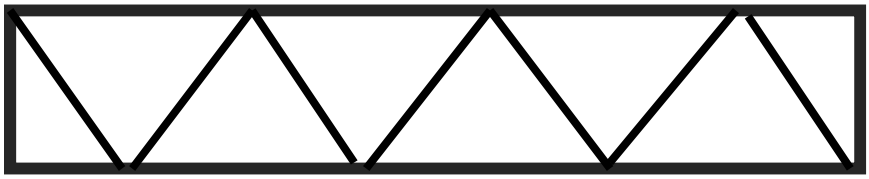
Northern Arizona University
American Society of Civil Engineers
Steel Bridge Competition 2016-2017



Final Proposal
December 13, 2016

2016-2017 Steel Bridge Team
Sabrina Ballard
Sean Hopper
Ryan Morofsky
Meg Stevens

Table of Contents

List of Figures

List of Tables

Appendices

1.0 Project Understanding

1.1 Project Purpose

Annually, the American Institute for Steel Construction (AISC) holds a design competition for engineering students. In this competition, students are asked to design and build a 1:10 scale bridge made completely from steel. The bridges are constructed, loaded, and judged at the American Society of Civil Engineers (ASCE) student chapter conferences. The team has been selected to represent Northern Arizona University (NAU) and design, fabricate, and construct a steel bridge in compliance with the current year's rules. The goal is to design a bridge with the highest overall performance in the judging categories of display, construction speed, lightness, stiffness, construction economy, and structural efficiency. By winning the Pacific Southwest Conference (PSWC), the design will be granted a contract for the Luckiamute subdivision bridge.

1.2 Project Background

A new subdivision is being planned for construction along the banks of the Luckiamute River and the bridge will need to be finished before the subdivision can be built. There are water and sewer lines running parallel along the river bank that could possibly interfere with the bridge construction depending on which footings and span are chosen. The bridge will be built in an environmentally sensitive area where no damage to the banks is permitted. If the end of the bridge is a cantilever, it will not interfere with the water and sewer lines or damage the banks. The bridge must meet the minimum bridge clearance height of 15' due to rising water levels in the spring. If the job is finished before water levels rise, construction costs will be minimized. Deck, foundations, and approaches are not included in the bridge contract and will not be included in the design. The proposed bridge span is 200 ft. Serviceability, construction cost and duration, material cost, and esthetics are critical considerations when designing the bridge.

Figure 1.1 shows the proposed building envelope of the bride over the Luckiamute River. The materials will be moved from the staging yard, through the transportation zone and into the construction zone where the bridge will be constructed.

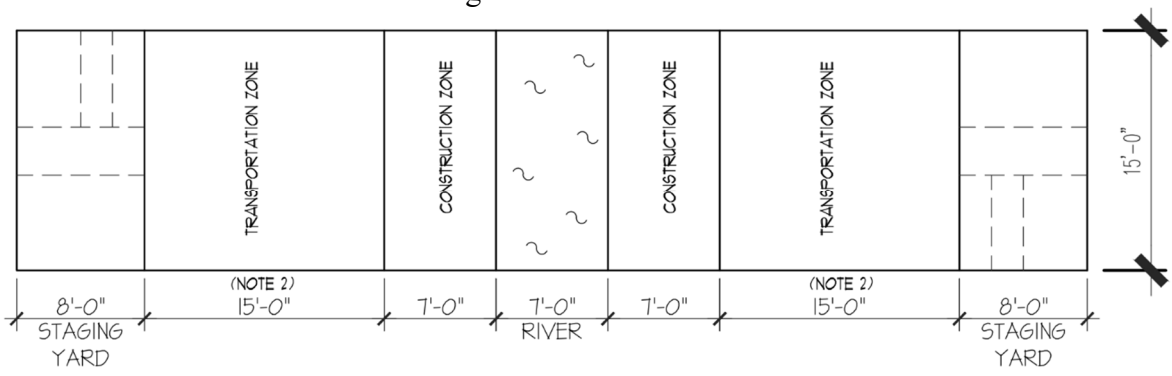


Figure 1.1 Proposed Building Envelope [1]

1.3 Technical Considerations

The bridge will be designed so the members are strong enough to withstand positive and negative moment, and vertical and lateral forces based on different loading combinations. The member's connections will be designed so they have sufficient bending moment and bearing capacity and can easily connect during timed construction. The legs will be designed to support the load placed on the members on any load case. The bridge will be

braced laterally to prevent side sway when loading the bridge laterally and vertically. After the bridge has been analyzed and designed, technical consideration will focus on constructability and speed of construction. The design portion will involve designing a bridge that presents a high aesthetic value and being engineered to meet the standards described in the ASCE/AISC steel bridge 2017 rules. A total of 2500 pounds will be applied to the bridge for the vertical load test, and a 50-pound lateral load will be applied at two different locations on the bridge for the lateral load test. Structural analysis software will be used to determine the projected bridge deflection and to ensure the design will pass the load testing.

After the design is complete, fabrication methods and constructability will be coordinated to ensure that the materials used are feasible and construction methods are reasonable. Jigs will need to be constructed to ensure that all of the members are welded identically so no extra moments are developed in fabrication. The connections need to be precision cut so they are more easily connected to each other reducing deflection in the joints. Members will need to be cut to the appropriate design size and holes will be drilled in appropriate locations on the members to properly follow the design ensuring the design plans and rules are followed. Fabrication methods will maximize strength while minimizing the amount of material needed to satisfy the requirements of this technical challenge.

1.4 Potential Challenges

One potential challenge will be obtaining the steel members in the sizes and grade of steel that will be required. This will be overcome by asking various steel shops for donations or fundraising to purchase the steel that is necessary.

Once challenge will be meeting the constraints of this project including but not limited to the following:

- Bolt lengths less than 3”
- Member sizes under 36”x4”x6”
- Bridge model total weight under 303 pounds without penalty
- Threads on bolts shall be continuous
- Deck surface must safely support a 3’6” decking unit
- Cannot exceed vertical deflection of 2” in the vertical load test
- Cannot exceed ½” vertical sway in the lateral load test.
- Bridge deck cannot exceed 5’ in width
- Deck support surface cannot exceed 2’7”
- No bridge component can extend more than 5’ above the ground
- No bridge component or builder can touch the river
- No more than 6 builders
- No tools can weigh more than 15 pounds
- No more than two temporary construction piers
- Bridge construction time must be under 30 minutes without penalty but 45 minutes is allowed
- Bridge decking must be continuous along the span(s)

Another potential challenge will be minimizing the deflections of the bridge while also minimizing the weight of the bridge. This will be dealt with by constructing a decision matrix

and optimizing the weight and deflection of the bridge in order to score the highest at the competition.

The timeline of this project is a potential challenge. The project must be fully completed before April 5th in order to compete in the Pacific Southwest Conference. In order to overcome this challenge, the team will aim to complete the 90% design by November 1, 2016. This will allow sufficient time to procure the materials, fabricate the members, and practice the timed construction.

1.5 Stakeholders

Some stakeholders of this project are the future owners of homes in Beaver Lodge Estates. This housing development is located adjacent to the Luckiamute River, thus a bridge would provide access to these new homes from across the river. They are stakeholders due to their need to travel across the river.

The NAU Civil Engineering Department and the NAU ASCE student chapter have a stake in the outcome of this project, as well. If this project ranks high at the competition, NAU ASCE and the Civil Engineering Department will receive recognition and will have an increased reputation.

2.0 Scope of Work

2.1 Task 1.0 Research

1.1 Competition Rules

The competition rules will be read in order to determine the potential loads combinations that could be applied to the bridge and to ensure the bridge meets all requirements.

1.2 Analysis Methods

Plate and shell models in RISA 3D will be researched in order to determine the deflections due to connections.

1.3 Materials Research

Research will be performed on grade of steel and shape of members to use. This will help to minimize deflection and weight.

2.2 Task 2.0 Fundraising

2.1 Bank Account

A bank account will be created in junction with the ASCE student chapter to house the donations received.

2.2 Sponsorships

The team will call and email local businesses to ask for donations and business to sponsor the steel bridge team.

2.3 Go Fund Me

A Go Fund Me page will be created and shared on social media in order to target donations from friends and family.

2.3 Task 3.0 Structural Analysis and Design

3.1 RISA Model

A RISA model of the bridge will be developed. The load combinations for the loading at the conference will be applied, and the deflections and member stresses will be determined. The base RISA model will be refined in order to best meet

the judging criteria. A final RISA model will be generated including member lengths, steel types, and all potential load combinations. The anticipated bridge deflection will be determined through the software analysis.

3.2 Connection Design

The connections will be designed to withstand the maximum moment as determined in RISA from the member forces by considering applicable moment capacity. A plate and shell model will be generated in RISA to obtain the deflections due to the connections. The overall anticipated deflection during the conference will be determined by adding the deflection from the members to the deflection of the connections.

3.3 Materials Analysis

Analysis will be performed in RISA on selected shapes and grades of steel to ensure the stiffest and lightest sections are chosen.

3.4 Fabrication Drawings

Shop drawings in AutoCAD will be created with plan view, profile view, details, and section cuts for plate members. These plans will be given to Page Steel so plates can be precision cut to specified dimensions.

2.4 Task 4.0 Fabrication

4.1 Construction Drawings

Construction drawings will be created in AutoCAD and will show an overall side view, front view and side view of the bridge, and details of members and connections. This will be done for the team to use during fabrication and construction.

4.2 Jig Creation

Jigs for the span members, cantilever members, lateral bracing members, center span members, and leg members will be designed and constructed to minimize fabrication variations in dimensions and help create parts that are constructed to specified dimensions. This will ensure that the capacity of the bridge is in accordance to the design.

4.3 Fabricate Components

Components will be fabricated using prescribed techniques to minimize distortions and maximize components strength. Members will be cut to specification and any needed holes will be drilled using guides to ensure accuracy and correct member placement when being constructed.

> **4.3.1** Two foot sections of each steel shape ordered will be cut. The pieces will then be tested in the Tinius Olsen machine to ensure the yield strength of the material.

4.4 Finalize Welding and Fabrication

Welds will be made approximately every six inches in order to minimize distorting and weakening of the metal. If material with a yield strength equal to or greater than 50 ksi, the steel will need be preheated to 50-125 degrees Fahrenheit before it is welded to ensure a full weld.

> **4.4.1** Material surfaces will be prepared by sanding and grinding the surface layer. All members will be inspected for quality and uniformity.

4.5 Inventory of Bridge Components and Final Layout

A final inventory of parts and members will be performed before construction practice begins.

2.5 Task 5.0 Construction

5.1 Construction Methods

Construction methods will be developed and tested. Construction methods that meet the conference criteria will be brainstormed.

5.2 Method Selection

After all construction methods have been tested and timed, a final construction method will be chosen. This will include assigning who will be constructing at conference, which side of the river they will be on, and what their role will be.

5.3 Construction Practice

The chosen method will be practiced under a similar setting to what is expected at conference. The building envelope including the footings, river, construction zone, and transportation zone will be taped out, and each time the bridge construction is being practiced, a mentee will keep track of the time and violations during building. After each practice, the pros and cons will be discussed and improved upon for the next construction practice.

2.6 Task 6.0 PSWC

The display board provided by the mentees will be printed. It will be printed in order for the display board to be set up next to the bridge on display day and be judged on aesthetics. The team will construct the bridge and display the poster provided by mentees for the display day at the PSWC for judging. The team will construct the bridge at the conference during timed construction. If the bridge is constructed in the allowable time and has not been disqualified, the bridge will undergo the vertical and lateral load tests.

2.7 Task 7.0 Project Management

7.1 Project Schedule

A project schedule and Gantt chart will be developed to ensure on time completion of the project.

7.2 50% Design Report/ Plans

A 50% design report and plan set will be submitted to the client and technical advisor for redlines and comments.

7.3 Final Design Report

A final design report will be written after the PSWC Steel Bridge Competition. The report will include the 100% design, results from the PSWC, and discussion on the performance of the bridge.

7.4 Final Presentation

A presentation will be given at the Undergraduate Research and Design Symposium (UGRADS) which will convey the objective and scope of the project, the design and analysis of the bridge, and results of the bridge at the PSWC Steel Bridge Competition.

7.5 Website

A website will be generated including team information, the final project proposal, final design report, AutoCAD drawings of the bridge, and results of the PSWC conference.

7.6 Team Meetings

The team will hold weekly meetings in order to ensure progress on the project.

7.7 Client communications

Meetings will be held with the client, grader, and technical advisor in order to receive feedback on the design and project deliverables. The technical advisor meetings will provide feedback about the design and technical aspects of the bridge. Meetings with the client will help guide the constraints of the bridge design. Meeting with the grader will provide clarity on course deliverables and feedback from redlines.

2.8 Exclusions

Exclusions of this project include arranging transportation and lodging for PSWC. Additionally, the design team is not liable for injury that occurs if the scaled steel bridge is used for anything other than its intended use. If the design team's steel bridge is selected to be designed as a full scaled bridge, the materials and construction labor shall be provided by other subcontractors.

2.9 Broader Impacts

Through completing this project, skills other than those directly relating to this project will be learned. Teamwork skills will be improved through working with the team for every aspect of the project. Through corresponding with sponsors, clients, and technical advisors, communication skills will improve. These skills will aid in a future career in civil engineering, since most projects will involve communication with subcontractors and clients and teamwork between coworkers in other departments.

3.0 Schedule

3.1 Fall 2016

Fall of 2016 will be dedicated to research, analysis, and design. The team scheduled research to take 85 days which will include research on the competition rules, analysis methods, and materials. Fundraising is scheduled for 182 days which includes efforts on creating a bank account, obtaining sponsorships, and creating a Go-Fund Me page. It is anticipated that the structural analysis and design will begin September 5th and end November 16th. During this time, materials will be analyzed, the RISA model is finalized, the connections will be designed, and fabrication plans will be generated. The material will then be ordered. While waiting for the steel to be ready to be picked up, the team will begin the construction drawings and will start creating the jigs for the members.

Team meetings will be held weekly on Mondays. A minimum of four meetings will be held with the technical advisor when the team has questions regarding the technical aspect of the project.

3.2 Spring 2017

Spring of 2017 will be dedicated to fabrication, construction, and the PSWC Steel Bridge Competition. After the steel arrives, all materials will be cut to appropriate sizes. The members will be tack welded in the jigs, and then fully welded in order to gain the full weld strength. Plates will be welded on the members per the construction plans. It is estimated that fabrication will take 90 days. It will commence after the steel has been ordered, and will be finished after all members have been cut, welded, and labeled for construction. Once all of the members are fabricated, construction practice will start. Construction practice will take 22 days. The Pacific Southwest Conference will be from April 5th to April 8th. Display day, timed construction, and load testing will take

place during this time. After PSWC, the final 25 days of the semester will be dedicated to the final design report, final presentation, and finalizing the team website.

3.3 Critical Path

The total time to complete the critical path is 364 days. The critical items follow the critical path from the beginning to the end of the project. The steel bridge project's critical path includes research of competition rules, analysis methods, and materials research; sponsorships; a RISA model and fabrication plans; construction drawings, jig creation, fabrication of components, and inventory and final layout; construction methods, method selection, and construction practice; and the PSWC. The critical path can be shown in red on the Gantt chart attached in Appendix A.

4.0 Staffing and Cost

4.1 Personnel

The design team consists of a project manager (PM), drafter (DRF), design engineer (DSNENG), fabricator (FAB), and six engineering interns (INT), as shown in Table 4.1.

Design Team	
Title	**Abbreviation**
Project Manager	PM
Drafter	DRF
Design Engineer	DSNENG
Fabricator	FAB
Engineering Interns (6)	INT

Table 4.1 Design Team

The project manager oversees the project, provides guidance for all aspects of the project, and ensures the project is on schedule. The drafter is in charge of the shop and construction drawings done in AutoCAD. The design engineer performs analysis in RISA 3D and Solidworks, as well as analysis for design of the joints. The fabricator is in charge of the drilling, cutting, welding, and organizing of members for construction practice. The engineering interns will perform various low-level tasks as assigned by the project manager, drafter, design engineer, and fabricator. The project manager's qualifications include the structural design of five steel buildings, analysis and connection design of four custom trusses, and extensive experience in RISA.

4.2 Estimated Personnel Hours

The following table, Table 4.2, shows the estimated hours each position will spend on specific tasks. It is estimated that the design team will spend 1241 hours on the Steel Bridge project.

Estimated Hours						
Task	**PM**	**DSNENG**	**DRF**	**FAB**	**INT**	**Total**
1.0 Research						
1.1 Competiton Rules	5	5	5	5	5	25
1.2 Analysis Methods	5	5	0	0	5	15
1.3 Materials Research	5	5	5	5	5	25
2.0 Fundraising						
2.1 Bank Account	4	2	0	0	0	6
2.2 Sponsorships	0	20	0	0	5	25
2.3 Go Fund Me	2	0	0	0	0	2
3.0 Structural Analysis and Design						
3.1 RISA Model	10	100	5	0	25	140
3.2 Connection Design	10	10	30	5	10	65
3.3 Materials Analysis	10	20	0	10	5	45
3.4 Fabrication Drawings	5	10	60	5	10	90
4.0 Fabrication						
4.1 Construction Drawings	5	5	20	10	0	40
4.2 Jig Creation	5	10	0	20	10	45
4.3 Fabicate Components	2	0	0	60	20	82
4.4 Finalize Welding and Fabrication	2	5	0	5	0	12
4.5 Inventory of Bridge Components	3	3	0	3	3	12
5.0 Construction Practice						
5.1 Construction Methods	5	5	5	5	5	25
5.2 Method Selection	4	4	4	4	4	20
5.3 Construction Practice	15	15	15	15	15	75
6.0 PSWC	25	30	25	40	40	160
7.0 Project Management						
7.1 Project Schedule	10	5	0	0	0	15
7.2 50% Design Report/ Plans	10	10	15	10	0	45
7.3 Final Design Report	6	6	6	6	0	24
7.4 Final Presentation	10	10	10	10	0	40
7.5 Website	10	0	0	0	0	10
7.6 Team Meetings	30	30	30	30	30	150
7.7 Client Communications	12	12	12	12	0	48
Total	210	327	247	260	197	**1241**

Table 4.2 Estimated Personnel Hours

4.3 Total Cost

The billing rate for each personnel classification is displayed showing their base pay and actual pay, then the attributes towards other expenses that need to be accounted for, as shown in Table 4.3. The overhead of 35% accounts for the cost of running the business, such as utilities, supplies, rent, vehicles, and administration. The profit of 20% is the gain for the company or organization.

Billing Rates						
Personnel	**Base Pay**	**Benefit**	**Actual Pay**	**Overhead**	**Profit**	**Billing Rate**
PM	$ 65.00	25%	$ 80.95	35%	20%	$ 116.70
DRF	$ 25.00	60%	$ 40.00	35%	20%	$ 53.75
DSNENG	$ 40.00	40%	$ 56.00	35%	20%	$ 78.00
FAB	$ 20.00	70%	$ 34.00	35%	20%	$ 45.00
INT	$ 11.00	0%	$ 11.00	35%	20%	$ 17.05

Table 4.3 Billing Rates

The billing rates are what each role is charged to the client for the steel bridge project. This creates an estimated cost of the project based on the amount of hours each role will be required to work to complete the project.

Cost of Personnel			
Title	**Total Hours**	**Rate per Hour**	**Cost**
PM	210	$ 117	$ 24,507
DSNENG	327	$ 78	$ 25,506
DRF	247	$ 54	$ 13,276
FAB	260	$ 45	$ 11,700
INT	197	$ 17	$ 3,359
Total			**$ 78,348**

Table 4.4 Cost of Personnel

The total cost of all services is broken down in terms of expenses for personnel, travel, testing, and materials in Table 4.5. The personnel cost breakdown is available in Table 4.4.

Total Cost of Services			
Service	**Rate**	**Unit**	**Total Cost**
Personnel			
PM	$117 per hour	210 hours	$ 24,507
DSNENG	$78 per hour	327 hours	$ 25,506
DRF	$54 per hour	247 hours	$ 13,276
FAB	$45 per hour	260 hours	$ 11,700
INT	$17 per hour	197 hours	$ 3,359
Travel			
Lodging	4 nights, 2 rooms	$140/night	$ 1,120
Car Rental	5 days	$150/day	$ 750
Testing	$100 per hour	20 hours	$ 2,000
Printing	Lump Sum	$100	$ 100
Materials	Lump Sum	$4,000	$ 4,000
Total			**$ 86,318**

Table 4.5 Total Cost of Services

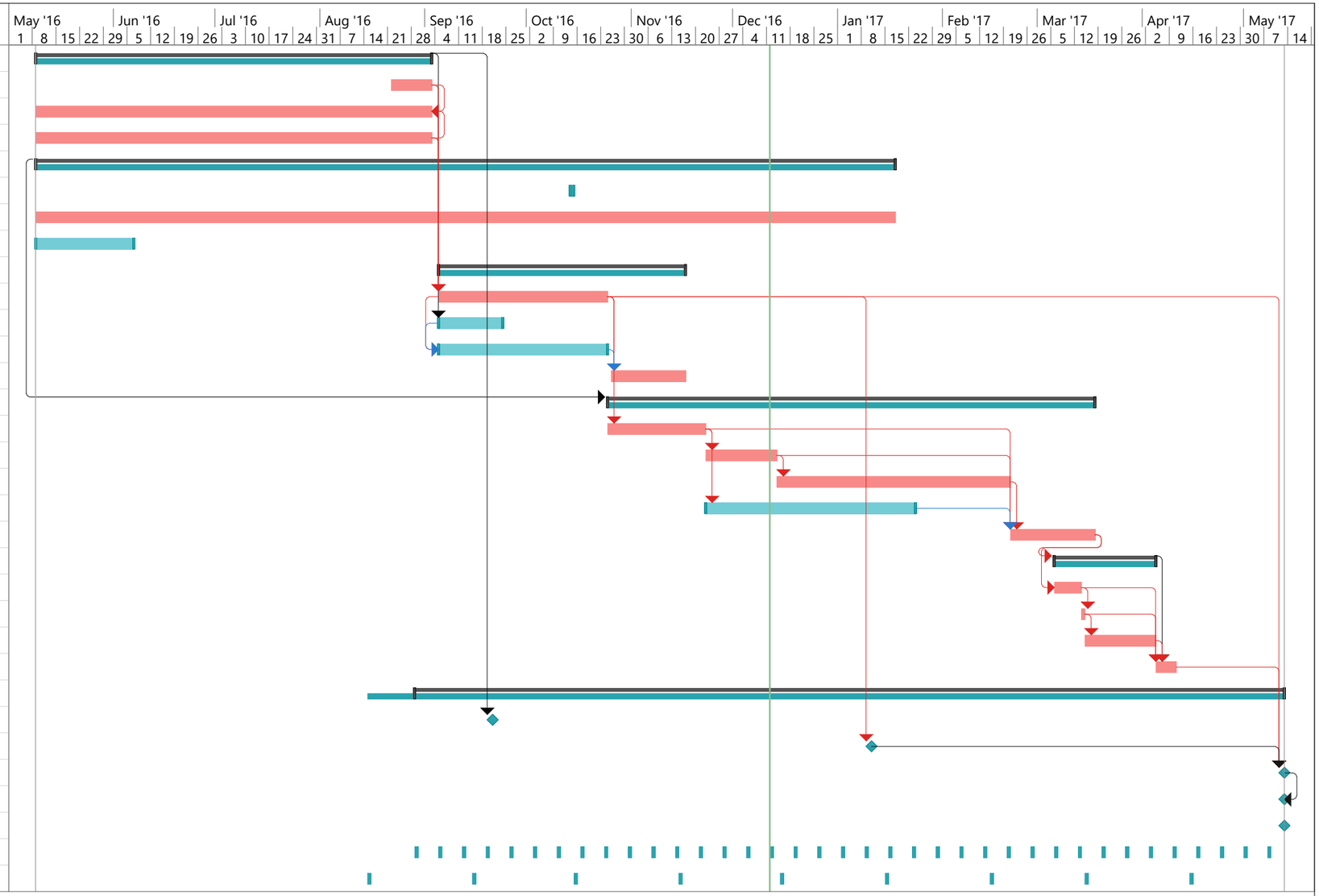
The travel cost was broken into lodging and car rental. The lodging is determined based on the need to have 2 hotel rooms for the four team members in Irvine, California for the four nights the team will be in California for the conference. The car rental is the cost of renting a vehicle to drive to the team members and the steel to conference. The testing fees are the based on the hourly rate of lab testing, and estimated hours that will be spent testing materials. The printing fees are for printing a full color poster board for the display day at the conference. Materials are based on the cost of the steel and tools required to complete this project. It is estimated that the Steel Bridge project will cost $86,318 to complete.

References

[1] "ASCE - AISC Student Steel Bridge Competitions", *Aisc.org*, 2016. [Online]. Available: http://www.aisc.org/content.aspx?id=780.

Appendix A – Gantt Chart

ID	Task Mode	Name
1		**1.0 Research**
2		1.1 Competition Rules
3		1.2 Analysis Methods
4		1.3 Materials Research
5		**2.0 Fundraising**
6		2.1 Bank Account
7		2.2 Sponsorships
8		2.3 Go Fund Me
9		**3.0 Structural Analysis and Design**
10		3.1 RISA Model
11		3.2 Connection Design
12		3.3 Materials Analysis
13		3.4 Fabrication Plans
14		**4.0 Fabrication**
15		4.1 Construction Drawings
16		4.2 Jig Creation
17		4.3 Fabricate Components
18		4.4 Finalize Welding and Fabrication
19		4.5 Inventory of Bridge Components and Final Layout
20		**5.0 Construction**
21		5.1 Construction Methods
22		5.2 Method Selection
23		5.3 Construction Practice
24		**6.0 PSWC**
25		**7.0 Project Management**
26		7.1 Project Schedule
27		7.2 50% Design Report
28		7.3 Final Design Report
29		7.4 Final Presentation
30		7.5 Website
31		7.6 Team Meeings
69		7.7 Client Communications



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