AISC STEEL BRIDGE

Final Proposal

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Table of Contents

1.0 Project Understanding

1.1 Project Purpose

The purpose of this project is to create a 1:10 scale steel bridge that will model a full scale bridge for the Katy Trail State Park located in Missouri. The bridge will provide access for pedestrians, bicyclists, equestrians, park vehicles, and emergency vehicles after recent flooding from higher than average precipitation washed out most of the Katy Trail along the Missouri River [1].

The bridge is required to be designed, fabricated, and built to follow the rules and guidelines outlined in the 2021 Student Steel bridge Competition (SSBC). Sponsored by the American Institute of Steel Construction (AISC), the team is anticipated to compete against other schools in early April 2021 pending COVID-19 restrictions.

The bridge will be judged based on aesthetics, construction speed, lightness, stiffness, construction economy, structural efficiency, overall performance, and cost estimation. The scoring categories will be explained further in the following sections, but the overall goal of this project is to enter a scaled bridge that will perform well in each category.

1.2 Project Background

1.2.1 Project Site Background

A feasibility study initiated in 2020 for the Katy Trail State Park is aimed to determine an ideal design for a limited access bridge through competition between colleges. The site resides beside a section of the Missouri River and is located between Clinton and Machens Missouri in the Katy Trail State Park and is depicted in figure 1. Due to site configuration, a five foot wide steel bridge has been commissioned to span a distance of twenty two feet and six inches across the river and parallel to the skewed waterway as depicted in figure 2.

1.2.2 Project Competition Background

The project in question is a competition based capstone project that will compete on behalf of Northern Arizona University at the 2021 Pacific Southwest SSBC event, which will be hosted by the University of California, Los Angeles (UCLA). Beginning in 1987 in the parking lot of Lawrence Institute of Technology, three schools competed in designing, fabrication and construction of a steel bridge in order to give students real world experience with a likely scenario. Competition has expanded in years with the first national competition happening at Michigan State University in 1992 and involving 13 competing teams from different schools. Over 200 schools now compete in eight categories at one of 18 regional SSBC events with the possibility of reaching the national event [3]. In previous years of the Pacific Southwest SSBC regional event, 17 colleges from California, Arizona, Nevada and Hawaii have competed in a real world scenario, involving the design, display and testing of a 1:10 scale steel bridge that meets the requirements dictated in the AISC Steel Bridge Competition Rules. In recent years, NAU has had mixed placement overall results with the 2015 team being deemed ineligible due to rule 11.5, 2016 placing 6th in regionals, 2017 placing 9th, 2018 placing 8th and a rule 11.1 disqualification in 2019. Due to COVID-19, the 2020 competition was cancelled resulting in NAU's team being unable to compete [4].

1.2.3 Categories of Competition

1.2.3.1 Aesthetics

One section of scoring for the Steel Bridge Competition is for aesthetics. Section 6.2.1 of the 2021 SSBC Rules outlines the guidelines for this section from the bridge appearance to the poster that will be included as well in the presentation of the bridge [1].

1.2.3.2 Construction Speed

Construction speed rules can be found in section 6.2.2 in the 2021 SSBC Rules. The bridge with the fastest construction time will win this category. Total time includes the time for construction plus construction penalties that are also described in the rules [1].

1.2.3.3 Lightness

The bridge with the least weight will declare the win for the lightness category. The total weight is measured by the addition of the weight and the weight penalties. Details for this category of the competition is found in section 6.2.3 of the 2021 SSBC Rules [1].

1.2.3.4 Stiffness

The stiffness of the bridge is determined by the aggregate deflection caused by the loads. The bridge with the lowest deflection will win the stiffness category. Rules are outlined in section 6.3.4 of the 2021 SSCC Rules [1].

1.2.3.5 Construction Economy

Section 6.3.5 outlines the 2021 SSBC Rules for the construction economy of the bridge. The bridge with the lowest construction cost will win this category through an equation that factors in total minutes, load test penalties, and number of builders [1].

1.2.3.6 Structural Efficiency

Section 6.3.6 of the 2021 SSBC Rules states that the bridge with the lowest structural cost will win this category. The overall structural cost is computed with an equation that is based on the measured weight of the bridge [1].

1.2.3.7 Overall Performance

The overall performance of the bridge follows the outline from section 6.2.7 of the 2021 SSBC Rules. The bridge with summation of the lowest value of construction costs, structural costs, and any fines [1].

1.2.3.8 Cost Estimation

Section 6.2.8 of the 2021 SSBC Rules states that the bridge with the best estimate of their overall performance rating and completion of the competition will win this section. Prior to the selection of the load case, the teams will submit their estimated overall performance rating into the scoring spreadsheet [1].

1.3 Technical Considerations

1.3.1 Design Strength

Engineering calculations shall be used to determine the structure’s design strength properties. A strength reduction factor will be determined for use in design processes to ensure the bridge will withstand the required loads. Influence of load placement on structural deflection shall be determined during design processes. Design will focus on structurally weak points based on “worst case” loading scenarios. Members, connections, and joints will be analyzed for potential failure and designed to withstand the required loads. Lateral and vertical deflection shall be the primary focus of analysis for bridge performance based on project requirements [6].

1.3.2 Materials

Research shall be conducted on available materials in compliance with design specifications. Materials shall be included in the category of high carbon steel with magnetic properties. Selected material properties such as ductility, strength, hardness, and brittleness, will be used in design processes to predict behavior under load and overall expected bridge performance. Design and fabrication of the steel used in each component will comply with the AISC Steel Construction Manual 14th Edition standards [5].

1.3.3 Fabrication

Fabrication methods shall be determined during the design process based on their influence on design strength. Welds and drilled holes are required to comply with the design requirements. The team will analyze the effect of any physical modification of members during the fabrication process on the ultimate design strength. The final fabrication plans shall be included in the final structure plans and shop drawings. The contracted fabricators will comply with fabrication specifications to ensure proper design performance [5].

1.3.4 Design Analysis

The design will be drafted using AutoCAD software and prepared for analysis. A structural modeling software such as RISA shall be used for structural analysis of the assembled bridge. Hand calculations are acceptable for individual members and connections during the design process. Multiple drafts of the assembled bridge shall be subjected to simulated loads to determine bridge performance. The team will repeat the drafting and design process until the design is satisfactory and has proven to meet strength requirements.

1.3.5 Plan Sets

The final design shall be drafted and approved by all team members using AutoCAD software. Upon design completion, the team shall create a full plan set showing design constraints, member details, connection details, and fabrication requirements for fabrication use. The team shall indicate which plans are approved for shop use. Revisions to plans are required for any significant changes to the final design. Contractors may request additional information, at which the team shall provide proper documentation and clarification.

1.3.6 Construction

Determination of construction methods shall be incorporated into the design phase of the project. Consideration of assembly time and difficulty shall influence the team during the entire structural design process. Testing may be done at a smaller scale for design research during the development of the bridge. Team members may research and handle materials that influence the assembly process as proof of concept.

Team members shall have full understanding of the final structure's intended construction process. The team shall hold practices in which the competition's construction event is simulated. These practices shall directly follow the AISC Student Steel Bridge Competition 2020 Rules.

Consistent negative occurrences or design flaws that cause delay in the construction process during practices shall be noted, removed when feasible, or mitigated to improve efficiency. A flaw causing delay significant enough to disqualify the design or severely impact the design's score shall warrant extensive design modification. Construction processes shall be finalized when all team members are satisfied with the process and their involvement.

1.4 Potential Challenges

Design challenges are factors that require extensive thought, planning, and calculations in order to meet design requirements and prove competitive results. This project will pose several design challenges for the team to overcome.

1.4.1 Design Constraints

The design requirements set forth by AISC for this project will limit the materials and connections the team must utilize. This will require the team to creatively design a bridge that holds the required weight while remaining relatively lightweight. Efficiency of the bridge (strength to weight ratio) will depend on the shape of the bridge and each member. The team must choose a design that fits within the required bridge dimensions while maintaining flexural capacity.

1.4.2 Aesthetics

The team must incorporate pleasing aesthetics into the bridge design and supplemental visual elements. Aesthetic considerations for the design and visual display will require multiple design considerations regarding color, proportion, and shape.

1.5 Stakeholders

Stakeholders for the project and the competition includes Northern Arizona University, as the team will represent the school at the AISC competition. The client for the overall project is Mark Lamar, and the technical advisors lending their time to provide professional guidance are Sabrina Ballard and Tommy Nelson.

Other clients include the Katy Trail State Park Services because of the location for the proposed bridge. The park is in need of this bridge because of recent heavy winter snow pack cause above average precipitation that washed out part of the trail. A steel bridge will allow users to pass a new waterway to maintain the functionality of the trail.

Sponsors of the Steel Bridge Team are stakeholders as they have contributed to the team by looking out for the success of the team and the students. The company logos will be presented in one way or another at the competition so the sponsors can receive some publicity.

2.0 Scope of Services/Research Plan

2.1 Task 1: Due Diligence

In order to develop a design that is successful and up to date with current industry standards, the team shall conduct due diligence to research current design standards and requirements.

2.1.1 Task 1.1: Analysis Methods

The use of RISA 3D software will be utilized in developing a model that allows for the virtual loading of our bridge model to test the dimensions of members, steel type and the six possible loading combinations outlined in the SSBC rules. Hand calculations shall also be used for individual members and connections. Team members shall be responsible for learning analysis software and applying analysis methods to the design process.

2.1.2 Task 1.2: Existing Bridge Designs

The team is responsible for researching existing bridge designs and incorporating relevant findings into the design process of this project. Several existing trusses and frames will be analyzed and studied, and feasible designs will be selected for implementation into the final design.

2.1.3 Task 1.3: Steel Design Principles

The team shall incorporate steel design practices outlined in the AISC Steel Construction Manual. The team is responsible for understanding this document and using it as a guide for member and connection design.

2.2 Task 2: Design Development

To complete this project, the team shall progress the design through several steps to ensure it is well developed and complete in all aspects.

2.2.1 Task 2.1: Selection of Design Features

The decision matrix will involve categories and ratings to determine the best material, member, connection, and truss style for the bridge. Each category will include options like weight, strength, cost, and more to again determine the best material, member, connection, and truss style for the bridge.

2.2.1.1 Task 2.1.1: Truss Style Selection

A truss style to be used for the design of the bridge shall be selected. This selection will include research of the different truss styles and how each handles different forces. The truss style may also be selected based on the previous years bridge design and the trusses used.

2.2.1.2 Task 2.1.2: Material Selection

The material shall be selected such that it is strong enough to withstand the inquired load. The selection of material is also dependent on cost and manufacturing limitations.

2.2.1.3 Task 2.1.3: Member Design

Each member of the structure shall be designed according to the required loads found during the analysis process. Members may also be used from the previous team's bridge design but further analysis will be required.

2.2.1.4 Task 2.1.4: Connection Design

Given the overall bridge design, the connections must be created such that they are easily assembled and strong enough to withstand the loads. Such connections have limitations according to the competition rule book and shall also be designed using automated analysis programs.

2.2.2 Task 2.2: Design Progression

A design for the bridge shall be selected by the team and proof of the design will be analyzed. Proof that the bridge meets the requirements and will serve its intended purpose is important to determine before proceeding with the selection of final design.

2.2.2.1 Task 2.2.1: Proof of Concept

Proof of the bridge concept must be established so that further analysis may be conducted on the bridge. Proof of concept includes small-scale testing of individual components to determine their actual versus theoretical limits.

2.2.2.2 Task 2.2.2: Proof of Design

Likewise, proof of the design shall be established to ensure that the client's needs are met and the bridge will adhere to the rules and guidelines. The proof of design includes small-scale testing of assembled design features to determine their actual versus theoretical limits.

2.2.3 Task 2.3: Design Calculations and Predictions

The team shall apply appropriate engineering analysis to the bridge design. These calculations will be representative of the initial predicted design performance. The following predictions shall be considered.

2.2.3.1 Task 2.3.1: Material Strength

Strength of the material used in the final design must be determined through research and testing to be used in further analysis.

2.2.3.2 Task 2.3.2: Member Strength

Strength of each member shall be analyzed to ensure it satisfies the required loading and stresses. If any member does not have sufficient strength, new material or a modified design may need to be determined before proceeding.

2.2.3.3 Task 2.3.3: Connection Strength

Connection strength according to the material and design will also be determined to be used in further analysis. These connections will need to be analyzed according to the determined loads in each member that meet at the joint.

2.2.3.4 Task 2.3.4: Sectional Strength

Sectional strength shall be determined for the designed bridge in order to ensure the load requirements are met.

2.2.3.5 Task 2.3.5: Overall Strength

The overall strength of the bridge will also be determined to ensure load requirements are met. Additionally, the vertical and lateral movements must be within the tolerable limits.

2.3 Task 3: Structural Analysis

The team shall calculate design predictions and analyze the overall capabilities of the finished structure.

2.3.1 Task 3.1: Truss Analysis

Through the use of computer software, the completed truss design shall be analyzed to ensure structural efficiency. If any component of the design fails during the analysis, redesign of that component and possibly more of the structure will be required.

2.3.2 Task 3.2: Analysis of Connections

Further analysis of the finished connections used in the design is required following the same techniques outlined above. Each connection shall be intentionally designed to carry the required loads and verified through mathematical analysis.

2.3.3 Task 3.3: Material Analysis

The team shall gather all final material properties that pertain to its strength capabilities, such as the modulus of elasticity. These steel properties shall be used in all final design strength predictions to determine the material's contributions to the design's overall strength.

2.4 Task 4: Plan Sets

The team shall create all necessary documentation for the final fabrication and construction of the bridge. Such documentation shall include plan sets, shop drawings, and material schedules.

2.4.1 Task 4.1: Shop Drawings

The team shall create shop drawings and material schedules for any outsourced work. Each contractor, including material suppliers and fabricators, shall receive a relevant plan set that clearly conveys the design requirements. These drawings shall be used for fabrication and material sourcing only.

2.4.1.1 Task 4.1.1: Steel schedule for Material Sourcing

A steel schedule shall be created to provide the steel manufacturer with a list of size, type, amount and cost of steel to be used in the fabrication of the bridge. This is to ensure that the proper materials are sourced in accordance with design specifications for fabrication.

2.4.1.2 Task 4.1.2: Shop Drawings for Connection Fabrication

Shop drawings of connections are to be created to provide guidance for fabricators on how material from the steel schedule is to be crafted in accordance with design specifications. Shop drawings are to include a set of CAD created designs detailing all dimensions for each connection and will include the amount of each connection to be fabricated.

2.4.1.3 Task 4.1.3: Shop Drawings for Member Fabrication

Shop drawings of members are to be created to provide guidance for fabricators on how material from the steel schedule is to be created in accordance with design specifications. Shop drawings are to include a set of CAD created designs detailing all dimensions for each member and will include the amount of each member to be fabricated.

2.4.1.4 Task 4.1.4: Hardware Schedule for Nuts & Bolts

A hardware schedule shall be created to provide a detailed list of the type and amount of nuts and bolts required to properly join all members and connections of the bridge together. This schedule will include an inflated amount of hardware needed to account for possible damaged or lost hardware from erection practice and transportation of bridge to competition.

2.4.2 Task 4.2 Construction Plans

The team may create a final plan set that conveys the process of assembling the final constructed bridge. This document set shall be used by builders for use in construction only.

2.5 Task 5: Fabrication

The scope of this project requires fabrication that must be completed by a subcontractor. Fabrication includes the sourcing of materials, machining, welding, and the sourcing of hardware to assemble each fabricated piece.

2.5.1 Task 5.1: Materials

A wide variety of materials are required for the fabrication and construction of the bridge. The team will acquire all locally sourced materials in preparation for the bridge fabrication and construction.

2.5.1.1 Task 5.1.1: Steel

Steel material that is to be used in the construction of the bridge will be sourced from Page Steel. Therefore, selection of members must be available from the distributor and may govern some of the design.

2.5.1.2 Task 5.1.2: Fittings

All fittings designed for the bridge will be professionally machined or purchased from a hardware supplier. Fittings to be machined shall be provided to the manufacturer in detailed drawings and required tolerances must be met.

2.5.1.3 Task 5.1.3: Nuts & Bolts

The nuts and bolts used in construction of the bridge will be sourced from Copper State Nut & Bolt. These fasteners are also regulated by the competition rules and shall be selected according to design analysis.

2.5.2 Task 5.2: Fabrication

Certain members of the final design will not be available in stock at typical suppliers and will require custom fabrication by a subcontractor.

2.6 Task 6: Competition Preparation

The team shall designate a set time period to making final preparations for the AISC Student Steel Bridge Competition. This includes the following sub-tasks.

2.6.1 Task 6.1: Construction Practice

The construction practice is used to optimize the construction time for the team. This practice will allow the team to bolt together the bridge in a time that is competitive for the competition.

2.6.2 Task 6.2: Visual Elements

The submission of the final completed bridge for the AISC Student Steel Bridge competition requires additional visual elements. The team must complete the visual requirements before the AISC competition.

2.6.2.1 Task 6.2.1: Poster

The poster must include the identification of the school, explanation of why the bridge configuration was selected, scaled and dimensioned side view of the bridge, free body diagram of a single beam that represents one of the bridge stringers, shear/moment diagrams of the beam, brief explanation of the team's use of Accelerated Bridge Construction, and acknowledgement of who helped fabricate the bridge. The poster must be flat with max dimensions of 2x3 feet, present all the information on one side, not have attached pages that can be lifted, and be in english.

2.6.2.2 Task 6.2.2: Bridge Aesthetics

The bridge aesthetics is one of the categories of judging in the steel bridge competition. The poster and the school name are two pieces of the aesthetics category that will cover the visual elements needed for that portion of the category. The poster requirements are found in the rules for the competition and the bridge must have the school name painted or stickered on the bridge.

2.6.3 Task 6.3: Construction Estimate

The construction estimate is the overall cost estimate for the bridge to turn in before the competition begins. Depending on the scoring of the bridge during the competition, the team with the closest score actual score to their estimated score wins this portion of the competition.

2.7 Task 7: Final AISC Competition

This task is split up into 10 different parts: Part one of this task is the construction estimate. The submission of the construction estimate puts the team in the running for the cost estimation portion of the competition. The closer the value of the construction estimate to the actual construction cost will be the winners of that category. The second part is the actual construction of the bridge. This includes the time it takes to build the bridge with additional time added for any acquired penalties throughout the competition. The third part is the load testing. Loads are split up into two, lateral testing and vertical testing. The vertical testing portion of the SSBC competition includes placing the load individually on the bridge and the amount of deflection determines whether or not the bridge can safely withhold the weight.

The fourth part is the aesthetics judgement of the competition which involves the overall look of the bridge, the poster and the name of the school on the bridge. The fifth part is the construction speed category of the judging. This is the total time needed to construct the bridge. Time penalties will be incurred for various violations. The sixth part of the competition is weighing the bridge. The judging will depend on the total weight of the bridge including penalties. Decking, tools, lateral restraints, and posters will not be included in the weight measurement. The seventh part of the competition is the bridge's overall stiffness, which is the total aggregate deflection of the bridge once loaded.

The eighth part is the judges construction cost. The construction cost of the bridge takes in the total construction time, the number of builders, the costs per person, and the load test penalties to come up with an overall construction cost. The team with the lowest cost wins the category. The ninth part of the competition is the calculation for the structural efficiency. Judges will determine the structural efficiency of the bridge by using the weight of the bridge, the cost of the bridge, the aggregate deflection, and the load test penalties to come up with an overall cost of the efficiency of the bridge. The team with the lowest cost wins the category.

The last part of the competition is the cost estimation determined by the judges. This cost will be the sum of the construction cost, the structural cost, and any other fines incurred as a violation to a Team contract. The lowest estimated value as well as the closest value to the actual one determined in the competition wins the category. The actual competition will require the team to travel to UCLA Spring 2021 from Northern Arizona University. The team will lodge for a few days in order to prepare, compete, and have time to travel back. The costs for lodging will be explained below in the costs portion of this proposal.

2.8 Task 8: Impacts

The scope of constructing a steel bridge at a 1:10 scale will impact the environmental surroundings due to the construction portion of the process which causes gaseous and particulate emissions to be thrown in the air. This also includes emissions from the trucks and vehicles needed to transport materials to and from Northern Arizona University. Economically, the cost of building a bridge, even at this scale, costs money for materials and labor. However, building a scaled bridge prior to the full-scale bridge saves money and time on materials and labor costs for the overall larger project. This scaled bridge allows for a beneficial social impact of providing safe, long-term, durable structures that can minimize site disruption, environmental impacts, traffic congestion, and accelerated bridge construction.

2.9 Task 9: Project Management

The scope of this project requires constant project management to ensure that the team is on task, the project deadlines are being met, the work is of high standard, and the subcontracted work is communicated properly.

2.9.1 Task 9.1: Budget and Fundraising

The budget is the total cost of the bridge project including design, materials, fabrication, transportation and lodging required for competition. Fundraising for the project is essential in order to gain money to afford the materials needed.

2.9.2 Task 9.2: Fabrication Management

Fabrication is the process of transforming raw steel into finished members and connections necessary in the construction of the bridge project. Proper coordination with fabricators and material providers is essential to ensure that fabrication is on schedule in order to avoid disruption and delay to the project schedule.

2.9.2.1 Task 9.2.1: Welding

All necessary welding for construction of the bridge will be completed by Mingus Welding. Fabrication efforts must be completed by March 12th, 2021.

2.9.2.1 Task 9.2.2: Machining

Any machining necessary will be completed by the selected contractor and must meet tolerances set out in the provided plan sets.

2.9.3 Task 9.3: Project Meetings

The team is required to keep track of any meeting time, this includes the team meetings as well as TA, stakeholder, client, etc... meetings. These times will be added together at the end of the year to come up with a total time spent on the project. The team is responsible for scheduling these meetings amongst each other and with additional stakeholders, clients, TAs, GIs, etc...

2.9.3.1 Task 9.3.1: Team Meetings

Regular team meetings are necessary for the team to stay on schedule and on the same page. These meetings are likely to occur once or twice a week as needed and will be summarized by meeting notes to record time and topics discussed.

2.9.3.2 Task 9.3.2: Stakeholder Meetings

The stakeholder meetings are to be used to update the relevant parties on project progression and any concerns moving forward. These meetings will not be as regular as the team meeting but are necessary when new developments arise in the design and construction processes.

2.9.4 Task 9.4: Report

Several report deliverables are required throughout the design process. The reports are outlined in the following sections. The team shall complete each report by it's assigned deadline, available in the project schedule.

2.9.4.1 Task 9.4.1: 30% Report

The team must complete and submit a 30% report. This is a preliminary report that shows the start of the project and the research that has been conducted.

2.9.4.2 Task 9.4.2: 60% Report

The team must complete and submit a 60% report. This report is similar to the previous one such that it updates the client on the progress of the project and allows for client feedback or concerns.

2.9.4.3 Task 9.4.3: 90% Report

The team must complete and submit a 90% report. The 90% report shows the client a mostly completed project that has only minor changes to be made.

2.9.4.4 Task 9.4.4: Final Report

The team must complete and submit a final report. The final report presents the final product to the client along with proving its success. This report is very similar to the 90% with minor additions such as overall cost and specifications of the bridge.

2.9.5 Task 9.5: Website

Development of a website shall be constructed to document the complete process of design, fabrication and competition of the bridge. Additional information will also include contact information for all team members and team advisors. This material will prove beneficial to future teams in developing a greater understanding of the overall scope of the project and the tasks at hand.

2.9.6 Task 9.6: Undergraduate Research Symposium Presentation

The undergraduate research project symposium at the end of the spring semester is a chance for the team to present to the public what they have researched and the overall project outlook. This presentation will depend on COVID restrictions.

2.10 Exclusions

The team shall not be responsible for any tasks that are outside of the project scope. Elements of engineering design that are out of the scope of this project include, but are not limited to: foundation design, geotechnical analysis, hydrology considerations, and surveying. The team is solely responsible for the design, analysis, fabrication, construction, and management of the project.

3.0 Schedule

3.1 Tasks

The major tasks for this project along with there time span are due diligence from August 18th to September 16th, design development from September 17th to November 27th, structural analysis from November 27th to December 11th, plan sets on January 4th to January 13th, fabrication from January 14th to March 12th, competition preparation from March 15th to March 31st, final AISC competition TBD, and project management from August 20th to April 30th. These tasks along with their associated subtasks are outlined above in section 2.0 and are shown in respect to the project duration in Appendix B which spans from August 18th, 2020 to April 30th, 2021. Deliverables from the tasks above include a 30% Report and 30% Presentation on February 9th, 60% Report and 60% Presentation on March 09th, 90% Report and 90% Presentation on April 6th, 90% Website on April 13th, Final Presentation on April 16th, and Final Report and Website on April 27th.

3.2 Critical Path

The critical path for this project involves all tasks that are necessary to complete the final project. These tasks are major items that must be completed in preceding order. The critical path is as follows:

1. Task 1.1 Analysis Methods
2. Task 2.1 Selection of Design Features
3. Task 3.0 Structural Analysis
4. Task 4.0 Plan Sets
5. Task 5.0 Fabrication
6. Task 6.2 Visual Elements
7. Task 6.3 Construction Estimate
8. Task 7.0 Final AISC Competition
9. Task 8.4 Report
10. Task 8.5 Website

A delay in any of the tasks included in the critical path will cause significant delay in the entire project. It is critical that the team selects design features, analyzes the final design, and creates plan sets so that acquisition of materials and fabrication can be initiated. Required visual elements and construction estimation must be completed before participating in the final AISC competition. To successfully close out the project, the team must provide a final report and website.

4.0 Staffing Plan

4.1 Required Positions

This project requires the following positions to be filled by each team member. No one member is assigned a specific staffing position. Each team member shall take on each of the following position's responsibilities.

Senior Engineer - SENG

Engineer - ENG

Engineer in Training - EIT

Lab Technician - LAB

Administrative Assistant - AA

4.2 Team Qualifications

M. Eric Barton

Eric has worked for multiple construction companies in various project management related positions. In addition to office related work experience, he also has field experience as a working foreman which will help with the construction of the bridge for competition. From studies at NAU, Eric has taken classes in statics, mechanics of materials and structural analysis which help correlate the understanding elements of bridge design into practice.

Mohammed Aadil Farried

Aadil has almost four years of administrative (Level 3) work experience from working at the Center for International Education (CIE) at NAU and one year work experience at HSBC Colombo Sri Lanka. Aadil has taken steel design, architecture, and mechanics of materials which correlates directly to the bridge design project.

Emma Keiser

Emma has worked in CNC machining, manufacturing, and currently holds an internship position with ADOT in construction. Her experience with project and construction oversight contributes to project management of this project. In addition, her metalworking experience is relevant towards the project's fabrication and construction requirements. She has taken NAU coursework in structural analysis and materials science.

Joshua Lamphier

Josh has worked on the transportation design project for the Pacific Southwest Conference in the past. He has also taken a steel design class at NAU that directly correlates to the project being conducted. Lastly he has completed an internship with Civiltec Engineering that lends experience for the project in general.

Tatianna Smith

Tatianna has worked for the Bureau of Reclamation as an intern in the concrete dams department, where she learned to become sufficient in AutoCAD, Civil 3D, and Revit. Through this job she has also gained project manager experience, leading a team to the construction of the addition to Guayabal Dam in Puerto Rico.

4.3 Work Plan

The project requires the services of an engineer in training, engineer, senior engineer, lab tech, and an administrative assistant. The Engineer in Training will be a part of the analysis and fabrication for the project. They will help set up and perform fundraising events as well as do the research alongside the interns. The EIT will attend the meetings and competitions, as well as help the team to create a final design report and website. The engineer is responsible for the overall progress of the project at all the stages of development. This includes ensuring the team stays on schedule, in budget, and the fundraising of the project is sufficient. It also includes monitoring the analysis, fabrication, and contacting various companies to request funds, materials, and services. The senior engineer provides the final check on all the milestones of the progression of the project before it continues. This involves reviewing reports, designs, calculations, and assisting in the design analysis and the AISC competition. The lab tech will focus directly on fabrication management and creating a set of shop drawings. The administrative assistant will run and do most of the fundraising and provide research materials for the project. They will frequently attend meetings, in which they will take notes and create agendas. The administrative assistant will also handle public relations and project imagery. The breakdown of each position’s estimated work for this project is shown in Appendix C.

4.4 Summary of Staffing Plan

The following rates are based on the average rates of engineers in Arizona plus an additional 175% to account for overhead costs.

Position Billing Rate ($/hr)	
SENG	$210
ENG	$150
EIT	$80
LAB	$100
AA	$55

Senior Engineer

The senior engineer will contribute approximately 80 hours to the project and will bill at $210/hr. The senior engineer shall be licensed and have over 10 years of working experience in structural engineering or related field. On this project, the senior engineer is responsible for design oversight, and critical review. The senior engineer shall approve final design decisions and plans. The total cost to staff a senior engineer on this project is estimated at $16,733.00.

Engineer

The engineer will contribute approximately 280 hours to the project and will bill at $150/hr. The engineer shall be licensed and have over 4 years of experience. The engineer shall be responsible for design development and project management. The engineer shall also communicate with all relevant parties regarding the project development and fabrication. The total cost to staff an engineer on this project is estimated at $42,010.00.

Engineer in Training

The EIT will contribute approximately 286 hours to the project and will bill at $80/hr. The EIT shall possess a degree and EIT certification. The EIT shall be responsible for project communication and design development. The EIT will be involved in all aspects of the project, not including drafting services. The total cost to saff an EIT on this project is estimated at $22,918.00.

Lab Technician

The lab technician will contribute approximately 317 hours to the project and will bill at $100/hr. The lab technician shall have at least 5 years of experience in drafting. The lab tech shall be responsible for creating the design's plan sets and managing fabrication processes. The total cost to staff a lab technician on this project is estimated at $31,692.00.

Administrative Assistant

The administrative assistant will contribute approximately 218 hours to the project and will bill at $55/hr. The administrative assistant shall have at least 2 years of experience in an administrative field. The administrative assistant is responsible for project fundraising, document management, public relations, and project visuals. The total cost to staff an administrative assistant on this project is estimated at $12,008.00.

5.0 Cost of Engineering Services

The total cost of engineering services amounts to the sum of service costs associated with the project. This breakdown is shown Appendix C.

5.1 Personnel Cost

Personnel cost accounts for the cost of all "hired" personnel billing rates per hour and required work hours. This rate, shown in the staffing plan summary, includes all overhead cost and other additional expenditures. The total estimated personnel cost is equal to $125,360.00 for a total of 1181 work hours.

5.2 Additional Cost

Materials

The cost of materials needed to construct the bridge will be determined according to the final design. An estimation of the required materials including steel members and connections is $2000 and is to be provided by Page Steel, Inc. and Copper State Nut & Bolt. Cost estimation may increase or decrease depending on finalized design requirements.

Equipment

Equipment needed for construction of the bridge are provided by Northern Arizona University, but additional costs may be incurred. These costs include power tools used in the fastening of connections of the bridge as well as various drilling and grinding attachments. The total cost of equipment for this project is $500.

Subcontracting

Subcontracting costs for the fabrication of the bridge have not been finalized for the project. Based on the previous team's estimate, fabrication will be conducted by the Mingus Welding team and service fees will be waived. Typical entry-level welding rates start at $60 per hour with an estimated 4 hours of labor, resulting in $240 total in subcontracting costs.

Travel

Travel costs incurred include van rental, lodging, and food allowance. Van rental through Northern Arizona University for four days and 600 miles round trip is calculated at $500. Lodging estimates through NAU documentation is $180 per person per day in Los Angeles, resulting in a maximum calculated cost of $2700 for three nights. This estimation is based on high end rates and is subject to change. Finally, food allowance estimates through NAU documentation is $56 per person per day in Los Angeles, resulting in a maximum calculated cost of $1120 for four days. This estimation is based on high end rates and is subject to change.

5.3 Total Cost

The total cost shall consist of personnel cost and all additional costs. The total cost for this project amounts to $132,396.

6.0 References

[1] Student Steel Bridge Competition 2021 Rules. 2020.

[2]"Entire Trail | Missouri State Parks", *Mostateparks.com*, 2020. [Online]. Available: https://mostateparks.com/page/57750/entire-trail. [Accessed: 06- Sep- 2020].

[3]"Student Steel Bridge Competition", *Aisc.org*, 2020. [Online]. Available: https://www.aisc.org/education/university-programs/student-steel-bridge-competition/about/. [Accessed: 06- Sep- 2020].

[4] "Past Results | American Institute of Steel Construction", *AISC.org*, 2020. [Online]. Available: https://www.aisc.org/education/university-programs/student-steel-bridge-competition/results/. [Accessed: 06- Sep- 2020].

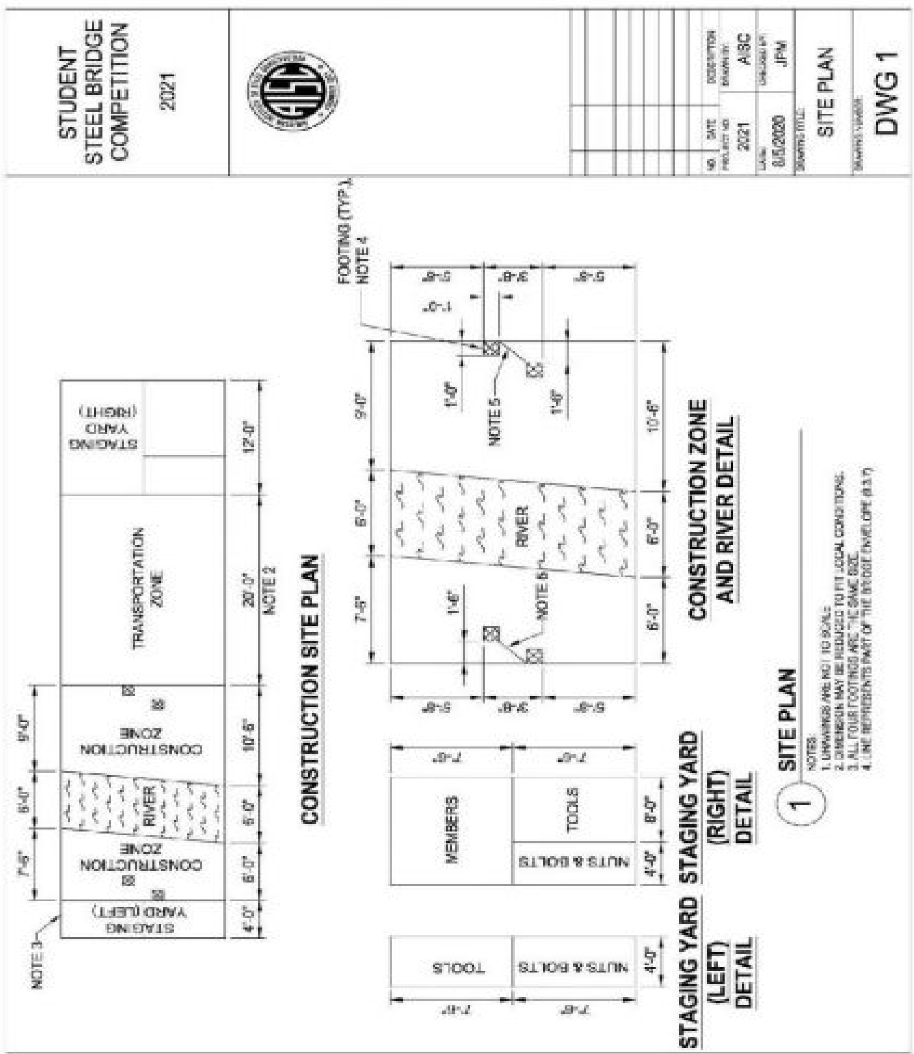
[5] *Steel Construction Manual*, 14th ed. American Institute of Steel Construction, 2011.

[6] R. Hibbeler, *Structural Analysis*, 10th ed.

7.0 Appendix

Appendix A

Figure 1: Site Plan [1].

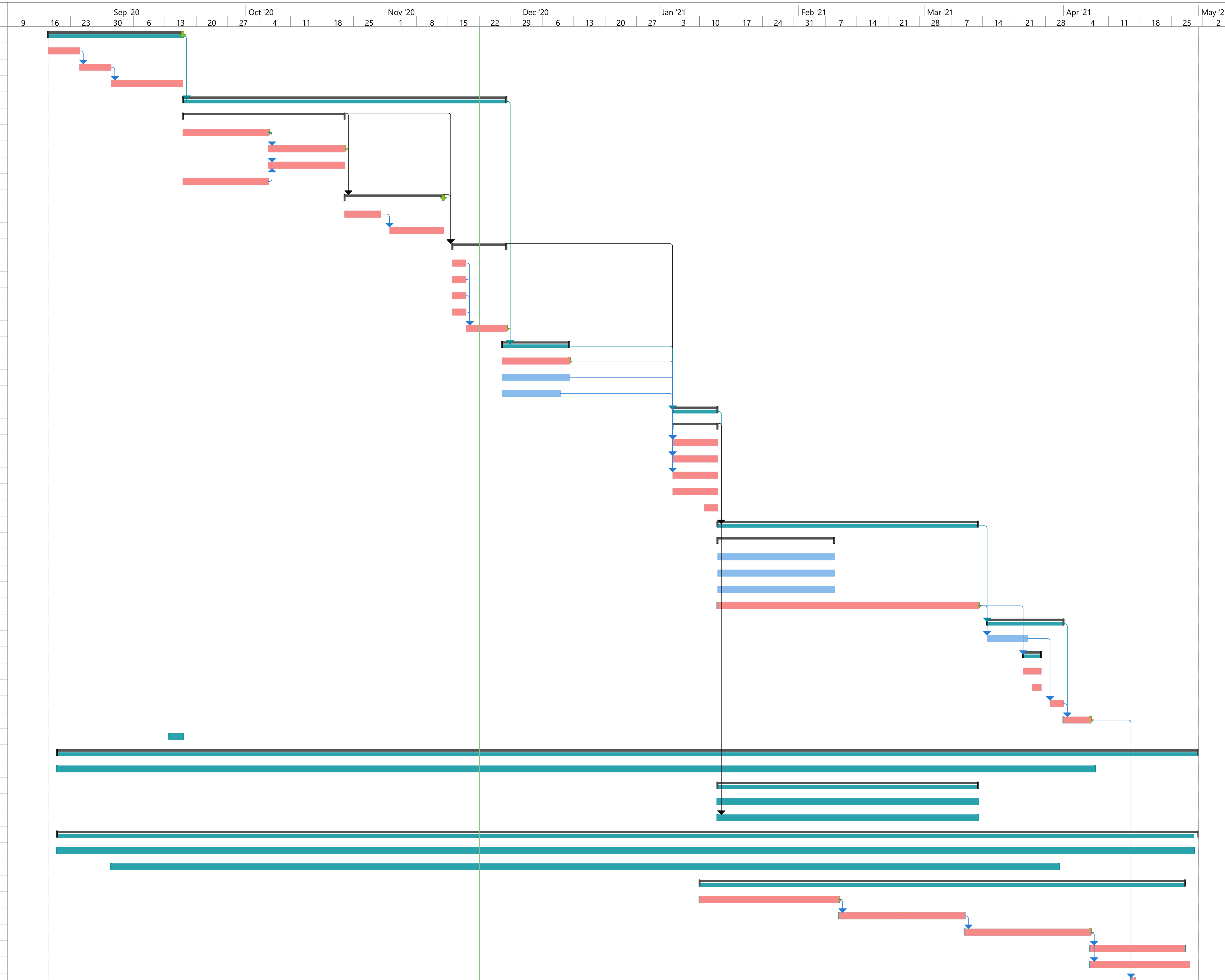


2021 Rules | 51

Appendix B

Figure 2: Gantt Chart (on following page).

ID	Task Name	Start
1	**Task 1: Due Dilligence**	**Tue 8/18/20**
2	Task 1.1: Analysis Methods	Tue 8/18/20
3	Task 1.2: Existing Bridge Designs	Tue 8/25/20
4	Task 1.3: Steel Design Principles	Tue 9/1/20
5	**Task 2: Design Development**	**Thu 9/17/20**
6	**Task 2.1: Selection of Design Features**	**Thu 9/17/20**
7	Task 2.1.1: Material Selection	Thu 9/17/20
8	Task 2.1.2: Member Design	Tue 10/6/20
9	Task 2.1.3: Connection Design	Tue 10/6/20
10	Task 2.1.4: Truss Style Selection	Thu 9/17/20
11	**Task 2.2: Design Progression**	**Fri 10/23/20**
12	Task 2.2.1: Proof of Concept	Fri 10/23/20
13	Task 2.2.2: Proof of Design	Mon 11/2/20
14	**Task 2.3: Design Calculations and Predictions**	**Mon 11/16/20**
15	Task 2.3.1: Material Strength	Mon 11/16/20
16	Task 2.3.2: Member Strength	Mon 11/16/20
17	Task 2.3.3: Connection Strength	Mon 11/16/20
18	Task 2.3.4: Sectional Strength	Mon 11/16/20
19	Task 2.3.5: Overall Strength	Thu 11/19/20
20	**Task 3: Structural Analysis**	**Fri 11/27/20**
21	**Task 3.1: Truss Analysis**	Fri 11/27/20
22	**Task 3.2: Analysis of Connections**	Fri 11/27/20
23	**Task 3.3: Material Analysis**	Fri 11/27/20
24	**Task 4: Plan Sets**	**Mon 1/4/21**
25	**Task 4.1: Shop Drawings**	**Mon 1/4/21**
26	Task 4.1.1: Steel Schedule for Material Sourcing	Mon 1/4/21
27	Task 4.1.2: Shop Drawings for Connection Fabrication	Mon 1/4/21
28	Task 4.1.3: Shop Drawings for Member Fabrication	Mon 1/4/21
29	Task 4.1.4: Hardware Schedule for Bolts and Nuts	Mon 1/4/21
30	**Task 4.2: Construction Plans**	Mon 1/11/21
31	**Task 5: Fabrication**	**Thu 1/14/21**
32	**Task 5.1: Materials**	**Thu 1/14/21**
33	Task 5.1.1: Steel	Thu 1/14/21
34	Task 5.1.2: Fittings	Thu 1/14/21
35	Task 5.1.3: Nuts and Bolts	Thu 1/14/21
36	**Task 5.2: Subcontracted Fabrication**	Thu 1/14/21
37	**Task 6: Competition Preparation**	**Mon 3/15/21**
38	**Task 6.1: Construction Practice**	Mon 3/15/21
39	**Task 6.2: Visual Elements**	**Tue 3/23/21**
40	Task 6.2.1: Poster	Tue 3/23/21
41	Task 6.2.2: Bridge Aesthetics	Thu 3/25/21
42	**Task 6.3: Construction Estimate**	Mon 3/29/21
43	**Task 7: Final AISC Competition**	**Thu 4/1/21**
44	**Task 8: Impacts**	Mon 9/14/20
45	**Task 9: Project Management**	**Thu 8/20/20**
46	**Task 9.1: Budget and Fundraising**	Thu 8/20/20
47	**Task 9.2 Fabrication Management**	**Thu 1/14/21**
48	**Task 9.2.1 Welding Management**	Thu 1/14/21
49	**Task 9.2: Machining Management**	Thu 1/14/21
50	**Project 9.3: Project Meetings**	**Thu 8/20/20**
51	Task 9.3.1: Team Meetings	Thu 8/20/20
52	Task 9.3.2: Stakeholder Meetings	Tue 9/1/20
53	**Task 9.4: Report**	**Sun 1/10/21**
54	Task 9.4.1: 30% Report	Sun 1/10/21
55	Task 9.4.2: 60% Report	Wed 2/10/21
56	Task 9.4.3: 90% Report	Wed 3/10/21
57	Task 9.4.4: Final Report	Wed 4/7/21
58	Task 9.5: Website	Wed 4/7/21
59	Task 9.6: Undergraduate Research Symposium Presentation	Fri 4/16/21



Project: CENE-476 Steel Bridge
Date: Sun 11/22/20

Critical Split · Summary · Manual Milestone · Rolled Up Manual Task · Manual Progress
Task · Manual Task · Manual Summary · Deadline · Critical

Appendix C

Table 1: Staffing and Cost Estimate

Task	Personnel					Sum
	SENG	ENG	EIT	LAB	AA	
Task 1: Due Diligence	**0**	**6**	**17**	**0**	**88**	**111**
Task 1.1: Analysis Methods	0	1	4	0	19	24
Task 1.2: Existing Bridge Designs	0	1	4	0	19	24
Task 1.3: Steel Design Principles	0	4	9	0	50	63
Task 2: Design Development	**23**	**115**	**92**	**0**	**0**	**230**
Task 2.1: Selection of Design Features	10	50	30	0	0	90
Task 2.1.1: Truss Style Selection	2	10	10	0	0	22
Task 2.1.2: Material Selection	2	5	0	0	0	7
Task 2.1.3: Member Design	3	15	10	0	0	28
Task 2.1.4: Connection Design	3	20	10	0	0	33
Task 2.2: Design Progression	5	50	55	0	0	110
Task 2.2.1: Proof of Concept	3	25	30	0	0	58
Task 2.2.2: Proof of Design	2	25	25	0	0	52
Task 2.3: Design Calculations and Predictions	8	15	7	0	0	30
Task 2.3.1: Material Strength	1	1	1	0	0	3
Task 2.3.2: Member Strength	2	4	2	0	0	8
Task 2.3.3: Connection Strength	2	4	2	0	0	8
Task 2.3.4: Sectional Strength	2	4	1	0	0	7
Task 2.3.5: Overall Strength	1	2	1	0	0	4
Task 3: Structural Analysis	**11**	**32**	**11**	**0**	**0**	**54**
Task 3.1: Truss Analysis	4	11	4	0	0	19
Task 3.2: Analysis of Connections	4	11	4	0	0	19
Task 3.3: Material Analysis	3	10	3	0	0	16
Task 4: Plan Sets	**2**	**2**	**0**	**30**	**0**	**34**
Task 4.1: Shop Drawings	1	1	0	30	0	32
Task 4.1.1: Steel Schedule for Material Sourcing	0.25	0.25	0	5	0	6
Task 4.1.2: Shop Drawings for Connection Fabrication	0.25	0.25	0	10	0	11
Task 4.1.3: Shop Drawings for Member Fabrication	0.25	0.25	0	10	0	11
Task 4.1.4: Hardware Schedule for Nuts and Bolts	0.25	0.25	0	5	0	6
Task 4.2: Construction Plans	1	1	0	0	0	2
Task 5: Fabrication	**0**	**30**	**10**	**148**	**10**	**198**
Task 5.1: Materials	0	15	3	48	5	71
Task 5.1.1: Steel	0	5	1	16	2	24
Task 5.1.2: Fittings	0	5	1	16	2	24
Task 5.1.3: Nuts and Bolts	0	5	1	16	1	23
Task 5.2: Fabrication	0	15	7	100	5	127
Task 6: Competition Preparation	**0**	**0**	**26**	**21**	**5**	**52**
Task 6.1: Construction Practice	0	0	24	20	0	44
Task 6.2: Visual Elements	0	0	0	0	5	5
Task 6.2.1: Poster	0	0	0	0	4	4
Task 6.2.2: Bridge Aesthetics	0	0	0	0	1	1
Task 6.3: Construction Estimate	0	0	2	1	0	3
Task 7: Final AISC Competition	**8**	**8**	**2**	**2**	**0**	**19**
Task 8: Impacts	**0**	**0**	**0**	**0**	**2**	**2**
Task 9: Project Management	**36**	**87**	**129**	**116**	**113**	**481**
Task 9.1: Budget and Fundraising	12	5	10	0	50	77
Task 9.2: Fabrication Management	0	15	7	100	5	127
Task 9.2.1: Welding	0	10	5	70	2	87
Task 9.2.2: Machining	0	5	2	30	3	40
Task 9.3: Project Meetings	9	12	12	12	8	53
Task 9.3.1: Team Meetings	6	6	12	12	6	42
Task 9.3.2: Stakeholder Meetings	3	6	0	0	2	11
Task 9.4: Report	6	50	95	4	0	155
Task 9.4.1: 30% Report	0	10	25	1	0	36
Task 9.4.2: 60% Report	0	10	25	1	0	36
Task 9.4.3: 90% Report	0	15	25	1	0	41
Task 9.4.4: Final Report	6	15	20	1	0	42
Task 9.5: Website	0	0	0	0	50	50
Task 9.6: Undergraduate Research Symposium Presentation	9	5	5	0	0	19
Total Personnel Hours	**80**	**280**	**286**	**317**	**218**	**1181**

Table 2: Cost Summary

Cost of Engineering Services				
1.0 Personnel	Classification	Hours	Rate, $/hr	Cost
	SENG	80	210	$16,733
	ENG	280	150	$42,010
	EIT	286	80	$22,918
	LAB	317	100	$31,692
	AA	218	55	$12,008
	Personnel Total	1181		$125,360
2.0 Materials	Steel members, connections and hardware			$2,000
3.0 Equipment	Tools required for construction and assembly			$500
4.0 Subcontract				$240
5.0 Travel Pending Covid Restrictions	Van Rental	4 days	$65/day	$260
	Fuel	600 miles	$0.36/mile	$216
	Food	4 days	$56/person/day	$1,120
	Lodging	3 nights	$180/room/night	$2,700
6.0 Total				**$132,396**