Evaluating Construction Management Techniques for an Electrical Transmission Station

Scope of Work

Andrew Canniff and Christopher O'Connor
Table of Contents

Introduction ............................................................................................................. 3
Project Description .................................................................................................. 3

Background ............................................................................................................. 4
Construction Techniques .......................................................................................... 4
  Concrete Masonry Unit (CMU) .............................................................................. 4
  Cast In Place Concrete ......................................................................................... 4
  Structural Steel ..................................................................................................... 5
  Pre-cast Concrete ............................................................................................... 5
Schedule .................................................................................................................. 5
Cost Estimate .......................................................................................................... 5

Methods .................................................................................................................. 6
Task 1 ....................................................................................................................... 6
Task 2 ....................................................................................................................... 6
Task 3 ....................................................................................................................... 6
  Cost ....................................................................................................................... 7
  Scheduling ........................................................................................................... 7
  Availability of Labor ............................................................................................ 7
  Availability of Supplies ......................................................................................... 7
Task 4 ....................................................................................................................... 7
Task 5 ....................................................................................................................... 8
Task 6. Perform Detailed Cost Estimating and Scheduling Analysis for the Most Viable Construction Technique: ................................................................. 8

Deliverables ............................................................................................................ 8

Capstone Design Statement ................................................................................... 9
Design Problem ....................................................................................................... 9
Engineering Standards and Realistic Constraints .................................................. 9
  Economic ............................................................................................................ 9
  Environmental .................................................................................................... 10
  Manufacturability (Constructability) ................................................................... 10
  Health and Safety .............................................................................................. 10
  Social and Ethical .............................................................................................. 11
  Political .............................................................................................................. 11

Eight Week Schedule ............................................................................................ 12

Works Cited ........................................................................................................... 13
Introduction

A transmission line connecting Newfoundland and Nova Scotia has been proposed to help ease the strain placed on the region’s electrical transmission system. This project will address several construction project management facets associated with the installation of a transmission station which will service the line. The Transmission Station will convert overhead electrical power lines to underground electrical power lines. The transmission station in question will be located in a remote location on Cape Breton island, Nova Scotia and will house sensitive electrical equipment. The main goal of the project will be to assess the feasible of four major construction methods/materials for the Transmission Station: Concrete Masonry Unit (CMU), Cast in Place Reinforced Concrete, Pre-cast Concrete, and structural Steel. Additionally, the project will conduct a preliminary assessment of both the necessary construction time frame and the cost associated with each of the four techniques. Once the most viable construction technique is selected, the final phase of the project will be to conduct a thorough evaluation of the construction schedule and costs associated with the chosen building method.

The final deliverables for this project will include a complete, multi-facet analysis of the potential application of alternative construction management on the transmission station, a final presentation illustrating all work completed at Stantec, a Capstone Design Statement, a poster displaying methodology and conclusions, and a Major Qualifying Project (MQP) report submitted Worcester Polytechnic Institute (WPI).

Project Description

The team for this project will be comprised of two senior, civil engineering students at Worcester Polytechnic Institute: Andrew Canniff and Christopher O’Connor. The project team will be working out of Stantec Consulting Limited (Located in Dartmouth, Nova Scotia) and will work closely with staff there to complete the necessary deliverables. In order to evaluate the most advantageous Construction Method for the Transmission Station, financial data, regarding the construction methods, must be collected and analyzed. Information and experiences from previous projects of similar scope will be provided by the Staff of Stantec will be extremely valuable. The collection of information mentioned above will allow the project team to select and subsequently thoroughly apply the most feasible Construction Method for the proposed Transmission Station. The majority of the work for the project will take place in Dartmouth, Nova Scotia between January 10, 2013 and March 1, 2013, while Pre-MQP preparation for the project will be conducted in B-term of the 2012-2013 academic year on-campus at Worcester Polytechnic Institute, under the close supervision of the project’s advisors.
Background

Construction Techniques

There are a variety of construction materials and techniques that can be used during the construction process. Our goal is to research multiple combinations of methods and materials and produce possible schedules and preliminary cost estimates to decide what the best option is that meets the needs of both the Transmission Station and the client. The materials that have been selected for our project include masonry walls (CMU), cast in place concrete, and structural steel. Pre-cast concrete will also be researched as a viable construction material.

Concrete Masonry Unit (CMU)

Concrete Masonry Unit (CMU) or concrete block as it is commonly called, is a mixture of Portland cement, gravel, sand, and water. This mixture can also include air-entraining agents, coloring pigment, and water repellent (Concrete Masonry Units). Concrete blocks are made by forming this mixture into its desired shape and curing it by heating it at a high temperature in a special chamber. Concrete blocks allow for the ability to create economical, energy efficient, and fire-resistant structures that involve minimal maintenance (Concrete Masonry Units).

Concrete block can be used to construct both small and large structures. The most common uses of concrete block include retaining walls, chimneys, fireplaces, and fire-rated shaft walls, elevator shafts, and storage vaults (Concrete Masonry Units). The different types of concrete masonry units include split-face concrete blocks, patented slotted concrete blocks, and glazed concrete blocks.

Concrete block walls can also be reinforced using different gauge wire reinforcement and rebar. Metal wire, welded together to form the shape of a truss, is used horizontally between courses to provide lateral strength. This technique resists “bowing” due to earth, wind, and seismic loads. Vertical rebar can be placed inside the openings in the block and filled with concrete-like grout. The rebar is spaced evenly throughout the wall, accommodating for larger vertical and lateral loads (Concrete Masonry Unit (CMU) Construction).

Cast In Place Concrete

Cast in place concrete or reinforced concrete is one of the most common building materials used in construction. Reinforced concrete is a mixture of water, cement, sand, gravel, and reinforcing steel rods or rebar. The process of creating a reinforced concrete structure involves the technique of using forms and cages. Reinforcing steel cages are built using rebar, steel mesh and forms are constructed around the steel creating the specified width and length and height of the walls/columns/beams etc. The concrete mixture is then poured into the form and set to dry or cure. Concrete is extremely useful in compression but not in tension, which is the reason for the reinforcing steel. The concrete and steel are bound together during the curing process, which allows for the concrete to support the structure under compression loads and the steel to support the tensile loads (Reinforced Concrete).
Structural Steel

Structural steel is the most popular framing material for non-residential buildings in the United States (Structural Steel Solutions). Structural steel is used to construct the skeleton of the building which will support all the other components that will be added to the building. There are two processes used to create structural steel, they are Electric Arc Furnaces (EAF) and Basic Oxygen Furnace (BOF). The EAF process uses mostly recycled material that is melted down to a liquid allowing for easy forming. The BOF process uses iron ore and coke (a processed form of coal) and less recycled metal than EAF (How Is Structural Steel Made?). The main reason for choosing structural steel is for the speed of construction. Just like precast concrete, structural steel is manufactured off site and once delivered the speed of construction is reduced greatly. Structural steel is also constructible in all seasons of the year and almost all weather conditions.

Pre-cast Concrete

Precast Concrete is a relatively new construction technique that has many advantages. Precast concrete is designed and manufactured off site. This allows for quick assembly on site when the precast pieces arrive. Piecing together precast concrete is much like piecing together a puzzle. The use of precast concrete is considered a green type of building material (Sustainability and Precast Concrete). Using this process allows the ability to reduce construction waste and debris on site as well as provide a stronger load capacity and longer possible spans. These increased load capacities are possible because precast concrete is much like reinforced concrete except that the manufacturing process off site allows for the ability to “pre-stress” the reinforced steel (Sustainability and Precast Concrete). Often times the material used in precast concrete is material obtained from local companies and local quarries. In terms of scheduling, the off site manufacturing time for pre-cast is longer, but onsite construction time is reduced greatly.

Schedule

A project schedule for multiple combinations of building materials will be produced that includes such items as projected lead times on materials, estimated transportation duration, and estimated construction time. The schedule for each combination will be combined with a cost estimate of the materials used to produce the best possible options. A construction project schedule is produced because it gives the owner or client an idea of when the project will be substantially completed and it gives the contractor a timeline to track the progress of the project while it is being construction. A project schedule is very important for the success of any construction project.

Cost Estimate

Preliminary cost estimates will be produced for each combination of building materials used. The cost estimates will be used in conjunction with the schedule for the chosen building materials to decide which combination and method is the most efficient in terms of time and cost. The client’s budget determines the materials used and the duration of time available for
Evaluating Construction Management Techniques for an Electrical Transmission Station

2012

construction. The designers must adapt to the budget with their design and project managers must ensure the project comes in on budget as best as possible.

Methods

Task 1. Evaluate the Transmission Station Construction Documents

The first step of the project will be to gain a complete understanding of exactly what Stantec’s client requires for the transmission station. An electrical station is a relatively unique structure and there will certainly a number of distinctive specifications. While the building will only contain three rooms, the amount of sensitive electrical equipment installed in each will drastically increase the complexity of the construction process. Other factors of the project which will be evaluated during this phase will include the budget, environmental restrictions, scheduling, and political issues. The Stantec Staff will be an essential resource for these activities because they will have experience with construction “status quo” for the Nova Scotia region. Examining previous projects of similar scope to the Transmission Station will not only provide examples of which construction techniques were utilized in the past, but also improve efficiency by identifying the short-comings in these application. Information collected during this phase will be crucial while assessing the feasibility of the four construction techniques.

Task 2. Research Regional Application of the Four Construction Techniques:

While the four major construction techniques in question have relatively uniform standards and applications, the accepted norm for the construction methods in the Nova Scotia region may be slightly different which could alter the data when the preliminary scheduling and cost-estimating are conducted. Becoming familiar with the local building practices and procedures of the region is essential to the accuracy of the project’s analysis. The major factors which influence construction management activities such as cost-estimating and scheduling include present labor costs, current building material costs, time frames for the local permit process, the availability of construction supplies, and specialty electrical equipment logistics. The last factor mentioned above, specialty electrical equipment logistics, will be especially crucial to the analysis phase of the project because the equipment necessary for the operation of a transmission station is extremely expensive, sensitive, and requires skilled installation. The increased complexities caused by the specialty electrical equipment, could dramatically alter the Cost-Estimating and Scheduling evaluations of the construction techniques.

Task 3. Conduct Preliminary Cost Estimating and Scheduling Evaluations for the Four Construction Techniques:

This phase will approximate the overall cost associated and time frame necessary to build the Transmission Station using each of the four major construction techniques. Essentially answering the questions of “how much will it cost?” and “how long will it take?” to construct the
Evaluating Construction Management Techniques for an Electrical Transmission Station

Transmission Station utilizing a given construction technique. Information concerning prices and time frames for the activities associated with each of the four Construction Techniques, collected from Task 2, will be essential to conduct preliminary cost-estimates and scheduling evaluations. While Task 3 will only produce approximate answers to the questions posed above, the estimates calculated during this phase of the project will be crucial in the process of selecting the most viable construction technique for the Transmission Station. Each of the following evaluation criteria should be considered for each of the four construction techniques:

**Cost**
- a. How much does the construction technique cost per a square foot?
- b. How much does the labor required for the construction cost per an hour?
- c. What additional costs does the construction technique require?

**Scheduling**
- d. How long is the local and provincial permitting process take?
- e. How long will the complete design of the transmission station take using the construction technique?
- f. How long will the construction phase of transmission station take?
- g. Is there any additional time necessary when utilizing the construction technique?
  - i. If so, what are they?
  - ii. How long will they take?

**Availability of Labor**
- h. Does the region contain sufficient labor capacity required to use the construction technique?
- i. Will there be sufficient amount of laborers available at the time of the project?
- j. Are skilled sub-contractors required to use the construction technique?
  - i. If so, are they available?
  - ii. How much do they cost per an hour?
- k. Are labor unions a necessary consideration?

**Availability of Supplies**
- l. What supplies doe the construction technique require?
- m. Are the required buildings supplies available in the region?
  - i. If not, what are the logistics involved with getting them transported to the site?

**Task 4. Compare the Advantages and Disadvantages of the Four Alternative Construction Techniques for the Transmission Station:**

The information collected in Task 2 and the preliminary evaluations performed in Task 3 will be utilized to compare the application of the four construction techniques for the instillation
of the transmission station. A uniform assessment criteria will be developed, tailored to the available information, in order to analyze the four construction techniques without bias. Instead of simply selecting the construction technique with the lowest preliminary cost-estimate and the shortest construction schedule, a number of other factors will be taken into consideration including availability of sub-contractors, transportation logistics, obtainability of necessary building supplies, and environmental impact. The assessment criteria will weigh all the factors mentioned above along with the preliminary cost-estimates and building schedules to gauge which construction technique is most viable for the construction of the Transmission Station.

**Task 5. Select Most Viable Construction Technique for the Transmission Station:**

Task 5 represents more of a check point than an activity. At this point in the project, the construction technique which is best applicable for the transmission station will be selected. The title of “most viable construction technique,” means that the given building method will provide the Transmission Station with the best opportunity to be completed on-time, within-budget, and within the constraints and specifications of the owner. Deciding which of the four construction techniques in question is the most viable for the installation of the Transmission Station will be completely objective and based upon the bulk of the work completed in Tasks 3 & 4.

**Task 6. Perform Detailed Cost Estimating and Scheduling Analysis for the Most Viable Construction Technique:**

While preliminary cost-estimates and building schedules were formulated in Task 3, the selection of the most viable construction technique will allow a substantially more detailed cost-estimate and scheduling evaluation for the construction of the transmission station to be conducted. A breakdown of the activities necessary for construction of the transmission station using the chosen building technique will be created. The breakdown of construction activities will include both the estimated cost and time for each activity. Performing the cost-estimate and scheduling evaluations in this manner will produce a much more accurate answers for the questions of “how much will it cost?” and “how long will it take?” to construction the transmission station using the chosen building technique. The cost and time estimates will be generated based off of projects Stantec has completed in the past and current market values of both labor and materials.

**Deliverables**

The final deliverables for this project will include a detailed report outlining the best construction materials and methods for a Transmission Station under the specified construction project management process. A formal presentation will be made to Stantec showing all of our final conclusions and relevant data. A capstone design addressing the economic, environmental, manufacturing, health and safety, social, and political aspects of construction materials and methods, will be included in a final report that is submitted to both Stantec and WPI. A final
Capstone Design Statement

The Accreditation Board of engineering and Technology (ABET) mandates that all accredited engineering programs are supplemented by a Capstone Design Experience. Undergraduate engineering programs at Worcester Polytechnic Institute satisfy this ABET requirement through the Major Qualify Project (MQP). The American Society of Civil Engineers (ASCE) states that the said Capstone Design Experience must include aspects of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political.

Design Problem

This Major Qualifying Project meets the requirements specified by both the ABET and ASCE by carrying out a “design process” which evaluates four major construction methods with several of the factors mentioned above and recommends the most viable construction method for the installation of an electrical transmission station in the Province of Nova Scotia, Canada. The four construction techniques in question are Concrete Masonry Units (CMU), Reinforced Concrete, Structural Steel, and Pre-Cast Concrete. Utilizing previous project experience of the Stantec Consulting Limited, research of local and regional standards of construction, construction method specific cost-estimates, and construction technique specific building schedule approximations, the feasibility of each construction technique will be evaluated and the most viable option will be selected. The construction techniques will be assessed in terms of cost, building time frame, constructability (manufacturability), environmental impact, health and safety, social opinions, and political influence. An unbiased evaluation criteria will be developed to decipher the most viable construction technique which will be subsequently recommended to the Dartmouth office of the Stantec Consulting Limited for the construction of a coastal electrical transmission station.

Engineering Standards and Realistic Constraints

As mentioned above, Capstone Design Experience must include aspects of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political. The following sub-sections will briefly explain how the Major Qualify Project will cover the necessary considerations of a Capstone Design Experience.

Economic

The evaluation of four alternative construction techniques for the construction of an electrical transmission station will involve economic considerations because of the cost-estimating procedures used to evaluate each of the four construction techniques. The preliminary cost-estimates produced in Task 3 will provide individual economic analyses of the four
Evaluating Construction Management Techniques for an Electrical Transmission Station

construction techniques. Finally, one of the major assessment criteria for the selection of the most feasible construction technique will be the economic or monetary cost of applying the building method for the construction of the transmission station.

Environmental

The evaluation of four alternative construction techniques for the construction of an electrical transmission station will involve environmental considerations by including the environmental impact of each of the four techniques into the assessment criteria for selecting the most feasible construction technique. As mentioned above, the selection of the most feasible construction technique will not be simply based off of the preliminary cost-estimating and scheduling evaluations. This is because there is a number of other factors which must be taken into consideration when making such a large decision. One of these factors is the environmental impact of the construction techniques in question. The environmental impact of building methods has increased significance because of the transmission stations site, which is set in a remote environment.

Manufacturability (Constructability)

One of the most crucial aspects in the evaluation process of the four alternative construction techniques for the construction of an electrical transmission station is the manufacturability of each building method. Assessing the manufacturability of each technique is a necessary step in both the cost-estimating and scheduling procedures. The degree of constructability of each building method is actually a value which combines both cost-estimating and scheduling. High Constructability will be weighed heavily in the assessment criteria because it represents the ability to build the transmission station on-time and within-budget using a given construction technique. The evaluation of constructability will also take into consideration the availability and transportation logistics for the materials necessary to apply the construction technique in question. Finally, the degree of constructability for each of the construction technique will be affected by not only the cost but also the availability of the labor necessary to implement it.

Health and Safety

The evaluation of four alternative construction techniques for the construction of an electrical transmission station will include health and safety considerations into the assessment criteria for the selection of the most feasible building method. The preliminary scheduling evaluations must take into consideration how quickly the transmission station can be built using the construction methods in question without sacrificing the health and safety of the workers. Attention to health and safety must be increased because of the dangers related to the high-voltage electrical equipment which is being housed within the transmission station. Small mistakes can become deadly when working in proximity to the high voltages power lines which run through the transmission station. Concerns for human health and safety will not end with the completion of the transmission station. A number of safety and security features must be
installed and maintained on the transmission station site. Because of the high voltage
environment, fences and security systems must be included into the construction of transmission
station to protect against trespassers.

**Social and Ethical**

The evaluation of four alternative construction techniques for the construction of an
electrical transmission station will include social and ethical considerations into the assessment
criteria for the selection of the most feasible building method. The installation of the
transmission station in Cape Breton is rather controversial because of various social issues
between the region’s citizens and officials. The assessment process of the construction
techniques will include a criteria which represents the Social and Ethical impact of the building
methods in question. Construction Techniques which ease social and ethical tension will have
increased feasibility.

**Political**

The evaluation of four alternative construction techniques for the construction of an
electrical transmission station will include political considerations into the assessment criteria for
the selection of the most feasible building method. As stated above, the installation of the
transmission station in Cape Breton is a rather controversial because of various political issues
between the region’s citizens, governmental officials, and the electrical company. The
assessment process of the construction techniques will include a criteria which represents the
political impact of the building methods in question. Construction Techniques which ease
political tension will have increased feasibility.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acclimation Period</td>
<td>1/9 - 1/11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move in to Housing</td>
<td></td>
<td>1/14 - 1/18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation of Stantec office and Dartmouth Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify possible resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify key Stantec employees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review project documents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review older related Stantec projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify site factors related to construction materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify site factors related to construction methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluate Combinations of Construction Materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assess pro's &amp; con's of each material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assess the ability to use materials on specified project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produce possible schedules for each combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produce cost estimates for each combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement Most Efficient Choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide detailed project schedule of project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide detailed cost estimate of project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Final Deliverables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyze results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finish final deliverables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present to Stantec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Evaluating Construction Management Techniques for an Electrical Transmission Station

Works Cited


"Getting the Best Value for Our Construction Dollars: A Primer on Construction Delivery Methods."


