NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

2015-2016 ASCE Steel Bridge Project Proposal

To
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December 16th, 2015

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Equation 1.4.1:

$$C_c = \text{Total Time (minutes)} \times \text{Number of Builders (persons)} \times 50{,}000\ (\$/\text{person-minute})$$
$$+\$30000\ \text{(If temporary pier is staged for construction)}$$
$$+\ \text{Load Test Penalties}\ (\$)$$

Equation 1.4.2:

(weight ≤ 400 lbs)

$$C_s = \text{Total Weight (Pounds)} \times 10{,}000\ (\$/\text{Pound}) +$$
$$\text{Aggregate Deflection (Inches)} \times 1{,}000{,}000\ (\$/\text{Inch}) + \text{Load Test Penalties}\ (\$)$$

Equation 1.4.3:

(weight > 400 lbs)

$$C_s = [\text{Total Weight (Pounds)}]^2 \times 25\ (\$/\text{Pound}^2) +$$
$$\text{Aggregate deflection (Inches)} \times 1{,}000{,}000\ (\$/\text{Inch}) + \text{Load test penalties}\ (\$)$$

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1.0 Project Understanding

1.1 Project Purpose

The objective of the steel bridge project is to design, analyze, fabricate, and construct a 1:10 scale model of a steel bridge. This bridge design and model will represent Northern Arizona University (NAU) at the American Society of Civil Engineers (ASCE) Pacific Southwest Conference (PSWC). This conference is a sponsored event by the American Institute of Steel Construction (AISC) and ASCE, and a set of provided rules and regulations for this competition are found on the AISC website. All bridges are evaluated for construction speed, weight, aesthetics, economy, and strength. The hypothetical situation the Steel Bride Team is that the winner of the bridge competition is "chosen to provide the standardized design will also design site-specific modifications and is likely to become Impecunia Department of Transportation's (ImpDOT) preferred firm for all other bridge work" [1]. The client and technical advisor on this project have been chosen, and through meetings with these two parties, project expectations and standards are set forward and made clear. It is the goal of the Steel Bridge Team to achieve a first place prize at the PSWC 2016.

1.2 Project Background

There is a fictional story provided in this year's competition rules involving the sale of Impecunia State University to a for-profit enterprise. Funds are being provided to repave state highways as well as replace several bridges that have been deemed deficient by age, increased traffic demand, overloading, and inadequate maintenance [1]. The project will be funded by ImpDOT, who has specified that the bridge be made of steel. Steel will be used because of its exceptional strength to weight ratio, its ability to be prefabricated, and ease of construction, all allowing for a fast and efficient construction process. ImpDOT has determined that design costs can be minimized by designing a generic superstructure that will only need minor modifications for each site [1]. From this standard, restrictions on transportation, site layout, temporary support, and access over water are revealed.

ImpDOT will provide a contract to the company with the most effective and efficient 1:10 scale steel bridge model. The bridge will be constructed in a timed fashion as part of the PSWC Steel Bridge Competition in order to determine constructability. The finished model will be tested against both lateral and vertical deflection and will be judged against other models alike. If any rules are broken or any part of the construction process and final completed model are deemed unsafe, the model will be disqualified and the company's eligibility for project will be terminated.

1.3 Technical Considerations

There are several types of technical work that must be considered to successfully complete this project by passing load testing. The two areas that require technical consideration in the project are the design and fabrication phases. These are the two main aspects of the project that require the most work. The design will require a fair amount of technical consideration to be successful such as choosing the best design out of three candidates, deciding which material properties to use to make the bridge an efficient design, and deciding which construction sequence will yield the fastest construction time. Extensive design work is necessary to account for potential failures that could occur throughout the bridge. A poor design can cause the fabrication and construction to essentially be a waste of time.

The design portion is critical to the project, but fabrication also requires significant technical consideration. Fabricating each steel member to match what the team designed requires a great amount of expertise. This includes cutting, drilling, welding, and potentially rolling each member. All of the fabricated members have to be similar so they can all be compatible and work together to create a strong section. Previous competitions have had great designs that failed due to a fault in the fabrication process.

1.4 Project Evaluation

1.4.1 Member Constraints

The 1:10 scale bridge will be designed within the parameters provided by ImpDot. The bridge can only be constructed with members, loose bolts, and nuts made of steel. Each member is limited to dimensions of three feet by six inches by four inches and each bolt must not exceed three inches in length. The members of the bridge must retain its shape, dimensions, and rigidity during timed construction and load testing.

1.4.2 Bridge Competition Constraints

Construction speed is the time it takes to construct the bridge model, with the addition of time penalties accrued during construction. Time penalties are added to the overall construction time each time equipment or a bridge member touch the river, the ground outside the staging area, or the ground inside or outside the construction area. The time to construct the bridge must be less than forty-five minutes, but anytime over thirty minutes will result in a total construction time of 180 minutes. Construction will be halted after 45 minutes regardless of build completion and inspected for safety. If the bridge is deemed unsafe, the bridge will be disqualified from the competition.

1.4.3 Bridge Competition Evaluation

Construction economy (C_c) determines the design cost and is calculated using Equation 1.4.1. There is a maximum of six builders allowed for construction, and a temporary pier is allowed to help span the river. Both factor into the construction costs and can vary depending on the team needs. Penalties can be added to the construction economy for every instance a builder or a part of their clothing touches the river or ground outside the construction area. The penalty will be recorded as an additional builder. The structural efficiency (C_s) is used to judge the structural design. Equation 1.4.2 or Equation 1.4.3 are used to calculate the structural efficiency, depending on the overall weight of the bridge, the overall performance of the bridge will be judged on the combination of the construction economy and the structural efficiency. The team with the lowest score is deemed the winner of the competition.

1.5 Potential Challenges

The team foresees several potential challenges during the course of this project. Time constraints cause some of the biggest challenges. First, the ASCE PSWC will occur in the beginning of April 2016. The Steel Bridge team has a limited amount of time to complete design and fabrication of the bridge. The Steel Bridge team must complete the bridge design by December 2015. The team must begin construction of the bridge by February 2016. The bridge must be fully constructed by March 2015 to be able to compete in the ASCE PSWC.

The team plans to work diligently to remain on schedule in order to complete design and fabrication before the conference. The team also has a specified time constraint for construction of the bridge. The team must design the bridge so that it can be built within a forty-five minute time limit. However, to achieve maximum points for construction time, the team plans to design the bridge to be built within thirty minutes. To achieve this goal and overcome the challenge of the construction time constraint, the team will minimize the number of connections and members for the bridge design.

Another potential challenge is the possibility of poor bridge fabrication techniques. The lack of proper equipment and skills needed to fabricate the bridge properly could lead to fabrication errors. Errors could ultimately result in a design failure during loading. To avoid fabrication errors, the team will make sure that proper tools and equipment are provided to help fabricate the bridge. The team will also make jigs that will help control accuracy when using specific tools. The use of jigs will ensure that all bridge members are fabricated the same way, which will help eliminate errors.

1.6 Stakeholders

This project is for the AISC and ASCE Student Steel Bridge Competition, and for this reason, the stakeholders are divided amongst two primary groups. The first group involves the people of Impecunia, for whom this model bridge is being designed and built for. The main client within this group of stakeholders is ImpDOT, who has requested this generic model in order to replace numerous deficient bridges around Impecunia. Since the bridge with the best overall strength, ease of construction, stability, and serviceability will be chosen to be constructed, all citizens of Impecunia are stakeholders for this project. The second group includes all people affiliated with Northern Arizona University including: the client, Mark Lamer, technical advisor, Thomas Nelson, Northern Arizona University, NAU CECMEE department, and the NAU ASCE Student Chapter. Other potential stakeholders include the donors of labor, design programs, and materials contributing to the Steel Bridge design and construction. From the competitiveness of the competition, the Steel Bridge Team will represent these stakeholders.

2.0 Scope of Services

The following tasks describe the proposed scope of services for the Steel Bridge Project.

2.1 Background Research

2.1.1 Competition Rules

Competition rules and design specifications were provided by the American Institute of Steel Construction (AISC). All rules and specifications were used as considerations for the design, fabrication, and construction of the bridge.

2.1.2 Bridge Designs

Different bridge designs were researched to determine the type of bridge that the team could design for this project. Bridge designs researched include different truss designs, such as the Warren and Pratt trusses, a beam bridge, and a suspension bridge.

2.1.3 Connections and Weld Types

Different weld types were researched including metal inert gas (MIG) welding, tungsten inert gas (TIG) welding, arc welding, and oxy acetylene welding. The team also discussed different types of connections for bridge members.

2.1.4 Materials and Member Types

Types of steel were researched such as alloy steel, carbon steel, and stainless steel, and the team discussed considerations for member strength, size, and shape.

2.2 Preliminary Design

2.2.1 Design Options

Members of the Steel Bridge Team will sketch ideas for three different design options that could be used for the final bridge design

2.2.2 Preliminary RISA 3D Models

Each preliminary design option is drawn in RISA. Loads are placed on the models to simulate loading during the competition. The preliminary models help determine which bridge design will have the least amount of deflection.

2.2.3 Decision Matrix

A decision matrix is made with the criteria named in the competition rules. The different preliminary bridge designs are ranked according to how well they would satisfy the criteria. After the ranking is complete, the preliminary design option with the highest overall ranking is chosen for the final bridge design.

2.3 Final Design

2.3.1 RISA 3D

The bridge is fully designed in RISA 3D before any detailing is performed in AutoCAD. Iterations are done in order to minimize both vertical and lateral deflections throughout the bridge. Although the team does not know the location of the offset loading before the competition, the team will use all load cases and design the bridge model for the worst load case.

The RISA model is saved at multiple different times to save progress and go back to previous iterations if necessary.

2.3.2 Member Design Details

The preliminary bridge design is refined from a preliminary stage to a final stage of design. All member sizes and dimensions are determined, as well as the overall aesthetic of the bridge. A final model is drawn in RISA 3D for an approximate estimate of member and joint deflection.

2.3.3 Connection Design

The joint connections are designed based on the overall configuration of the bridge design. Plates are designed for each member and bolt capacity is determined. From the bolt capacity, a bolt size is chosen for each connection.

2.4 Bridge Design Plans

2.4.1 30% Drawings

The 30% drawings will include general plan and elevation views of the bridge showing preliminary dimensions

2.4.2 60% Drawings

The 60% drawings will include detailed plan and elevation views of the bridge showing final dimensions

2.4.3 90% Drawings

The 90% drawings will be comprised of all bridge details including detailed plan and elevation views, connection design details, and member cross sections. All drawings will show final dimensions.

2.5 Fabrication

2.5.1 Preparation

At the start of the fabrication phase, the team will perform numerous tasks to make fabrication go as easy and fast as possible. Some of these tasks include fully cleaning all steel acquired through donations and making several jigs so every piece will be of equal size for multiple different member lengths.

2.5.2 Cutting

All bridge members and plates are measured to the appropriate size according to the dimensions specified in the design plans, and then cut based on the measurements.

2.5.3 Drilling

After plates are cut to the correct dimensions, locations of all bolt holes are measured out per the design plans, and are then drilled to the correct bolt size using a drill press.

2.5.4 Welding

Bridge members and plates are welded together according to the design plans.

2.6 Construction

2.6.1 Numbering

A numbering system is created for all bridge members to help with ease of construction.

2.6.2 Construction Practice

Team members will practice constructing the bridge to determine an efficient way to build it during the competition as well as to reduce the construction time.

2.7 Pacific Southwest Conference

2.7.1 Display Day

The first day of the Pacific Southwest Conference is the display day for each team's steel bridge design. A display board is made showing the name of the university, why the bridge design is chosen, a scaled side view of the bridge, a free-body diagram for one of the six load cases, shear and moment diagrams for the chosen free-body diagram, provisions for Accelerated Bridge Construction (ABC), and acknowledgement of all sponsors and donors who helped in any way throughout the entire bridge design build process. An award is given for display and is judged on the following criteria: appearance including balance, proportion, elegance and finish, and permanent identification of the bridge showing the university name exactly as shown on the ASCE student web page.

2.7.2 Off-Center Load Case Location Determination

Before conference, every team is given six different load cases to design for. The night before the construction day, all conference captains meet with the head judge to ask any final questions. Also at this meeting, a die will be rolled to determine the location of the off-center load.

2.7.3 Timed Construction

The day of the competition, all teams are to build their designed bridge in a timed fashion. Before starting, all bridge members, fasteners, temporary pier (if used), and tools are staged and inspected by the judges. Every team is given a thirty-minute time limit to build the bridge without any penalties and a maximum time limit of forty-five minutes to build the bridge without being disqualified from the competition.

2.7.4 Loading and Weight

After timed construction is completed, each team moves their bridge to the loading area. The judge decides an "A" side of the bridge by a random process and the other side is determined as the "B" side. The decking units are then placed; one is placed at 8'-9" from the right side and the other is placed at the location of the load case chosen the night before construction, specified as distance "D". Three vertical deflection gauges are placed, one on the "A" side at a distance D + 3'-0" from the right end of the decking unit, and two on the "B" side, one at a distance D + 1'-6" from the right end of the decking unit and the other at a distance 10’-3” from the right end of the decking unit.

Lateral loading is tested first and seventy-five pounds is placed on the “B” side of the bridge to help restrain the bearing surfaces of the bridge from uplifting. Then, fifty pounds of lateral load is placed as close to the decking unit as possible. One inch of sway is allowed for the bridge to pass lateral loading. The next loading condition is the vertical loading test. Fifty pounds of pre-load is evenly distributed across the decking units. From there, 1000 pounds of additional load is placed on the off-center decking units and 1400 pounds of additional load is placed on the center-decking unit. All loads are placed in a manner of individual twenty-five pound pieces of angle iron. Three inches of aggregate deflection is allowed for the bridge to pass vertical loading. Last, if the bridge passes both lateral and vertical loading, the bridge is moved to be weighed on four scales, one for each foot of the bridge, and the totals are summed to gain a final weight.

2.8 Project Management

2.8.1 Scheduling

A schedule is created to stay on track during the course of the project. Each major task is listed on the schedule with approximate start and finish dates, along with subtasks that are included as a part of the critical path.

2.8.2 Budget

A budget is created based on the amount of time needed to complete the project, as well as the resources required. This includes the personnel and materials that are necessary for the completion of the project. The budget also takes into account any donations that are received to help fund the project.

2.8.3 Meetings

The team will have weekly meetings to discuss the progress of the bridge. The team will also meet with the Technical Advisor and Client as necessary.

2.8.4 Fundraising and Donations

The team will contact different resources in the hopes of acquiring donated materials or funds. For any donated materials, the team will be in contact with vendors throughout the course of the design phase of the project. This helps ensure that all materials that will be used for final bridge design are readily available when the fabrication phase begins.

2.9 CENE 486 Deliverables

2.9.1 50% Design Report

The Steel Bridge Team will prepare and submit a 50% design report summarizing the preliminary design of the bridge. The report serves as a rough draft for the final design report.

2.9.2 Final Design Report

The final design report will provide an overview of the scope of work completed for the project. This work includes the design, fabrication, and plans used in the project.

2.9.3 Website

A website will be created to show all aspects of the project, including the final chosen design, AutoCAD shop drawings, and results from the ASCE Pacific Southwest Conference.

2.9.4 Final UGRADS Presentation

The team will present the all details for final project along with the results from the ASCE Pacific Southwest Conference.

2.10 Exclusions

2.10.1 Site Visit

The Steel Bridge Team will not be visiting the construction site prior to the day of construction and loading.

3.0 Schedule

3.1 Fall Semester

In the fall semester, the team will focus primarily on completing the steel bridge design. This is shown in the Gantt chart by the research, decisions, and designs scheduled. The fundamentals to the bridge design will be researched to give the team a better understanding of what needs to be completed. The three different preliminary designs will be modeled and evaluated to determine the best option for a final bridge design. Once a final design is chosen, the connections and member details will be designed. Ninety percent of the design will be completed by Thanksgiving to ensure the team has enough time to pick up materials from sponsors.

3.2 Spring Semester

In the spring semester, the team will primarily be fabricating and building the bridge. After the team receives the steel, fabrication of the bridge can begin. The team plans to work on the bridge as soon as the semester begins. Cutting, drilling, and welding take most of the time to complete and are the bulk of the fabrication work. The team will allot forty days to complete the three tasks because of the large amount of work required. After all of the pieces are fabricated, the team will schedule a day to number the pieces to make construction of the bridge easier. The team will then begin construction practice to achieve a build time under thirty minutes. The team will also submit class deliverables on their respective due dates.

3.3 Critical Path

The critical path for this project consists of two major tasks. The critical path includes both the design and the fabrication of the bridge. These two tasks are the main components of the bridge and will take the longest to complete. The team estimates the design will take 40 days to complete with another 20 days for finalization of the design and AutoCAD shop drawings, and the fabrication will take 40 days to complete. This totals to approximately 100 days to complete the critical path of the project.

The Gantt Chart showing the full project schedule and critical path (shown in red) can be seen in Appendix A.

4.0 Staffing and Cost of Engineering Services

Staffing costs and costs of engineering services are determined based on the scope of services that are necessary for completing this project.

4.1 Staffing

The team that will complete the Steel Bridge Project is comprised of eight team members total: four engineers and four interns. The team of engineers consists of a project manager, a conference captain, a RISA 3D design engineer, and an AutoCAD design manager. The project manager is in charge of oversight for the project, making sure deadlines are met and that the team stays on task. The conference captain coordinates all scope items related the ASCE PSWC, which includes acting as safety manager and captain during construction and loading at the competition. The design engineer manages the overall design of the bridge and the RISA model created for the design. The AutoCAD manager is in charge of the full set of AutoCAD plans for the bridge after the design is complete. The four interns on the project will be assigned small tasks for various scope items, consisting mostly of assistance with fabrication and construction. Table 4.1 shows job classifications for the steel bridge project with abbreviations for each position that will be used for reference for all staffing hours and costs.

Table 4.1: Staffing Position Abbreviations

Title	Abbreviation
Project Manager	PM
Conference Captain	CNFCPT
RISA 3D Design Engineer	DSNENG
AutoCAD Design Manager	CADMGR
Intern (Four)	INT (4)

4.2 Staffing Hours and Costs

Based on the scope tasks for the project, the team compiled a table of estimated hours for all personnel. The hours are projected for the total approximate hours each team member will spend on each task item. Table 4.2 shows the estimated personnel hours for the duration of the project. The major tasks are listed in bold print and the subtasks for are listed below each major task. The hours in bold for each major task are the total amount of hours that will be spend on that item, and the hours for each subtask sum to the total hours for each major task. The team projects a total of 1080 hours for the Steel Bridge Project.

Table 4.2 Estimated Personnel Hours					
Task	**PM**	**CNFCPT**	**DSNENG**	**CADMGR**	**INT (4)**
1.0 Background Research	**0**	**5**	**5**	**5**	**5**
2.0 Preliminary Design	**0**	**5**	**20**	**10**	**20**
3.0 Final Design	**20**	**40**	**80**	**80**	**60**
3.1 RISA 3D	10	20	60	10	20
3.2 Member Design Details	5	10	10	35	20
3.3 Connection Design	5	10	10	35	20
4.0 Bridge Design Plans	**5**	**10**	**40**	**60**	**40**
4.1 30% Shop Drawings	1	5	20	30	20
4.2 60% Shop Drawings	2	3	10	20	10
4.3 90% Shop Drawings	2	2	10	10	10
5.0 Fabrication	**20**	**60**	**40**	**40**	**60**
5.1 Preparation	5	15	10	10	15
5.2 Cutting	5	15	10	10	15
5.3 Drilling	5	15	10	10	15
5.4 Welding	5	15	10	10	15
6.0 Construction	**15**	**40**	**25**	**25**	**40**
6.1 Numbering	5	5	5	5	5
6.2 Construction Practice	10	35	20	20	35
7.0 Pacific Southwest Conference	**15**	**40**	**15**	**15**	**20**
8.0 Project Management	**15**	**10**	**10**	**10**	**5**
9.0 CENE 486 Deliverables	**5**	**15**	**15**	**15**	**0**
9.1 50% Design Report	1	5	5	5	0
9.2 Final Design Report	2	5	5	5	0
9.3 Website	1	3	3	3	0
9.4 UGRADS Presentation	1	2	2	2	0
Total Hours/Personnel	**95**	**225**	**250**	**260**	**250**
Total Hours	**1080**				

Billing rates per hour for each project team member are determined based on percentages of benefits, overhead, and profit. Table 4.3 shows the billing rates per hour for each member of the staffing team based on the applied multipliers.

Table 4.3: Billing Rate Calculation						
Personnel	**Task Name**					**Billing Rate [$/hr.]**
	Base Pay	**Benefit [%]**	**Actual Pay**	**Overhead [%]**	**Profit [%]**	
PM	60	20	72	30	10	105
CNFCPT	55	15	63.25	30	10	90
DSNENG	50	15	57.5	30	10	85
CADMGR	35	15	40.25	30	10	60
INT (4)	10	0	10	30	10	15

From the billing rate calculation and the total estimated hours for each staffing member, a total cost for personnel is estimated. Table 4.4 shows the total cost of personnel for the Steel Bridge Project.

Table 4.4: Total Cost of Personnel			
Position	**Total Hours**	**Rate/Hour**	**Cost**
PM	95	$105	$9,975
CNFCPT	225	$95	$21,375
DSNENG	250	$85	$21,250
CADMGR	260	$60	$15,600
INT (4)	250	$15	$15,000
		Total Cost of Personnel	$83,200

4.3 Total Cost of Engineering Services

The team estimated costs for all engineering services, including rates for the ASCE Pacific Southwest Conference and fabrication by subcontractors, as well as lump sums for materials. Overall costs also include the cost of personnel. Table 4.5 shows all estimated costs of engineering services. The team estimates a total project cost of $86,585.

Total Cost of Engineering Services			
Service	**Rate**	**Unit**	**Total**
1.0 Personnel	Varies	1080 Hours	**$83,200**
2.0 Pacific Southwest Conference			
2.1 Travel Mileage	$0.45/mile	1630 Miles	**$735**
2.2 Hotels (2 Rooms)	$125/night	4 Nights	**$1,000**
2.3 Van Rental	$50/day	5 Days	**$250**
3.0 Subcontractors			
3.1 Steel Fabrication	Lump Sum	Dollars	**$100**
3.2 Water Jet Name Plate	Lump Sum	Dollars	**$200**
4.0 Materials	Lump Sum	Dollars	**$1,100**
		Total Cost	**$86,585**

5.0 References

[1] Aisc.org, 'Student Steel Bridge Competition Rules', 2015. [Online]. Available: https://www.aisc.org/WorkArea/showcontent.aspx?id=21576. [Accessed: 30- Sep- 2015]