Design of a Sustainable Transmission Building

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Abstract
To be added at a later date.
Capstone Design Statement

As part of the Accreditation Board for Engineering and Technology (ABET) requirement, a Capstone Design Experience must be completed by all students seeking a degree in Civil Engineering. The capstone design addresses eight, realistic constraints of a project of which include: economic, sustainability, environmental, constructability or manufacturability, ethical, health and safety, political and social aspects. The project will include all of these aspects in the final report that is submitted to both Stantec and WPI.

a. Economic

To address the aspect of economic feasibility the project will determine multiple general cost estimates for the varied design ideas and one specific one for the final design.

b. Sustainability & Environmental

Sustainability will be addressed through the alternate structural design and green materials that are proposed. The environmental aspect will be dealt within the analysis of the property.

c. Constructability & Manufacturability

The constructability constraint for the project will be reflected in the structural design of the transmission station and the multitude of design options implemented.

d. Health & Safety

Health and Safety will be considered through following the set standards of Canada, such as the National Building Code of Canada (2010).

e. Social & Political

The social needs of the community will be addressed through this project bringing electricity to the area.
# Table of Contents

Abstract ................................................................................................................................. ii

Capstone Design Statement ................................................................................................. iii

List of Figures ....................................................................................................................... vi

List of Tables ....................................................................................................................... vi

Introduction .......................................................................................................................... 1

Background ........................................................................................................................... 2

  Traditional & Sustainable Build Design Options ............................................................... 2

  Structural Materials: Concrete ......................................................................................... 2

  Structural Materials: Structural Steel ............................................................................... 3

Component & Product Information ...................................................................................... 3

LEED ................................................................................................................................... 3

Certified ............................................................................................................................... 3

40-49 Points ......................................................................................................................... 3

Silver .................................................................................................................................. 3

50-59 Points ......................................................................................................................... 3

Gold .................................................................................................................................... 3

60-79 Points ......................................................................................................................... 3

Platinum ............................................................................................................................... 3

80+ Points ............................................................................................................................. 3

Cost Estimate ....................................................................................................................... 3

Methodology ...................................................................................................................... 4

  Task: Project Statement ................................................................................................. 4

  Task: Designs .................................................................................................................. 4

  Task: Sustainable Design ............................................................................................... 4

  Task: Traditional Design ................................................................................................. 4

  Task: Combined Designs ............................................................................................... 4

  Task: Evaluation – Sustainability (Green) ...................................................................... 4

  Task: Evaluation – Functionality .................................................................................... 5

  Task: Evaluation – Building Codes .................................................................................. 5

  Task: Evaluation – Cost Efficiency .................................................................................. 5

  Task: Evaluation – Investment ....................................................................................... 5
Goals Listed Chronologically ........................................................................ 6

a. Pre-Qualifying Project: Design: Problem Statement ........................................ 6
b. Week 1: Background Research ........................................................................ 6
c. Week 2&3: Designs ....................................................................................... 6
   i. Sustainable Designs .................................................................................... 6
   ii. Traditional Designs ................................................................................. 6
   iii. Joint Designs ......................................................................................... 6
d. Week 4&5 Evaluation Criteria ........................................................................ 6
   iv. Sustainability (Green) ............................................................................... 6
v. Functionality ............................................................................................... 6
vi. Building Codes .......................................................................................... 6
vii. Cost Efficiency ........................................................................................ 6
viii. Investment ............................................................................................... 7
ix. Added value for innovation ......................................................................... 7
e. Week 6: Finalize Designs & Deliverables ...................................................... 7
  x. Designs and Evaluations .......................................................................... 7
  xi. Presentation & Paper .............................................................................. 7
f. Week 7: Formal Presentation - Written & Oral ............................................. 7
Deliverables .................................................................................................... 8
Results ........................................................................................................... 8
Conclusions .................................................................................................... 8
Works Cited .................................................................................................... i
List of Figures
Figure 1: LEED Ratings (LEED 2009, 2009) ........................................................................................................ 3
Figure 2: 7-Week Schedule ............................................................................................................................. 7
Figure 3: Deliverables....................................................................................................................................... 8

List of Tables
Introduction

The Maritime Link Transmission Project from Newfoundland to Cape Breton, Nova Scotia is to be a link designed to connect communities to the supply of sustainable electrical power. The three main components of the Project are to implement a new transmission line in Newfoundland, a second transmission line in Nova Scotia and add two subsea cables spanning the stretch between the two. In the proposed Major Qualifying Project, students are to design and form a proposal for one of the two converter stations that house the diffusion of the transmission line’s alternating currents. The team will document multiple project design options and cost estimations for the structure. The proposal will discuss fiscal responsibilities and sustainable options as to discern the most effective option that uses both traditional and green building options. (Emera, 2012)

The project will use a multitude of materials to research the many options for design and cost of the building. Including, Canadian and local Nova Scotia codes that will be used to meet all structural requirements. One national code the group will use, yet will not be limited to, is the National Building Code of Canada (2010) specifically for the structural design work. For the sustainable and green options Canadian LEED requirements will be analyzed and implemented.

In addition to the Design Team’s efforts a second project team from WPI will be proposing a document on the construction management for the same structure being designed. Quality assurance for both projects will be provided through weekly meetings with the Worcester Polytechnic Advisors and daily meetings with both the Management Major Qualifying Project Team and the Stantec Consulting limited (Stantec) Project Mentor Team.

The project will aim to complete a full design of these structures from foundation to roof and to discuss the many benefits of building green. The Design MQP Team aims to provide multiple options for these designs to incorporate sustainable building, such as use of innovative materials, new economic systems encompassing the mechanical, electrical and plumbing. Going beyond the required sustainable building requirements, the team plans to propose a final product that will be the most fiscally and environmentally responsible.

As the Design Team develops the structure the cost estimates for the designs will be composed. These cost estimates will look at components including, sustainability, functionality, cost efficiency, return on investment and any added value for innovative practices. Once the financial aspects are compiled, the designs and cost estimates will be compared and reviewed to find the most viable project.

With the collaboration between student groups, the Management Team and Design Team, Stantec’s mentorship and the advisors from Worcester Polytechnic Institute, the Major Qualifying Project will prepare a construction report discussing the options for structures along a transmission line’s path including the design and cost estimate.
Background

Traditional & Sustainable Build Design Options
The traditional build option is a Design/Bid/Build process, where there are three parties involved. The owner of the project hires a designer, and all the design work is done prior to the bidding or involvement of contractors. When the design is complete, contractors are invited to bid on the expected cost for to complete the project. Based on the owner’s criteria, a subcontractor is chosen to complete the job. This process can be time consuming if the design is complex. If a design is complex, it is more likely changes will be made to the design during the construction phase. However, design is a significant fraction of the total project cost, and having it completed independently can cut costs. This project also allows the owner to keep a tighter rein on the project progress and decisions. Deciding to use Design/Bid/Build process would allow the owner to be more involved in building sustainably.

Building sustainably pertains to both the decisions made in the design phase and the construction phase. In design, there are many different components to consider including longevity, additions, and efficiency. The least expensive material may not be the best material for the job if it doesn’t last as long. Wood beams would not be a good choice for a large multiple story building, as the strain would eventually cause the wood to break. Additions to the project are things added to reduce energy demand or impacts on the environment. Examples include an enhanced ventilation system, extra insulation, motion sensors, and solar water heaters. These pose an additional cost to the project, but may have a return on investment or preserve an invaluable natural resource. Efficiency is closely related to the materials chosen. Glass windows, for example, relate to the efficiency through their quality. If the window leaks, it means more heating is required in the colder months. If it is thin, the window can break more easily and also loses heat more easily. There are windows designed to retain heat through the use of thicker panes and pockets of air. The type of window is just one choice in the world of building efficiently and sustainably. Sustainability in construction has a lasting impact by reducing demands on natural resources & using local ones.

Structural Materials: Concrete
Concrete is commonly employed in construction due to its ability to fit a number of different shapes and durability. Concrete is also typically reinforced with steel frames within the cast. Concrete has many different types, three of which include slab, reinforced, and pre-stressed. Slab concrete is a thicker concrete, and used for foundations. It is reinforced with steel or metal framework along with precast concrete. The extra thickness allows for it to support the weight of the building. Reinforced concrete is designed to deal with higher levels of tensile stress. Accordingly it has steel bars placed inside it to allow it additional flexibility. Without the bars, the concrete might crack extensively. Some cracks in concrete are permissible, but too many is a cause for concern. Pre-stressed concrete is similar to reinforced concrete, but uses wires instead of bars to deal with active loads.
Structural Materials: Structural Steel
Structural steel is rated and prepared for a specific purpose. Solid bars are not always the best way to build. Based on stress analysis, reinforcement bars in certain shapes makes building more effective and more efficient. One common shape is the I-beam. As the name suggests, it looks like an “I” and is used to build the frame and skeleton. The skeleton is the framework of the building. It includes columns and supports, but no walls. Essentially, it looks like a birdcage with supports inside.

Component & Product Information
This proposal will contain and details materials chosen or recommended for the completion of the transmission building. These details discuss why each item was chosen and the purpose it is to fulfill. Different parts of the building face different demands, and thus some components must face more scrutiny.

LEED
Leadership in Energy and Environmental Design is relatively new, but becoming more common in the building world after its creation in 1998. LEED certification is based on numerous categories and the categories vary from whether the building is for commercial, residential, health care, military, or other purposes. These categories include efficiency in water, heat, and light use. Anything that saves resources saves money also. Buildings need to be healthy places to live, whether this means protecting of the water sources in a home or mold prevention in a school. There are numerous other categories, and points are earned in each category. Based on the total number of points, a LEED rating is given. The possible rankings are below.

<table>
<thead>
<tr>
<th>LEED Rating</th>
<th>Points Range</th>
</tr>
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<tbody>
<tr>
<td>Certified</td>
<td>40-49 Points</td>
</tr>
<tr>
<td>Silver</td>
<td>50-59 Points</td>
</tr>
<tr>
<td>Gold</td>
<td>60-79 Points</td>
</tr>
<tr>
<td>Platinum</td>
<td>80+ Points</td>
</tr>
</tbody>
</table>

Cost Estimate
Estimating the cost of a project accounts for in design, materials, labor, and delays. The design component is the rate charged by the design firm. This could be a lump sum, or a sum based on hours of work. Material costs are based on the market cost and transportation. Some materials are better to be purchased in another location, providing the cost of transportation does not outweigh buying closer. Labor costs are determined by the contractor and amount of work to be done. Delays are also a factor. Every day behind completion, the owner loses money. With regards to all these factors, the method of payment is important. Lump sum is paying one large amount all at once. Hourly work is paying a set rate, regardless of completion. There are also other payment methods including covering expenses with a guaranteed maximum price.
Methodology

Task: Project Statement

The team researched the project and other design projects. Based on the information and the research, the team made identified key components and questions to answer in the design project. After discussing the components and research, the team decided what the goal of the project would be. This goal is reflected in the project statement, outlined tasks and task chart see Figure 2: 7-Week Schedule.

Task: Designs

Design of the transmission building included code familiarization, interviews with the Stantec staff, on-site research when permitted, and use of design software. The interviews with the Stantec team allowed for the WPI crew to get a basic understanding about starting points. The design had to comply with all the codes, and thus the design had to be cross-checked by all listed specifications and codes. The completion of these designs was aided through the use of computer software.

Task: Sustainable Design

During the process of the original design, the team identified components that could be made sustainable. The team then analyzed each of these possibilities based on criteria including local impacts and resources, return on investment, and complying with future regulations. This design has as many sustainable ideas as were conceived in the design process. The team also identified the cost and materials used in this design.

Task: Traditional Design

This design is the result of the design previously discussed. The team chose the most cost-effective material for the climate and codes of the present day.

Task: Combined Designs

The team took the sustainable and traditional designs and used components from each to create a hybrid design. This allows for a less expensive building, while still considering impacts on the environment.

Task: Evaluation – Sustainability (Green)

The team reviewed all the designs and made decisions about using components based on their social and environmental impact. These decisions were based on available codes, environmental impact studies, availability of resources, return on investment, and future demands.
Task: Evaluation – Functionality

The team reviewed the building to ensure its durability in the environment. The team ran simulations when possible and researched how similarly constructed building or components fared in adverse conditions. Based on the research, the team made estimates as to the life expectation and maintenance of the building.

Task: Evaluation – Building Codes

The team reviewed the designs and all available building specifications & codes. All designs were revised when there was conflict.

Task: Evaluation – Cost Efficiency

Using some of the calculations from other evaluations, the team estimated when the building would need to be replaced in part or in total for each design.

Task: Evaluation – Investment

The team prepared a return on investment for applicable components. The team also considered the yearly maintenance costs in these calculations.

Task: Evaluation – Innovation

The team considered any additional value to add aesthetically pleasing or other components to the building. The criteria included return on investment, esthetic value, and future needs.

Task: Proposal Paper

The team prepared the paper to explain why the project is needed and how it was completed. This paper was written on a week-by-week basis in order to allow for revision. The team explained all relevant details to the process so it could be duplicated and understood.

Task: Presentation

The team prepared an oral presentation, supplemented with a poster and slide show when needed, to explain the design project to the Stantec and WPI community. The team summarized the project and brought out key components. These points were decided on by internal discussion among the WPI teams as well as discussion with the Stantec teams.
Goals Listed Chronologically

a. Pre-Qualifying Project: Design: Problem Statement
Before arriving in Halifax, the team will have an approach for designing a transmission building. This approach will include scheduling, structural research, and proposed design.

b. Week 1: Background Research
The week of January 14, the team will continue researching any details needed before solidifying designs by becoming familiar with codes & specifications, site visits, interviews with staff, design research, and other preparations.

c. Week 2&3: Designs
The weeks of January 21 & 28 will be devoted to the actual designing of all the plans. The WPI team will share their work with the Stantec members on the project to verify the project being done correctly.

i. Sustainable Designs
This design will be crafted with the intent of reducing the impacts and demands on the earth and supporting the local area where reasonably possible.

ii. Traditional Designs
This design will be crafted to meet codes & basic criteria.

iii. Joint Designs
These designs will be crafted as hybrids between the traditional & sustainable designs to offer more economical alternatives.

d. Week 4&5 Evaluation Criteria
The weeks of February 4 & 11 will be spent reviewing and revising the designs. The WPI team will be meeting with Stantec team members for in-depth feedback.

iv. Sustainability (Green)
The building will be evaluated to see if there are components which could be altered to make the project less taxing on the environment.

v. Functionality
The building must act as a transmission station and be reliable in the conditions in Halifax.

vi. Building Codes
The building must be in accordance with all relevant codes set by Canada’s Government.

vii. Cost Efficiency
The building cannot be high maintenance & must have a long lifespan.

viii. Investment
The building must have a reasonable return on investment. The term reasonable will be defined in the section.

ix. Added value for innovation
The analysis of the building will also consider the benefit of having other components added to improve it at an elevated cost.

e. Week 6: Finalize Designs & Deliverables
The week of February 18 will be spent finishing the designs based on the feedback given by the Stantec team.

x. Designs and Evaluations
Based on the changes to the project, criteria will be reapplied.

xi. Presentation & Paper
The team will finish the written proposal and supporting documentation for the project along with preparing a presentation to accompany this proposal.

f. Week 7: Formal Presentation - Written & Oral
The week of February 25 will be spent reviewing & revising the final report along with preparing to present all findings to Stantec.
**Deliverables**

At the end of the time with Stantec the team aims to present two documents, one for the Capstone Design Requirement of the university and one for the final design of the Transmission Station for Stantec, and a final presentation summarizing the team’s conclusions. The documents will cover the design requirements and cost estimate for the Transmission Station. A formal presentation will be made to detail the methodology, design aspects and final conclusions. For Worcester Polytechnic Institute the students will also present the findings in a poster presentation. The following chart categorizes these deliverables.

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**Figure 3: Deliverables**

**Results**

**Conclusions**
Works Cited
