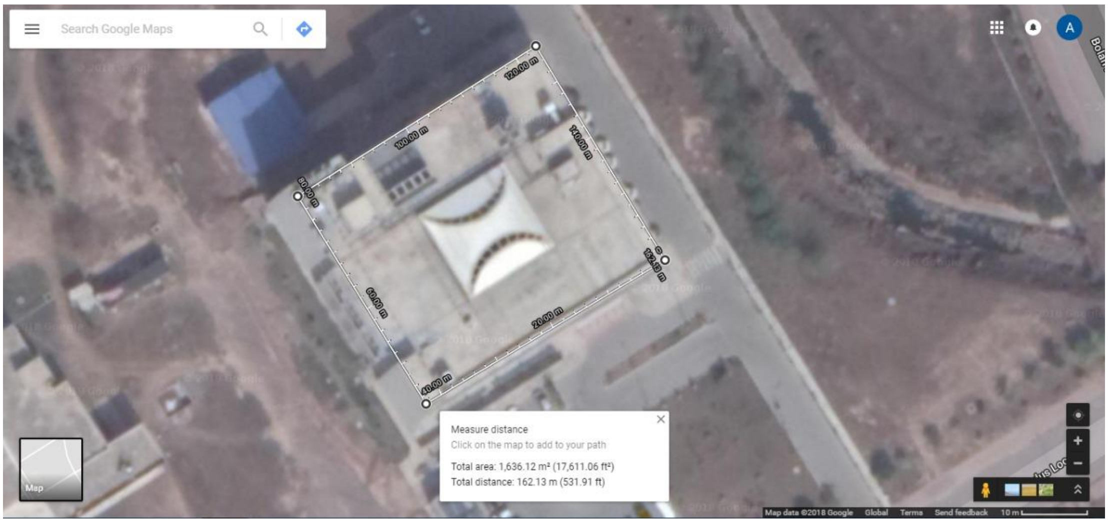

Figure 9: Total outdoor area

Outdoor vegetation area = 11900.22+426.64= 12327 sq.ft (greater than 25% of outdoor area i.e. 11770 sq.ft)

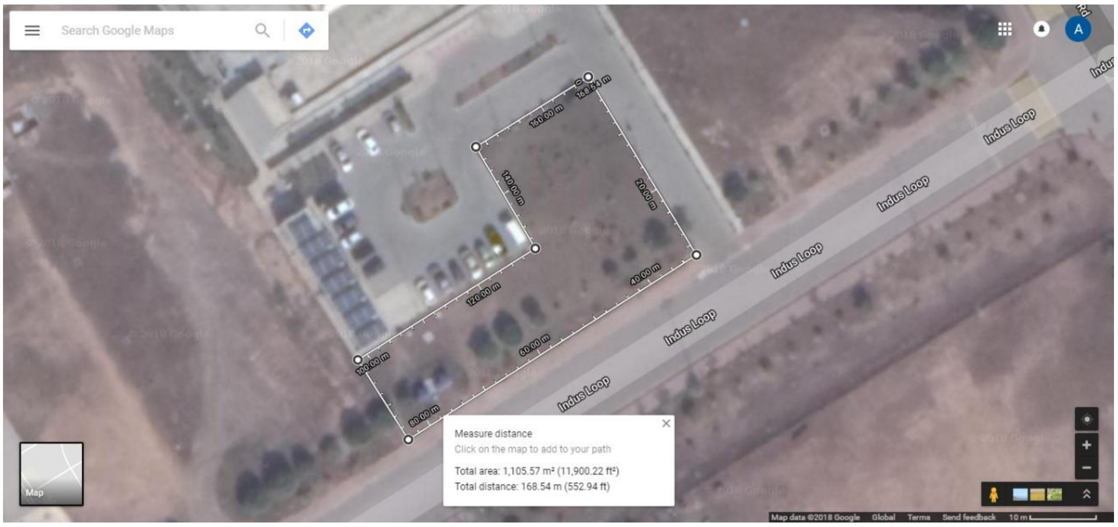

Figure 10: Total outdoor vegetation area

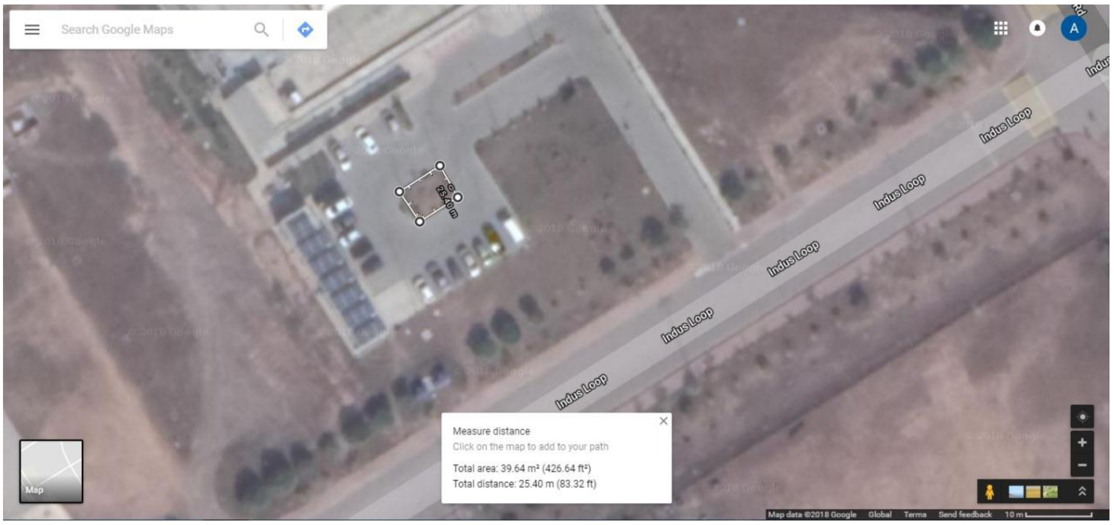

Figure 11: Total Vegetated Area

This credit category also requires that the provided outdoor space should be physically accessible and should have variety of vegetation and plants that fosters visual interest.

Credit Achieved: 1

4.3.5 SS Credit: Rain Water Management

This credit aims to scale back the volume of runoff generated due to rainfall and improvement in quality of water by the replication of natural hydrology and balance of water in the region.

Following calculations show the annual increase in runoff (Option 2):

Annual Precipitation = $P_{Islamabad}$ = 1142.1mm per year

Before Construction

For farmland, park, pasture etc. K= 0.3

Runoff = R= P*k

R1 = 1142.1*0.3 = 342.6 mm/year

After Construction

For commercial etc. K=0.9

R2 = 1142.1*0.9 = 1027.89 mm/year

Annual Increase in runoff = R2-R1 = 1027.89-342.6 = 685.3 mm/year

Annual increase in runoff generated per year is 685.3 mm. Runoff water being generated is not too much that a separate tank to be constructed to store it instead generated runoff is being routed to NUST Lake where it will contribute to underground water recharging.

Credit Achieved: 3

4.4 Water Efficiency (WE)

4.4.1 WE Prerequisite: Outdoor Water Use Reduction

This mandatory category targets to achieve reduction in water use in outdoors.

As grass and plants used in landscaping on site gets mature within 2 years and doesn't require a permanent irrigation system beyond that period hence it complies with Option 1 that says no permanent irrigation system to be provided beyond maximum of 2 years.

4.4.2 WE Prerequisite: Indoor Water Use Reduction

This mandatory category targets to achieve reduction in water use in indoors.

Baseline and Design Calculations are done using "Indoor Water Use Reduction Calculator_v03_0" provided by USGBC.

It is recommended to install Aerators (Niagara 0.5 GPM N3205N-PC Dual Threaded Aerator) in public/private lavatory and kitchen faucets and Water efficient WCs (Niagara 77001WHCO1 Stealth) in whole building. As a result of these 54% reduction in water consumption compared to baseline can be achieved.

Following figure shows the summary of indoor water use reduction calculations:

Summary for Design and Construction Rating Systems

Note: All information on this tab is READ-ONLY. To edit, see the previous tab(s).

Refresh Groups

Group Name	Baseline Case (gallons/year)			Design Case (gallons/year)		
	Annual Flush Volume	Annual Flow Volume	Annual Consumption	Annual Flush Volume	Annual Flow Volume	Annual Consumption
Group 1	452,500.30	653,887.85	1,106,388.15	236,456.75	268,343.60	504,800.35

Annual baseline water consumption (gallons/year)	1,106,388.15
Annual design water consumption (gallons/year)	504,800.35
Percent water use reduction (%)	**54.37%**

Figure 12: Summary of indoor water use generated by LEED Calculator

4.4.3 WE Prerequisite: Water Metering

The aim of this mandatory category is to encourage management of water use within building and determining opportunities which can lead to further decrease in water consumption.

It is recommended to install water meter at main supply pipeline to comply with this prerequisite.

4.4.4 WE Credit: Outdoor Water Use Reduction

This mandatory category targets to achieve reduction in water use in outdoors.

Grass and plants used in landscaping gets mature within 2 years and doesn't require a permanent irrigation system beyond that period. Following plant types are present there:

a) Alestonia
b) Casia
c) Persian Mulberry (Shahtoot)

d) Peach
e) Platanus Orientalis (Chinar)
f) Fiddle Board
g) Sanatha

Credit Achieved: 2

4.4.5 WE Credit: Indoor Water Use Reduction

This mandatory category targets to achieve reduction in water use in indoors.

As per pre-requisite recommendation we can achieve about 54% reduction in water consumption, referring to Table-1 we claim 6 points.

Credit Achieved: 6

4.4.6 WE Credit: Water Metering

This mandatory category aims to encourage management of water use within building and determining opportunities which can lead to further decrease in water consumption.

Install water meters for following subsystems:

a) Indoor Plumbing Fixtures and fittings (10 water meters)
b) Domestic hot water (8 water meters)

Credit Achieved: 1

4.5 Energy and Atmosphere (EA)

4.5.1 EA Credit: Enhanced Commissioning

This credit aims to accomplish the projects aims related to energy and water consumption, building's environmental conditions and endurance by assisting in the process of planning, construction and ultimate operational processes of the building.

To achieve this credit requires the completion of commissioning process as per the requirements mentioned in guidelines provided in ASHRAE 0-2005 and ASHRAE 1.1-2007

To fulfill above demands a commissioning authority (CA) is required to be hired which will perform commissioning process for 10 months according to LEED guidelines given in LEED Criteria. Enhanced and Monitoring based commissioning and Envelope Commissioning to be performed by the CA.

Credits Achieved: 6

4.5.2 EA Credit: Optimize Energy Performance

The aim of this category is to lessen financial and environmental impacts related with excessive consumption of energy by attaining energy performance of building above prerequisite standard.

Existing Building's energy performance is evaluated using Autodesk Insight 360. Following are the assumptions and results of energy analysis:-

Assumptions:

Building Type: University or School

Operating Schedule: 12/5

HVAC Type: High Efficiency Package System

Results:

Baseline Consumption as per ASHRAE 90.1 standard = 49.4 kBTu/ft2/yr

Mean Value of Current Energy Consumption of Building = 38.9 kBTu/ft2/yr

Following figure shows AUTODESK INSIGHT 360 results showing benchmark comparison of existing building's energy consumption:

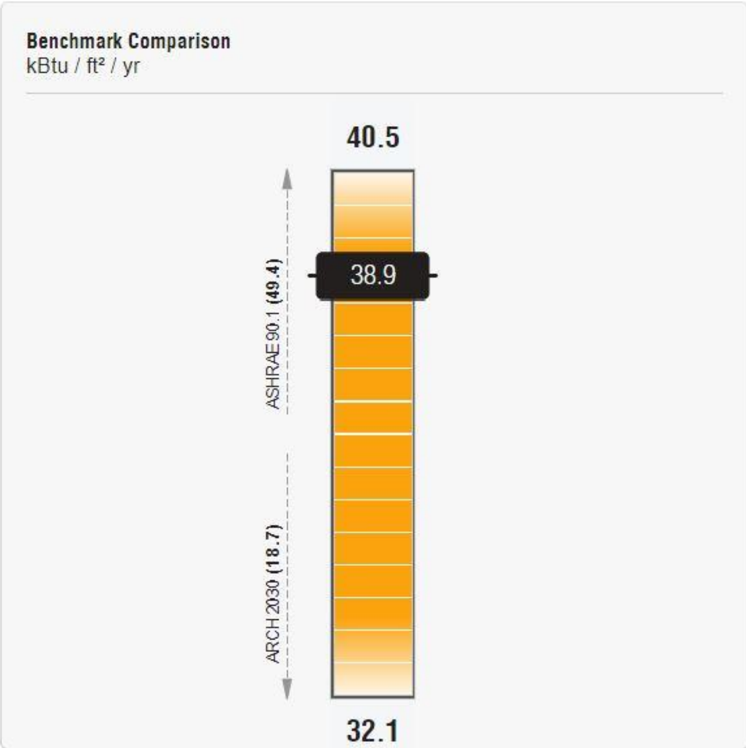

Figure 13: INSIGHT 360 results showing existing building's energy consumption.

Current Energy Consumption is 21.25% less than ASHRAE 90.1 baseline, hence according to LEED Criteria, existing building achieves 9 points in optimize energy performance credit.

Credits Achieved: 9

4.5.3 EA Credit: Advanced Energy Metering

The aim of this category is to track energy consumption of building and individual systems installed in building to assist in energy management and identifying opportunities for further decrease in energy consumption.

To achieve this credit energy meters are required to be installed to measure energy being taken from different sources and to measure any specific energy end use which accounts for greater than or equal to 10% of annual energy consumption of the building.

This credit is not being aimed in our research study.

Credits Achieved: 0

4.5.4 EA Credit: Enhanced Refrigerant Management

The aim of this category is to reduce building's environmental impacts which can contribute to climate change.

This credit is not being aimed in our research study.

Credits Achieved: 0

4.5.5 EA Credit: Green Power and Carbon Offsets

This category aims to foster reduction in greenhouse gases by adoption of renewable energy sources and projects that lead to carbon mitigation.

This credit is not being aimed in our research study.

Credits Achieved: 0

4.6 Materials and Resources (MR)

4.6.1 MR Prerequisite: Storage and Collection of Recyclables

This mandatory category requires reduction in waste which is being produced by the occupants of building and improper disposal of this waste

Separate waste bins are already provided within building for recyclable and organic waste.

4.6.2 MR Prerequisite: Waste Management Planning

This mandatory category aims to scale back waste which is produced during construction and waste produced due to demolition and improper disposal of this waste.

It is recommended that a comprehensive waste management plan to be developed and implemented during retrofitting project to comply with this prerequisite.

4.6.3 MR Credit: Reduction in Life Cycle Impact

This category aims to foster reusing of materials and optimization of environmental performance of products and materials being used in building.

This credit is not being aimed in this research study.

Achieved Credit: 0

4.6.4 MR Credit: Environmental Product Declarations

This credit aims to foster the employment of such materials and products which have environmentally, financially and socially desirable life cycle impacts and remunerate those projects that have chosen products of such makers that produce products with less life cycle impacts.

This credit requires the disclosure of at least 20 such products that are permanently installed within the building which are purchased from more than four different manufacturers. During the proposed retrofitting project, total products used are less than 20 and data of products previously used in building isn’t available hence this credit can’t be aimed to achieve.

Credit Achieved: 0

4.6.5 MR Credit: Sources of Raw Materials

This credit aims to foster the employment of such materials and products which have environmentally, financially and socially desirable life cycle impacts and remunerate those projects that have chosen such products which have been produced through a responsible process.

This credit requires the disclosure of at least 20 such products that are permanently installed within the building which are purchased from more than four different manufacturers. During the proposed retrofitting project, total products used are less than 20 and data of products previously used in building isn’t available hence this credit can’t be aimed to achieve.

Credit Achieved: 0

4.6.6 MR Credit: Material Ingredients

This credit aims to foster the employment of such materials and products which have environmentally, financially and socially desirable life cycle impacts and remunerate those projects that have chosen such products which have been produced through a responsible process and reduce the employment and development of harmful substances.

This credit requires the disclosure of at least 20 such products that are permanently installed within the building which are purchased from more than four different manufacturers. During the proposed retrofitting project, total products used are less than 20 and data of products previously used in building isn’t available hence this credit can’t be aimed to achieve.

Credit Achieved: 0

4.6.7 MR Credit: Waste Management

This mandatory category aims to scale back waste which is produced during construction and waste produced due to demolition and improper disposal of this waste.

The requirement to achieve this credit as per option 2 is that the total waste produced during construction should not be more than 20 ton. During execution of proposed retrofitting process total estimated waste produced doesn't exceeds this limit

Credit Achieved: 2

4.7 Indoor Environmental Quality (EQ)

4.7.1 EQ Prerequisite: Minimum Indoor Air Quality

This mandatory category aims to establish minimum requirement for air quality within building and as a result increasing the comfort level and contentment of building occupants.

Designed HVAC complies with the requirements of this prerequisite.

4.7.2 EQ Prerequisite: Environmental Tobacco Smoke Control

This mandatory category aims to prevent building’s occupants, building’s interior and ventilation system to be exposed to tobacco smoke

Smoking is not allowed in NUST hence requirement of this prerequisite is already met.

4.7.3 EQ Credit: Indoor Air Quality Strategies

The aim of this credit is to enhance buildings air quality level as a result increasing the comfort, contentment and productivity of building’s occupant.

This credit is not being aimed in this research study.

Credit Achieved: 0

4.7.4 EQ Credit: Low-Emitting Materials

The aim of this credit is to improve quality of air, health of humans, their productivity and environment by scaling back chemical pollutants in environment.

As data related to materials and equipment previously installed is not available hence this credit can’t be aimed to achieve.

Credits Achieved: 0

4.7.5 EQ Prerequisite: Construction Indoor Air Quality Management Plan

This credit aims to minimize buildings air quality issues during construction as a result of which promoting the building occupants and workers well being.

To achieve this credit it is recommended to develop and implement a comprehensive indoor air quality management plan. LEED AP who will be hired for proposed retrofitting project will develop and implement this management plan.

Credits Achieved: 01

4.7.6 EQ Credit: Indoor Air Quality Assessment

The aim of this credit is to ascertain higher air quality within building after the completion of construction work and during occupancy.

This credit is not being aimed to achieve in this research study.

Credits Achieved: 0

4.7.7 EQ Credit: Thermal Comfort

The aim of this credit is to promote occupants’ thermal comfort which can lead to higher levels of occupants’ productivity.

This credit is not being aimed to achieve in this research study.

Credits Achieved: 0

4.7.8 EQ Credit: Interior Lighting

The aim of this credit is to promote higher quality lighting within building which can lead to higher levels of occupants’ productivity.

This credit is not evaluated in this research study.

Credit Achieved: 0

4.7.9 EQ Credit: Daylight

The aim of the category is to scale back the electricity consumption due to lighting loads within building by the introduction of daylight into the building.

Simulations are not run to evaluate this credit as this credit is not being aimed to achieve in this research study.

Credit Achieved: 0

4.7.10 EQ Credit: Quality Views

This credit aims to provide building occupants with quality views to connect them to the natural environment outside building.

As windows are provided in all the indoor spaces i-e regularly occupied floor area of CASEN building both towards inside and outside of the building hence CASEN Building complies with the requirement of this credit

Credit Achieved: 01

4.7.11 EQ Credit: Acoustic Performance

The aim of this category is to promote effective acoustic design which can lead to building occupants' increased level of productivity and effective communication.

This credit is not aimed to achieve in this research study.

Credits Achieved: 0

4.8 Innovation

4.8.1 Innovation Credits

The aim of this credit is to foster projects to have extraordinary or innovative performance. After recommended retrofitting process, four credit points can be claimed for CASEN Building in this category on the basis of below mentioned reasons:

a) **Use of Aerators**; with faucets to reduce water consumption around 50%.
b) **Fiber Glass Dome**; at the top of the building which allows diffused sunlight to enter building and significantly reduces electric lighting loads within building.

c) **Rain water management**; Quantity of runoff water being generated on site as a result of rain isn't very large so that a separate tank to be constructed on site for it, instead we routed it to lake where it will contribute to underground water recharging.

d) **Louvers at entrance**; which allows diffused sunlight to enter building and significantly reduces electric lighting loads within building during daytime.

Credits Achieved: 04

4.8.2 LEED Accredited Professional

The aim of the category is to foster the integration needed for a LEED project. To achieve this credit the requirement it that a minimum of one principal participant of the project team should be a LEED accredited professional with a specialty suitable for the project.

It is recommended that during the proposed retrofitting project a LEED Accredited Professional shall be hired to supervise this project and complete all the necessary documentation required for project's LEED certification.

Credits Achieved: 01

4.9 Regional Priority

This credit category aims to provide an associate incentive for the achievement of credits that address geographically specific environmental, social equity, and public health priorities. These credits are recognized by the regional councils of USGBC as having additional regional importance for the project's region.

Following figure shows the regional priority credit points for the region of "Islamabad, Pakistan" as specified by LEED Website:

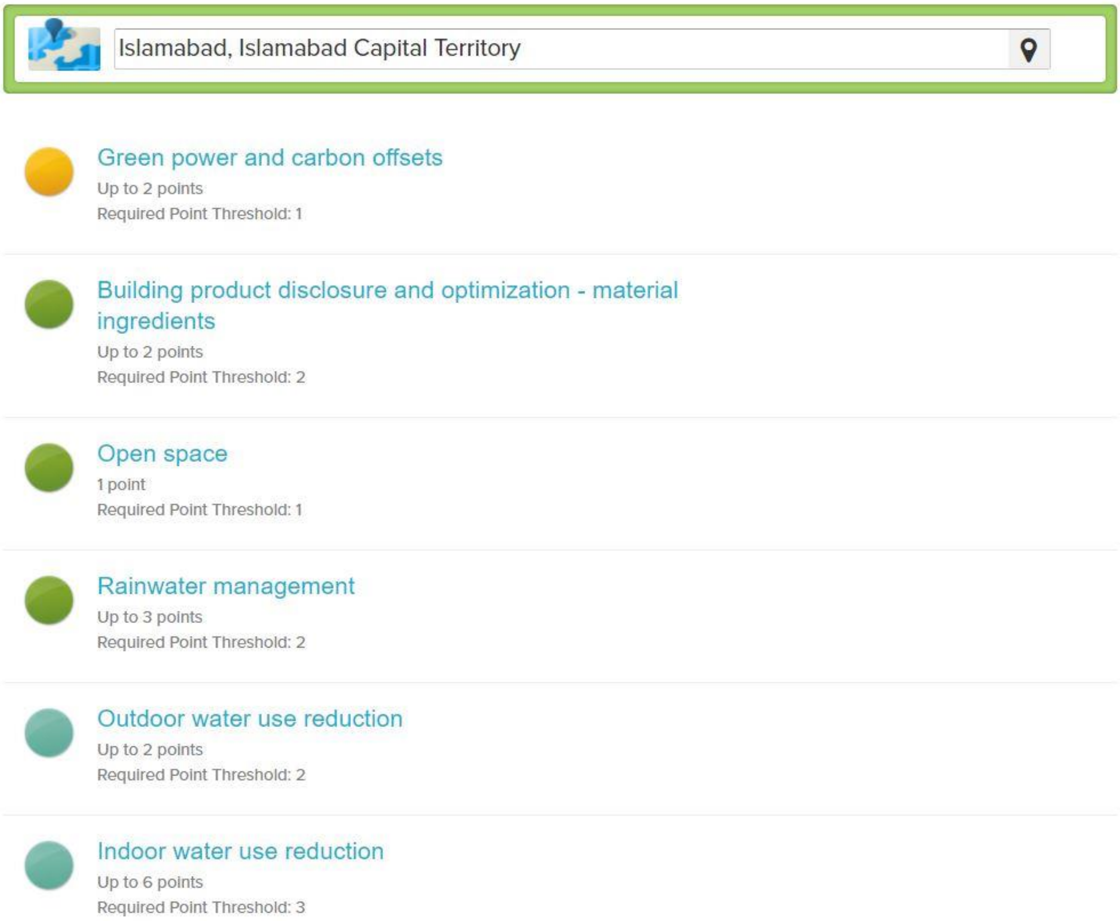

Figure 14: Regional priority credits for Islamabad

Following Regional Priority credits can be gained for CASEN building after the execution of retrofitting project:

a) Open Space
b) Rainwater Management
c) Outdoor Water Use Reduction
d) Indoor Water Use Reduction

Credits Achieved: 04

4.10 Conclusions

Total Credit Points = 110

Total Credit Points Achieved by Existing Building = 29/110

Total Credits which can be Achieved after proposed retrofitting = 53/110

CHAPTER 5

RESULTS AND CONCLUSIONS

5.1 General Introduction

This chapter is focused on the outcomes of this research study which include the proposed retrofit solutions that can be executed to achieve Silver Category of LEED certification, cost estimation, relation between cost and LEED credit points in the form of a graph, proposed schedule of retrofitting project.

5.2 Retrofit Recommendations

After evaluation of existing CASEN building following retrofitting recommendations are proposed to achieve LEED Silver Category:-

a) Cyqik stand to be provided in CASEN parking area and three on site washrooms having showers and changing facility to be constructed for cyclists.

b) Three parking Slots to be painted green to show dedicated parking for green vehicles and one Electrical Vehicle Supply Equipment to be installed in any of these parking slots for changing of green vehicles

c) Install Aerators in public/private lavatory and kitchen faucets and Water efficient WCs (Niagara 77001WHCO1 Stealth). As a result of these we can achieve about 54% reduction in water consumption compared to baseline.

d) Install water meters for following subsystems:

- Indoor plumbing fixtures and fittings (10 water meters)
- Domestic hot water (8 water meters)
- Main supply (1 meter)

e) Hire commissioning authority which will perform commissioning process as per LEED requirements

f) Hire a LEED Accredited Professional who will supervise the retrofitting project and will complete the necessary documentation for LEED Certification.

5.3 Cost Estimation

Following Table shows the cost breakdown for the proposed retrofitting project:

Table 2: Cost Breakdown of proposed retrofitting

Credit Title	**Cost**
Bicycle Facilities	250000
Green Vehicles	69400
Indoor Water Use Reduction	1039825
Building-Level Water Metering	6798
Water Metering	122357.7
Enhanced Commissioning	5000000
LEED Accredited Professional	220000
USGBC Charges	273390
Sum	**6981770**
Contingency @ 10%	**698177**
Total Cost	7679948

Total Estimated Cost which will incur on proposed retrofitting project is approximately equal to PKR 76,80,000/-

5.4 Relation between Cost and LEED Credit Points

Following Graph shows the relation between LEED Credit Points and Estimated Cost of Retrofitting Project to achieve LEED Silver Category for CASEN Building:

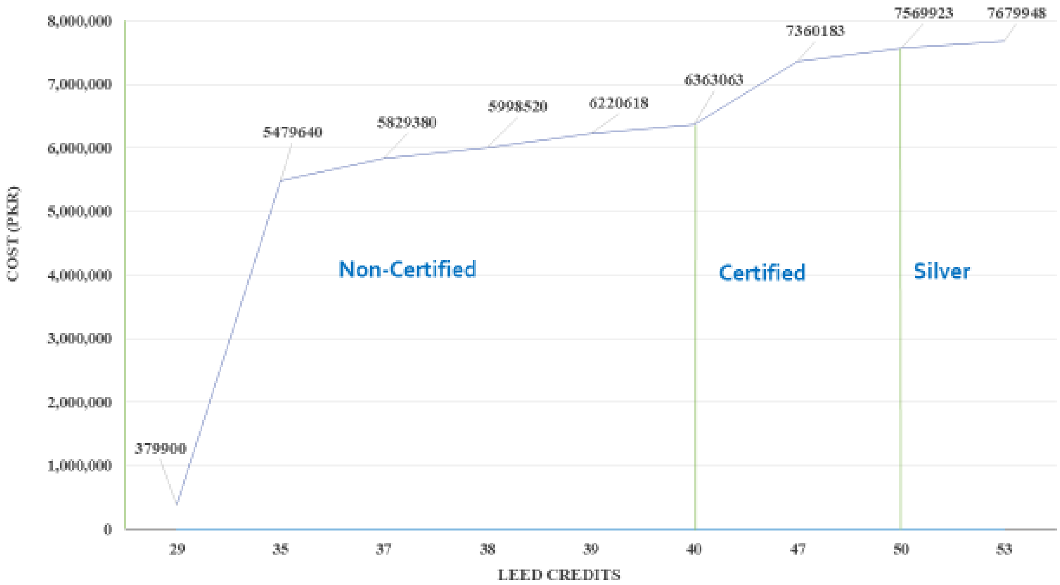

Figure 15: Graph between categories and estimated cost

5.5 Proposed Schedule

Figures below are showing the proposed schedule of retrofitting project. It is assumed that the proposed project will start from January 1, 2019. Total duration of project is 298 days and the longest activity is of Commissioning.

Activity ID	Activity Name	Original Duration	Start	Finish
1.1	**Retrofitting of CASEN Building**	298	01-Jan-19 A	06-Dec-19
A1000	Documentation for Registration of Project	15	01-Jan-19 A	17-Jan-19
A1010	Order Materials and Shipment	15	17-Jan-19	04-Feb-19
A1020	Hire a contractor and CA for Retrofitting	15	17-Jan-19	04-Feb-19
A1025	Washroom Construction	15	04-Feb-19	20-Feb-19
A1030	Paint Parking Slots	1	04-Feb-19	05-Feb-19
A1040	Install Water Meters	3	21-Feb-19	23-Feb-19
A1050	Install EVSE	2	05-Feb-19	07-Feb-19
A1060	Commissioning	266	04-Feb-19	04-Dec-19
A1070	Documentation for LEED Certification	37	17-Jan-19	28-Feb-19
A1075	Documentation Completion	1	05-Dec-19	05-Dec-19
A1080	Online Submission of Documents to LEED	1	06-Dec-19	06-Dec-19

Figure 16: Activities of Retrofitting Project

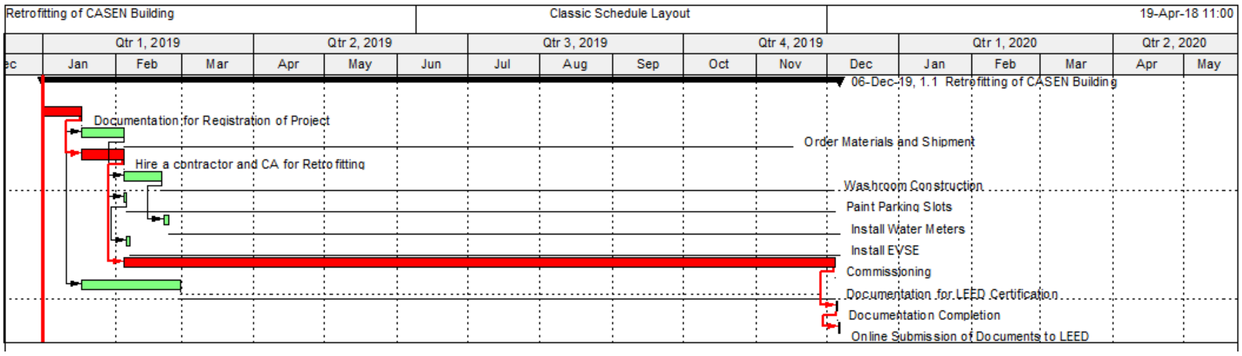

Figure 17: Gantt chart of Proposed Retrofitting Project

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