Bamboozle Engineering

CENE 476

Bamboozle Engineering Project Bid

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FUTS- Flagstaff Urban Trail System
RISA- Rapid Interactive Structural Analysis
NAU- Northern Arizona University

1.0 Project Understanding

This section identifies the purpose, background, technical considerations, challenges within the design, and the stakeholders for the Bamboo Bridge Capstone Project. Having a clear understanding of what the project entails will strengthen the team's knowledge and help establish a concise contract between the client and Bamboozle Engineering.

1.1 Project Purpose

Constructing a bridge of bamboo to allow safe passage for pedestrians and bicyclists is the purpose of this project. This project requires analysis and construction of a bridge that can withstand pedestrian live loads using bamboo as the main bridge design material. Therefore, the problem that will be addressed is the need for a low-impact bridge span, made primarily of bamboo materials, which will carry pedestrian live loads in conjunction with its own self-weight.

1.2 Project Background

Many members of the Flagstaff community use the City of Flagstaff Urban Trail on a daily basis. The trail currently uses a treated wood bridge design, just off South Beullah Boulevard near the Interstate 40 overpass, to serve as a crossing point of the existing flood plain at this location. This project will address the need for a more aesthetic bridge design at this location, as per the client, Dr. Bridget Bero. The design of this new bridge will be made of bamboo, an eco-friendly material, which will serve as a replacement of the existing structure.

1.2.1 Project Location

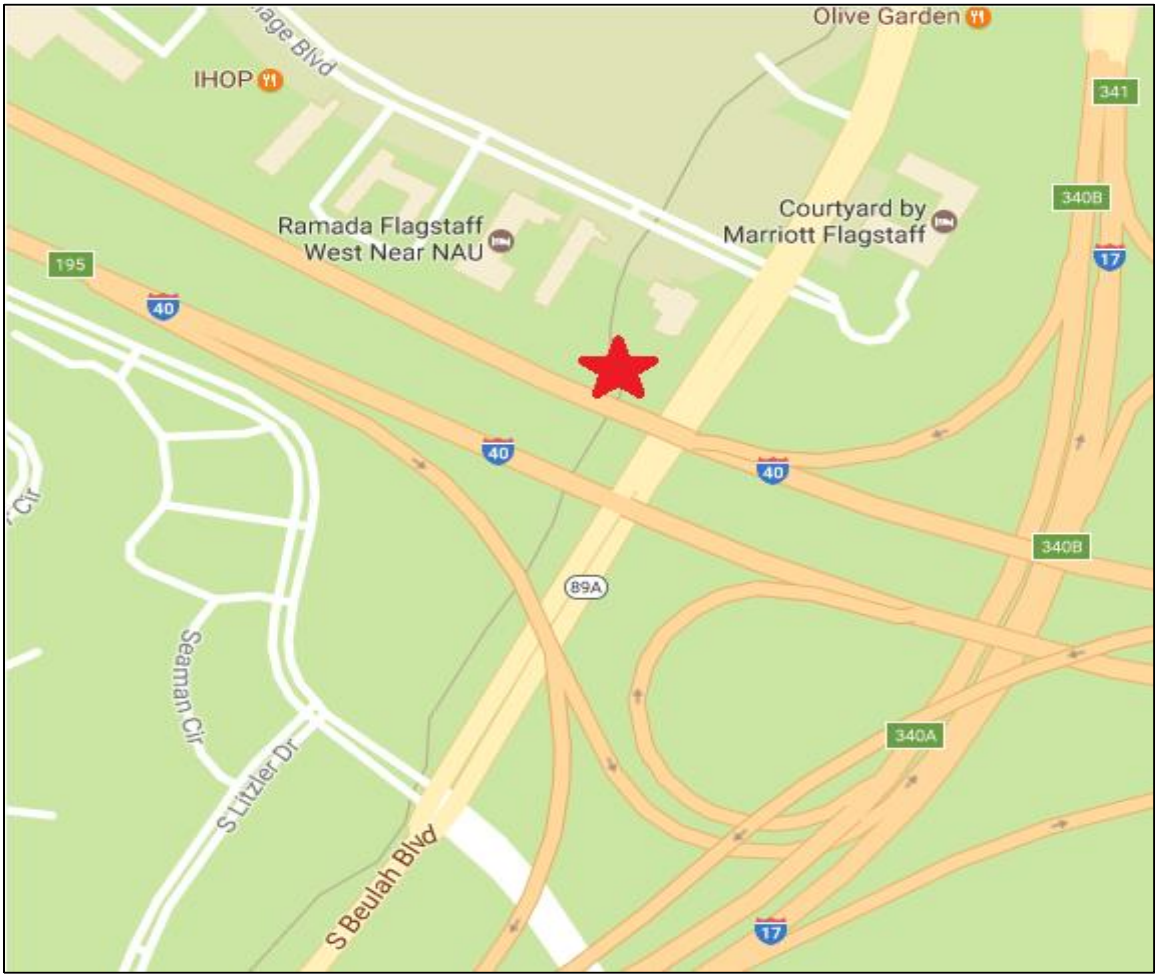

Figure 1: Site Map of Project Site, Google Maps

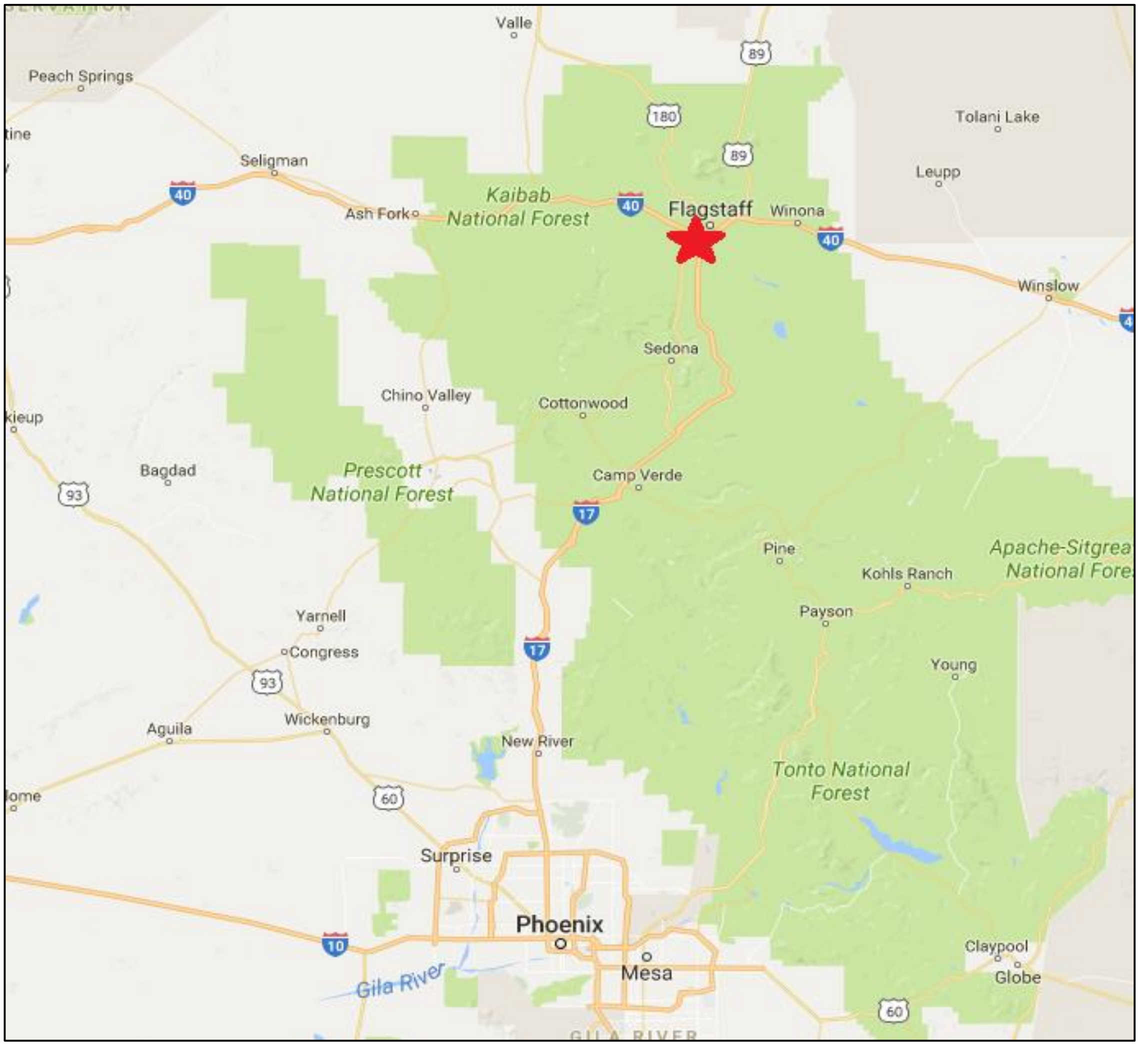

Figure 2: Vicinity Map of Project Location, Google Maps

1.2.2 Existing Structure

The existing structure at the project location is a standard pedestrian bridge made of treated lumber. The bridge currently joins two segments of the City of Flagstaff Urban Trail System, and spans across a floodplain detention basin. Figure 3 below shows the existing structure as seen from South Beulah Boulevard looking West.

Figure 3: View of Existing Structure with Dimensions Annotated

1.3 Technical Considerations

The development of civil engineering infrastructure is vital to the foundation of our modern day societies. More specifically, bridges and large infrastructure development depends heavily on steel and concrete materials throughout the design and construction processes. Bamboozle Engineering will use these typical materials as a starting point for comparative analysis, However, the project team expects to utilize bamboo to develop a structurally sound pedestrian bridge. In conjunction with these architecture types, the team will analyze bamboo material as structural components and connections in a lab test setting to optimize design for shear, buckling, bending, and strength. Computer software technologies such as Rapid Interactive Structural Analysis (RISA) and AutoCAD will be used to analyze design changes based on material differences, structural member design, and life expectancy of the structure [1]. In developing the design for this project, the team will work to construct the design and implement the structure for pedestrian use, minimizing design impact to surrounding environment.

1.3.1 Bridge Architecture

Bridge architecture types that we will analyze and possibly incorporate into our design include, but are not limited to, beam, cantilever, and truss bridges. Analysis of bamboo's material properties in conjunction with aesthetic features will help navigate the overall direction of the architectural aspects of this project.

1.3.1.1 Beam
Typically, these bridges are supported at either end of the span, and undergo compressive forces across the top of the spanned beam, and tension forces at the bottom [2]. With beam bridges the larger the distance between the two supports, under loading the greatest induced moment is at the center of the beam under. The load endured in a beam bridge is transferred to its supports so therefore they are designed to withstand maximum loading [2].

1.3.1.2 Arch
The curvature of an arch bridge allows for high levels of resistance to internal moments. Arch bridges are built from material resistant to compressive forces [3]. Many arch designs incorporate a heavy dead load on the top of the bridge to activate its natural strength gaining process. Arch bridges have a limit on how long they can span in order to keeps their strength, and certain length may need multiple arches. Arch bridge designs also take more time to construct than and require extra maintenance [3].

1.3.1.3 Truss
A truss bridge is a rigid structure composed primarily of triangular elements. All truss beams are either in tension or compression [4]. There are several differences for building a truss, which all depend on the traffic surface alignment. Pony and through trusses are similar in that the traffic surface flows through trusses on both sides of the bridge. A through truss is joined at the top with another truss configuration and is designed for extended spans and substantial loads and pony trusses are not. A deck truss is designed for carrying the traffic surface completely above the truss [4]. Truss bridges require an efficient design in order to eliminate unnecessary zero-force member beams [5].

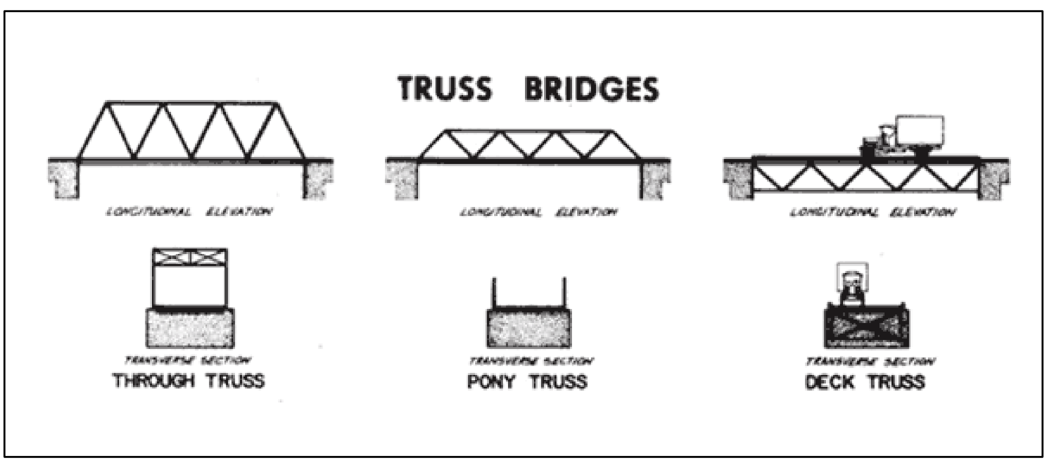

Figure 4: Truss Bridge Type [4]

1.3.2 Bridge Design Properties
The bridge design properties that will be analyzed in this project are materials and connections. However, the material that will be used in this project is bamboo. The foundation types of this project are bolt and welded.

1.3.2.1 Materials
The beams and columns in the bridge design will be composed of bamboo products. Our client has allowed metal connections to be used when joining members. As requested by the client the bamboo will be manipulated to make our model bridge aesthetically pleasing. Bamboo has the ability to reproduce rapidly making it a viable building resource for our design and future projects [6].

1.3.2.2 Connections
In bridge design, there a many different types of connections used for various applications. In general, the two main types of connections of connections are bolted and welded connections [7]. They can be used for mid-span joints while brackets would be more feasible for boundary connections. Bolts are generally manufactured using steel and resist shear or tension forces. Since they can only resist a limited amount of loading, multiple bolts are normally used to create a stronger connection. Welding connections are normally fabricated on-site and resist all forces and moments. Welding is only applicable when dealing with steel and other metals. Different styles of welds (such as butt welds or fillet welds) are available depending on the loading. Welding also requires a certain weather condition and if it's not met, temporary shelters will be needed [7].

1.3.3 Software Applications
The different software below offer a variety of services that make designing and simulating quicker and easier.

1.3.3.1 RISA
RISA analyzes structural design loading using computer based modeling. RISA has the ability to integrate and analyze design changes based on material differences, loading types, structural member design, and life expectancy of the structure [1]. The 2-D software provides the user with the ability to analyze members in a 2-dimensional space and design in adherence to the software’s output. The 3-dimensional RISA program allows the user to analyze the structural members and connections in a 3-D space, which provides an interactive example of how the structure will function and carry various loading types. Standard calculations and methods of analysis are made far more efficient and adaptive with this software, primarily due to the software's ability to generate instant feedback to the user [8].

1.3.3.2 AutoCAD/ Civil 3D
AutoCAD allows objects to be drafted with any dimensions so that makes it easy for civil and architecture and electrical design. Civil 3D is an engineering software application used for mapping, soil elevation design, design water systems and transportation [9, 10].

1.3.3.3 SAP 2000
SAP2000 incorporates a variety of features that can generate user, wind, wave, bridge, and seismic loads and then compare them to different materials. Additional features this program has to offer includes: user interface modeling, structural components, and analysis [11]. SAP2000 is capable of exploring joints, frames, and cables. Springs, hinges, or links are modeled at connections. The analysis aspect of SAP2000 applies static and dynamic loads to measure buckling and deflections [11].

1.4 Potential Challenges
Bamboozle Engineering will have to overcome a way to connect members of the bridge. The team will also have to physically construct a prototype bridge. With none of the team members being experienced in bridge building, this will be a huge challenge. In order to overcome the challenges, the team will have to seek guidance from professional engineers and other experienced workers in the field to succeed.

1.4.1 Technical Challenges
Of all the technical challenges the team will face, the boundary conditions and connections will be the toughest to overcome. The existing structure already has footings made of material that has yet to be determined, as specifications research from the previous design is currently being conducted. The presumed concrete footings will have to be analyzed in its current condition and incorporated into the bamboo design. With metal connections being an option, the engineering team will have to find out a way to efficiently connect members together while still remaining its structural integrity.

1.4.2 General Concerns
Using bamboo as a building material comes with many challenges. In the United States, it is a relatively new idea in the structural analysis world so there is not much research and laboratory testing on the idea. One of the key challenges the team will face is verifying the modulus of elasticity and rigidity in the laboratory. Bamboo has a natural ‘joint’ that could pose a serious challenge when determining the yield strength of the material. Depending on the properties of the varying cross-section, the minimum yield stress will have to be used when implementing it into the design.

1.5 Stakeholders

In order to develop a successful design, the stakeholders an their concerns must be clearly defined. Those affected will include Dr. Bero, the users of our bridge, the city of Flagstaff, and Western civilization. Understanding the client needs of Dr. Bero will narrow our scope of work. The bridge we are focused on is located towards University Heights and Wal-Mart. Cyclists and pedestrians in the region are our primary users of the bridge. Our team will be building a scale model of that bridge. Making sure our scale is secure, easily accessible, allows pedestrians and cyclists to cross safely are main concerns. In addition, all stakeholders are affected by the success of the design. Further projects within the City of Flagstaff using bamboo as the primary material may arise based on the outcome of Bamboozle Engineering's bridge design. This can give further interests in bamboo being used as building material in the West, where it is less common. As a team we all stand to benefit from the success of our model bridge.

2.0 Project Scope

The scope of work for this project is described in this section. The description of tasks that will be completed are described in more detail utilizing subtasks and descriptions of these subtasks. The project scope directly follows the project work breakdown structure.

2.1 Literature Review

The compilation of state of the art case studies will allow Bamboozle Engineering to gather knowledge of previous uses of bamboo in structural engineering. These studies will help the group gain a better understanding of the recent achievements and failures of bamboo as a structural material. Information regarding the pre-existing project site and plans will be researched and analyzed to develop a full understanding of the existing location.

2.1.1 Analyze Existing Bridge Plans on Current Flagstaff Urban Trail System Bridges

The accumulation of past site data will be gathered to help the group better understand the environmental factors we should be made aware of prior to designing the pedestrian bridge. Accessing the FUTS bridge plans and change orders for the pre-existing structure could help us understand any past difficulties of the previous design.

2.1.2 Research Bamboo Bridges Across the World

Bamboo applications as it pertains to structural design will be researched heavily prior to the design phase. The purpose is to collect general knowledge about how and how not to utilize this material, and gain a general understanding of the atypical material we will incorporate into our design.

2.1.3 Properties of Bamboo

Bamboo as a structural material will be analyzed in regards to its general mechanical functionality including strength, bending, shear, and torsional properties. To do this, analysis of projects worldwide will be investigated to determine the optimal design structure of the material.

2.1.4 Research Current Bamboo Structure in the US

A compilation of existing bamboo structures (taken from the literature review) in the United States will be used to show the public how it has worked in the past. Additional research on the public acceptance and reactions to old bamboo projects would provide a good estimate on the outcome of this project.

2.2 Develop Preliminary Designs

Polling will be conducted on the NAU campus and in public locations around the City of Flagstaff to gather a general opinion of the constituents' structural aesthetic preferences.

2.2.1 Develop Three Designs

Prior to the polling period, three potential design structurally sound design alternatives will be developed and incorporated into a simple survey poll. Each design alternative will vary in aesthetic appeal as to provide the public with a variety of options to choose from, and allow the project team to gage the general consensus of public architectural aesthetic preference.

2.2.2 Conduct Survey within Engineering building (other locations may also be added)

Flyers will be passed out in the Engineering building as well as other locations on campus and possibly around Flagstaff to gain a better understanding of which design people find most appealing. The results of this survey will be incorporated into discussions with the client and help the project team select the most suitable design alternative for the project's final design.

2.2.2.1 Address comments from poll

After the polling, a preferred design will be chosen. Along with that, the comments made on the sketches could have an impact on the final design. The poll will only impact the aesthetic needs wanted by our client and possible future users of the bridge.

2.3 Detailed Analysis of Selected Design

The development of the selected bridge design will be done using various structural analysis design software programs. The design calculations will be verified with manual hand calculations in order to ensure accuracy and precision. In order to do this, the project team will consult our technical advisor and grading instructor regularly in order to meet all client needs.

2.3.1 AutoCAD Analysis

The use of Autodesk's AutoCAD and Civil 3D will allow the project team to develop a basic blueprint that will provide vital information for potential constructability of the project.

2.3.1.1 Plan and Profile View of Design Solution

Information that will be included in the plan and profile assessment of the design solution includes the elevations, stations, and critical dimensions of the bridge. These critical dimensions will include, but are not limited to, span length, maximum height, width of walkway, height above underlying wash, and arch length (if arch span is used).

2.3.2 RISA Analysis

RISA is a software that helps analyze structures to see if they can withstand loading and survive the real world rather than doing hand calculations. This software will save time and provide assurance that the final design is structurally sound.

2.3.2.1 Design main truss, frame, and fittings

The primary truss and frame components of the bamboo bridge design will be heavily software based, however hand calculations will be conducted to verify calculated values. The use of RISA software, and SAP 2000 if necessary, will allow our team to integrate bamboo bridge members with structural steel fittings and attachments. This plan will allow the team to execute the bridge design selected most strongly by the client and the public.

2.4 Construct Scale Model

The selection of material for the scale model of the team's design solution will be based heavily on cost and availability. The required dimensions of the 4 foot scale model material may require the team to order the material from outside the U.S.

2.4.1 Contact Bamboo Suppliers

Contact bamboo suppliers and gather price estimates to find the most viable material option suitable for our design solution. After reviewing available sources for materials, an order will be placed to receive all bamboo members and additional supplies to construct a prototype of the final proposed design.

2.4.2 Fabrication

Due to the intricacy of bridge design, the project team will construct the scale model in a fixed location and avoid the movement/transportation of the model while it is being built. This will require the team to designate a specific space to the construction of the scale model, in which the space should be properly organized as to accommodate all construction.

2.4.3 Complete structural work and transport model

The scale model will be constructed in at the CECMEE Field House and will adhere to design requirements and specifications from the software output. Upon completion of the scale model construction, the model will be used during the final presentation and will be given to the client.

2.4.4 Client Feedback

Once model is developed and presented to client based on original design plan. We will take clients feedback into consideration. This will be done in order to incorporate any design aesthetic design modifications or alterations desired by the client that do not impact the structural integrity of the design and model.

2.5 Dissemination

A website will be helpful to keep the public and other parties interested on the project up to date on how the process of the bridge is developing. Doing so will require the need for coding and an overall theme for the website.

2.5.1 Website Development

The final design plans of the bamboo bridge along with the pertinent documents of the project's development will be incorporated into the website design. Information regarding the specifications of the design will be described, and basic information regarding the project team members will be presented.

2.5.2 PowerPoint Presentation

The team will create a PowerPoint to present for the final presentation at the end of the Fall 2017 semester. All information for the presentation will be associated directly with the final proposal.

2.5.3 Develop Final Report

The final report phase will consist of a three submittals, which includes the 50% report, the 90% report, and the final project report. The final report with be reviewed with the team's technical advisor prior to final submittal.

2.5.4 Final Report

The team will develop the final analysis report of the design solution and submit to client.

3.0 Project Schedule

Based on the projected scope from Section 2.0, Bamboozle Engineering has allocated time durations to each task and compiled it into a formal chart in Figure 5 on Page 13. The project will commence on the first day of the Fall 2017 semester, and will have a hard deadline of December 5th, 2017. Milestones are noted using the red diamond symbol, and the critical path for the project can be followed by reading the thin red line. The critical path is the shortest possible time to complete all aspects of the project.

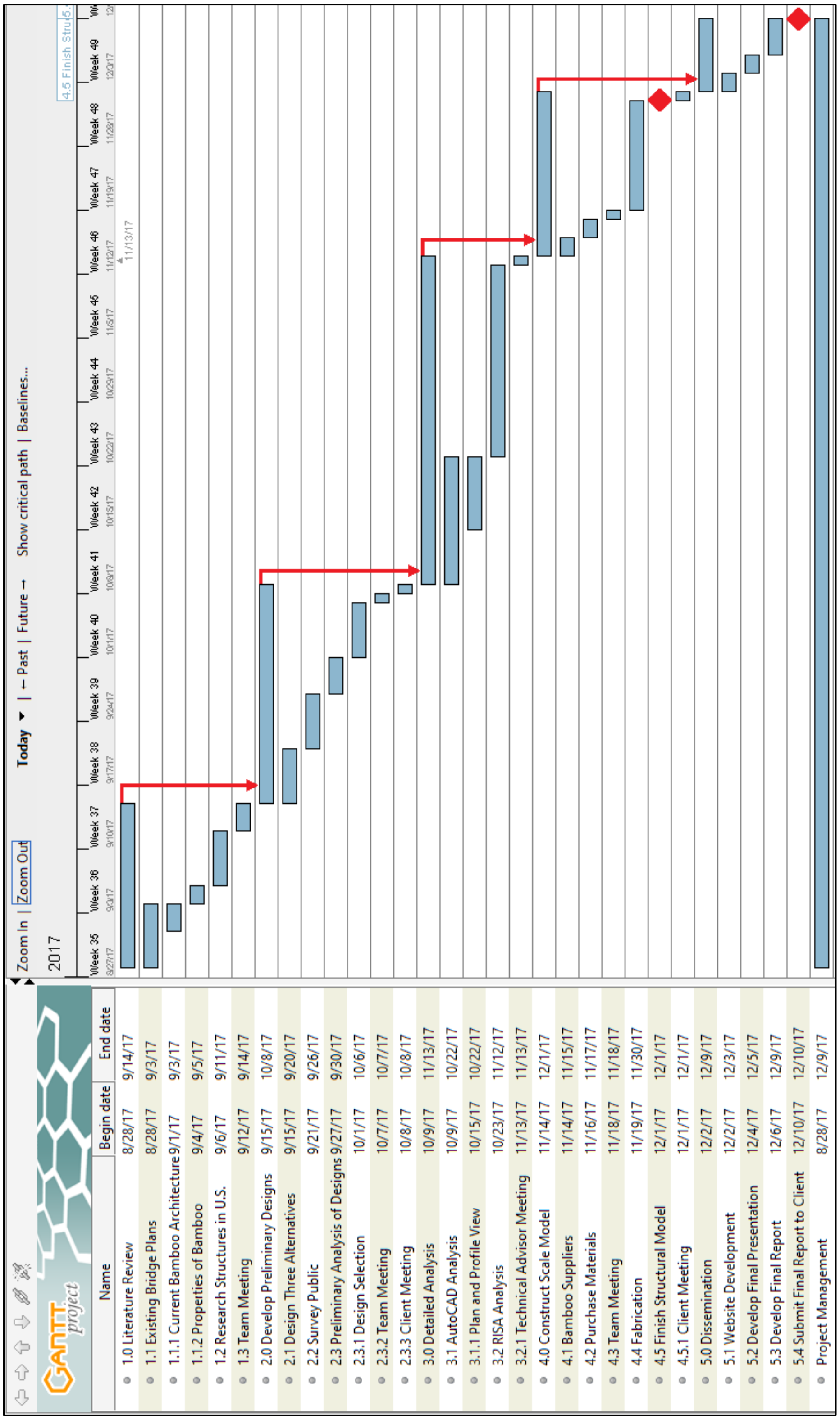

Figure 5: Project Schedule Gantt Chart

4.0 Staffing and Budget

The development of the staffing and budget for is predicated off of the Work Breakdown Structure, shown in Table 1, below. Table 2 atop Page 15 describes the projected total hours for each team member position, and calculates the total projected cost as per billing rates (also listed in Table 2). Table 3 describes the projected cost summary of the scale model, which includes material cost and fabrication of the final design solution.

Table 1: Work Breakdown Structure

Work Breakdown Structure		
Phase	**Code**	**Task**
1	**1.0**	**Literature Review**
	1.1	Existing Plans
	1.1.1	Current Bamboo Architecture
	1.1.2	Bamboo Properties
	1.2	Current Bamboo Structures in U.S.
	1.3	Team Meeting
2	**2.0**	**Develop Preliminary Designs**
	2.1	Develop Three Alternatives
	2.2	Survey Public
	2.3	Analysis for Selected Designs
	2.3.1	Design Selection
	2.3.2	Team Meeting
	2.3.3	Client Meeting
3	**3.0**	**Detailed Analysis**
	3.1	AutoCAD Analysis
	3.1.1	Plan and Profile View of Design Soultion
	3.2	RISA Analysis of Design
	3.2.1	Technical Advisor Meeting
4	**4.0**	**Construct Scale Model**
	4.1	Contact Bamboo Suppliers
	4.2	Purchase Materials
	4.3.1	Team Meeting
	4.4	Fabrication
	4.5	Finish Structural Work of Model
	4.5.1	Client Meeting
5	**5.0**	**Dissemination**
	5.1	Website Development
	5.2	Develop Final Presentation
	5.3	Develop Final Report
	5.4	Submit Final Report to Client

The Labor Cost Table below (Table 2) describes the projected hours per position for the project. The total hours of the project are a projected 717 hours, and the project overall cost for staffing and budgeting is $67,297.00. Table 3, the Material Cost Analysis Table, describes the costs directly associated with the fabrication and materials cost for the scale model. The projected overall cost for the scale model is $1,010.95.

Table 2: Labor Cost Table by Position and Total Hours

	Staffing and Budget							
	Task 1	Task 2	Task 3	Task 4	Task 5			
Position	Duration (Hour)	Duration (Hour)	Duration (Hour)	Duration (Hour)	Duration (Hour)	Total Hours	Rate (USD)	Costs (USD)
Senior Engineer	10	20	80	10	30	150	194	29100
Project Engineer	16	30	100	15	30	191	67	12797
Project Manager	10	30	80	15	30	165	90	14850
EIT	16	35	110	20	30	211	50	10550
						717		$67,297.00

Table 3: Materials Cost Analysis

Materials Cost Analysis				
Material Code	Material Description	Material Rate (ft)	Quantity	Material Cost (USD)
1.0	Bamboo (30 X 1')	110.95	1	110.95
2.0	Fabrication Costs (Machine Shop)	30	30	900
			Total Cost	$1,010.95

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