NORTHERN ARIZONA UNIVERSITY

Steel Bridge Team
Project Proposal

CENE 476-001

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NORTHERN ARIZONA UNIVERSITY

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1.0 Project Understanding

1.1 Project Purpose

The purpose of this project is to design a 1:10 scale model of a hypothetical wildlife bridge to be judged at the regional Student Steel Bridge Competition during March or April of 2022. Exact competition dates are unknown until released by the host school. This project will entail using various design and analysis methods to design and construct a functional bridge that can support a defined amount of loading and meet the specifications as defined by the competition rules and requirements. The final design will be graded according to various criteria outlined within the provided competition guidelines and ranked to determine a winner for the 2022 Student Steel Bridge Competition.

1.2 Project Background

1.2.1 Competition Details

Arizona falls within the Intermountain Southwest Region for the competition, and therefore the team will be competing in the regional competition located in Las Vegas, Nevada. The competition will take place between the end of March and the beginning of April in 2022 with exact dates to be determined and announced by the host school. Final products from each participating team will be submitted and graded based on performance in different categories as outlined below. The teams with the highest collective score in all of the categories will place the highest in the regional competition. This competition is sponsored by both AISC and ASCE.

1.2.2 Scoring

1.2.2.1 Aesthetics

The competition will have scoring based on the aesthetics of the bridge in terms of its appearance, balance, proportion, including how the bridge is constructed. Another criteria of the aesthetics is the poster for the bridge and will be judged on what the poster has on it, such as the classification of the bridge and why a design was chosen, name of the school presenting, scaled dimension of the bridge, analysis method explanation, free body diagram that shows the performance of the stringers, shear and moment diagrams for the free body diagrams, use of Accelerated Bridge Construction (ABC), acknowledgement of those who have helped with the bridge construction, planning, and fabrication.

1.2.2.2 Construction Speed

The speed of the construction will be a factor in determining the overall performance of the bridge and how fast the construction can be done. The fastest overall time in the safest manner will score the highest and give an advantage in the competition.

1.2.2.3 Lightness

The lightness of the bridge will be judged based on the overall weight on the bridge and the one that weighs the lightest will be the one that scores the highest for the category.

1.2.2.4 Stiffness

The stiffness will be judged based on the lowest overall aggregate deflection due to the loading in the competition and will be given the highest score for the competition for this category.

1.2.2.5 Construction Economy

This category will judge a team based on the cost of their respective bridge and the lowest costing successful bridge will receive the highest score for that category.

1.2.2.6 Structural Efficiency

The way that structural efficiency is scored is based on the formulas outlined in Student Steel Bridge Competition 2022 Rules section 6.2.6. Then the steel bridge team with the lowest score will win this category.

1.2.2.7 Overall Performance

The way that overall performance is scored is the judges will take the score of construction cost and structural cost and add them together. The steel bridge team that receives the lowest score will win this category.

1.3 Technical Considerations

The bridge to be designed must have parts building and sustaining it below the actual bridge itself so that animals cannot damage it by hitting. It must also be a cantilever bridge with all necessary parts out of the reach of the wildlife. The work for this project requires designing the bridge through design software such as Civil 3D, going through the appropriate loading and combinations of loading that may go onto the bridge using structural analysis, and determining the amount of force the bridge can sustain through Statics. Being able to determine the right type of material using multiple tests and multiple materials, as taught in the Mechanics of Materials course, will lead to finding how much tensile strength the materials can withstand in order to best one for the

bridge. Being able to determine the loads and the different materials that will be the best to ensure that the bridge is a success is the biggest aspect of this project. Another aspect that needs to be considered is the materials needed for fabrication of the bridge, including the connections for the members. The biggest consideration is that due to rules of the competition, the bridge needs to be a cantilever. Because of that, this will limit the design of the members and how they fit together.

1.4 Potential Challenges

The potential challenges of this project pertain to the design of the bridge itself. An appropriate design would have to be a design that enables and enforces the users of this bridge to be able to get onto the bridge without straying for the path. Maintaining a design that works for everyone and doesn't allow for accidental misleading into dangerous areas would be ideal. This will be met with multiple different ideas and designs and the best one will be voted on and determined to be the final approximate design. A big challenge for this project is ensuring that the bridge can withstand the amount of loading required, and that it doesn’t overtake the limits of the weight specified in the rules of the competition.

1.5 Stakeholders

The stakeholders for this project are Northern Arizona University, because the steel bridge team of 2020-2021 is directly representing Northern Arizona University. Another stakeholder is the Client Mark Lamer as being the client means they are the one the team is building the bridge for. A third stakeholder is the AISC, as they are the ones who put on the competition and therefore govern and enforce the rules of the competition. These people are stakeholders since the performance of this project will help with the overall travel of their area. This would also allow for people to use their highway without more risk of getting into an accident due to an animal getting in the way of traffic.

2.0 Scope of Services

2.1 Task 1: Competition Due Diligence

Thoroughly read the provided competition rules and determine the ways in which the information will be applied to the bridge design process. Make note of the grading criteria for the competition and follow closely to design and construct a high-scoring final product. This is necessary to ensure the team cannot be disqualified for rule violations and the overall team performance leads to a high rank at the competition.

2.2 Task 2: Impact Analysis

Analyze the potential environmental, social, and cultural impacts the project might have in the area of study. Ensure the construction process can take place within the given area parameters to avoid major disruption of the surrounding environment. This is necessary to reduce the negative impacts that result from the project.

2.3 Task 3: Conduct Material Research

Conduct research on various construction materials by noting respective tensile strength, ultimate strength, modulus of elasticity and other relevant material specifications. Use the aforementioned research to determine the most effective material with which to construct the steel bridge members and connections. This is necessary to identify the ideal material options to be used in the design and maximize positive results.

2.4 Task 4: Research Potential Bridge Designs

2.4.1 Task 4.1: Cantilever Design

Conduct research on common cantilever designs in similar scenarios to the project objective and the potential setbacks and benefits of each design option. Conduct analysis through RISA to test different cantilever designs and make note of weak points and/or areas of failure that must be adjusted in the design. This is necessary to verify the success of failure of the cantilever design and identify any areas needing improvement.

2.4.2 Task 4.2: Member Design

Conduct research on common member shapes, sizes, etc. and the applications in scenarios similar to the project statement. Conduct analysis through RISA to test different member designs and

make note of weak points and/or areas of failure that must be adjusted in the design. This is necessary to verify the success of failure of the member configuration and identify any areas needing improvement.

2.5 Task 5: Conduct Connections Design Research

2.5.1 Task 5.1: Material Specifications

Conduct research on the various possibilities of connection materials that comply with the project specifications and compare them to determine the best possible connection to use to maximize strength while minimizing weight and cost in the design. This is necessary to ensure the connections in each part of the design are capable of withstanding the necessary loads without failure.

2.5.2 Task 5.2: Connection Schematics

Conduct research regarding the options of commercially available connection types and the corresponding advantages and disadvantages of each. Research entails making note of possible connection dimensions, prices, weights, and material. Hand calculations will be made to account for the impact at each point of connection. This is done to verify there are no points of failure in the design at points of connection and identify any points of improvement.

2.6 Task 6: Conduct Modelling and Analysis of Design

2.6.1 Task 6.1: Loading Calculations

Conduct loading calculations to determine loads the bridge can withstand that follow the parameters defined by competition rules. Conduct analysis through RISA to determine the amount of loading the bridge can withstand at various points along the span. Ensure the design can withstand at minimum, the loads set to be applied at competition and make note of any weak points and/or area of failure to be adjusted. This is necessary to determine the loading capabilities of the design and identify any points of failure that must be adjusted.

2.6.2 Task 6.2: Calculate Stress and Strain Values

Calculate the stress and strain values using the aforementioned material specifications to determine what loads the bridge is capable of withstanding before cracking and/or breaking. Conduct analysis through RISA to determine the stress and strain values within members and connections for various loading combinations on the bridge. Consider stress and strain resulting from both dead

and live load combinations. This is done to determine the maximum loading values the materials can withstand so they can be accounted for in the final design.

2.6.3 Task 6.3: Log Data of Tensile Tests

Collect and record the data outlining results for tensile strength testing as it pertains to members and connections and graph the collected data. This is done to determine the relationship between stress and strain to show the yield strength, ultimate strength and point of fracture for each material.

2.7 Task 7: Shop Drawings

Develop shop drawings outlining profile, plan and perspective views of final design as developed in RISA. Clearly outline all member and connection dimensions, materials and locations in a professional and organized manner so that drawings may be easily read by subcontractors. This is done to provide a comprehensible guide for subcontractors to follow in attempts to minimize error during manufacturing.

2.8 Task 8: Coordinated Assembly: Member Fabrication

Facilitate with the subcontractors that are responsible for the steel member fabrication and welding and provide them with the chosen material specifications necessary for the design. This is done to ensure the successful fabrication of the members within the necessary timeframe of the project.

2.9 Task 9: Coordinated Assembly: Connection Fabrication

Facilitate with the subcontractor that is responsible for connection fabrication and provide them with all the necessary material specifications such as size and materials. This is done to ensure the successful fabrication of the connections as outlined in the shop drawings within the necessary timeframe of the project.

2.10 Task 10: Team Assembly: Modifications and Member Connection

As a team, conduct member connection practice upon the completion of member and connection fabrication by the contracting companies. Ensure that the member and connection dimensions are compliant with the competition requirements and verify that they match the details provided in the shop drawings. Make note of any variance in dimensions or material and if necessary, modify parts accordingly. This is done as a means of quality assurance to ensure the manufactured pieces align with the final RISA design.

2.11 Task 11: Team Assembly: Construction Practice

As a team, practice assembly of the bridge and ensure construction time is under the limit defined within the competition rules. Repeat the process as needed until the time limit as defined in competition rules is not exceeded and safe assembly of the bridge with no faults or hindrances can be consistently achieved. This is done so adjustments can be made as necessary in attempts to minimize construction time as much as possible, resulting in a higher score in the construction time category at the competition.

2.12 Task 12: Compete in Regional Competition

Compile all bridge members and connections and transport to the competition location. Assemble the bridge and submit to be subjected to load tests as outlined in the competition guidelines. Present poster outlining final design and the summary of steps followed to develop the final product. Execution of each task is necessary for successful performance in the competition.

2.13 Task 13: Project Deliverables

2.13.1 Task 13.1 30 Percent Deliverable

Complete the 30 percent deliverable containing the completed competition research and planning. It must include the provided dimension parameters and required loading capacity for the bridge as defined within the competition rules. In addition, background research, steel design/analysis, material selection, decision matrix and preliminary design for the bridge must be included. This is necessary to ensure the successful progression of the project.

2.13.2 Task 13.2: 60 Percent Deliverable

Complete the 60 percent deliverable containing a complete model of the bridge including the shop drawings and schematics of every component of the bridge. Begin construction of the bridge upon the arrival of the materials received from subcontractors. This is necessary to ensure successful project progression along the given timeline and allow for time to make potential member and connection adjustments.

2.13.3 Task 13.3: 90 Percent Deliverable

Complete the 90 percent deliverable containing the completed product. This deliverable requires the bridge to be completely fabricated and ready for competition, with all respective calculations and records of construction documented. For instance, the fastest recorded time constructing the

bridge as a team, the loading and stress and strain calculations will all be included in this deliverable. This is meant to serve as quality assurance before the final presentation and highlight any areas that need further improvement.

2.13.4 Task 13.4: Final Report

Generate a final report outlining all processes of design, analyses and results. Compile aforementioned items into organized sections to be presented in a professional report format. This is needed to effectively present and summarize all steps of the design process and the supporting calculations and factors behind the final design.

2.13.5 Task 13.5: Plans

Compile the completed portfolio of plans and generate both in the presentation and as a hard copy. Plans should effectively illustrate the bridge appearance and dimensions from every relevant perspective. In addition, tables generated through RISA should be provided. This is necessary for providing the client with a neat and comprehensible illustration of the final design.

2.13.6 Task 13.6: Product

Complete the physical construction of the bridge and present it as a finished product. This is necessary for the aesthetics and loading tests in the competition.

2.13.7 Task 13.7: Presentation

Prepare a presentation outlining the design process and clearly display preliminary and final bridge designs. This is necessary to effectively illustrate the full design process and the adjustments that were made throughout the course of the project.

2.14 Task 14: Project Management

2.14.1 Task 14.1 Schedule Management

Coordinate between team members to ensure everyone knows which tasks are on the schedule and by when individual jobs need to be completed. This is necessary to maintain organization and ensure the team functions as efficiently as possible. The schedule itself is discussed in Section 3 and can be seen in Appendix A.

2.14.2 Task 14.2 Resource Management

Coordinate between team members to ensure that resources are being distributed correctly and efficiently. This is done by overseeing inventory in what specific equipment and materials need to be utilized by both the Steel Bridge Team and the fabricators. A main aspect of resource management is overseeing the budget of the project with the staff rate breakdown and the cost of the engineering services.

2.14.3 Task 14.3 Meetings

Coordinate between team members to ensure that meetings are done routinely, verifying that the progression of the project is being done correctly and efficiently. Meetings will include the client, technical advisors, sponsors, and faculty grading instructors when necessary. All communication with these individuals and groups will be organized and handled by the Steel Bridge Team.

2.14.4 Task 14.4 Coordination with Fabricators

Contact and coordinate with potential donors to fabricate steel members and connections, and steel plates needed for design. This is necessary to save money on potential steel costs and help maximize the efficiency of the project.

2.14.5 Task 14.5 Coordination with Mentees

Coordinate with the NAU ASCE Student Chapter to start a Steel Bridge mentee group. The mentee group would help with construction practice and competing in the Regional Competition. This is done in order to provide guidance and experience for future potential Steel Bridge teams.

2.15 Exclusions

Exclusions include providing the exact coordinates of the bridge within the given location area, application of a green surface to the top of the bridge, and full-scale construction of the bridge.

3.0 Schedule

The schedule for this project begins in October 2021 and continues through May 2022, resulting in a total time frame of approximately 8 months. This time frame includes all tasks including bridge competition due diligence, research of possible materials, bridge design, ordering materials, constructing and loading the bridge, and lastly, competing in the Intermountain Southwest Conference. *Table 1: Schedule Outline* below, shows a general overview of the schedule and the

projected start and end dates for each task. The deliverables entail the 30, 60 and 90 percent deliverables and the final report, plans, product and presentation. The Gantt chart detailing the project schedule can be found below in Appendix A.

	Start Date	End Date
Task 1: Competition Due Diligence	10/14/21	10/25/21
Task 2: Project Management	10/14/21	10/26/21
Task 3: Conduct Material Research	10/26/21	11/8/21
Task 4: Research Potential Bridge Designs	11/9/21	11/22/21
Task 5: Conduct Connections Design Research	11/23/21	11/12/21
Task 6: Conduct Modelling and Analysis of Design	11/12/21	12/2/21
Task 7: Shop Drawings	12/24/21	1/20/21
Task 8: Coordinated Assembly: Member Fabrication	1/21/22	2/9/22
Task 9: Coordinated Assembly: Connection Fabrication	1/21/22	2/9/22
30% Deliverable	2/7/22	2/7/22
Task 10: Team Assembly: Modifications and Member Connection	2/10/22	2/23/22
Task 11: Team Assembly: Construction Practice	2/24/22	3/29/22
60% Deliverable	3/31/22	3/31/22
Task 12: Compete in	4/1/22	4/4/22

Regional Competition		
90% Deliverable	4/19/22	4/19/22
Final Report	5/2/22	5/2/22
Project Management	10/14/21	5/1/22

3.1 Critical Path

The Gantt chart shown in Appendix A specifically outlines the tasks in the project and the projected amount of time needed to complete each one individually. The critical path can be seen highlighted in red on the chart and illustrates the order of tasks that directly determine the finish date of the project. Each task is dependent on another therefore, an unexpected delay anywhere along the critical path will shift the schedule for each successive item. Closely monitoring team progress along the critical path is necessary to ensure the project is completed efficiently and effectively by our projected end date of May 1, 2022.

4.0 Staffing Plan

The following section describes the qualifications of the Steel Bridge Team and the anticipated hours and expenses that will be required for this project. All values that are included in this document are meant to be taken as an estimate and are subject to change.

4.1 Statement of Qualifications

The members of the 2021-2022 NAU Steel Bridge Team are McKenna Hughes, Janett Hernandez, Thomas Himpelmann, and Christian Gunderson. All members of the Steel Bridge Team are senior civil engineering students at Northern Arizona University. The following lists outline the qualifications of each member that pertain to the Steel Bridge Project.

4.1.1 McKenna Hughes

- 2019-2020 Steel Bridge Mentee
- Some experience in RISA
- AutoCAD experience
- Microsoft Word, Excel, and PowerPoint experience

4.1.2 Janett Hernandez

- 2018-2019 Steel Bridge Mentee
- Some experience with RISA
- AutoCAD experience
- Proficiency in Microsoft Office

4.1.3 Thomas Himpelmann

- Completion of Structural Analysis I & II, and Mechanics of Materials
- Familiarity with RISA
- AutoCAD experience
- Microsoft Office experience

4.1.4 Christian Gunderson

- Completion of Structural Analysis I & II, and Mechanics of Materials
- Familiarity with RISA
- AutoCAD experience
- Microsoft Word, Excel, and PowerPoint experience

4.2 Division of Labor

The following section identifies all of the staff positions that will complete work on this project with their abbreviations included. The staff rate breakdown can be found below in Section 5 in Table 2.

4.2.1 Senior Engineer (SENG)

The senior engineer will provide the final check on all milestones prior to progressing on the project. Specifically, this involved reviewing the reports, calculations and design details. Also, the senior engineer will be present during all meetings.

4.2.2 Project Engineer (PENG)

The project engineer will oversee the progression of the project at all stages of the development. Specifically, they will ensure that the project stays on schedule and within the budget. They also oversee fabrication and contacting different companies to request funds, materials, and services. However, the project engineer will not be present in the meetings.

4.2.3 Engineer in Training (EITs)

The EITs will perform the majority of the analysis and fabrication required for the project. They perform fundraising alongside the project engineer and research alongside other interns. EITs will attend meetings frequently, attend the ISWC competition, and will compile a final design report, redline shop drawings, and create and project website.

4.2.4 Interns (INTs)

Interns will perform the majority of the research for the project, fundraising, and will help the EITs with the fabrication of the bridge and at the ISWC competition. Interns will also attend meetings frequently.

4.2.5 Drafter (DRF)

The drafters will create a set of shop drawings for the bridge, which will be a guide for the fabrication and construction of the bridge.

4.2.6 Administrative (ADM)

The administration will ensure that the scheduling and budgeting are complete for the project.

4.3 Staff Rate Breakdown

As shown below in Appendix B, the table shows the expected hours that each staff member will spend for each individual task. Additionally, the cumulative number of hours that will be spent on each task and the total hours required for the overall completion of the project are displayed. A total of 870 hours is projected for the completion of the Steel Bridge project. The project is expected to cost a total of about $66,935.00 in labor costs.

5.0 Cost of Engineering Services

As seen below in Appendix C, the table shows the estimated breakdown of all of the engineering services included for this project. This specifically includes the personnel and their individual pay rates, cost of materials, cost of equipment, the cost of a subcontractor who will be doing the labor, as well as the cost for travel with van rental, fuel, food and lodging. The estimated cost for the Steel Bridge Project is approximately $145,899.

6.0 References

[1] *Aisc.org*, 2021. [Online]. Available: https://www.aisc.org/globalassets/aisc/university-programs/ssbc/ssbc-2022-rules.pdf. [Accessed: 20- Sep- 2021].

[2] WSDOT.WA.GOV [Online] Available

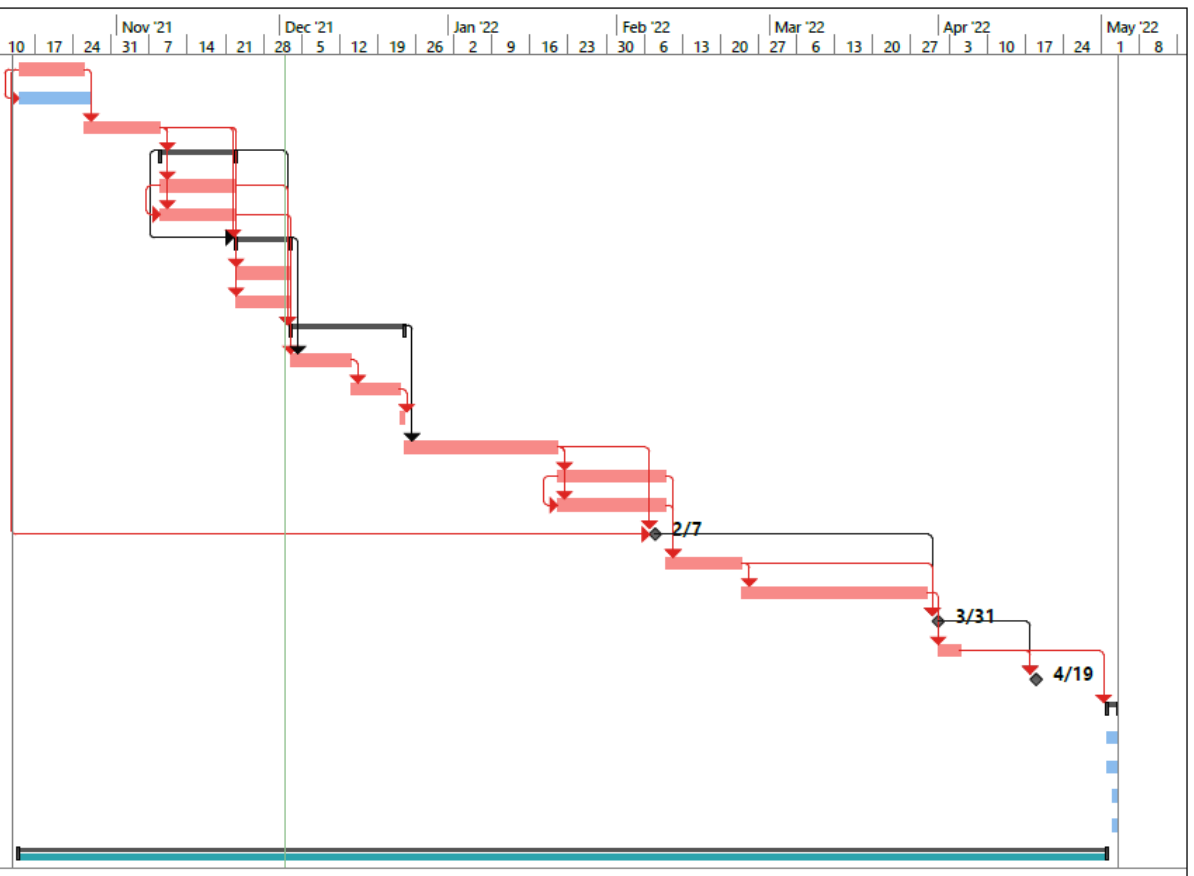
https://wsdot.wa.gov/Projects/I90/Map.htm

[Accessed 28-Oct-2021].

7.0 Appendices

7.1 Appendix A: Schedule

ID	Task Mode	Task Name
1		**Competition Due Diligence**
2		**Impact Analysis**
3		**Conduct Material Research**
4		**Research Potential Bridge Design**
5		Cantilever Design
6		Member Design
7		**Conduct Connections Design Research**
8		Material Specifications
9		Connection Schematics
10		**Conduct Modelling and Analysis of Design**
11		Loading Calculations
12		Calculate Stress and Strain Values
13		Log Data of Tensile Tests
14		**Shop Drawings**
15		**Coordinated Assembly: Member Fabrication**
16		**Coordianted Assembly: Connection Fabrication**
17		30 Percent Deliverable
18		**Team Assembly: Modifications and Member Connec**
19		**Team Assembly Construction Practice**
20		60 percent Deliverble
21		**Compete in Regional Competition**
22		90 Percent Deliverable
23		**Project Deliverables**
24		Final Report
25		Plans
26		Product
27		Presentation
28		**Project Management**



Project: Schedule December 2,
Date: Thu 12/2/21

Task	Inactive Task	Manual Summary Rollup	External Milestone
Split	Inactive Milestone	Manual Summary	Deadline
Milestone	Inactive Summary	Start-only	Progress
Summary	Manual Task	Finish-only	Manual Progress
Project Summary	Duration-only	External Tasks	

7.2 Appendix B: Staff Rate Breakdown

Task	Personnel						SUM
	SENG	PENG	EIT	INT	DRF	ADM	
Task 1: Competition Due Diligence	2	2	4	4	0	4	16
Task 2: Impact Analysis	1	1	3	3	0	4	12
Task 3: Conduct Material Research	0	3	8	6	0	8	25
Task 4: Research Potential Bridge Designs	0	4	10	10	0	10	34
Task 4.1: Cantilever Design	0	2	5	5	0	5	17
Task 4.2: Member Design	0	2	5	5	0	5	17
Task 5: Conduct Connections Design Research	8	10	15	15	0	0	48
Task 5.1: Material Specifications	4	5	10	10	0	0	29
Task 5.2: Connection Schematics	4	5	5	5	0	0	19
Task 6: Conduct Modelling and Analysis of Design	12	36	18	15	0	0	81
Task 6.1: Loading Calculations	4	12	6	5	0	0	27
Task 6.2: Calculate Stress and Strain Values	4	12	6	5	0	0	27
Task 6.3: Log Data of Tensile Tests	4	12	6	5	0	0	27
Task 7: Shop Drawings	4	2	0	0	35	0	41
Task 8: Coordinated Assembly: Member Fabrication	0	0	0	0	0	0	0
Task 9: Coordinated Assembly: Connection Fabrication	0	0	0	0	0	0	0
Task 10: Team Assembly: Modifications and Member Connection	5	10	50	20	0	0	85
Task 11: Team Assembly: Construction Practice	5	10	50	20	0	0	85
Task 12: Compete in Regional Competition	0	84	84	84	0	0	252
Task 13: Project Deliverables	7	19	70	21	0	14	131
Task 13.4: Final Report	1	5	10	3	0	2	21
Task 13.5: Plans	1	2	10	3	0	2	18
Task 13.6: Product	1	2	5	3	0	2	13
Task 13.7: Presentation	1	1	10	3	0	2	17
Task 14: Project Management	16	20	4	4	0	16	60
Task 14.1: Coordination of Teammates and Duties	10	14	1	1	0	4	30
Task 14.2: Steel Donation Contact	2	2	1	1	0	4	10
Task 14.3 Fabricator Contact	2	2	1	1	0	4	10
Task 14.4 Mentors Contact	2	2	1	1	0	4	10
Total	60	201	316	202	35	56	**870**

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7.3 Appendix C: Cost of Engineering Services

Cost of Engineering Services					
1.0 Personnel	Classification	Hours	Rate, $/hour		Cost
	SENG	60	170		$10,200.00
	PENG	201	150		$30,150.00
	EIT	316	50		$15,800.00
	INT	202	30		$6,060.00
	DRF	35	55		$1,925.00
	ADM	56	50		$2,800.00
	Personnel Total	870			$66,935.00
2.0 Materials	Steel members, connections and hardware				$1,800.00
3.0 Equipment	Tools required for construction and assembly				$450.00
4.0 Subcontract	Labor	120 hours	$60		$7,200.00
5.0 Travel	Van Rental	4 days	$65/day		$260.00
	Mileage	500 miles	$0.36/mile		$175.00
	Per Diem	5 days	$64/person/day	4 people	$1,200.00
	Lodging	4 nights	$118/room/night	2 rooms	$944.00
Total					**$145,899.00**