

Undergraduate Research on the Design and Cost Analysis of a Green Building

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Abstract: In this research endeavor, undergraduate senior civil engineering students from California State University, Northridge, under the supervision of Dr. Tadeh Zirakian and Dr. David Boyajian, introduced a design that maximizes sustainability of an infrastructure while limiting cost. The design consisted of a residential home with a two-story structure and steel moment resisting frame. A modern open concept theme was implemented that followed ASCE 7 safety features while incorporating multiple LEED (Leadership in Energy and Environmental Design) certified features to achieve high sustainability. The purpose of this study was to conduct a comparative cost analysis between a traditional and LEED supported design. Findings using RS Means software showed that a structure with LEED features (estimated at \$876,357) was 46% more costly than one without LEED features (\$600,000); however, LEED implementation led to substantial cost savings over a nine-year period, ultimately reducing cost over time by \$176,000. Completion of this project achieved several educational endeavors, namely enabling the students to apply their acquired engineering skills to real life scenarios and promoting the practice of communication and sharing of ideas in a diverse team setting. It is hoped that future generations will be able to benefit from the review of this study process and be able to apply similar models to inspire sustainable and cost-effective designs.

Key words: Diversity, LEED, sustainable, cost-efficient, engineering education.

1. Introduction

Engineers must consider several factors such as code requirements and project costs. Engineers must meet the specified needs with the consideration of public health as well as global, environmental, and economic factors. Through the research, students have had the ability to apply civil engineering design skills towards a residential unit.

Parr and Zaretsky [1] published a book to bridge the gap between the theory and practice of implementing LEED (Leadership in Energy and Environmental Design) features into building designs in order to support more environmentally friendly architectural designs. Researchers with an understanding of what thinking sustainability entails. White and Duram [2]

presented case studies and examples of successful green building implementations. Furthermore, they illustrated the impact of the green lifestyle of Americans. Many researchers [3] have also studied the effect of acoustics on infrastructure as acoustics have the opportunity to create synergies; however, there are also various conflicts. Dobias and Macek [4] provide research that reveals the degree of cost savings when LEED is implemented during the design and construction process. Stevens and Brown [5] discussed how LEED neighborhood development affects the physical activity of those who live within a community; it was shown that those with LEED neighborhood development were more active. In China, researchers [6] studied the willingness of individuals to pay for green residential buildings. This serves as valuable information as designers must satisfy the needs of society. Williams [7] also provided an architectural perspective of LEED certification and introduces

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innovations to minimize greenhouse gas emissions while addressing the issue of climate change.

As resources are limited, it is important to consider the sustainability of an infrastructure as many infrastructures are difficult to maintain. In order to maintain the sustainability of the project, the team had decided to pursue LEED certification [8]. The construction, materials, and cost have been determined for both the LEED and non-LEED infrastructure in order to find the most suitable design. In this research, students have decided to include several features such as solar panels, thermal windows, and recycled material in order to achieve 47 LEED points. With this research, one has the ability to understand the advantages and disadvantages of using LEED features [9]. Through the pursuit of LEED certification, students have had the ability to apply their knowledge from the following courses: steel design, concrete design, and construction management.

“Not only is the sustainability of the project important, but also the structural design of the infrastructure using steel beams and steel columns in order to support the loads applied to the infrastructure” [10]. The student research team decided to include W8x40 and W10x68 beams as well as W12x65 columns. Structural engineers must consider the stability, strength, and rigidity of infrastructures. Structural engineers must also consider the sustainability and the cost of their design. Through the research, individuals have the ability to improve their design based on the model provided.

2. Architectural Features

The residential home consists of a two-floor structure with approximately 1,700 square feet of space for each floor (see Figs. 1 and 2 for the first and the second story floor plans). Structurally, the home will not have any bracing, thus the framing of the home will act as its own support called a “steel moment resisting frame”. The main concept that was implemented into the structure was including a modern open concept

theme. With that said, there were specifications that we had to follow that included the following: four to six bedrooms, four to six bathrooms, two kitchens, one to two libraries, one gym, one living room, one dining room, one laundry room, a staircase, a great room, and a garage [11]. The building incorporates a top view from the second floor down to the first floor. In addition, since there is a strong consideration for LEED features, there are a lot of windows which contribute to the maximization of natural light that can get into the building. Solar panels as well as a garden on the second floor above the garage was implemented to increase the points for LEED on our LEED scorecard.

3. Structural Design

A residential house had been constructed with the ASCE safety measures by following the codes of American Society of Civil Engineers. The design philosophy was to provide the minimum amount of steel required with maximum safety standards. The LRFD load combination method was applied in designing for joists, girders, and columns to make sure that our structure is capable of supporting the loads resulting from the basic load combinations then it was critical to make sure that deflection and buckling are within the safe zone [12]. A seismic analysis had been performed to make sure that our structure can stand natural disasters. Table 1 shows the structural summary results.

4. Design for Sustainability and LEED Certification

Recognizing the importance and impacts of green buildings on human health and the environment, we have considered multiple features to get our design certified by LEED. We have chosen the adequate fixtures that will make a financial difference over the years. For example, solar panels, which will help minimize the power usage throughout the years. We have made a table to show the features we have considered: Table 2.

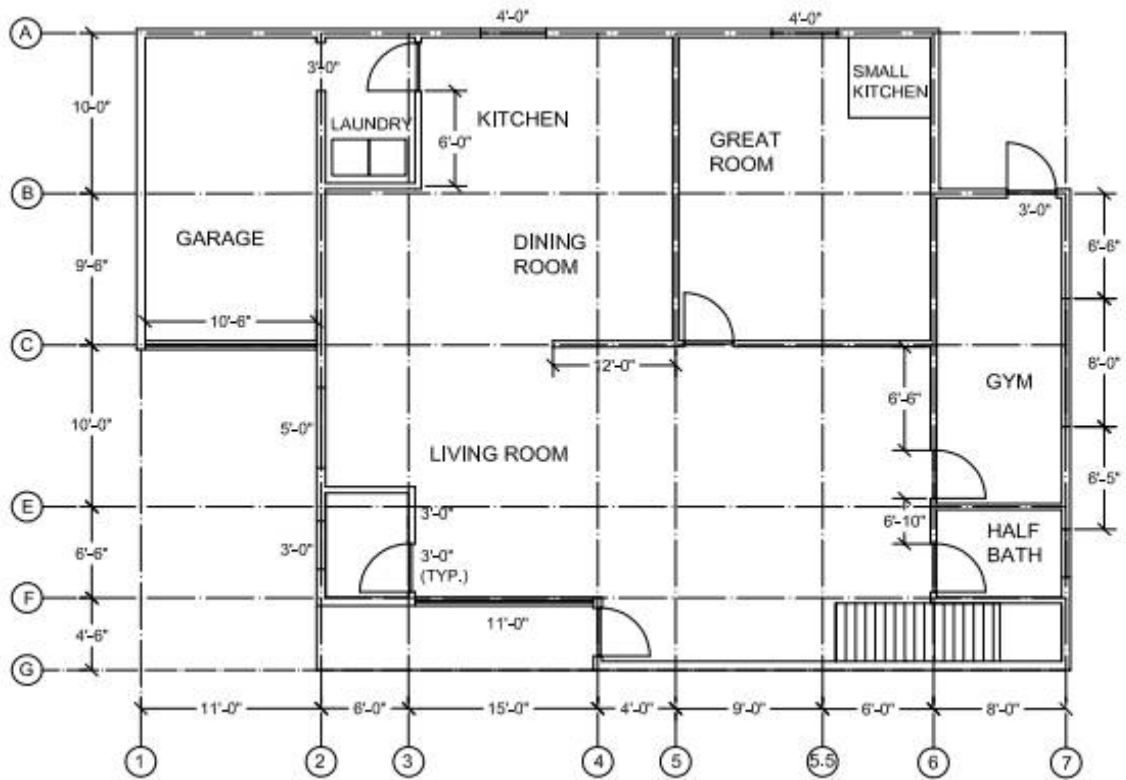


Fig. 1 First story floor plan.

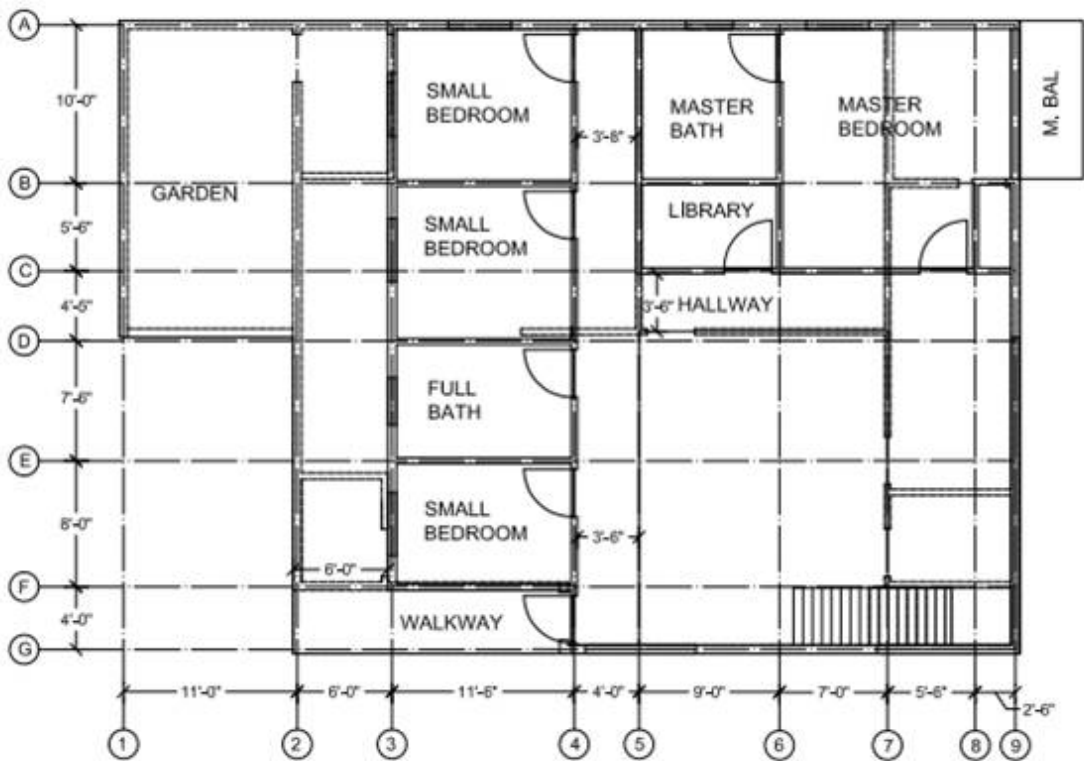


Fig. 2 Second story floor plan.

Table 1 Structural design results.

Structural element	Design results	Additional explanation
Beams	W8×40, W10×68	Joists and girders
Columns	W12×65	-
Foundation	5'×5' with 6 #8 bars	Reinforcement bars

Table 2 LEED features.

Item No.	LEED features	LEED points	Cost (\$)
1	Solar panels	6	65,667
2	R-30 & R-21 insulation	7	15,200
3	Recycled mix concrete	7	67,740
4	Recycled mix insulation	6	89,130
5	Thermal windows	5	16,700
6	Nest AC control system	4	592
7	Additional meter & sub-meter	2	2,195
8	Energy star labeled appliances	2	2,322
9	LED Lighting	3	4,800
10	Water treatment	5	12,000
Total points		47	276,357

5. Cost Analysis

After completing the design of a two-story building, there is a need of estimation for the whole project. RS Means is one of the best softwares that stimulated the cost of construction based on its location in detail with high accuracy. The purpose of this project is to have a building with high sustainability and for that reason LEED was considered to be added to the building to save energy and make it more modern. The cost analysis was done on both traditional and LEED design. Based on the price estimation, the total for the traditional design is \$600,000 and after considering LEED is \$876,357. Although the total price is 40% higher after considering LEED, but by adding LEED to the building, there will be a big difference in the total saving in nine years. For example, solar panels absorb the sun's energies and rays to produce electricity and that can save a huge amount of money during these nine years. "The solar panels can generate energy for at least 30 years that save up to \$2,000 per year" [13]. Furthermore, adding thermal windows can also retain about energy 55% of the home energy, especially in winter. By considering all savings from LEED features, the total savings will be approximated to be \$176,000.

All LEED features and costs are shown in Table 3 and Fig. 3.

6. Educational Objectives

The senior design project has been a great opportunity for the students in order to learn the applications of engineering in a real-life matter. The scholars have been given the ability to improve their communication skills by working in a research team that consists of members from different nationalities and cultures. The researchers were given a chance by this diversity to understand different views and mentalities within a friendly work/research environment. Another important aspect of this project, other than teamwork and diversity within the members, was the noticeable participation of women in this group, which consisted of two very strong and creative women engineers. As the world is going towards using more of technology and paying more attention towards earth's environment, working on a LEED building has been an encouraging project for these future engineers. With the highly skilled member, who applied work ethics in their tasks, this research team has been able to deliver a research that could be a critical steppingstone into the

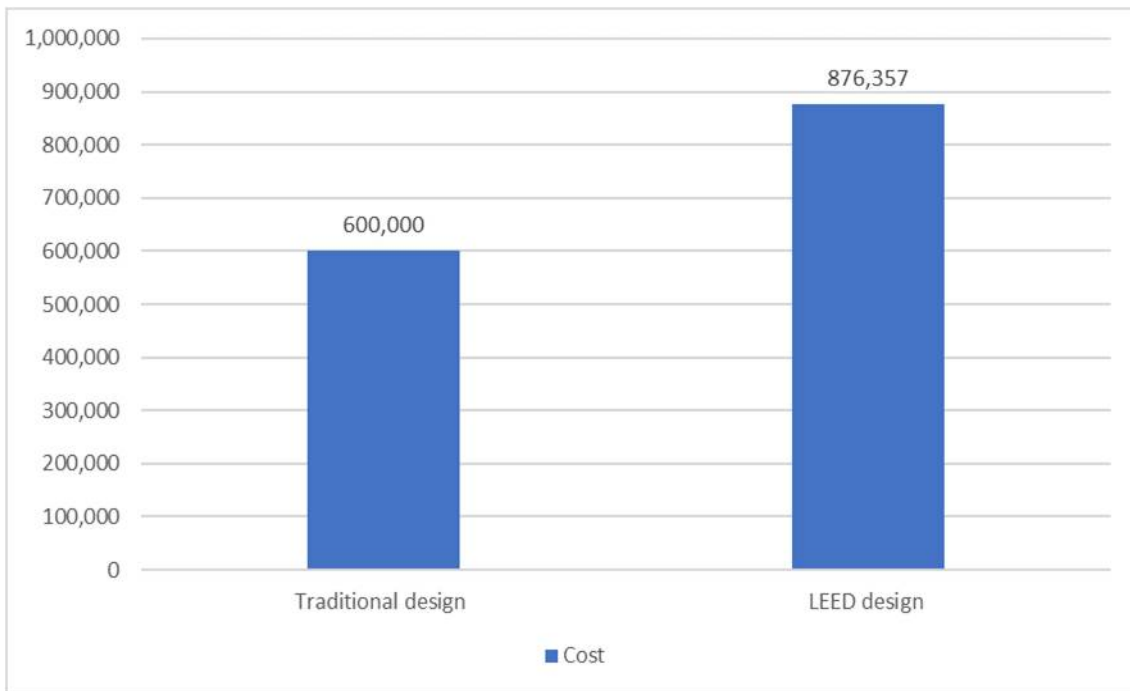


Fig. 3 LEED cost difference.

scholar's path of becoming a successful civil engineer. As a summary, this project has helped the students to prepare for successful engineering or management careers in architecture, engineering, and construction industry or related fields.

7. Conclusions

As this undergraduate research team consisted of seven student civil engineers from different backgrounds and cultures, the scholars were able to design a two-story single-family home that would be certified by LEED features. The raw cost of this single-family building came out to be \$600,000. After adding the LEED features, the cost of the building increased by 46%, which can be paid off in 9 years. Since the location of the home was chosen in the city of Beverly Hills, the scholars decided to include certain architectural features that would be matched with a house in that area. With the consultation from our architectural team, these future engineers were able to deliver a high-tech modern home on the high elevation area of the city. As the scholars moved forward towards the end of the project, they were able to have a better

understanding of how all the calculations that they had learned in the previous years of our college can be used on a real-life application. Also, working with different computer programs such as AutoCAD, gave the scholars the opportunity to understand the importance of technology in engineering and design. Therefore, this entire research was a huge success for the members to gain experience in regard to a real-life project. From the educational aspect, this research gave a great chance to the scholars to experience within a diverse team and learn more about building a LEED certified home.

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