Pedibus - Spring 2015 Final Report

Kyle Anderson[#1], Stephen Avery [#2], Alejandro San Segundo [#3], Brett Willenbacher [#4]

[#] *Mechanical Engineering Department, FAMU-FSU College of Engineering*
2525 Pottsdamer Street, Building A, Suite A229
Tallahassee, Florida; United States 32310-6046

[1] kca10@my.fsu.edu
[2] sja12@my.fsu.edu
[3] as10s@my.fsu.edu
[4] blw11c@my.fsu.edu

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Mr. Ronald Goldstein: Project Sponsor
Dr. Chiang Shih: Project Mentor/Mechanical Engineering Chair
Dr. Nikhil Gupta: Project Co-Mentor
Mr. Keith Larson: Project Advisor

Team Biography—

Mr. Ronald Goldstein: Founder of Capital City Pedicabs, has traveled all around the United States working in a variety of industries including hospitality, imports, real estate and public service. It was during a family vacation in 2005 that the seed was planted for the pedicab business [1].

Kyle Anderson: Kyle is a senior seeking his B.S. degree in Mechanical Engieering at the FAMU/FSU College of Engineering. Being involved with SAE his entire college career, Kyle proves to be a key aspect to the vehicle designing and leadership of the project. His experience consists mostly of hands-on builds.

Stephen Avery: Stephen is a senior seeking his B.S. degree in Mechanical Engieering at the FAMU/FSU College of Engineering. Being the chassis designer for SAE Baja 2014-2015 vehicle and SAE Senior member, he brings a lot to the table with the structure and safety of the project.

Alejandro San Segundo: Alejandro is a senior seeking his B.S. degree in Mechanical Engieering at the FAMU/FSU College of Engineering. With past professional and leadership experience involving fast paced professional environments, his skills bring a strong contribution for the Pedibus project. Alejandro also has a strong background in cycling and ergonomic design, which is a large majority of the Pedibus project.

Brett Willenbacher: Brett is a senior seeking his B.S. degree in Mechanical Engieering at the FAMU/FSU College of Engineering. With track courses in both vehicle and machine design, he helps bring the transportation aspect of the project to life.

Abstract— ***Capital City Pedicabs has sponsored a project to create a multi user, pedal powered vehicle for the purpose of customer entertainment known as the Pedibus. The following document outlines the process associated with the design and manufacturing of the vehicle in its entirety. The breakdown of the design evolution as well as***

reasoning for the final design choices are explained as well as the fabrication processes utilized in the making of the Pedibus. Design calculation and concept explanations are depicted in this document giving reason for the design choices made by the team. The financial cost analysis for the fabrication and possible future manufacturing of the vehicle are outlined in this report. Lastly the team dynamics, parts procurement as well as the operation manual for the vehicle are included in this report. The Pedibus 2.0 has been fully fabricated and finalized at this point and the project manufacturing process is complete.

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I. PPROJECT INTRODUCTION

In response to the finalized product that was delivered last year, the Pedibus senior design project has been assigned again for the 2014-2015 school year. The sponsor has instructed the current team assigned to this project to design and fabricate another fully functional, multi-user, pedal powered vehicle called the Pedibus 2.0. The scope of the project is to have a fully functional product by Springtime Tallahassee, thus the team received the date of March 14, 2015 as a completion date constraint. The sponsor and owner of Capital City Pedicabs, Ron Goldstein, has given the team minimal design constraints and has allowed the group with almost unrestricted creativity for the design. Mr. Goldstein plans to add the Pedibus to his fleet of pedal powered vehicles, with hopes to increase his exposure.

Several design considerations have been determined from pre-existing models of this vehicle. However, the team plans to integrate numerous new design ideas not seen in the market before. The final product must be simple and rugged in nature to ensure minimal maintenance and optimal functionality. The design and build will be oriented around maximizing potential revenue sources. The potential business model for the implementation of the Pedibus has been discussed with the sponsor and the designs have been created in consideration with Mr. Goldstein's business plan. The Pedibus is planned to serve as an entertainment venue around the city. A modular design will be adopted in order to allow the sponsor freedom to expand the use of the vehicle across many demographics. This modularity will help provide additional revenue and exposure for Capital City Pedicabs.

A. PROBLEM STATEMENT

The Pedibus project is sponsored by Ron Goldstein, owner of the Capital City Pedicabs. The sponsor wants to have a fully functional multi-user bike in order to institute a new business model to the city of Tallahassee. While this project was completed by the previous team, the product that was delivered was not satisfactory. Many of the design objectives originally set in place by Mr. Goldstein, were not met. This led to the sponsor having to hire a third party fabricator in order to complete the vehicle.

" Currently, the sponsor is without a usable vehicle to support this new business model."

B. DESIGN REQUIREMENTS

The following list contains the design requirements desired by the project sponsor for the Pedibus. These design requirements have successfully been met while still maintaining full functionality of the vehicle.

1. Accommodate a minimum of 10 occupants powering the vehicle
2. Accommodations for additional occupants, other than those powering the vehicle
3. Simple construction for easy maintenance, fabrication, and reproduction
4. Ability to be transported by a standard full-size truck
5. Modular accessories to allow for accessory expansion post-fabrication
6. Able to transverse a 8% grade comfortably
7. Rolling chassis must weigh under 1499lbs.
8. Able to hold a 3000lb payload
9. Ability to move with input from a single rider

C. PROJECT OBJECTIVE

The Pedibus senior design team plans to deliver a fully-functional and optimized Pedibus to Ron Goldstein by March 28, 2015. The goal of this project is to design and fabricate a multi-person, human powered vehicle for the purpose of customer entertainment. This vehicle should be able to support the sponsor's business model as well as operate efficiently under Tallahassee's unique needs.

The vehicle must be fully fabricated and operational by March 28, 2015 as it will participate as a float in the Tallahassee Spring Weekend parade.

II. BACKGROUND RESEARCH

The concept of a multi-user bike utilized for leisure and group entertainment is an existing concept. Typically, this type of vehicle is used as a mobile attraction, often including on board entertainment and refreshments. In other cities this type of vehicle has existed through a variety of different names [1]. This business model is a fairly recent development for major cities in the United States. A handful of private investors have had one of these vehicles fabricated to fit a specific business model. These vehicles vary in design and performance since there is no single manufacturer that has monopolized production. Although different in detail, all party bikes share several characteristics, such as the seating arrangements and similar frame construction.

Capital City Pedicabs, has requested an original design based on the aforementioned vehicles as a new business venture. This is a unique design challenge due to the environmental constraints present in Tallahassee. Because of the custom nature of these machines, literature regarding the design specifications is difficult to source, therefore the team will be working closely with the sponsor to ensure an acceptable product The fabrication of this project was attempted last year by another senior design team and some of their design concepts will be implemented into this build, but most of the final product will remain original and one of a kind.

III. CONCEPT GENERATION

The overall final design has greatly evolved from the initial proposed rendering, this was done in order to abide to the specified project design requirement as well as to stay within the regulation for the Florida towing laws. The following subsections outline the evolution of the vehicle frame and its subcomponents respectively.

A. FRAME DESIGN EVOLUTION

The team developed three main design ideas for the frame. These three design ideas include a box style frame, supported ladder frame, and a C frame. These three designs will be discussed in detail in the next few paragraphs.

Box Style Frame

The box style frame consists of a central rectangular box structure with supports extending out from the side. This design allowed for all of the drive and electrical components to be contained inside the box section of the frame. Additionally, this design had the best separation of the passengers from any moving parts and was therefore considered one of the safer designs. However, this design used significantly more material and had a much larger foot print than desired.

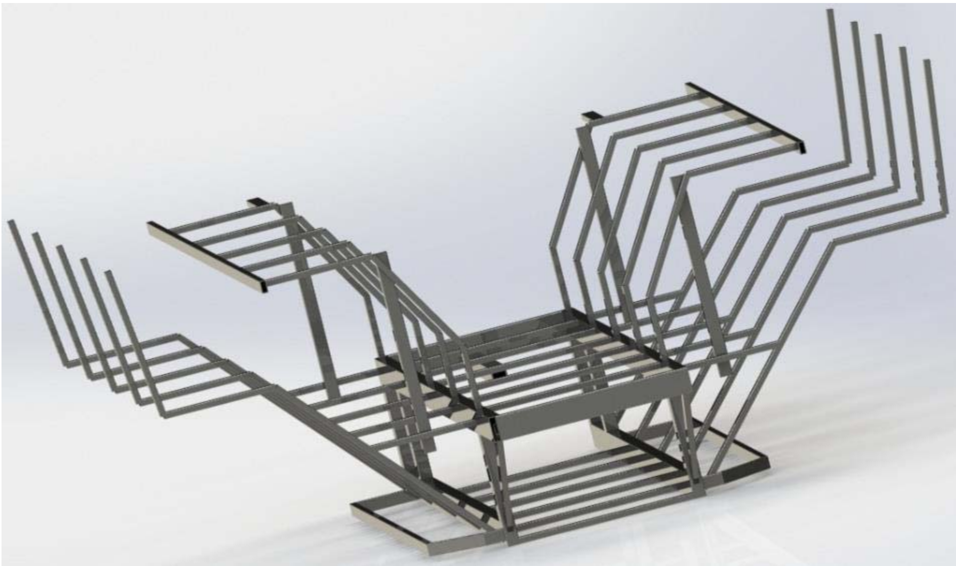

Figure 1. *Box style frame render for the Pedibus.*

C-style frame

This frame design was the simplest of the three and consisted of primarily 2x4 and 2x2 members cut at 90º angles and arranged in a horizontal C shape. This design is very similar to the stringer setup on some boats. While this design allowed for the most variability in component selection it was also the least durable in terms of not allowing the frame to flex. Additionally, the frame offered no built in separation of components from the peddlers.

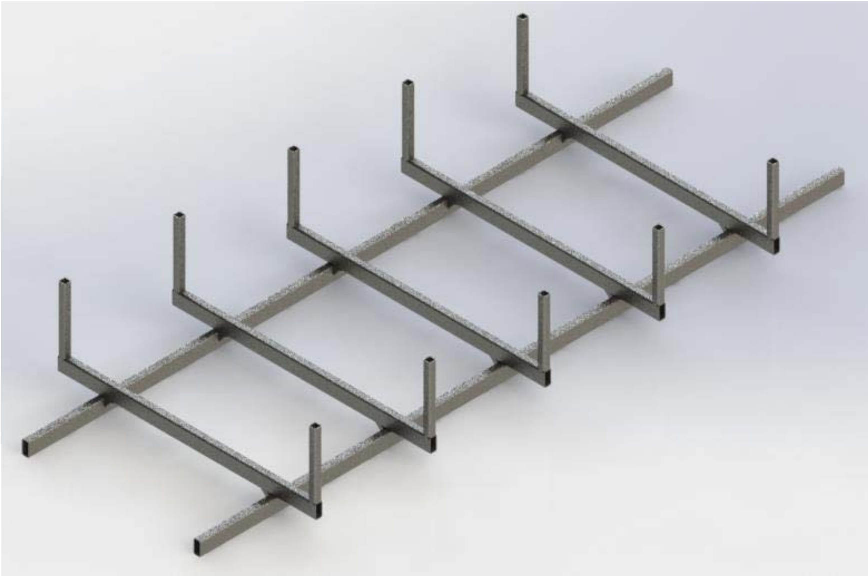

Figure 2. *C-Style frame render for the Pedibus.*

Supported Ladder Style Frame

The ladder style frame is a mix of the two frames mentioned above. It has a wider center to center width of the primary lower frame rails. This allowed for greater axle support, a wider track width, and more subtle angles than either of the two previous designs. It also gave some degree of separation of components from the peddlers, less moment on the seats, and greater support of the seat tubes than either of the two previous designs.

Figure 3. *Ladder style frame for the Pedibus*

Frame Design Selection

Ultimately, the Supported ladder style frame was chosen due to the simplicity and ease of manufacturing of the design. Additionally, this design offered the best mix of efficient space utilization and structural rigidity. Below a design matrix outlining the major pros and cons of each style is shown.

Table 1. *Decision matrix for final frame style selection for the construction of the Pedibus*

	Strength	Fabrication	Complexity	Weight	Cost	Weighted Sums
Box-Style Frame	8	6	4	4	7	170
C-Style Frame	2	9	9	7	4	160
Supported Ladder Frame	6	7	6	5	6	183
Weight Decision	6	8	4	5	7	

Pre-fabrication Changes to Final Selection of Ladder Style Frame

Frame width alteration; the geometry and dimensions of the Pedibus frame were altered in order to shorten the total width of the vehicle to a magnitude below 102in. This was done because of the Florida Law Statutes for street towing, which states that the vehicle must not surpass 102 inches in width. The team was able to do this by simply altering the dimensions of the frame by a small margin, relocating the positioning of the pedal cranks, and shortening the width of the bar area by two inches. The new design meets the width requirement while still maintaining the ergonomics desired by the sponsor.

B. SUBSCOMPONENTS DESIGN GENERATION

The following sections outline the design development of the different main subcomponents of the Pedibus vehicle. The final design were chosen based on critical analysis and consideration for the design requirements. The following subsection include the different designs that were considered for the subsystems of the Pedibus as well as decision matrices and explanations regarding the choices made for the final design.

1. PEDALING INPUT

As a subsection of the drivetrain components some design analysis was performed on how peddlers would input power into the drivetrain. For this three designs were developed and considered. All designs also include a freewheel for each peddler as a safety measure in order to prevent injuries to a rider.

Crossed Chain Linkage

The previous year Pedibus used a cross chain linkage to connect to pedal cranks on one end and a driveshaft on the other. This design was very simple and allowed for a single driveshaft to be used for the entire bus. However, this design also had some problems, especially in regards to reliability. Chain wear was more extensive due to the chains on one side of the bus rubbing up against a wear material. Additionally, this repair material was custom fabricated and has to be replaced when the system wears down. This resulted in less reliability, higher downtimes, and more repair costs.

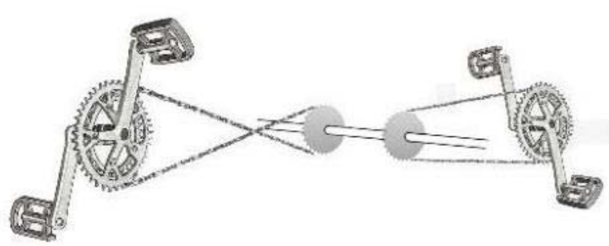

Figure 4. *Crossed chain design for pedaling to shaft interface.*

Dual Drive Shaft Chain Drive

The second design that was considered consisted of two parallel drive shafts attached to the cranks on either side of the Pedibus. These drive shafts would then be interconnected by a spur gear in order to make the power output in the same direction. This design is slightly more complex but also does not require chains to be crossed. This results in much higher reliability and durability albeit at an increase in complexity and cost. This design is the final choice that will be implemented onto the Pedibus. This will increase chain stability since the chains will no cross and the entire system will be aligned. Not crossing the chain will also reduce the price of the design since extra parts, such as chain tensioners and guides, will not need to be implemented onto the design. Overall this is clearly the best design choice from an engineering and a financial standpoint.

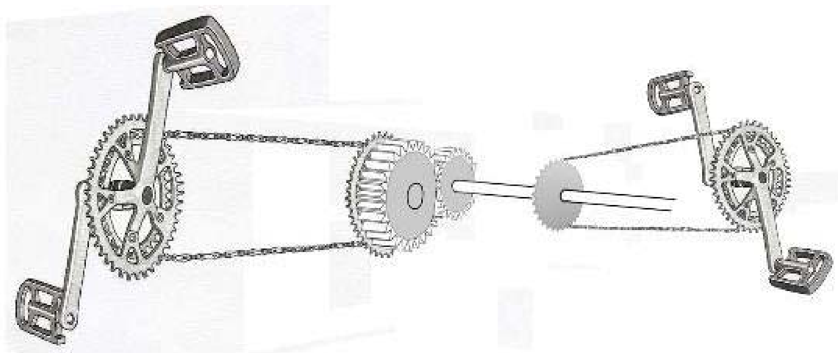

Figure 5. *Double shaft pedal to shaft interface design.*

Pedalling Input Selection

For the peddler input decision, it was ultimately chosen to utilize the dual drive shaft configuration. While this design was more complicated than the crossed chain design it also adds a level of stability and reliability that is lost by crossing the chains. The third design was heavily considered due to the novelty and apparent simplicity of the concept. However, because this design would require a fair amount more custom fabrication than the previous two options, the dual drive shaft was chosen.

Table 2. *Decision matrix for the selection of the pedal to shaft interface design.*

	Safety	User Comfort	Complexity	Reliability	Weighted Sums
Cross Chained Linkage	6	6	7	2	132
Dual Drive Shaft Chain Drive	6	7	4	7	161
Weight Decision	9	6	4	7	

2. DRIVETRAIN

For the purpose of this report the drivetrain section deals primarily with power delivery from the end of the driveshaft to the driven wheels. All of the peddler input methods outputs directly to a driveshaft that can be connected to some sort of axle in order to transmit power to the wheels. Additionally, all of our designs were made assuming a rear wheel drive configuration for simplicity. A front wheel drive system was considered but was rejected due to significant amount of additional complexity involved.

Solid Rear Axle

The initial design consideration regarding the drivetrain was to use an automotive rear axle. While this system was very durable and was a commonly used solution for this type of vehicle (CITE THIS) there were some disadvantages. The most important of which was the lack of reverse gear. If this design were to be used an additional gearbox would also be used in order to allow for the vehicle to travel in reverse. Additionally, the lack of multiple forward gears was a serious disadvantage in the area of which the bus is being designed for. Multiple forward gears allows for the bus to be operated in more locations including areas with hills.

Hydrostatic Rear Transaxle

Another drivetrain configuration that was considered consisted of a hydrostatic transaxle and possibly accompanying pump. This transaxle acted similar to an automatic transmission in a car but using a hydraulic continuously variable transmission. This would have allowed the bus to be driven without the need of being shifted while still having the advantages of being able to traverse multiple landscapes.

Manual Rear Transaxle

The second transaxle that was considered was a full manual geared rear transaxle. This transaxle shared the same footprint as the Hydrostatic transaxle discussed above. It is less complicated but it also requires a clutch system in order to change gears on the fly. Because of this it has a significantly higher torque rating than the equivalent hydrostatic model.

Drivetrain Selection

Due to the additional benefits that the manual rear transaxle had over the single speed rear axle it was chosen over the other options. The hydrostatic transaxle would have been an excellent choice, however, there were very few options that would be strong enough at a reasonable price. Unfortunately, the manual transaxle generates additional design considerations regarding the transaxle that are less relevant in the other two options, but it offered the most useful options to make the Pedibus more rider friendly.

Table 3. *Decision matrix for the design selection of the drivetrain rear axle components.*

	Durability	Cost	Modularity	User Fatigue	Maintenance	Complexity	Weighted Sums
Hydrostatic Transaxle	2	8	6	6	4	2	110
Manual Transaxle	7	5	9	9	8	3	168
Vehicle Axle	8	6	2	2	7	8	162
Weight Decision	8	4	2	6	6	2	

3. STEERING

The steering for this particular vehicle is the last thing to be designed. A rack and pinion with custom made tie rods will be used to turn the wheels, uprights, spindle and hubs for steering. All inboard steering components have been selected. However, the sourcing and designing of uprights, hubs, and spindles is still being determined. Although many design ideas have been contemplated, all design concepts have been narrowed down to a few basic designs.

Existing Vehicle Components

The original idea was to use specific working dimensions, wheel base and track width, so that the front upright, bearings, hubs spindles, etc, can be sourced from a pre-existing road vehicle. This would simplify fabrication if these components could be bolted into place without the need of additional fabrication. This would also provide a front hub bearing that could handle the weight and highway speeds expected for this vehicle.

Trailer Hub " Cut and Weld"

The second consideration is trailer hubs as a potential for this design. Since trailer hubs are usually held straight, steering components for these hubs would need to be fabricated. A "cut and weld" design is being considered. This means a simple, two dimensional, sheet metal frame or bracket would be cut and welded into place. The manufacturing of this is less involved and would only require basic shop tooling. It also allows for flexibility in how the vehicle turns and an optimum steer radius can be achieved. This design still avoids the need of complicated three dimensional parts that would require a CNC.

Custom CNC Components

The final idea that is being considered is complete CNC uprights, hubs, and spindles. Designs would be drawn from scratch and all parts would be made at the College of Engineering machine shop. Although the complexity of the designs is not particularly involved, the fabrication would be time consuming. The use of a CNC also increases future complications and costs if one of the steering components were to fail, or if the sponsor chose to have the vehicle reproduced. Original designs make parts unique and one of a kind; making them harder to replace. In the spirit of the project constraints this design concept will only be considered if the other two concepts are not viable.

Steering Selection

The selection of the steering was less straightforward then many other design subsystems this vehicle consists of. The original plan was for sourcing of already existing components from existing road vehicles. After some thinking and group discussion the idea of the Cut and Weld uprights started to seem more realistic. As the decision matrix below shows, Cut and Weld became the final design path that will be taken to allow the vehicle to steer.

Table 4. *Decision matrix for the design selection of the steering subcomponent of the Pedibus.*

Set Up	Fabrication Requirements	Cost	Complexity	Ease of Implementation	Weighted Sums
Pre-existing Vehicle Parts	8	6	6	2	144
Cut and Weld	6	6	7	7	169
CNC parts	2	2	4	8	106
Weight Decision	8	5	6	7	

4. SUSPENSION

When considering the suspension for the pedibus project, the cost, viability, and necessity of the suspension was analysed. Initially, the suspension design was to have both front and rear axles to be directly mounted to the frame, essentially eliminating the suspension. However, after discussing the design further, especially, with respect to the feasibility of towing, the suspension was re-evaluated. The following designs have been considered.

Dual Leaf Sprung Solid Axle

When the suspension redesign began the initial concept included front and rear suspension utilizing eye-slipper leaf springs. This concept added significant complexity to the drivetrain. In order to utilize a rear suspension either the transaxle would have been able to move in the vertical direction, requiring u-joints on the driveshaft. Additionally, another consideration would have been to move to axle shafts that utilized a CV-joint to apply power to the wheels.

Front Leaf Sprung Axle

The second design concept that is currently being considered, is to only implement a front suspension. This consideration was made as the bus while in use does not require suspension. However, when being towed, the axle that is on the ground would benefit greatly from a simple suspension. This design concept has significantly less complexities then the first concept but also lacks the additional comfort that a rear suspension would add.

Torsion Trailer Axle Suspension

The third and final design selected was from already existing trailer parts. The torsion axle selected is a bolt on part that will take little alteration to the design of the frame of the vehicle. Tabs will welded to the frame so the axle can be attached to the frame and out of the way of normal operations. The axle will only be in use while towing. While in normal operation, the axle may either stay on the vehicle, or can be removed. To tow the vehicle, the wheels from the rear of the bus will be removed and attached to the towing axle. Eliminating the need for additional wheels.

Suspension Selection

As one can see from the below decision matrix, the final selection was the Trailer Torsion axle. Key factors to this decision is the fabrication requirements to the chassis, overall strength, and ease of maintenance compared to the other options. This was the option that the team was most likely going to use and the matrix proves that it is the correct choice.

Table 5. *Decision matrix for the design selection of the towing platform subcomponent.*

Set Up	Fabrication Requirements	Cost	Complexity	Maintenance	Weight	Strength	Weighted Sums
Dual Leaf Sprung Solid Axle	2	3	2	4	4	3	98
Front Leaf Sprung Axle	6	6	5	6	6	7	208
Torsion Trailer Axle Suspension	8	4	8	7	4	6	215
Weight Decision	8	6	4	5	3	8	

5. BRAKES

Different brake systems will be used for the operational and towing use of the Pedibus. Below are the two different transportations and the brake systems that will go along with each of them.

Operational Use

10” hydraulic disc brakes will be used on both of the axles during operational use. The size of the brakes were chosen based on the necessary brake force required to stop the Pedibus and by common availability. These brakes will be operated by a pedal to master cylinder system. With a pedal ratio of 6:1, the driver will have ease applying force to the brakes. Hydraulic brake lines will run from the master cylinder to each of the four disc brakes. One of the main concerns for this project is making it as easy to maintain as possible. Disc brakes have much lower maintenance requirements when compared to drum brakes. Also, with low speeds during operational use, the brake disc life span will be much longer than that of a standard vehicle.

Upon later analysis, the size of the rear brakes was reduced from the original size of 10 inches to a smaller diameter of 8 inches. This was done in order to accommodate clearance with the ground while the vehicle is being towed. This will ensure that when the torsion axles flex to absorb road imperfections the disc brake assembly will not make contact with the ground under any circumstance and thus keeping the rear brake system undamaged.

Towing

While being towed, there will be one separate axle on the ground. This is necessary because the transaxle’s inability to handle highway speeds. For this separate axle, a torsion bar will be used to help act like a suspension. Because of the weight of the Pedibus, 10” electric drum brakes will be used on the two tires during the towing. These electric brakes will be controlled by an in-cab remote. This remote will be tuned depending on the overall weight of the Pedibus and the driver’s preferences.

6. PEDALING ERGONOMICS

Ergonomics is a serious consideration for this vehicle as the vehicle might be in use for an extended period of time. Therefore, the team has researched the difference between different types of bicycle riding positions in order to determine a comfortable design that is compact enough to fit on the bus. The three rider positions are listed below. The pedaling platform design has been chosen in order to best accommodate a wide range of peddlers of different sizes. The crank mount positioning on the frame has been strategically calculated to be 30 inches from the hipbone of the rider, as shown in the figure below. This length is the average extended leg length for a 5’0 height person. The downward angle has also been chosen to comfortably accommodate a person up to a height of 6’5.

Standard Riding Style

A standard riding style would be where the rider’s legs are nearly directly below the tailbone. While this design is the most compact, it is also very difficult to implement given that the team has decided to use bench seating in the vehicle. This means that the riders’ legs would have to tuck behind the bottom of the bench seat. This would lead to a very uncomfortable riding position leading to heavy rider fatigue. A diagram showing this type of riding position is shown below.

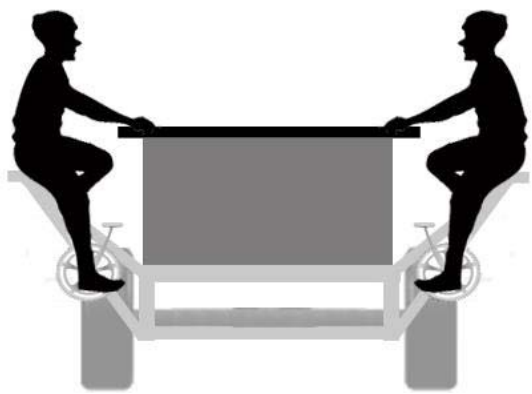

Figure 6. *Upright pedaling stance.*

Recumbent Riding Style

A recumbent riding style works better with a bench seating design. However, this riding position requires a significant amount more space. Additionally, the riding position would make adjustments very difficult for people of different sizes. The angle of the back and bottom of the bench, as well as the height of the crank would be critical to the success of this design. A diagram showing this style of riding position is shown below.

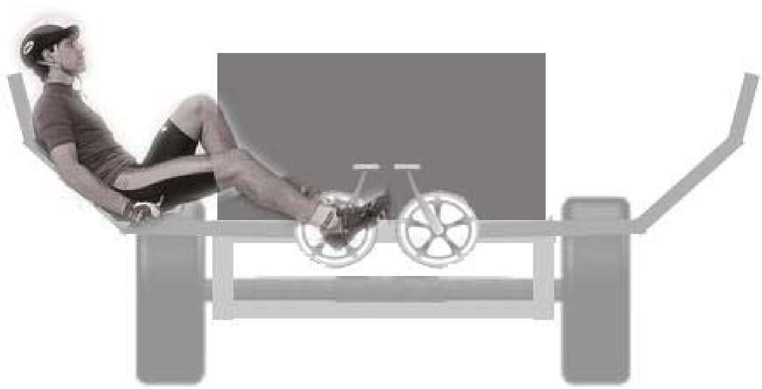

Figure 7. *Recumbent pedaling stance.*

Hybrid Riding Style

In order to incorporate a riding position that will fit in the vehicle while still minimizing the fatigue of the riders, a hybrid position may need to be required. This design is less compact than a standard position but much more comfortable, like the recumbent stance. In a nutshell, this design is a mixture of both the standard and the recumbent stance. Additionally, it does not take up nearly as much space as the recumbent riding style. The angle of the seat back and seat bottom will also be less critical to the overall user experience. This design does have some drawbacks in the fact that the ergonomic positioning would have to be designed by the team instead of going with standard dimensions. While off the shelf components can still be used, the components may have to be mounted in a non-standard orientation.

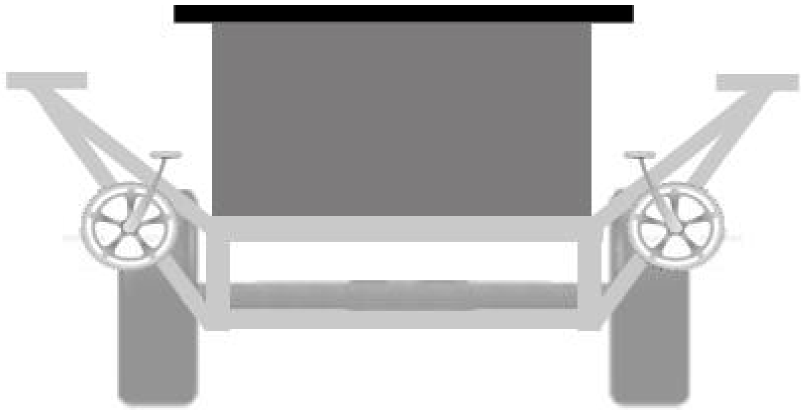

Figure 8. *Optimized hybrid, compact pedaling stance for maximum passenge comfort.*

In order to further increase the comfort level of the rider, an inclined cushion will be added in the future works to the bench. This will simulate the angled seat from a recumbent stationary bicycle and provide proper support for the rider. Adding the cushion will not only prevent the riders' legs from falling asleep, but it will also create the perfect alignment angle for comfortable riding. This angle, used for correct recumbent bicycle size fitting, is usually 90°; and it is the angle the back and legs of the rider make when the crank arms are in neutral position. A closer proximity to this angle will ensure a more comfortable pedaling experience. The placement of this angled bench cushion is shown below in the figure. The angle of the seat will be about 20º from the horizontal, which will bring the rider closer to a correct stance hip angle and thus ensuring comfort.

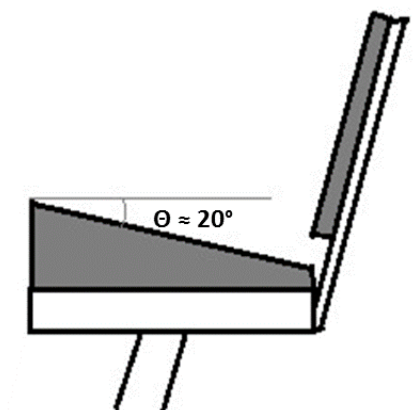

Figure 9. *Angled seating cushion for maximum passenger comfort.*

IV. THE FINAL DESIGN

The final design of the Pedibus was based on the final selections of the different design components based on reliability, simplicity, and efficiency of design. The final product abides to the original design requirement set by the sponsor prior to the fabrication of the vehicle. The following subsections outline in detail the specifics regarding the final vehicle design and fabrication.

A. FINAL DESIGN VEHICLE SPECIFICATIONS

The Pedibus 2.0 is composed of several, semi-complicated subsystems with many specifications each. The following subsections are a breakdown of the specific components utilized in the Pedibus project.

1. FRAME

The frame of the Pedibus is a ladder style frame fabricated of A500 box steel. The vehicle, and frame, length is 16ft with a max with of about 100in. Staying under 102in. of vehicle width was crucial in order to stay in regulation with the Florida towing laws which states that vehicle must be under said length to be legally registered as a towable trailer. The CAD renders of the finalized frame design is depicted in the figures below. These frame renders show the dimensions of the vehicle under the allowed legal limit as well as depict the ladder style after much optimization and simplification.

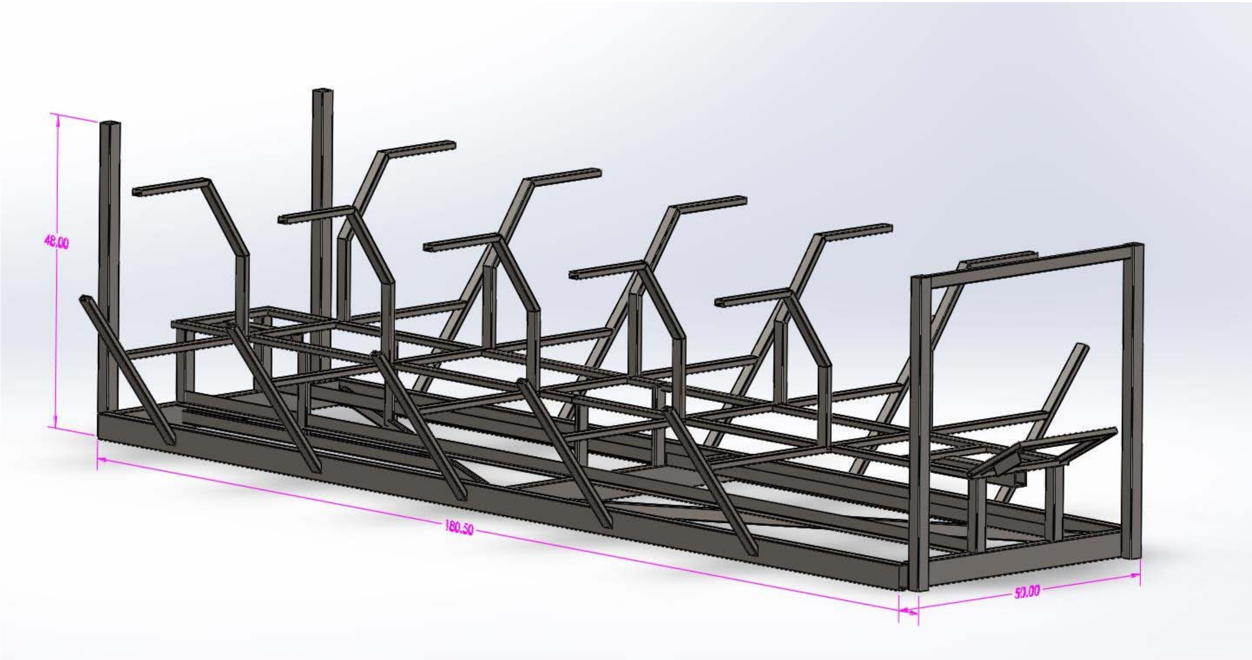

Figure 10. *Finalized frame render with major dimensions.*

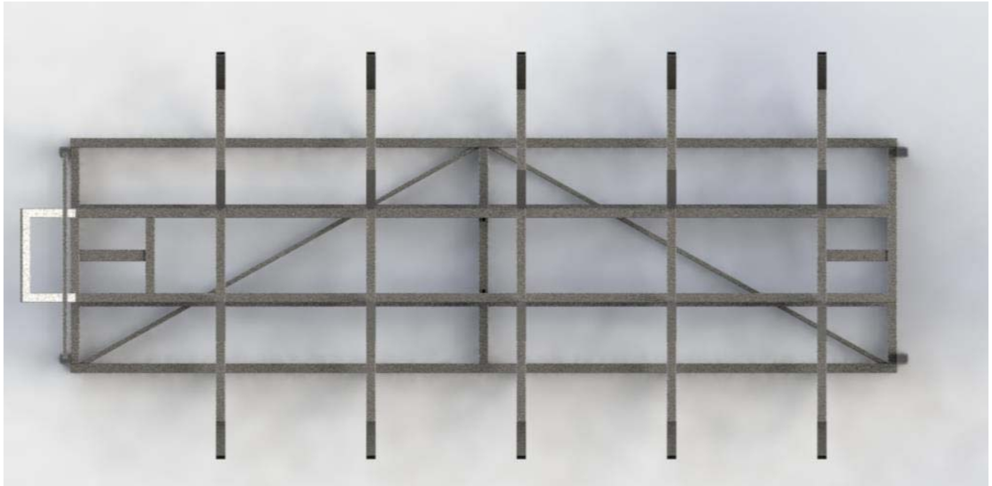

Figure 11. *Top view render of the final ladder style frame design for the Pedibus.*

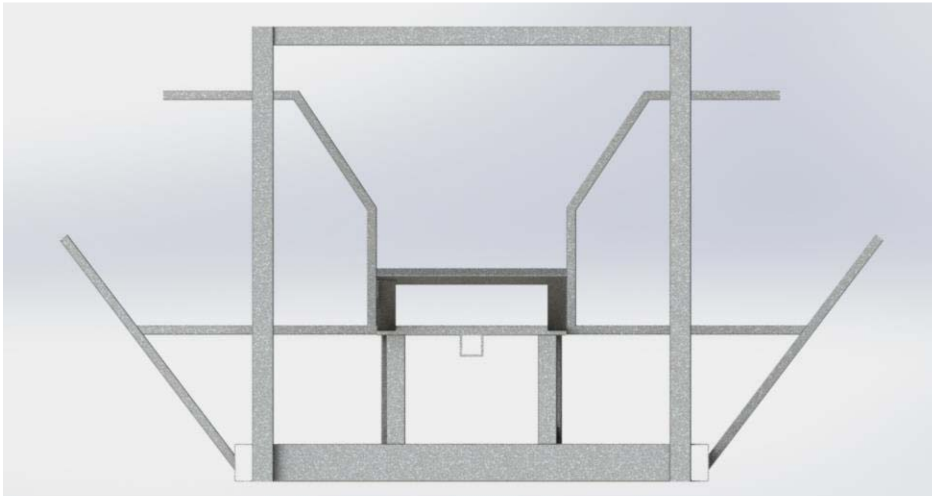

Figure 12. *Front view render of the final ladder style frame for the Pedibus.*

2. POWERTRAIN

The powertrain of the vehicle includes several different components that efficiently transfer the power input from the pedals to the wheels of the vehicle. The cranks are mounted of the bottom brackets attached to the frame and the freewheel gears on the shafts with adapters; then the chains, and chain tensioners were mounted on one of two cold rolled shafts. The single speed bicycle chain utilized connects the crank to one of the two drive shafts under the vehicle.

The 1 inch cold rolled steel shafts run the length of the vehicle and connect to the transaxle. The transaxle used is a Peerless 820 lawnmower transaxle that feature 6 forward speed and a reverse gear. The transaxle acts as an integrated transmission and differential. The system was mounted to the rear of the frame using independently supported axle shafts. A render of the Peerless 820 transaxle as well as the integrated system that was mounted to the vehicle is shown below in the figure**.** Further specifics of the actual transaxle can be found in the manufacturer's user manual for the part.

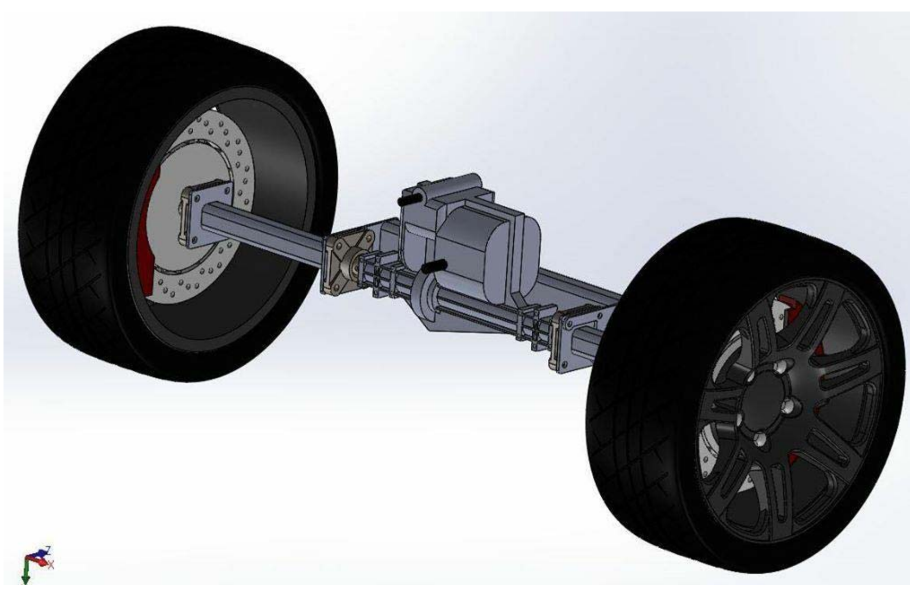

Figure 13. *CAD render of finalized rear axle design including transaxle and axle shafts.*

3. BRAKES AND WHEELS

The Pedibus design utilized automotive brake systems. These are hydraulic disc brakes that work simultaneously from the brake pedal. The vehicle features 10in. disc brakes in the front axle and 8in. discs on the rear axle. Besides the hydraulic normal operation breaking system, an emergency hand brake was implemented to the bus. It is a mechanical car hand brake that is connected via steel cable from the cockpit to the rear right wheel. The Pedibus also features 10in. electric drum brakes that were mounted onto the torsion axle; this will allow for safer towing.

The Pedibus features 16" trailer wheels with a 5 on 4.5" bolt on pattern. The wheels utilized on the project are shown in the figure below.

Figure 14. *16" trailer wheels utilized on the completion of the Pedibus.*

4. TOWING TORSION AXLE

A rubber torsion axle was implemented onto the design to allow for the ability of towing. It is attached to the frame on a 2:3 ratio from the front, as it is standard for single axle towing platforms. The rubber torsion axle is rated by the manufacturer for a maximum load of 3500lbs, which more than enough for what is needed in this application.

5. STEERING

The Pedibus features a custom fabricated rack and pinion steering with a straight axle set up. The steering design implemented allows for a curb to curb of under 45ft, which is comparable to that of a Ford F150. The figure below shows a render of the steering design implemented as well as the actual rack and pinion system that purchased.

Figure 15. *Rack and pinion steering CAD rendering and the actual rack and pinion mechanism purchased for the subassembly.*

B. FINAL VEHICLE DESIGN AND ASSEMBLY

The final vehicle design renders are depicted in the figure below. This figure shows the overall render of the vehicle which includes the mounted bar tops, benches, and roof awning. The dimensions, in inches, of the final vehicle are also seen in the figure below. The main subcomponents, such as the steering and the powertrain, can be seen in these renderings as well as they're placement on the vehicle. Other render views of the vehicle and the frame from different angles are found in Appendix A.

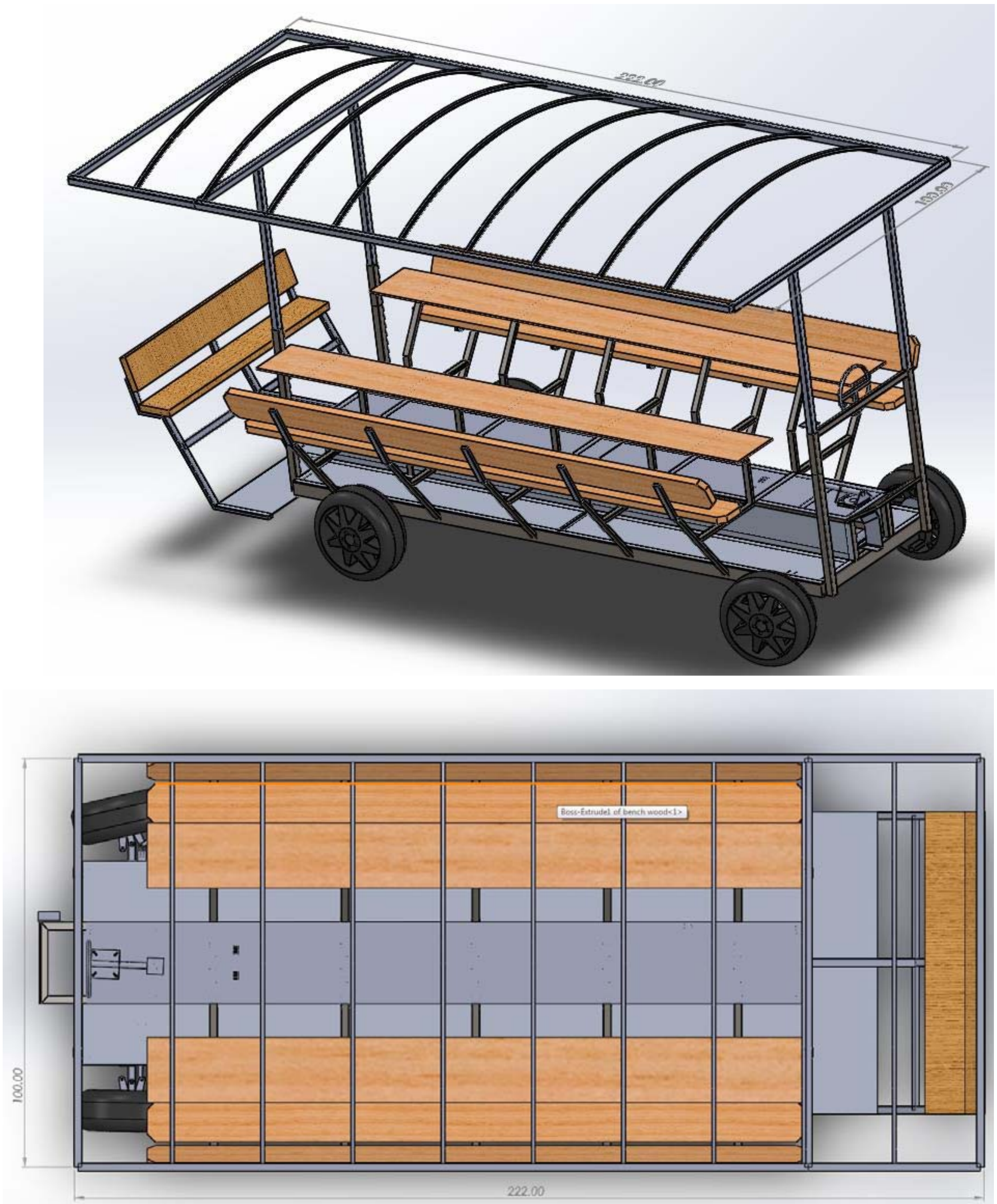

Figure 16. *CAD renders of entire Pedibus vehicle including the roof awning and major subcomponents.*

The vehicle CAD model is, as expected, not a perfect replica of the physical vehicle as there were slight changes that occurred upon manufacturing that were not drastic enough to merit a re-render of the Pedibus in the CAD program. The figure below shows pictures of the physical vehicle after its finalized fabrication and assembly.

Figure 17. *Complete Pedibus after fabrication and integration of outsourced components.*

C. DESIGN CALCULATIONS AND ANALYSIS

The following subsections outline the analysis done on the vehicle prior to its fabrication in order to ensure proper function and safety of the Pedibus. The frame structure was analyzed using computerized finite element analysis modeling on SolidWorks. Other subcomponents were analyzed using vehicle system calculations learned in technical electives.

1. FRAME FINITE ELEMENT ANALYSIS

For the purpose of this report a factor of safety is assumed at 1.3 and that the frame performs similarly and effectively in all bracing configurations in the vertical loading direction based on previous finite element analyses. This assumption will be tested at a later date after the deadline of this report. Bench rigidity testing in the long horizontal direction still needs to be analyzed however, torsional stiffness of the frame with various bracing configurations have been analyzed.

The vertical loading tests were produced in the standard bracing configuration containing no cross bracing on the primary lower frame. The frame was fixed in the vertical and horizontal directions, roughly at the location of the front and rear axles. It was then loaded with 4,500 lbf evenly across the 10 bench seat supports. An additional 500 lbf was applied to the 10 bar top mounts. The maximum deformation was found to be 0.892 in. This deformation was seen at the center of the vehicle at the top of the seat post. The primary frame of the vehicle had a maximum deformation of less than 0.7 in over the entire 180 in frame length.

The torsional loading was performed in 3 different lower frame bracing configurations. Additionally, these three configurations were tested with and without the middle vertical frame supports attached to the bar top supports.

Table 6. *Tabulated results of the FEA performed on the frame of the Pedibus.*

	Max. Disp (in)	Weight (lbs)	Test type	Load (lbf)
Standard w/o bar bracing	13.43	599	torsional	10000
Standard w/ bar bracing	12.65	630	torsional	10000
Full Cross Bracing w/bar bracing	12.18	682	torsional	10000
Full Cross Bracing w/o bar bracing	12.74	650	torsional	10000
Half Cross Bracing	14.85	560	torsional	10000
bi-directional bracing	14.48	584	torsional	10000

The results indicate that the current frame bracing that was being considered is sufficiently rigid under torsion. However, it was also found that the additional vertical supports offered only a marginal increase is rigidity. If the lower bracing were to be changed to a lighter 1x2x.125 diagonally oriented bracing configuration, a potential weight savings of 90 lbs with an acceptable very small loss in rigidity. This configuration would also save costs because the metal usage is significantly less.

The frame FEA analysis proved successful giving the team a confident result on the reliable structural performance of the frame. The team estimated a factor of safety of 1.3 for the structural yield of the frame. The detailed views of the FEA testing are found in Appendix B of this document.

2. VEHICLE COMPONENT CALCULATIONS

The following section depicts the breakdown of the theoretical computations and concepts that were utilized on her design and fabrication of the entire Pedibus vehicle. These include the specifics and schematics behind the computation process for the steering of the Pedibus.

The steering system design consisted of a simple rack and pinion mechanism mounted to a straight support on the frame. The range of motion calculated for vPedibus steering system were adjusted to reflect a turning radius, curb to curb, of under 45ft. This is equivalent to the turning radius of a Ford F-150. The team considered this value to be sufficient in order to efficiently maneuver throughout the streets of Tallahassee. The schematics that were used in the theoretical calculations of the steering component are depicted in the figures below. The figures show the schematic of what the turning radius of the vehicle was defined as well as a general schematic for a rack and pinion steering set up. In the image below, the final render of the steering system is show along with the dimensions that were expected for this component.

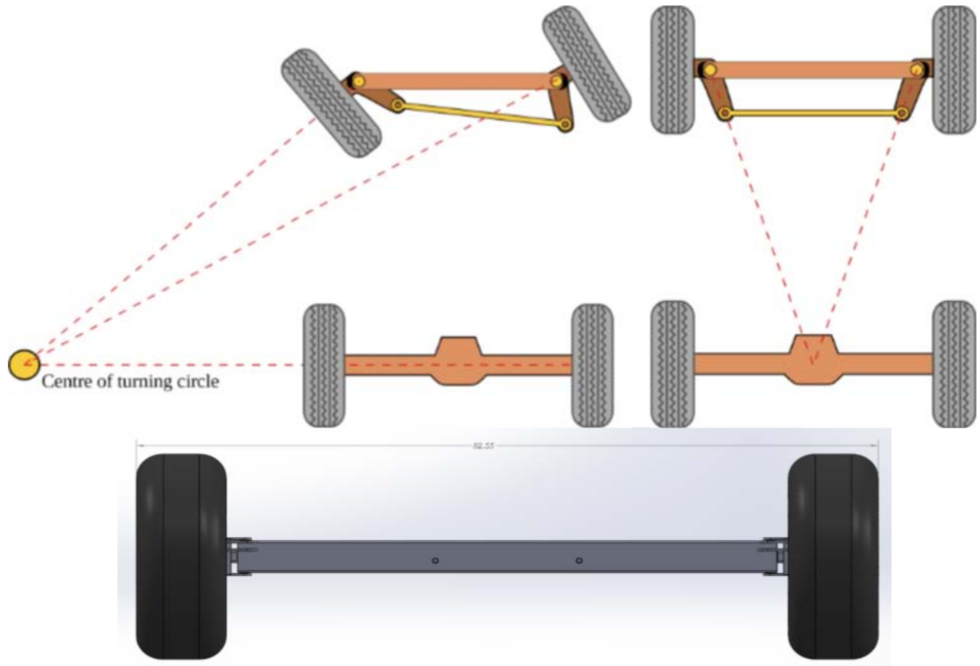

Figure 18. *Schematics behind the design concept of the steering mechanism used on the final Pedibus.*

D. PROJECT DEVELOPMENT FLOWCHART

The team followed a rigorous work flowchart in order to ensure the project deadline of March 28th was met. This flowchart, picture below, represents the design and fabrication process for the Pedibus. The work flowchart is divided into two main subsections representing the two semester that the project was divided over. Some areas of the flowchart overlap, this is because there were separate parts of the project that were being worked on simultaneously and thus they lie side by side on the chronological work flow of the project. The overall project, both design and fabrication, took almost the entirety of the academic year but was successfully managed in order to meet the required deadline.

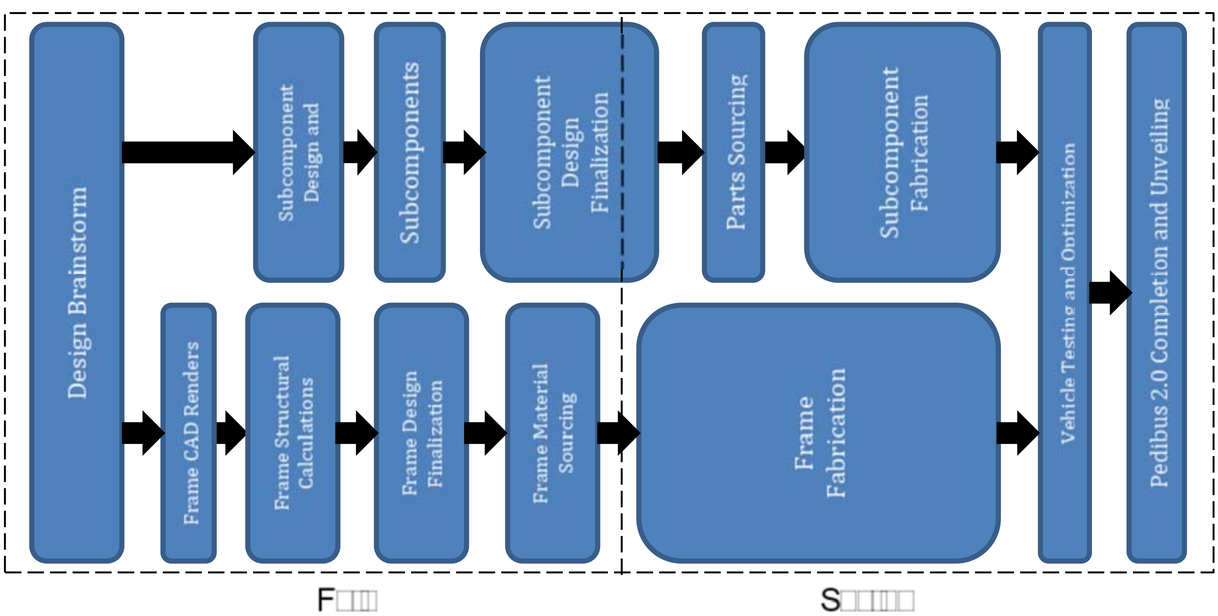

Figure 19. *Work flowchart for the development and fabrication of the Pedibus.*

E. MANUFACTURING AND RELIABILITY

The following subsections outline the manufacturing processes that took part throughout the fabrication of the entire vehicle as well as the reliability analysis of the final product assembly.

1. DESIGN FOR MANUFACTURING

The Pedibus 2.0 project was extremely intense in actual fabrication work and much more than any other project required hands on machining and fabrication. The overall fabrication process starting with the frame and ending with the final product took approximately 3 months. The Pedibus fabrication from start to finish required an approximated 800 hours of actual manual labor distributed between the four team members. The Pedibus required extensive custom fabrication as machining, thus the process took the majority of the semester. The main reason for this was that all of the fabrication was distributed among only four team members, two of which were not very proficient machinist. The build could have been accelerated a significant amount with the addition of extra team members as well as the help of machinists at the shop dedicated to this project only. The lack of ability to work over the weekends or after hours greatly hindered the team's ability to speed up the build, especially when the hour that the shop is open coincides with classes.

The build began with the fabrication of the fame, followed by the seat post and bar structure. This was then followed by the integration of the torsion axle, transaxle mounts, and drive shafts. The cranks were then mounted on the bottom brackets and aligned, corresponding freewheels on the shafts. This was followed by the fabrication of the steering system and its integration to the vehicle. The benches where cut and stained over the weekends and then mounted onto the posts. The transaxle gearing ratio was determined and the gearbox assembled in unison to the fabrication of the coupling mechanisms between the drive shafts and the transaxle. The breaking system was the assembled and mounted onto the frame followed by the necessary brake lines. Meanwhile, the wiring for all the lights was being done as well as the fabrication of the instrument cluster and installation of lights. All chains and gears were then mounted and fastened. The last component fabricated was the emergency brake and the mount for the leaver. The rest of the build was integration rather than fabrication. The bar top was mounted on the vehicle, followed by the stained benches, the floorboards and the roof. Lastly, the brakes were bled, and all systems tested. The final Pedibus build is shown below in the figure.

Figure 20. *Finalized Pedibus after completion of fabrication and integration of outsourced components.*

The following breakdown is to further outline the manufacturing of the subcomponents of the Pedibus including the frame, steering and powertrain.

1.1. FRAME MANUFACTURING

The frame of the Pedibus was the first thing that was manufactured. The steel was order and cut at the school shop and then tacked in place. Once the finalized design was agreed upon and approved by the sponsor the frame was the fully welded in place. The chassis consists of a ladder style frame of approximately 100 inches in width and 16ft in length. The following figures show the CAD rendering for the frame of the vehicle prior to fabrication.

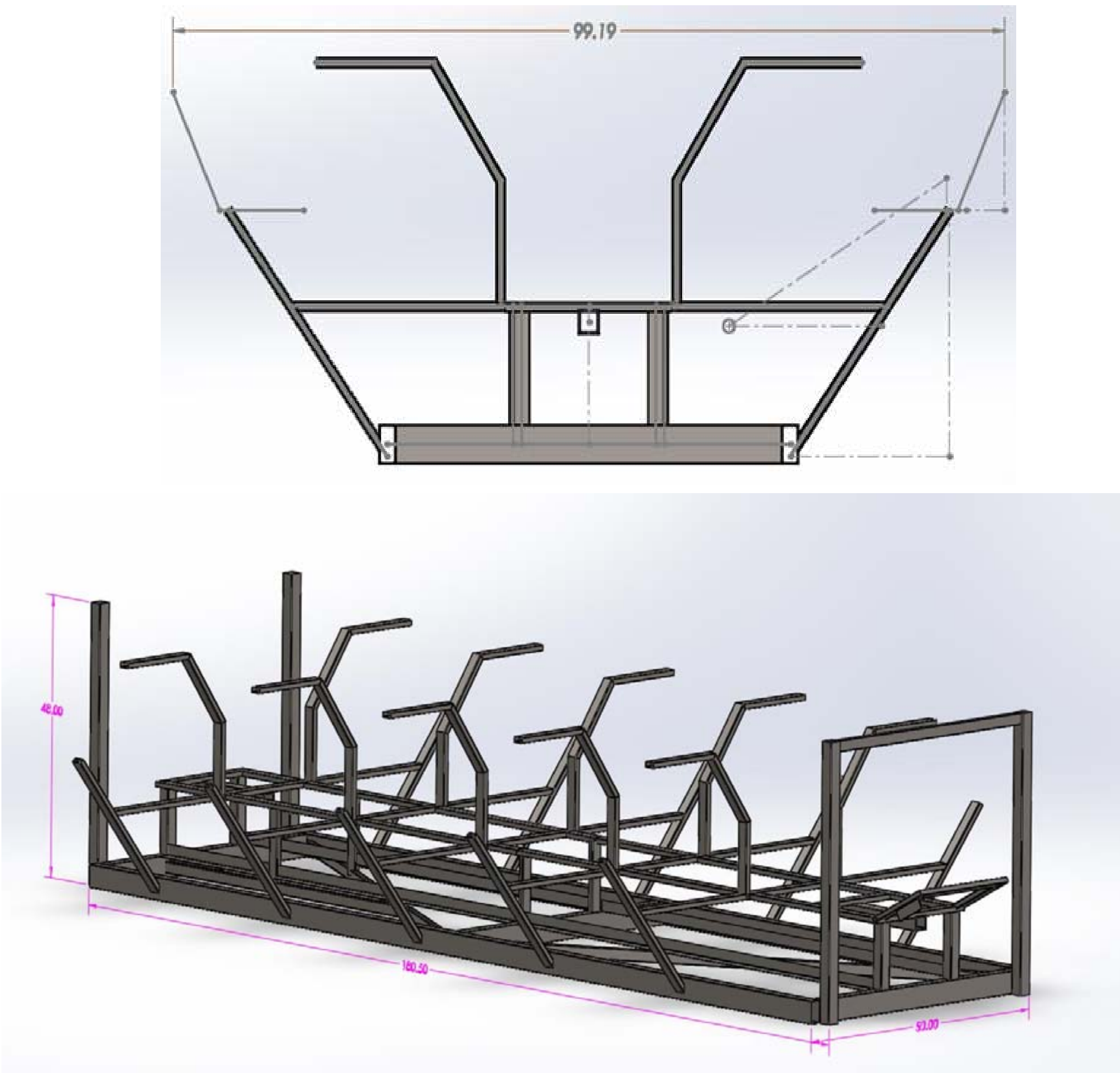

Figure 21. *CAD renders of the final frame design for the Pedibus including the major dimensions.*

Figure 22. *A depicted fabrication progress of the Pedibus frame near its completion.*

The main frame fabrication took, from start to finish, approximately 3 weeks. This includes the time for welding and cutting but not the weekends. The frame was not fully finished until the end of the fabrication process as there were consistently components being worked on in parallel and well as parts being mounted on. The following images show the fabricated frame of the Pedibus prior to adding the floorboards or any wooden components.

1.2. SUBCOMPONENT MANUFACTURING

Running in parallel to the fabrication of the frame and the integration of outsourced components, many of the subassemblies had to be partially machined and fabricated. This process took approximately the length of the entire build, 2.5 months, as is was an ongoing process throughout the entire fabrication. The following two sections outline the detailed manufacturing of the steering as well as the drivetrain subassemblies.

1.2.1. STEERING

The Pedibus features a custom fabricated rack and pinion steering with a straight axle set up. The steering design implemented allows for a curb to curb of under 45ft, which is comparable to that of a Ford F150. The fabrication of this subsystem required extensive machining as many parts required milling. The rack and pinion system was outsourced and integrated onto an axle built in house. The axle consisted of a piece of box steel mounted onto the frame. The steering rack and pinion was adapted onto this shaft and integrated onto the front wheel mounts. The steering rods as well as the u-joints were fed through the frame and secured with brass bushings. The steering took a team member solely dedication to its fabrication about two weeks to complete. The figure below shows a render of the steering design implemented on the vehicle.

Figure 23. *CAD renders of the finalized steering subassembly for the Pedibus including the appropriate dimensions.*

1.2.2. DRIVETRAIN

The powertrain of the vehicle includes several different components that efficiently transfer the power input from the pedals to the wheels of the vehicle. The cranks are mounted of the bottom brackets attached to the frame as seen in the figure. The single speed bicycle chain utilized connects the crank to one of the two drive shafts under the vehicle as seen in the figure below.

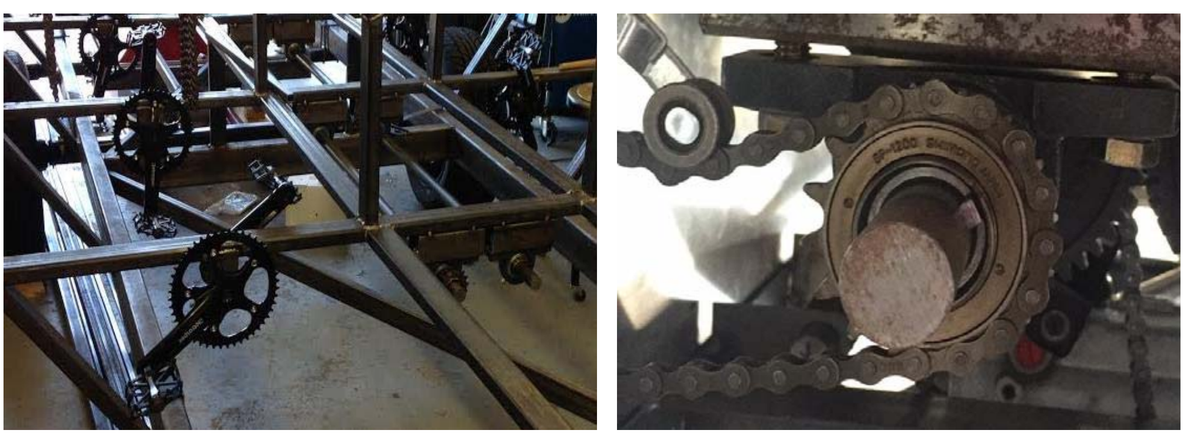

Figure 24. *Cranks mounted on frame as well as the freewheels mounted on the shafts. Both systems aligned and coupled with a tensioned bicycle chain.*

The 1 inch cold rolled steel shafts run the length of the vehicle and connect to the transaxle. These shafts were ran using pillow blocks mounted on the underside of the frame as seen in the figure above. The transaxle used is a Peerless 820 lawnmower transaxle that feature 6 forward speed and a reverse gear. The transaxle acts as an integrated transmission and differential. The system was mounted to the rear of the frame using independently supported axle shafts. A render of the Peerless 820 transaxle as well as the integrated system that was mounted to the vehicle is shown below in the figure**.**

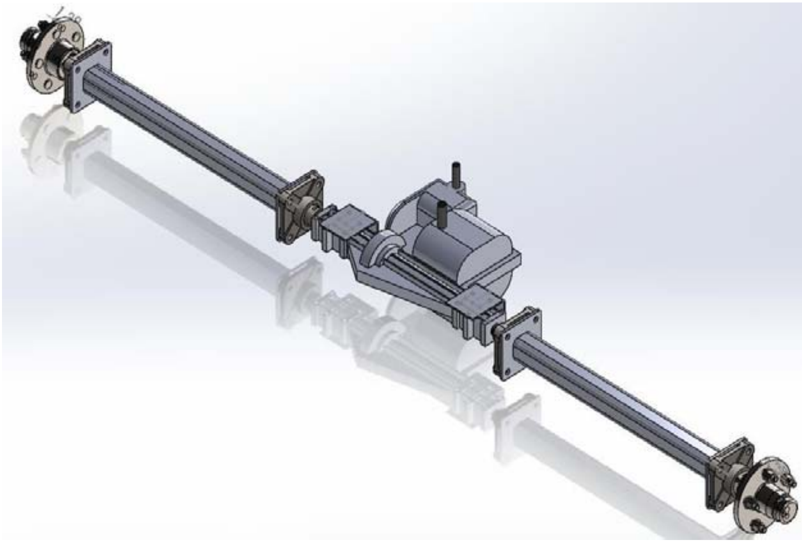

Figure 25. *CAD render of the finalized assembly and design of the rear axle subcomponent of the Pedibus.*

1.3. WOODEN COMPONENTS

The wooden components of the Pedibus include the bar top as well as the benches. The bench fabrication was very simple and straight forwards. The planks of wood were bought, sanded, stained and then mounted to the bench brackets using quarter inch bolts. The bar was outsourced as per request of the sponsor, this was because of the professional cosmetic finish the sponsor desired on this component of the vehicle. The integration of the bar top to the frame was simple and required just a few nuts and bolts going from the underside of the bar to the brackets. The figure below shows the mounted benches on the frame as well as the mounted bar top.

Figure 26. *Finished wood components of the vehicle including the benched and the bar top.*

1.4. ROOF AWNING

The roof of the vehicle, both the structure and the frame construction, was outsourced locally in Tallahassee. This was done in order to speed up the overall fabrication process as well as to relieve some workload from the team. The desired dimensions were sent to the sponsor who took care of the local outsourcing of this part. The roof assembly can be seen in any of the finalized pictures of the Pedibus.

2. RELIABILITY

The team is beyond confident in the performance and lasting operation cycle of the vehicle. The team ensured a robust design with well fabricated components that will come together to ensure long lasting life of the vehicle and its components under normal, suggested operation.

2.1. EXPECTED LIFE CYCLE

The Pedibus is a very robustly built vehicle that will perform well over time. There are not many parts subjected to extreme wear and tear. The team expects the Pedibus to continue to perform as long as proper maintenance is given periodically to the vehicle. Some parts are expected to have a shorter life cycle than that of the entire vehicle and should be replaced when appropriate due to age and wear. These include parts like the benches and bar top which will be exposed to sun and water as well as the bike chains which will stretch. All of the off the shelf components utilized are automotive or trailer grade and have been rated for much more strenuous usage than what these will ever see on this vehicle. The team is confident in the robust build of the vehicle and its performance reliability.

Other careful considerations and calculations were performed in order to ensure the safety and reliability of the vehicle. These include FEA calculation of the frame structure as well and

2.2. POSSIBLE RELIABILITY CONCERNS

Current reliability concerns are very similar to those an automotive manufacturer would take into account. The testing and calculations have been done in order to ensure that the Pedibus will function and perform as well as it is intended too. There are outside factors that can’t always be anticipated from the drawing board, and thus one must use engineering intuition towards minimizing these possible future failures. The team is confident in the structural stability of the frame well and in the performance of the different subcomponents. The team has possible concerns with fatigue failure from the overloading the powertrain, such as the fatigue failure of the shifter of chains. The main concern of the team is failure of a part due to improper use or overlooking routine maintenance. The vehicle will be stored outdoors and thus the components will be exposed to the elements, making it difficult to predict their performance in the far future.

F. ECONOMIC ANALYSIS OF PEDIBUS

The following is a financial analysis of the Pedibus vehicle. It consists of a detailed manufacturing cost analysis for the fabrication and possible reproduction of the vehicle as well as a comparison with other current manufactures of similar vehicle. This provides an insight into the cost that goes into the fabrication of this vehicle as well as a clear comparison of the team’s efficiency in developing a top tier product for a fraction of the competitor’s price.

1. MANUFACTURING COST OF PEDIBUS 2.0

The fabrication of the Pedibus proved to be quite expensive compared to the norm seen in senior design projects. This is due to not only the extensive list of parts on the vehicle but also the amount of material utilized in the fabrication. The team was given no budget by the sponsor but was told to try and under thirteen thousand; which the team successfully did. Not accounting for the cost of labor, which in the case of a usual machinist is around $20 to $25 per hour, the Pedibus 2.0 vehicle had a net cost of $13,550. This value reflects all parts and materials purchased as well as the outsourced components such as the roof and bar top. A detailed procurement list containing all purchased parts along with all important information and cost is located in Appendix C of this document. The invoices for the outsourced roof awning as well as the bar top are located in Appendix C of this document; these receipts reflect the cost of material as well as labor. A graphical representation of the cost break down of the Pedibus 2.0 with major pertinent components is shown below in the figure; this graph shows a comparison of the cost of all major components compared to one another, not including labor costs or the additional cosmetic add-ons such as powder coating.

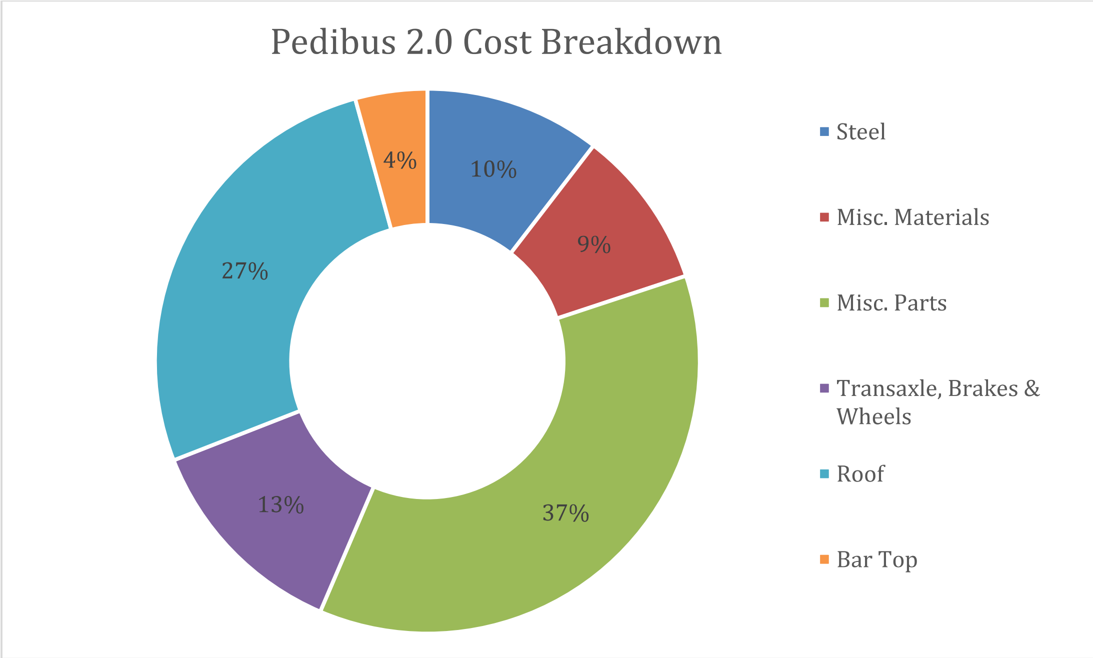

Figure 27. *Graphical cost breakdown of all components of the Pedibus with respect to the cost of the entire vehicle.*

If the Pedibus were to be outsourced to a third party machinist, not involved with the University, the cost of production would be much higher to account for hours of hand labor. Distributed amongst the four team members, the Pedibus fabrication process took an estimated 800 hours of labor. The team estimates that an outsourced fabrication of a comparable vehicle, assuming an average of $22.50/hour, would have a total cost of around $29,000.

2. INDUSTRY COST COMPARISON

The Pedibus, is a one of a kind, custom build multi-user pedal powered vehicle. Although there are vehicles similar in concept the Pedibus, they are also custom fabricated to order and none are the same to each other. This is because there are currently no mass productions of this type of vehicle in the market. All of the existing multi-user, pedal powered, entertainment vehicles are made to order and built with the scope of the particular sponsor. There are a few shops around the United States that have been known to produce these type of vehicles, but none with a fully standardized design. The team reached out to one of these machine shops, Atek customs, which offered a quote for a similar vehicle ranging around $50,000.

The Pedibus 2.0 turned out to be a much cheaper build than the outsourced competitor with the added bonus of innovative features never seen on a vehicle of this type before. This was mainly due to the team's effort to outsource parts with the best possible price to value ratio as well as not receiving any pay for the hours of labor invested into this project. Even when accounting for the hours of labor, the Pedibus 2.0 still proves to be a cheaper option by almost $20,000. One must note that the compared vehicles are fully finished with all cosmetic and entertainment accessories. This means that the vehicles are powder coated, have lights, stereos and finished bar backs. The team worked towards simplicity of the design and thus the team members are confident that this vehicle could be finished with all the cosmetic and entertainment accessories for well under the $50,000 price tag of the competition. The following schematic shows a visual comparison between the costs of the Pedibus and other industry manufacturers. It clearly shows the team’s efficient use of the budget as the total cost of the Pedibus 2.0 is much cheaper than the competition.

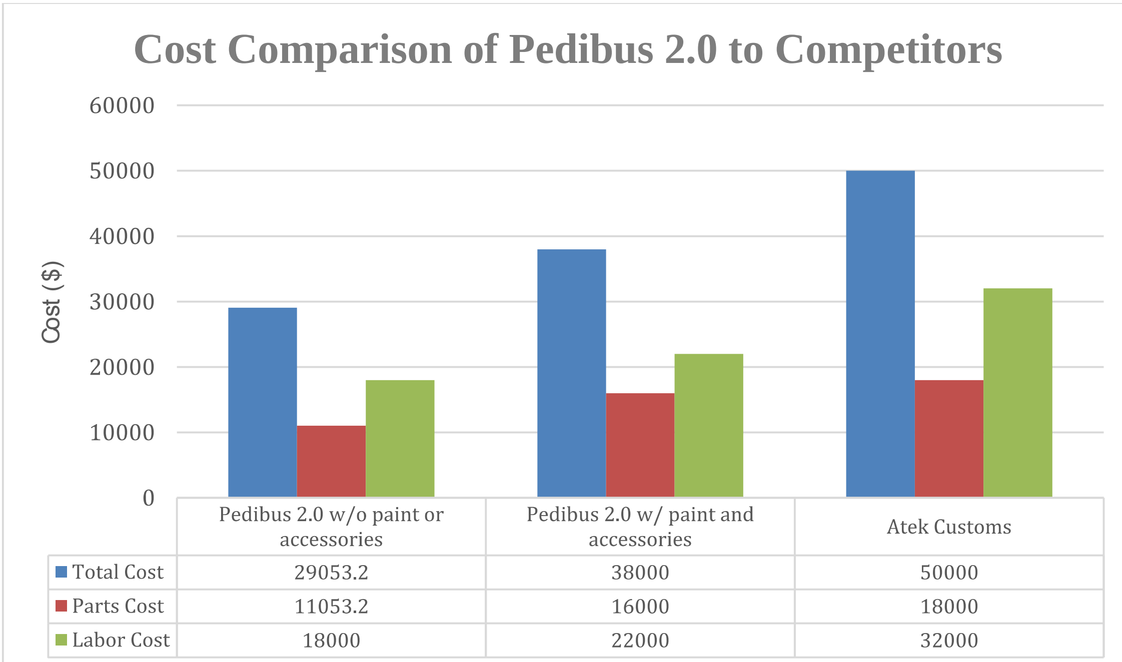

Figure 28. *Graphical manufacturing cost comparison of the Pedibus with respect to other manufacturers in the industry.*

G. VEHICLE OPERATION MANUAL

The following subsections provided a detailed explanation towards to functionality of the vehicle as well as the instructions for operation. This section will provide knowledge on vehicle maintenance as well as repair and troubleshooting information.

1. PEDIBUS FUNCTIONAL ANALYSIS

The Pedibus 2.0 is a multi-user pedal powered vehicle made for the sole purpose of customer entertainment. The vehicle consists of a ladder style steel frame similar to those used in commercial automotive applications. It features a bench seating arranged that accommodates ten peddlers with extra room for non-pedaling passengers. The Pedibus 2.0 project is sponsored by Ron Goldstein, owner of Capital City Pedicabs. The main scope of the Pedibus is to serve as a leisure vehicle in which riders can enjoy refreshments while pedaling around the Tallahassee downtown area. More specifically, the vehicle will serve as a bar on wheels that will attend customers while transporting them between destinations. As of now, the sponsor has no exact business model as to how this vehicle will be implemented into the fleet or which areas it will service.

The functionality and operation of the vehicle itself is quite simple. The customers will board the vehicle and situate on a spot on the bench depending on whether they’re pedaling of not. If pedaling, the passenger will situate themselves in front of a crank. Upon the cranks are mounted in such way that upon pedaling the chain will transfer the motion to one of two drive shafts that run under the frame along the length of the vehicle. The chains are mounted on the shaft with freewheels which not only prevent back drivability but also allow for riders to hold different pedaling cadences. These shafts connect to the transaxle on the back of the vehicle with spur gears which transfer the motion through the transaxle and subsequently to the wheels. This is the scope overview for how the Pedibus works under standard operation. The passengers hold no responsibility other than pedaling. The driver of the vehicle has a set of simple controls to operate which include: a hand brake, a brake pedal, the steering, the shifter and turn signals. The manual transaxle implemented allowed for the vehicle to have six forward speeds and a reverse gear. This gave a vehicle better maneuverability which the ability to reach comfortable cruising speeds but also having low gears for better torque output for hill climbing. The vehicle driver is responsible for understanding the dynamics of a manual transmission in order to efficiently shift the vehicle into the appropriate gear ratios depending on the current driving conditions.

The Pedibus 2.0 was also designed to be free weight towable; which means that it can be towed by any truck with a standard hitch mount. A torsion axle was added to the design in order to eliminate the need for added suspension on the frame. The versatility of the towing allows the sponsor to expand his business model further than the confines of Tallahassee. The sponsor has plans of utilizing this vehicle in nearby towns such Panama City and Pensacola.

The following document outlines the specifics regarding the operation and maintenance of the Pedibus 2.0 vehicle.

2. VEHCILE OPERATIONS INSTRUCTION

Prior to vehicle operation, there is a simple check list that the operator must check in order to ensure safe and successful operation. The actual checklist that has been handed off to the sponsor is shown in Appendix D. This checklist includes simple task such as checking the tire air pressure, checking for leaks in the brake lines as well as battery charge status. The pre-operation completion of this checklist is crucial in order to ensure safe operation.

Upon usage, the vehicle operation is relatively simple. The passenger have the sole responsibility of pedaling, all other operation of the vehicle will be performed by either the bartender of the driver. The passengers must stay alert for any further instructions from the driver during vehicle operation.

The driver has responsibilities similar to those of any driver of a commercial vehicle. The operator is in charge of steering the vehicle as well as maintain a safe route while in motion. The operator is also responsible for the controls of the vehicle. These include: turn signals, which the driver must utilize accordingly during operation, a regular foot pedal brake similar to that of a car, and an emergency hand brake leaver that will lock the wheels in the need of a sudden stop. The diver must also understand the working of manual transmission and he or she will be responsible for shifting between the different speeds of the gearbox depending on the driving conditions. The gear box shifts linearly with the reverse gear being in the most upright position of the shifter, followed by neutral and the six forward speeds subsequently. When vehicle is parked, the hand brake must be engaged in order to reduce load on the transaxle as well as to avoid any undesired rolling.

Upon flatbed towing of the vehicle, the operator must ensure that the emergency brake is engaged. When free weight towing the vehicle, the operator must switch the rear wheels of the bus from rear axle onto the torsion axle. After that, he or she must hitch the Pedibus onto the towing vehicle and connect the trailer lights into the tow plug on the towing vehicle. This is crucial as it will activate the electric towing brakes as well as the brake and turn signals of the Pedibus while in tow. Before towing, the operation must ensure that the roof awning of the vehicle is either removed completely of the tarp covering untied and take off. This is of most importance as failure to do so will create large amounts of wind resistance, a parachute effect, while in tow and can cause the vehicle to bounce or flip.

3. TROUBLESHOOTING

The troubleshooting of the Pedibus is complicated as failures would be more than difficult to predict and thus a solution will most likely have to be generated upon inspection of the particular failure. The general design of all subsystems utilized on the vehicle closely resemble those on many commercial vehicle. The team worked hard to ensure simple and common designs that any car mechanic would be able to repair and work on. Upon failure of any particular component that was outsourced, it is most advised to contact manufacturer for either repair or replacement of the part.

4. VEHICLE MAINTENANCE

The regular maintenance of the Pedibus is simple and any person with slight mechanical knowledge can perform it. The following text breaks down the maintenance into the main subcomponents and explains what the procedure for each case will be.

Steering Components:

Steering Rack: Never. If problem occurs contact automotive repair specialist
Heim Joints: 6 months. Grease with Automotive Bearing Grease.
Steering U-joints: Never. Replace if failure occurs.
Steering Mount Bushings: Pre-lubricated, Impregnated Brass/Bronze. Oil or replace when worn

Pedaling Components:

Cranks: Pre-lubricated, replace if failure occurs.
Driveshaft Pillow Block Bearings: 6 months. Grease with Automotive Bearing Grease.
Freewheels: Never. Replace if failure occurs.
Bicycle Chains: Check tension before every use. Lubricate with 80w90 or equivalent every 3 months.

Drivetrain Components:

Transaxle: Never. Pre-lubricated. Contact Lawn and Garden Service Professional if problems occur.
Axle Support Bearings: 6 Months. Grease with Automotive Bearing Grease.
Driveshaft Gears: 6 months. Automotive Bearing Grease.
Transaxle Chain: 3 Months, Lubricate with 80w90.

Brakes and Tires:

Brake Fluid: Dot 3 Brake Fluid. Bleed yearly. If brakes feel soft check fluid and bleed again.
Brake Pads: Inspect for consistent wear and replace when worn once yearly.
Tires: Check tire pressure before each use.
Tire Replacement: Replace when tread depth is below 1/16", if sidewall damage occurs, or every 7 years
Tire Rotation: Check tread depth at 3 points widthwise, if difference is more than 1/16" rotate tires.

Following the advised maintenance schedule will ensure proper function throughout the life of the vehicle. Most components utilized were outsourced, off the shelf part. This allows for easy and quick replacement of any damaged parts which will ensure minimal vehicle downtime as well as ease of repair.

V. VEHICLE TESTING AND EXPERIMENTATION

The testing performed on the vehicle consisted of physical testing once the Pedibus was fully fabricated in order to ensure proper performance and function of the project. Structural testing was done on the frame by hanging several team members as well as other bodies at the shop walk on the frame all at once to ensure no major deformation or cracking of welds. The team also had several people hanging and jumping on the bar posts and seat post in order to simulate dynamic loading. No failures or major deformation were seen on the frame thus proving the accuracy of the FEA results of the analysis performed on the frame.

The second part of the testing consisted of performance testing, this included experiment very similar to those seen in the automotive industry when testing vehicles. The different tests are listed in the table below along with specifics for what each test entailed. This testing was done on the parking of the college of engineering with the help of fellow students who volunteered to pedal the vehicle while the team noted results. Some alterations were needed throughout the testing, such as changing the transmission gear ratios, in order to fully optimize the performance of the vehicle and ensure proper function. Once the vehicle was fully tweaked and optimized, testing was performed once again to ensure proper operation of all the components of the Pedibus.

Table 7. *Tabulated successful performance test results for the Pedibus.*

Performance Test	**Result**
Pedaling performance (movable by single rider)	Pass
Max speed cadence comfort and vehicle reaction	Pass
Hill Climb (10^{o} grade climb with 10 passengers)	Pass
Steering testing (ease of steering/curb-to-curb < 45ft)	Pass
Breaking (max speed to full stop < 25ft)	Pass

The testing concluded with the Pedibus successfully passing all of the performance testing it was subjected too. The team is confident in the performance and operation of the vehicle based on the results of the design calculations and physical testing.

VI. CONSIDERATIONS FOR EVIROMENT, SAFETY AND ETHICS

The main considerations for this project were those in the areas of safety and ethics. Environmental considerations were redundant since the vehicle will not come into direct interaction with the environment nor have any source of potential environmental damage. The main consideration in the design and fabrication of the vehicle was that of safety, particularly passenger safety. It is imperative, since the vehicle is for commercial use, that it abides to certain standards of customer safety. Some of the considerations taken were the pedaling stance of the rider to ensure comfort and minimize the potential for muscle or bad posture injuries while pedaling on the vehicle. This was done by setting up the seating and pedaling geometry to exhibit that of a recumbent style pedaling stance in which passage in the proposed optimal pedaling height, 5’0” to 6’2”, will not undergo a knee bend of more than 70^{o}. Another consideration was the addition of spacers under the bar top in order to ensure taller riders do not hit their knees against the bottom of the bar top resulting in injury. The last consideration will be a future add on to the vehicle which is the integration of a seat belt system onto the bench; this will ensure passengers with slippery clothing do not slide of the bus in case of harsh breaking. One trivial safety consideration the team took was the grinding down of all possibly sharp corners or edges. This was imperative as it will prevent any possible injury of the passengers if contact is made with these sharp edges.

On the topic of ethics, the team took several considerations. The team maintained open and honest communication with the sponsor which helped both parties stay on the same page throughout the duration of the project. The team, went above and beyond to ensure the vehicle met all the requirements set by Florida Law in regards to towing. Many decisions had to be taken during the evolution of the vehicle in which the team was faced with staying true to their design requirements are make the ethical choice to abide by the law.

VII. PROJECT MANAGEMENT

A. PROJECT DEVELOPMENT SCHEDULE AND GANTT CHART

The team had to abide by a rigorous and very well thought out schedule in order to ensure the completion of the Pedibus fabrication by the proposed deadline. The overall timeline of the project was divided into two main sections, one being the fall semester and the other the spring semester. The fall semester consisted mostly of design development and CAD design, as well as vehicle calculations and theoretical analysis. The spring semester consisted mostly of actual the fabrication work for the Pedibus. The frame structure was the first component fabricated, followed by the integration of the drivetrain components and rear axle. The fabrication of the steering and integration of other components later followed. Lastly, once the fabrication of the vehicle was fully finished, the performance testing took place. The team maintained constant communication with the sponsor resulting in a clear relationship which led to a successful project outcome. The detailed schedule and timeline followed throughout the completion of the project can be found in the team Gantt charts in the Appendix E of this document.

B. RESOURCES

The fabrication of this vehicle required numerous resources, mostly consisting of machining skills, machine shops and labor time. Other trivial resources were utilized by the team throughout the duration of the class such as computers and CAD programs. The main resource that was utilized was the school machine shop. This resource was fully utilized as the team recorded around eight hundred hour of actual shop time while fabrication this vehicle. The machine shop personnel was also utilized for their expertise and previous knowledge in machining certain parts as well as vehicle fabrication. Other resources utilized were outside of the machine shop and sought out by the sponsor himself, these were the outsourcing of the bar top and the roof awning of the vehicle. For future reference, although the team was able to complete the fabrication of the vehicle, having extra shop personnel collaborating with the actual fabrication process would be extremely helpful and would more than definitely produce a better quality vehicle.

C. VEHICLE PARTS AND MATERIALS PROCUREMENT

One of the main scopes of the team was to utilize as little custom fabrication of any of the components and to integrate as many off the shelf parts as possible. This was done in order to facilitate the possible replacement of any part on the vehicle. A complete procurement list of all the specific parts purchased for the full fabrication of the Pedibus as well as information on the vendors and cost is located in Appendix F of this document.

D. TEAM COMUNNICATION

The main challenge the team overcame was lack of efficient communication. This has been resolved by challenging ourselves to communicate more and learn each other's styles of leadership and work ethic. This has allowed for more effective communication with higher levels of understanding within the team. Another challenge that the team faced was being able to collaborate as a group and meet consistently despite of our very different rigorous schedules. The team has successfully tackled this challenge by making our entire schedule available to each other via Google Drive. This has allowed us to coincide on meetings times and create a more successful team environment. The team mostly communicated using Facebook messenger which proved to be the most efficient method of which communication within the team

The communication between the team and the sponsor was very satisfactory and constant. The team and sponsor spoke on a constant basis via email, phone and text. Bi-weekly meeting were also held with the sponsor in order to keep him in the loop with the current status of the build. This kept the sponsor happy and aware of the current project progress as well as kept the team near resources provided by the sponsor. This close communication line proved to be key for the successful development and fabrication for the Pedibus. All other external communication, not within the team, took place via email from the central team account, pedibus2015@gmail.com.

Overall the team was able to effectively communicate within itself as well as with the sponsor and advisor. This was more than helpful in order to successfully complete the vehicle in the time allotted.

VIII. CONCLUSION

As the entirety of the project comes to a close, the team is proud in the outcomes and results of the Pedibus 2.0. The vehicle fabrication has been completed and the Pedibus is currently in fully functional status. Several challenges were encountered throughout the year both on the design phase and fabrication. The team was able to successfully overcome these and produce a final design and product that is innovative, efficient and stays in accordance with all the pre-determined design requirements desired by the project sponsor. The finalized Pedibus vehicle consists of a ladder style frame complete with bench seating, a transaxle transmission which provides six forward speed configurations and a reverse, a rack and pinion steering which increases the maneuverability of the vehicle and a modular torsion axle for towing ability. The vehicle fabrication costs hovers around fifteen thousand dollars, which is much lower than current industry competitors. This manufacturing cost includes the procurement of all parts and materials used, as well as the outsourced components such as the roof and bar top. Constant communication with the sponsor, advisor, and shop personnel allowed the team to design and fabricate a fully functional Pedibus in the most efficient and cost friendly manner. The Pedibus was unveiled at a local Tallahassee parade where countless people around town witnessed the vehicle and expressed their excitement towards riding it. This gives the proposed business model validation as much interest was expressed in riding the vehicle. The sponsor is more than pleased with the final outcome of the fabrication and so is the team. After some optimization and last minute tweaking, the Pedibus passed all of the performance testing it was subjected. This gave the vehicle the final seal of approval concluding the fabrication and testing phase of this year long project. The team is ending this journey with much knowledge and new skills gained both in engineering and vehicle manufacturing. The team is proud of the final product and stands behind its functionality and optimized operation.

REFERENCES

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[3] PedalPub (2014)[Online]. Available: http://pedalpub.com/

[4] Green Zebra Creative(2014). The Party Bike[Online].Available: http://www.thepartybike.com/the-party-bike-photo-gallery

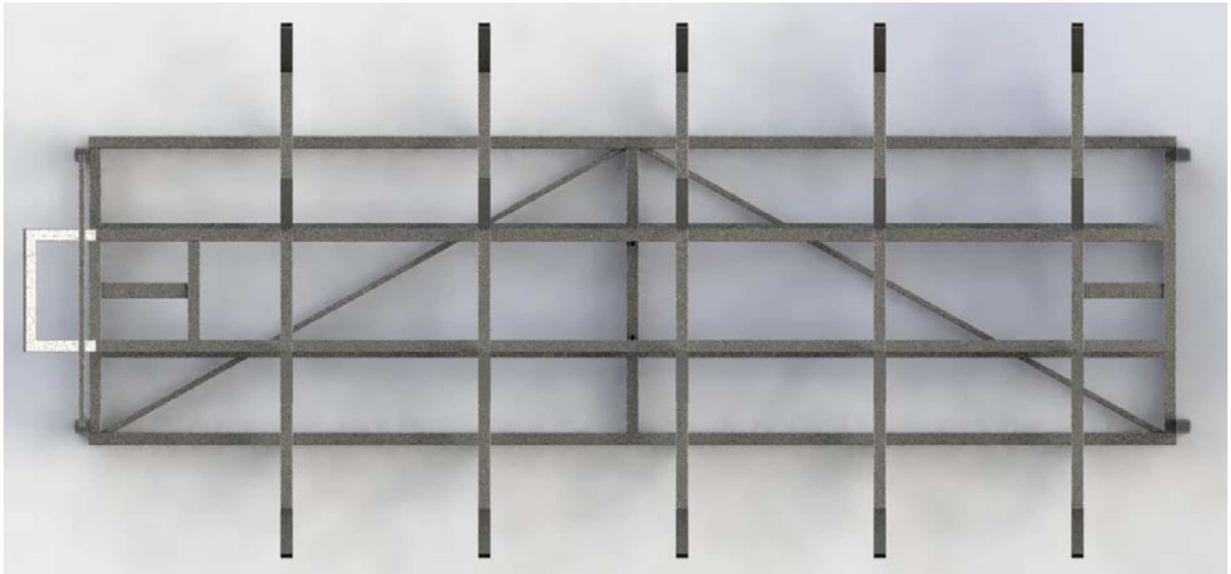
[5] W.W. Grainger, INC. (1994-2014) Grainger[Online].Available: http://www.grainger.com/content?currenturl=%2FGrainger%2Fwwg%2Fstart.shtml

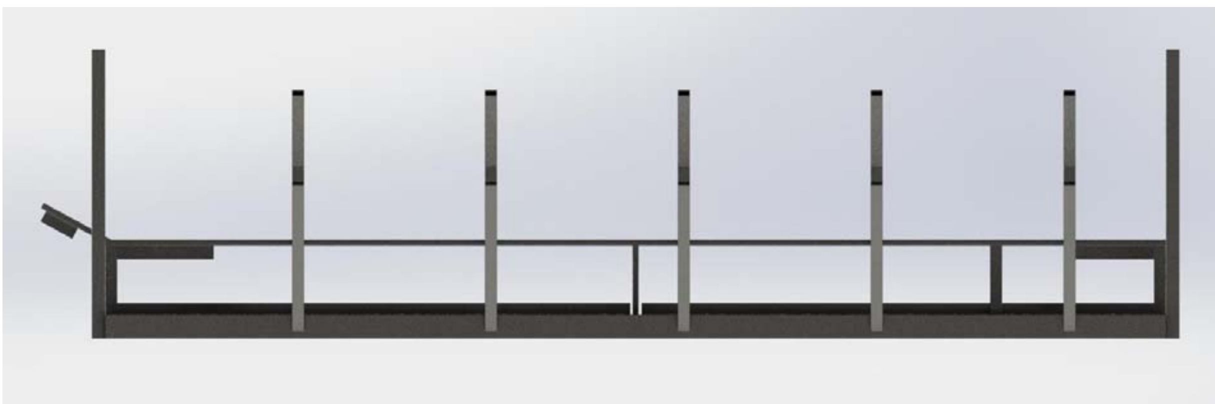
APPENDIX

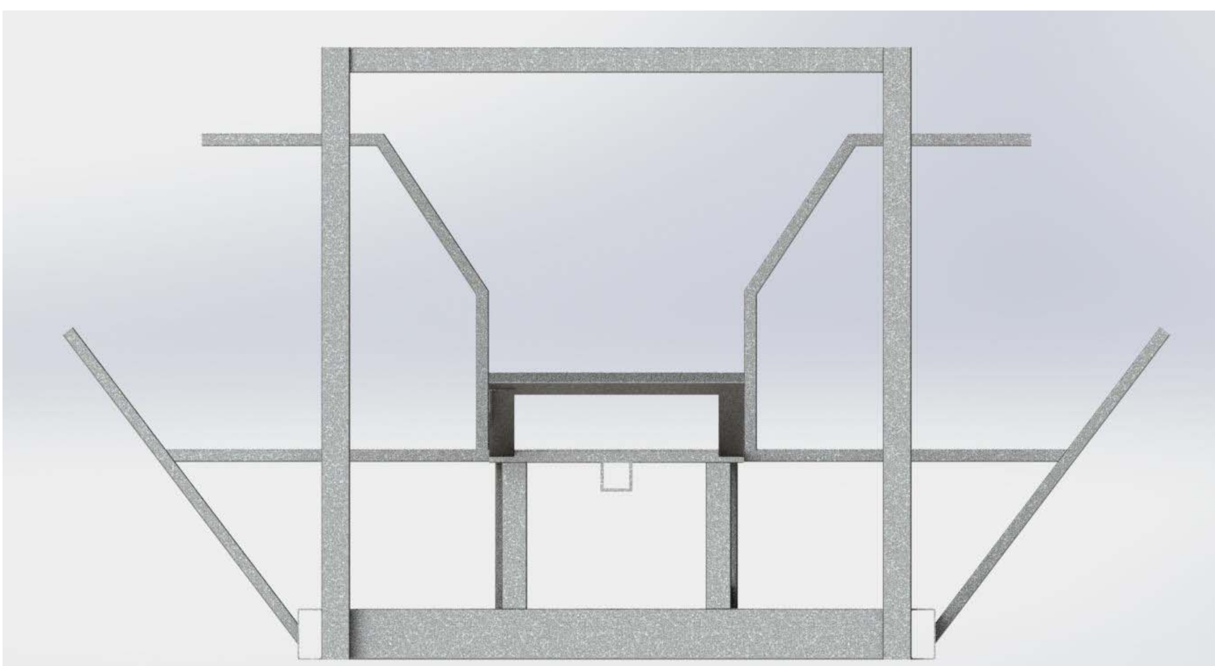
APPENDIX A

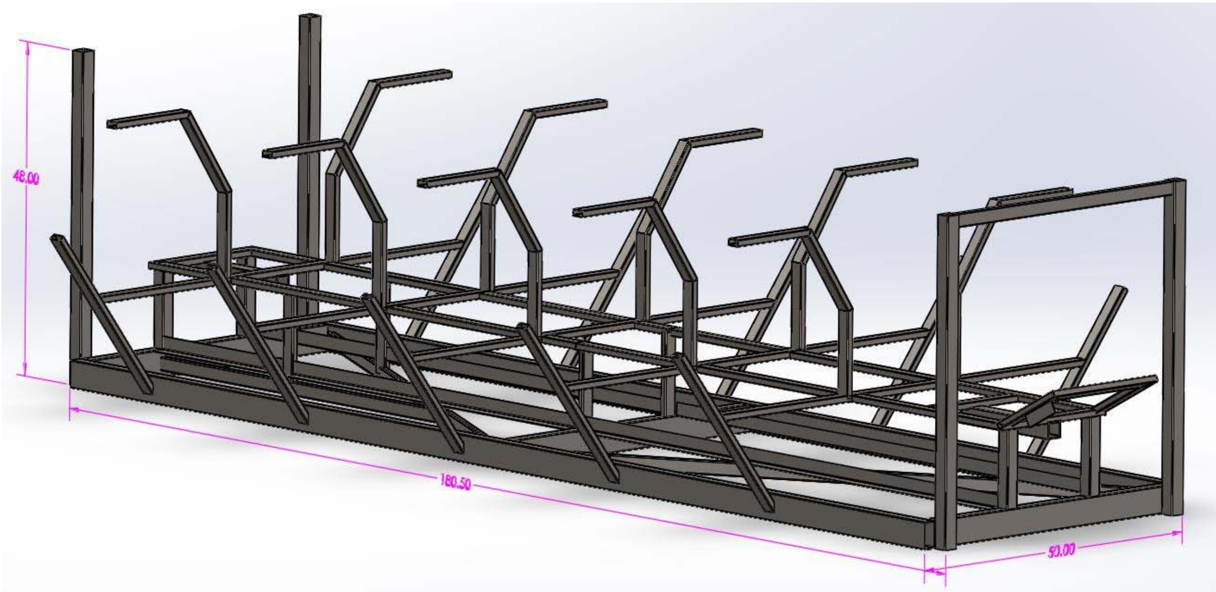
The following appendix contains renders of both the finalized frame design as well as the final renders of the entire vehicle with and without the roof awning.

The following are the final frame renders from different angles including the necessary dimensions.

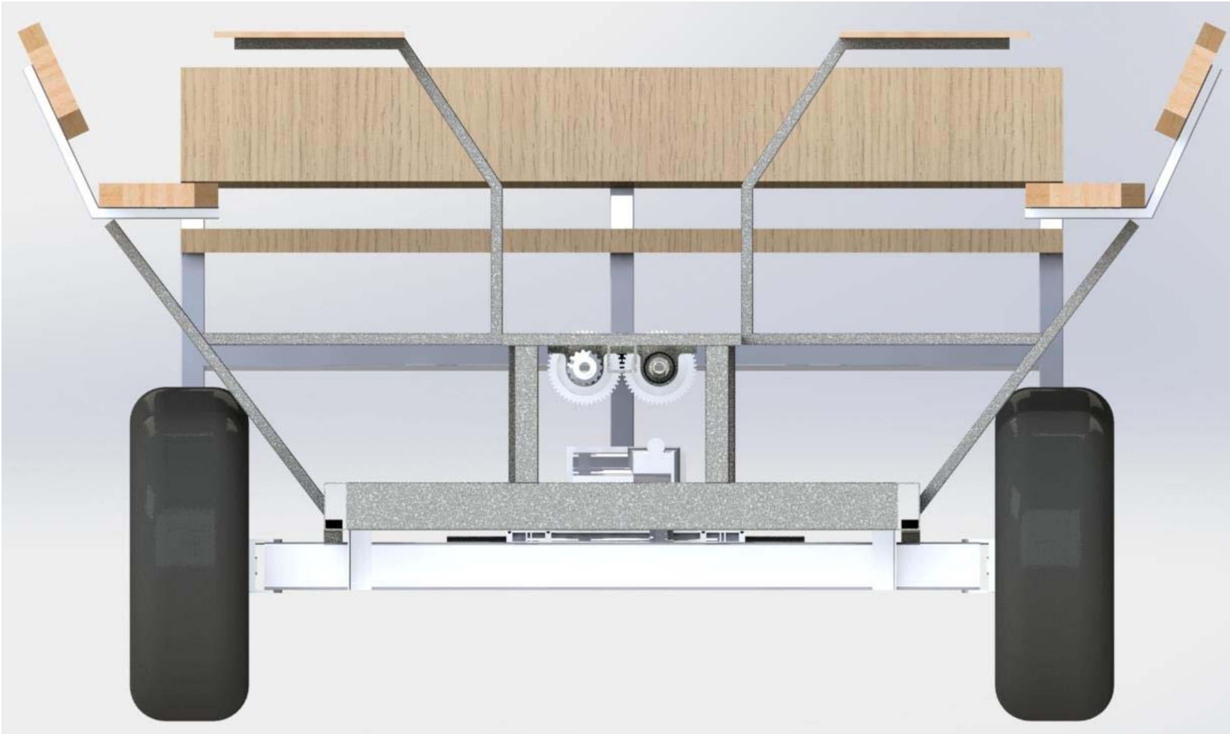




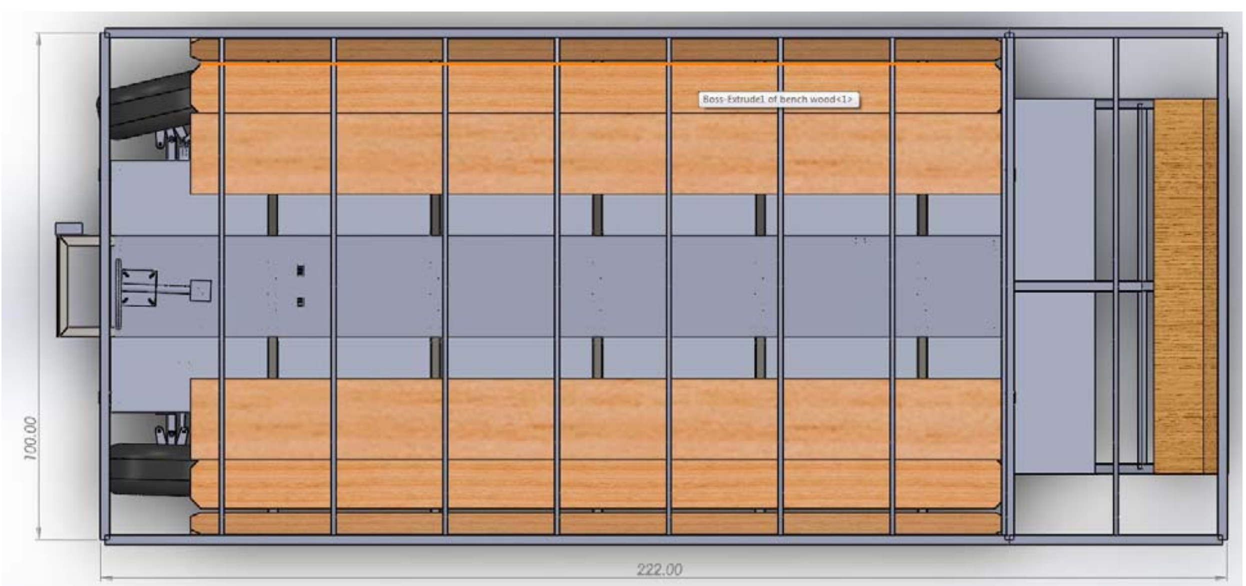




Following are the renders of the final Pedibus assembly with the respective subcomponents but not including the roof awning structure.



The following images are the renders of the Pedibus vehicle including all subcomponents and the roof awning structure. The renders include the main vehicle dimensions in inches.

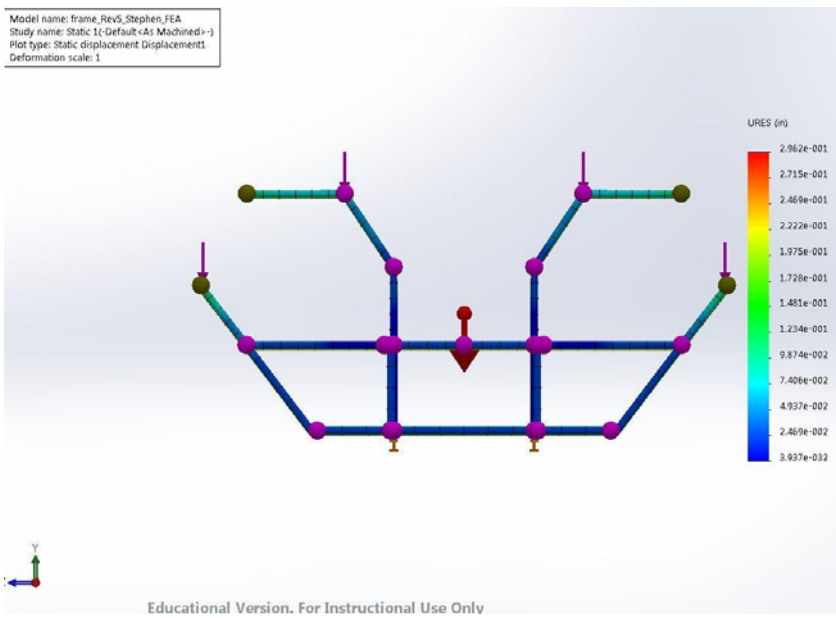


APPENDIX B

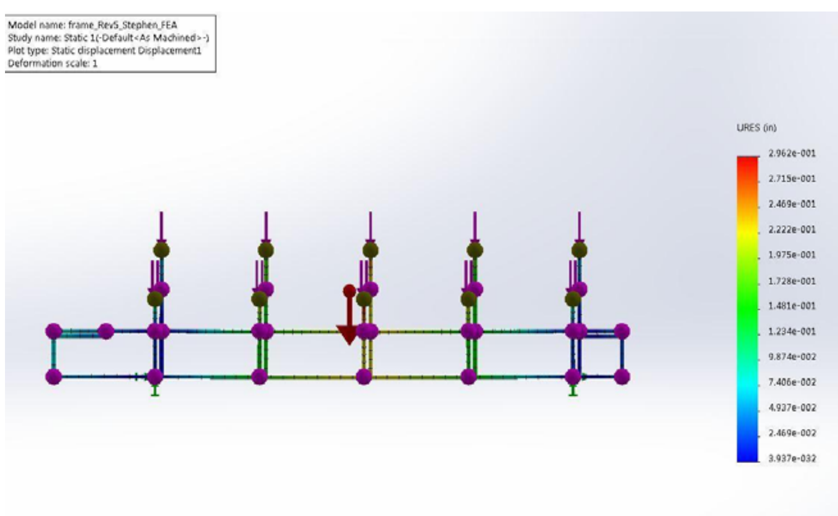
The following images represent the FEA testing that was performed on the frame of the Pedibus. All testing proved successful as team saw no failures. The following pictures depict both the vertical loading tests as well as torsional loading.

Vertical Loading

The vertical loading tests were produced in the standard bracing configuration containing no cross bracing on the primary lower frame. The frame was fixed in the vertical and horizontal directions, roughly at the location of the front and rear axles. It was then loaded with 4,500 lbf evenly across the 10 bench seat supports. An additional 500 lbf was applied to the 10 bar top mounts. The maximum deformation was found to be 0.892 in. This deformation was seen at the center of the vehicle at the top of the seat post. The primary frame of the vehicle had a maximum deformation of less than 0.7 in over the entire 180 in frame length.

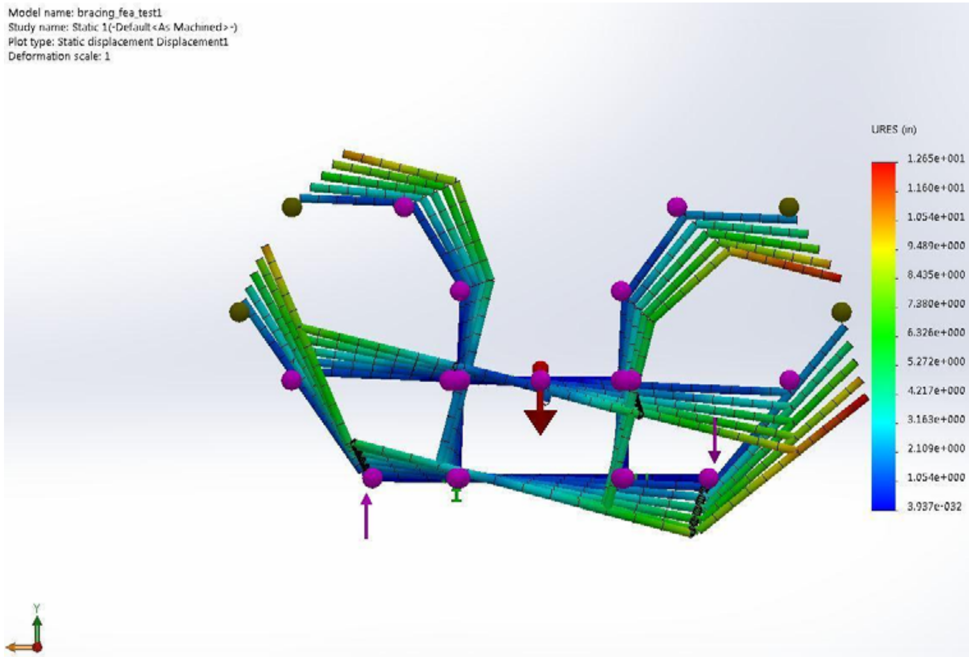


Vertical Displacement, 5000 lbf, Front View

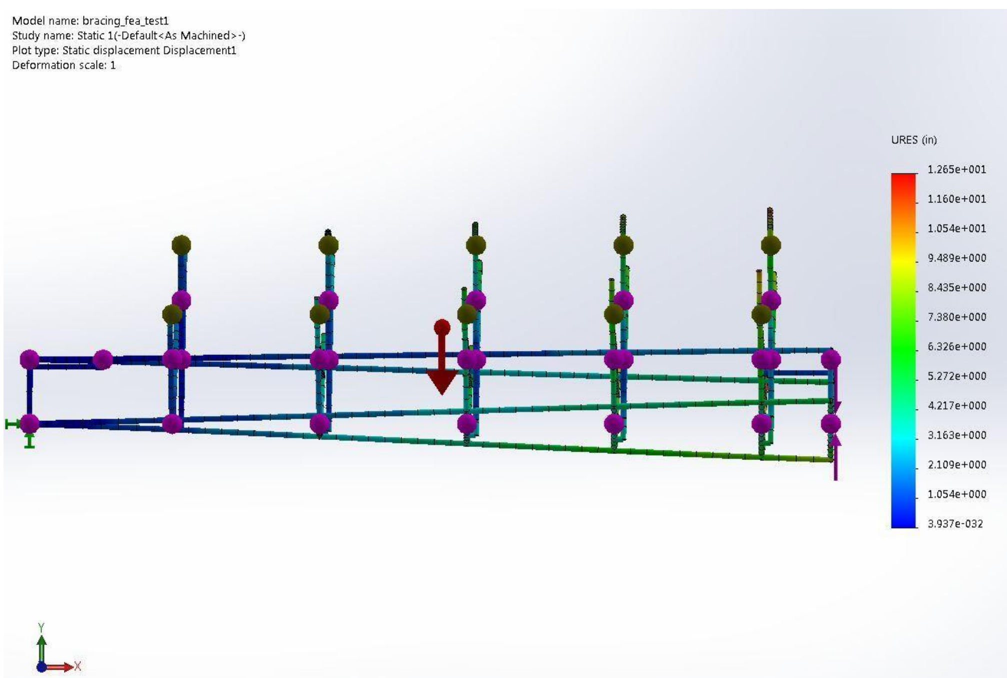


Vertical Displacement, 5000 lbf, Front View

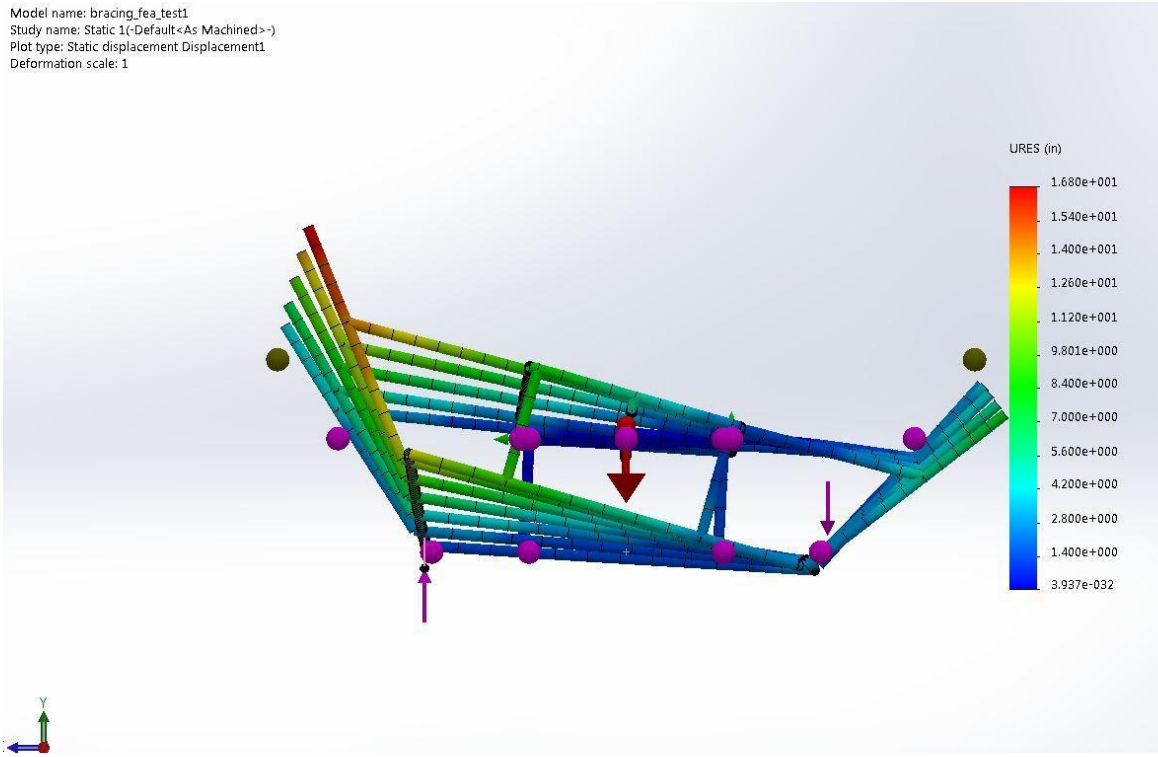
The torsional loading was performed in 3 different lower frame bracing configurations. Additionally, these three configurations were tested with and without the middle vertical frame supports attached to the bar top supports. The visual results are as follows.



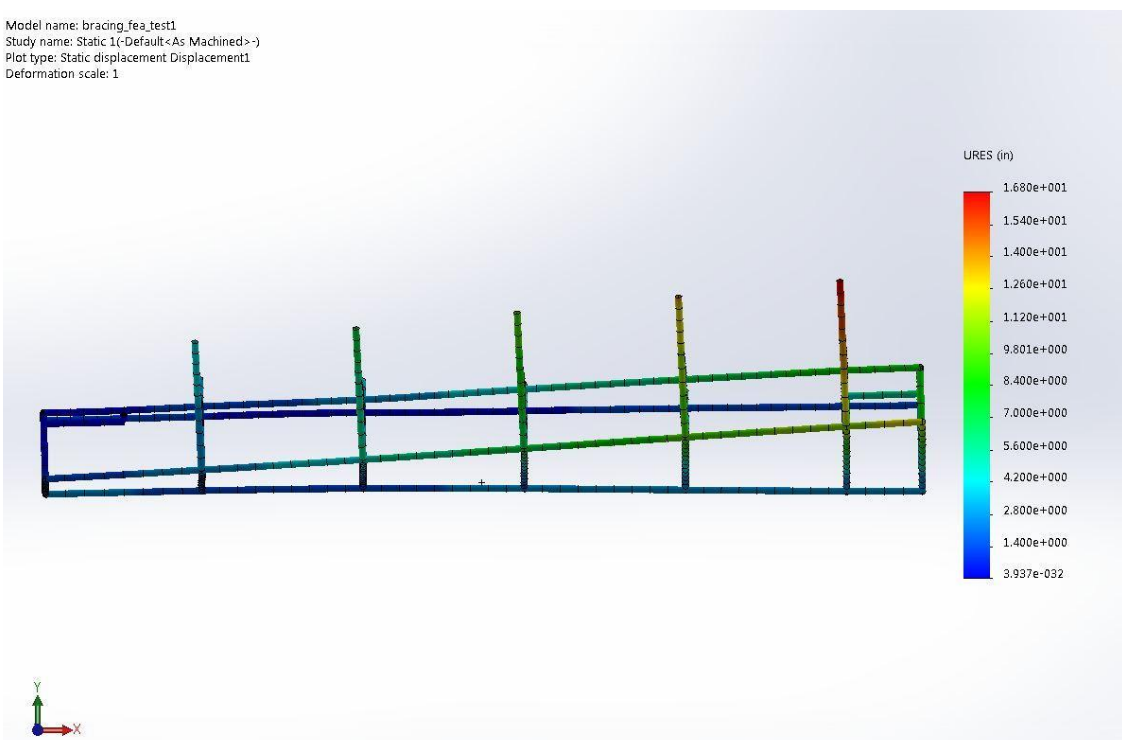
Torsional Displacement Horizontal Bracing w/ vertical supports: 10000 lbf (front view)



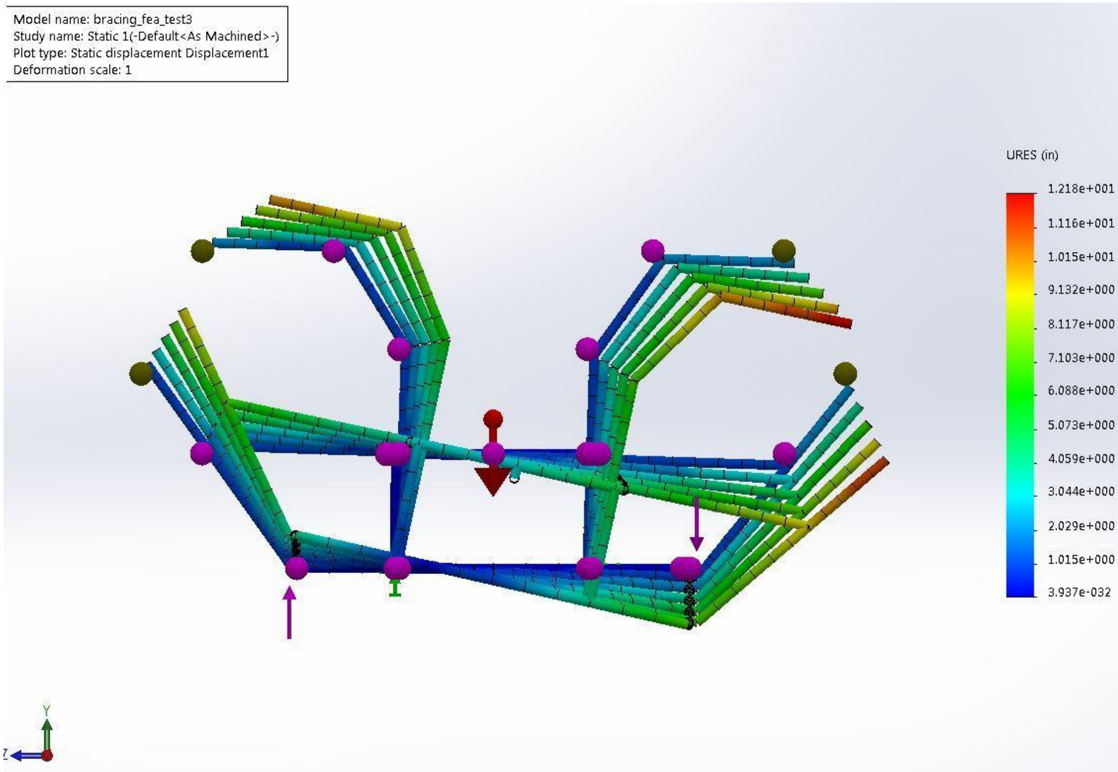
Torsional Displacement Horizontal Bracing w/ vertical supports: 10000 lbf (side view)



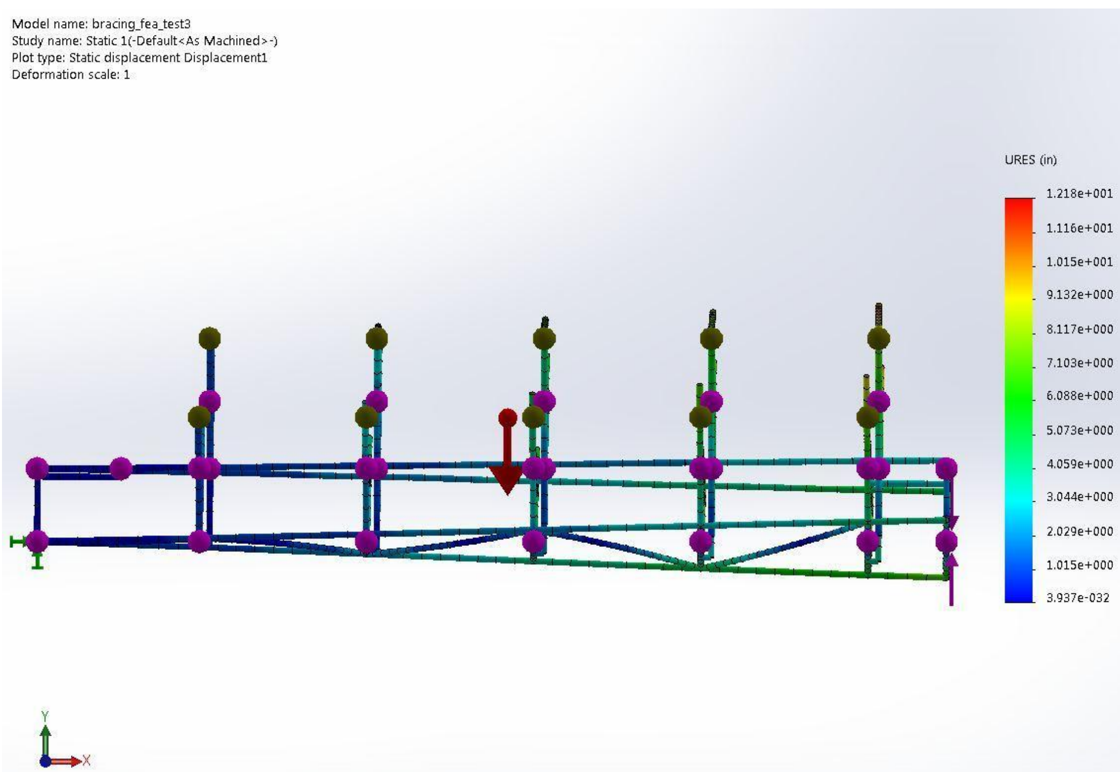
Torsional Displacement Horizontal Bracing w/o vertical supports: 10000 lbf (front view)



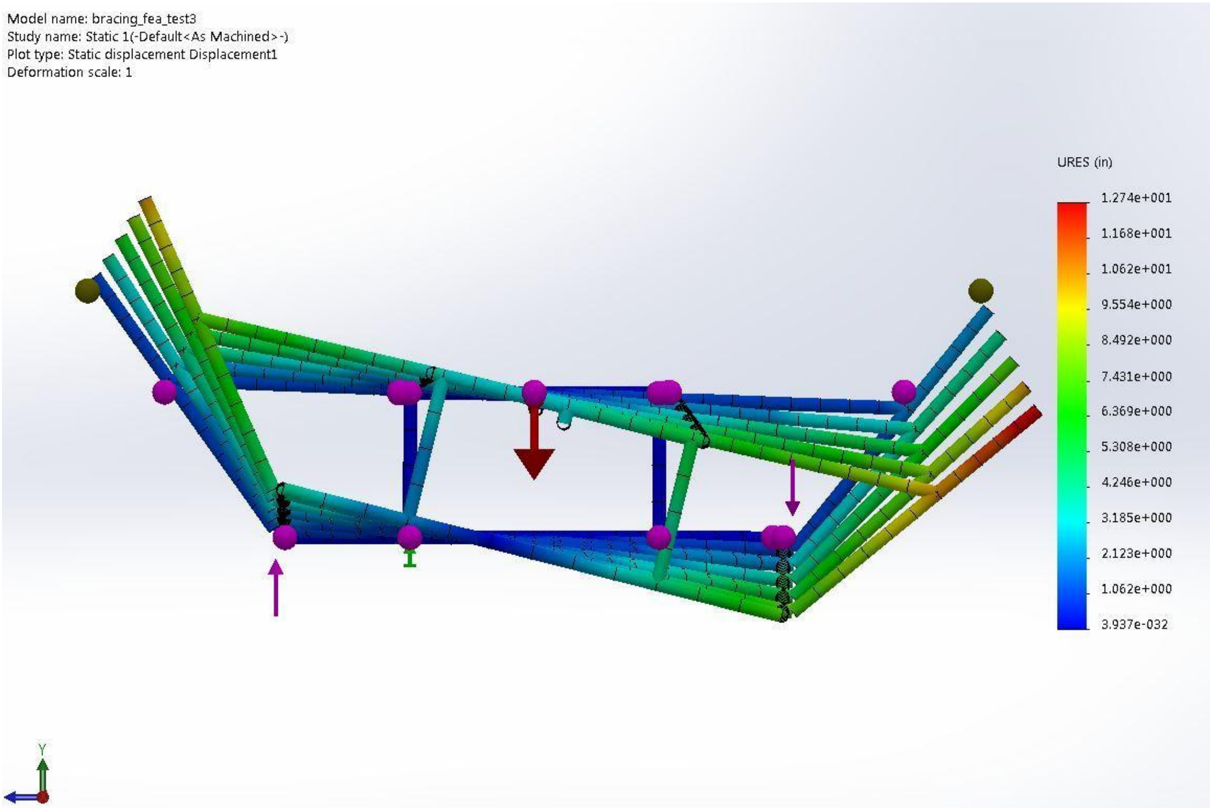
Torsional Displacement Horizontal Bracing w/o vertical supports: 10000 lbf (side view)



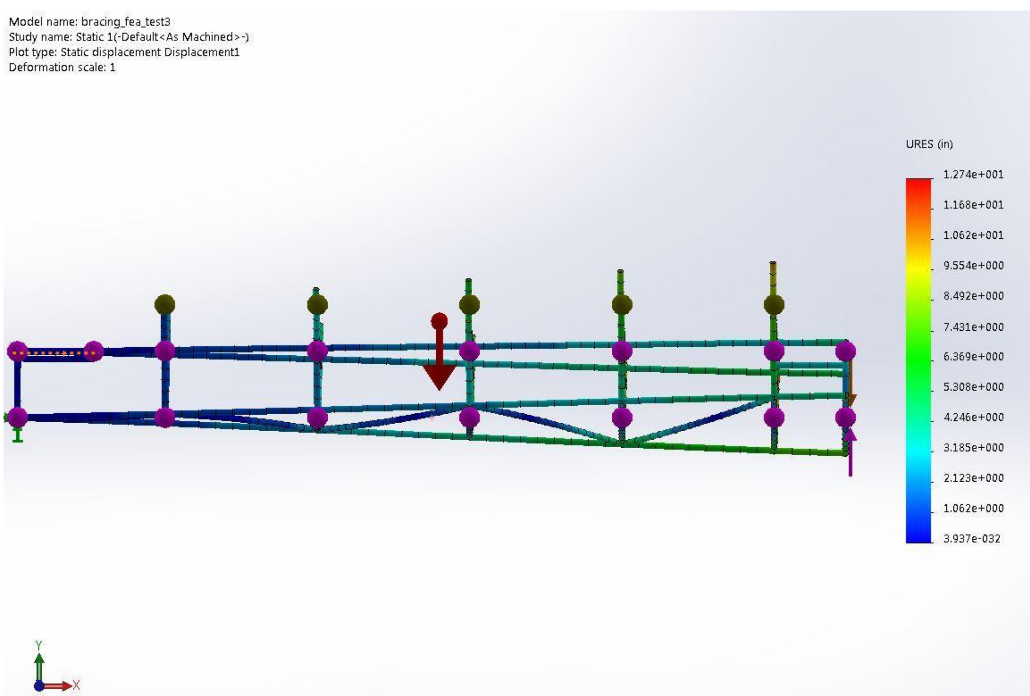
Torsional Displacement Full Cross Brace w/ vertical supports: 10000 lbf (front view)



Torsional Displacement Full Cross Brace w/ vertical supports: 10000 lbf (side view)

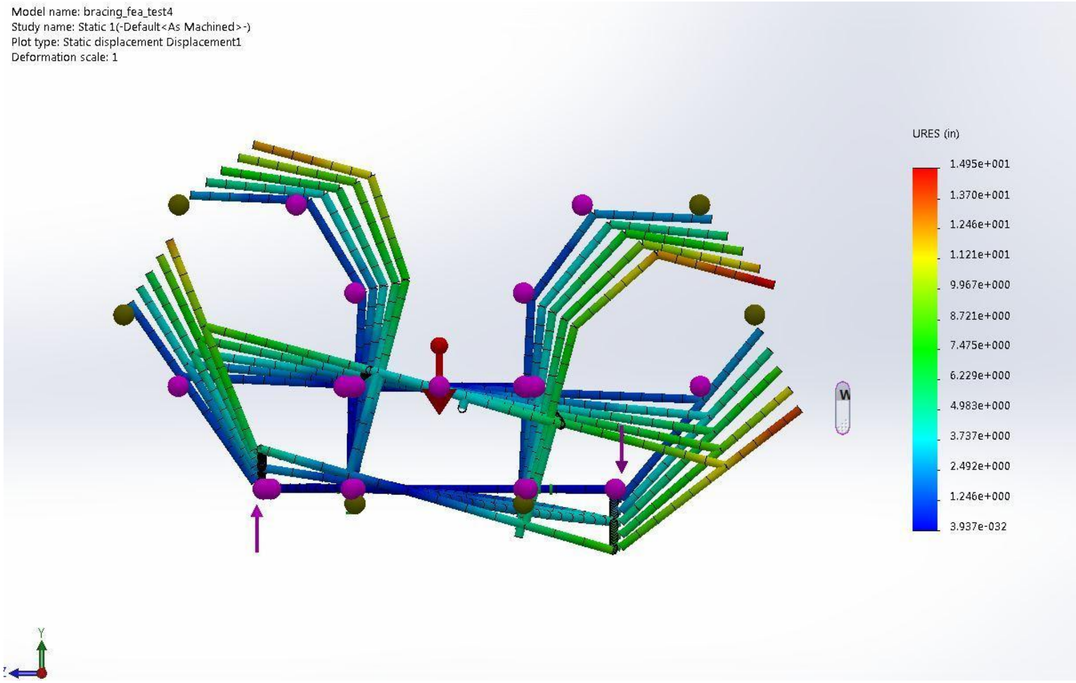


Torsional Displacement Full Cross Brace w/o vertical supports: 10000 lbf (front view)



Torsional Displacement Full Cross Brace w/o vertical supports: 10000 lbf (side view)

For the half cross bracing a model without vertical supports was not made as the design eliminated mounting points for the vertical supports.



Torsional Displacement Half Cross Brace: 10000 lbf (front view)

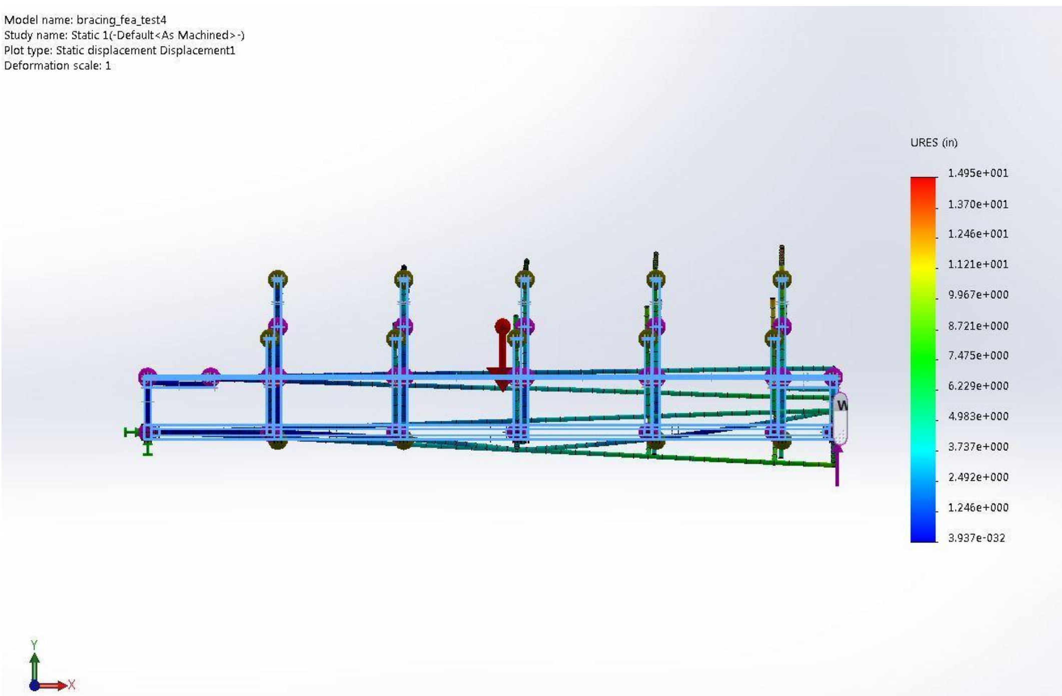


Fig. 12. Torsional Displacement Half Cross Brace: 10000 lbf (front view)

APPENDIX C

The following is a procurement list that shows all the parts that were used on the Pedibus 2.0 fabrication. This list includes information regarding costs, shipping, purchase source and other pertinent financial information of the parts and materials utilized of the build. The list also shows a breakdown cost analysis of the different major subcomponents of the project as well as a total value for all the parts outsourced.

Part	Brand	In-Store/Online	Ordering Source	Source Part #	Price Per Unit	Quantity	Shipping Price	Total Price	Order Date
2x4x1/8 Construction Box Steel (A500)	N/A	In-Store	Sabel	N/A	$84.48	3	$5.00	$258.44	11/19/2014
2x1x1/8 Construction Box Steel (A500)	N/A	In-Store	Sabel	N/A	$58.56	8	$5.00	$473.48	11/19/2014
6 Speed Transaxle	Peerless	Online		N/A	$697.00	1	$39.00	$736.00	11/25/2014
Floor Mount Brake Pedal	Wilwood	Online	Amazon.com	B003XVLGN8	$59.27	1	$0.00	$59.27	11/19/2014
1" Bore Master Brake Cylinder	Wilwood	Online	Amazon.com	B003XVJOHS	$48.05	1	$0.00	$48.05	11/19/2014
5-Hole Brake Drum	AL-KO	Online	Amazon.com	B001IN5KUI	$34.95	2	$20.25	$90.15	11/19/2014
10" Trailer Electric Drum Brake (Left & Right)	TruRyde	Online	Amazon.com	B0098M5LUK	$67.90	2	$0.00	$135.80	11/19/2014
Rubber Torsion Trailer Axle	Reliable	Online	Amazon.com	B000F5861K	$249.99	1	$50.70	$300.69	11/19/2014
Trailer Spindle (#84)	Shadow	Online	Amazon.com	B009COAXVQ	$44.33	2	$9.50	$98.16	11/19/2014
Spindle Bearings	Western Prime	Online	Amazon.com	B00MMSOZAO	$12.95	2	$3.50	$29.40	12/3/2014
10" Trailer Disc Brake Assemblely (1 Axle Kit)	Kodiak	Online	Amazon.com	B006UH5IMC	$237.95	1	$26.50	$264.45	11/19/2014
Bicycle Crank	Retrospec	Online	Amazon.com	B00FNT1BJ2	$35.99	10	$0.00	$359.90	11/19/2014
Bicycle Pedal	Coromose	Online	Amazon.com	B00LXQBXDS	$11.31	10	$1.00	$114.10	11/19/2014
Bicycle Bottom Bracket	Sunlite	Online	Amazon.com	B003COD29C	$15.20	10	$0.00	$152.00	11/19/2014
Bicycle Free Wheel	Shiamno	Online	Amazon.com	B001GSSIIG	$24.65	10	$0.00	$246.50	11/19/2014
Bicycle Chain	KMC	Online	Amazon.com	B0013C7M6E	$7.37	12	$0.00	$88.44	11/19/2014
Wheels/Tires		In-Store	Discount Tire		$169.85	4	$0.00	679.4	12/24/2014
Freewheel Sprocket Adaptor	N/A	Online	Staton-Inc	N/A	$11.69	10	$10.12	127.02	1/16/2015
Lawn Mower Idler	ICpower1	Online	Amazon.com	B001V6OE1S	$11.91	1	$3.99	$15.90	1/14/2015
Pillow Block Mounted Bearing	Hub City	Online	Amazon.com	B00ECZZG7G	$16.97	10	$0.00	$169.70	1/14/2015
Spur Gear	Martin	Online	Amazon.com	B004BDO0EY	$89.65	2	$0.00	179.3	1/14/2015
Bottom Bracket Shell	N/A	Online	Amazon.com	B001GSSL1A	$10.06	10	$0.00	100.6	1/16/2015
1" Bore Diameter Sheave	TB Woods	Online	Amazon.com	B003N17P0Q	$17.35	1	$0.00	17.35	1/14/2015
5/8" Bore Diameter Sheave	TB Woods	Online	Amazon.com	B003N17JRU	$17.09	1	$0.00	17.09	1/14/2015
Hitch Mount Receiver	PMD Products	Online	Amazon.com	B00PB7UV1A	$20.99	2	$25.00	66.98	2/4/2015
Trailer Swivel Mount Jack	Flagline	Online	Amazon.com	B000CQOIVO	$29.59	1	$0.00	29.59	2/4/2015
Husky Ball Coupler	Husky	Online	Amazon.com	B004OK86O4	$18.49	1	$0.00	18.49	2/4/2015
Towing Trailer Lights	ucostore	Online	Amazon.com	B0041AOHZ2	$31.95	1	$5.99	37.94	2/4/2015
Driver Seat	Wise Economy	Online	Amazon.com	B00LG7VIRU	$34.00	1	$0.00	34	1/26/2015
Rear Axle Shaft	Dorman	Online	Amazon.com	B000C14QES	$102.86	2	$0.00	205.72	1/26/2015
Rear Disc Brake Rotor	Dura International	Online	Amazon.com	B00BLYZ9P0	$26.66	2	$0.00	53.32	1/26/2015
30 mm Mounted Bearing	VXB	Online	Amazon.com	B002BBOF5W	$17.79	2	$0.00	35.58	1/26/2015

5/8 Mounted Bearing	SKF	Online	Amazon.com	B00DBNPQ5M	$47.35	2	$9.95	104.65	1/26/2015
Right Rear Disc Caliper	ARC	Online	Amazon.com	B0001YFTXQ	$60.61	1	$0.00	60.61	26-Jan
Left Rear Disc Caliper	ARC	Online	Amazon.com	B0001YFTYK	$59.95	1	$0.00	59.95	26-Jan
Seat Swivle	Springfield Marine	Online	Amazon.com	B000KKB811	$24.60	1	$9.08	33.68	1/26/2015
Bench Seat Wood Planks (2x10x16)	ACQ Top Choice	In Store	Lowes		$19.97	4	$0.00	79.88	2/5/2015
Bar Top Wood Planks		In Store	Lowes		$19.97	4	$0.00	79.88	2/5/2015
Bench 3/8 by 2.5" Carriage Bolts (Box of 100)	HM	In Store	Lowes		$37.00	1	$0.00	37	2/5/2015
Bench 3/8" Washers (Box of 100)	HM	In Store	Lowes		$11.00	1	$0.00	11	2/5/2015
Bench 3/8 Hex Nuts (Box of 100)	HM	In Store	Lowes		$10.00	1	$0.00	10	2/5/2015
1-1/4" x 3ft 12 GA Bench Brackets		In Store	Lowes		11.15	6	0	66.9	2/5/2015
1-1/4" x 6ft 12 GA Bench Brackets		In Store	Lowes		22.59	2	0	45.18	2/5/2015
^^LOWES TAX AMOUNT					$23.37	1	$0.00	23.37	
1/8 X 8ft Sheet Metal		In Store	Kelly Sheet Metal		$31.18	1	$0.00	31.18	2/2/2015
1" Round Driveshaft Steel (20')		In Store	Sabel Steel		$34.01	2	$10.00	78.02	2/9/2015
3/4" Round Steering Column Steel (20')		In Store	Sabel Steel		$19.07	1	$0.00	19.07	2/9/2015
2" x 1/4" Square Tubing		In Store	Sabel Steel		$80.40	1	$0.00	80.4	2/9/2015
1/4" Coil Plate (for mounting brackets)		In Store	Sabel Steel		$45.89	1	$0.00	45.89	2/9/2015
Steering 3/4"-10x5.5" Hex Cap Screw		Online	Fastenal.com	13374	$4.79	2	$10.84	20.42	1/26/2015
Steering 3/4"-10 Nylon Nut		Online	Fastenal.com	169783	$2.86	4	$0.00	11.44	1/26/2015
3/8"-16x2"x7" U Bolts (with nuts and washers)		Online	Fastenal.com	156516	$11.34	4	$0.00	45.36	1/26/2015
^^FASTENAL TAX AMOUNT					$5.80	1		5.8	1/26/2015
Steering Rack & Pinion		Online	Summitracing.com	HFM-HEXSR2	$123.45	1	$0.00	123.45	1/26/2015
Steering Wheel		Online	Summitracing.com	REB-270-8675	$41.97	1	$0.00	41.97	26-Jan
U Joint		Online	Summitracing.com	UIS-8052510	$22.99	2	$0.00	45.98	1/26/2015
Rear Brake Pads	Dura Int	Online	Amazon.com	B001UCGPVU	$15.13	1	$1.59	16.72	2/25/2015
Sheave	TB Woods	Online	Amazon.com	B003N17JU2	$6.01	1	$0.00	6.01	2/25/2015
McMaster Order (**see invoice**)		Online	McMaster.com					$142.48	2/17/2015
Chain Tensioners	Razor	Online	Amazon.com	B008BPNIVY	$14.51	10	$24.39	$169.49	
McMaster Order (**see invoice**)		Online	McMaster.com					$10.48	2/24/2015
McMaster Order (**see invoice**)		Online	McMaster.com					$259.64	2/23/2015
U-Joint, 9/16 In 26-Spline to 3/4 Round	Sweet Mfg	Online	Speedway.com	91032237	$49.99	1	7.3	$57.29	2/23/2015
Fastenal Order (**see invoice- 106648)		In Store	Fastenal					$23.18	2/24/2015
Fastenal Order (**see invoice- 106537)		In Store	Fastenal					$17.47	2/20/2015
Cold Rolled 1" Shafts		In Store	Sabel Steel					$97.76	2/16/2015
2 x 1 Rectangular tubing		In Store	Sabel Steel					$117.12	2/16/2015
Lowes Order (**see invoice- 02707)		In Store	Lowes					$72.48	2/25/2015
Lowes Order (**see invoice- 67005)		In Store	Lowes					$241.22	2/25/2015

Total Price $10,132.40

Steel	1155.47
Misc. Materials	1046.27
Misc. Parts	6532.58
Transaxle, Brakes & Wheels	1397.68
Roof	2945.50
Bar Top	472.50
Total	**$13,550**

The following two scans show the invoice for the outsourcing of the roof awning as well as the bar top respectively. Both of these costs are included in the price breakdown of the project and these include material and labor costs.

Capital Quality Services, Inc.
d.b.a
CAPITAL AWNING COMPANY
1510-2 Capital Circle S.E.
Tallahassee, Fl. 32301
850-878-5383 Fax 850- 878-3167
www.capitalawningfl.com

4/3/2015

Invoice

121937

Balance Due $2,945.50

Bill To	Job/Project
Tally Pedal Tours LLC Tall. Fl.	Tally Pedal Tours LLC Tall. Fl.

PAID 04/03/2015

Serviced	Item	Description	Qty	Amount
	Awnings/New	Fabricated one half barrel flat face awning Front and back panels 100" Wide 222" Long Solid Acrylic fabric--Black		2,200.00T
	Powder Coat Frame Work	Black		540.00T

Terms **On Receipt**

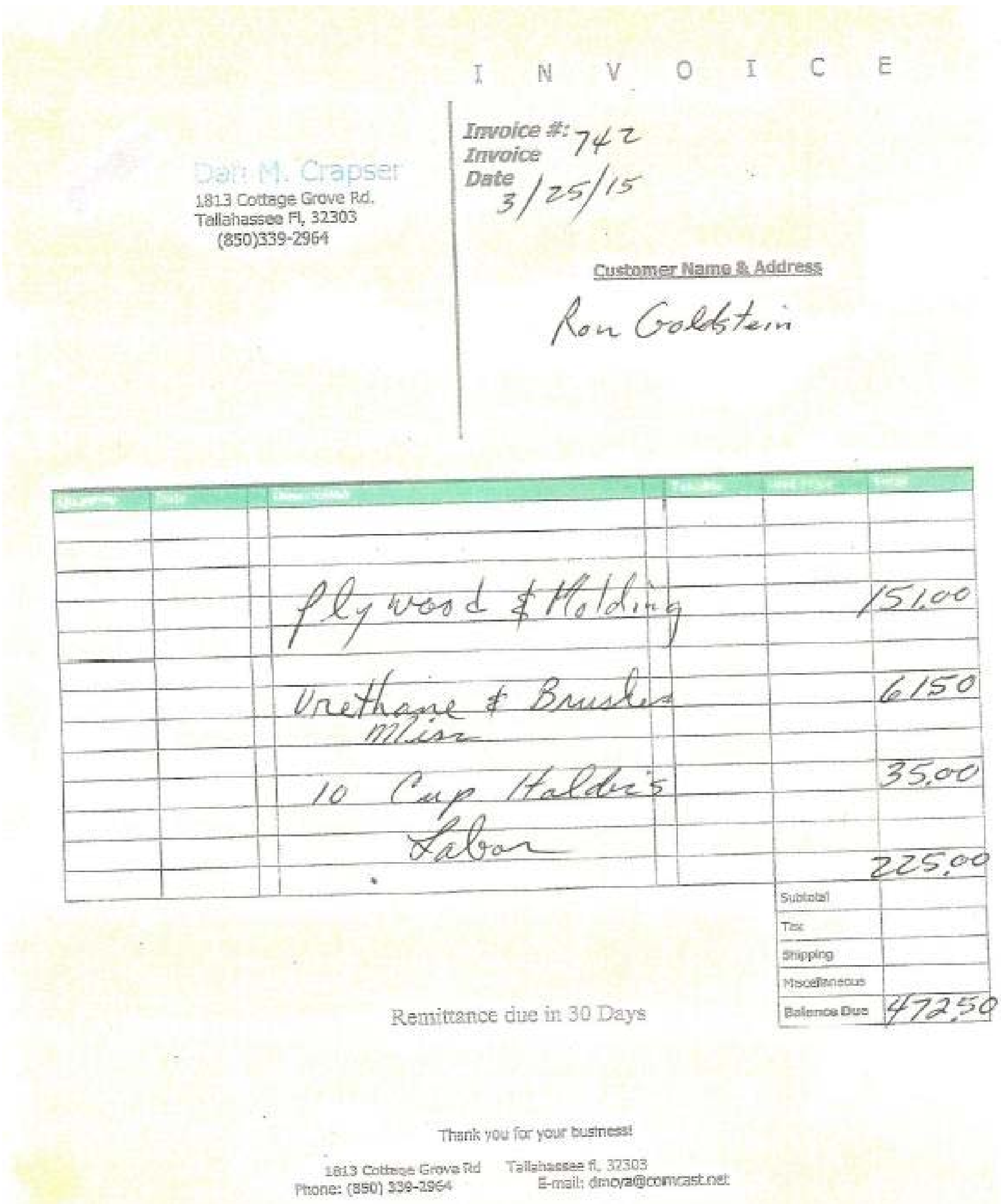
P.O. #

Subtotal	$2,740.00
Sales Tax (7.5%)	$205.50
Payments/Credits	-$2,945.50

Capital Awning warranties the workmanship, framework materials & fabric materials against defects for the period of 2 years from installation.

Payment due on receipt of invoice. If not paid within 10 days, a service charge of 1-1/2 % of unpaid balance or $5.00, whichever is greater, will be added

Invoice for the outsourced roof awning of the Pedibus.



I N V O I C E

Dan M. Crapser
1813 Cottage Grove Rd.
Tallahassee Fl, 32303
(850)339-2964

Invoice #: 742
Invoice Date 3/25/15

Customer Name & Address

Ron Goldstein

Plywood & Molding	151.00
Urethane & Brushes Misc	61.50
10 Cup Holders	35.00
Labor	225.00
Subtotal	
Tax	
Shipping	
Miscellaneous	
Balance Due	472.50

Remittance due in 30 Days

Thank you for your business!

1813 Cottage Grove Rd Tallahassee fl, 32303
Phone: (850) 339-2964 E-mail: dmcya@comcast.net

The scan of the invoice for the outsourced bar top for the Pedibus project.

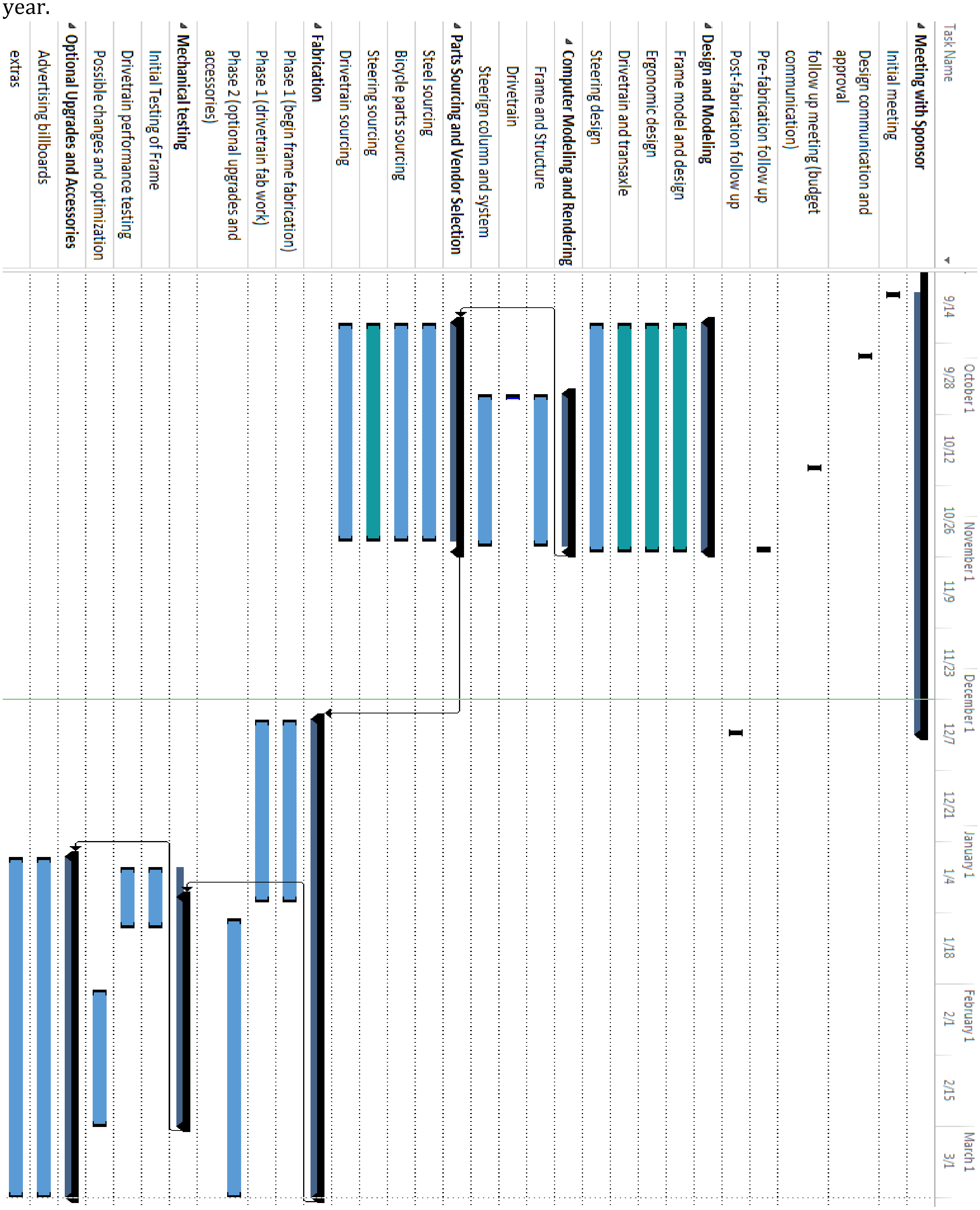
APPENDIX D

The following table is a generic pre-operation checklist created by the team in order to minimize possible failure of the vehicle during regular operation and ensure maximum safety and reliability of the vehicle components. The checklist should be completed before each vehicle use.

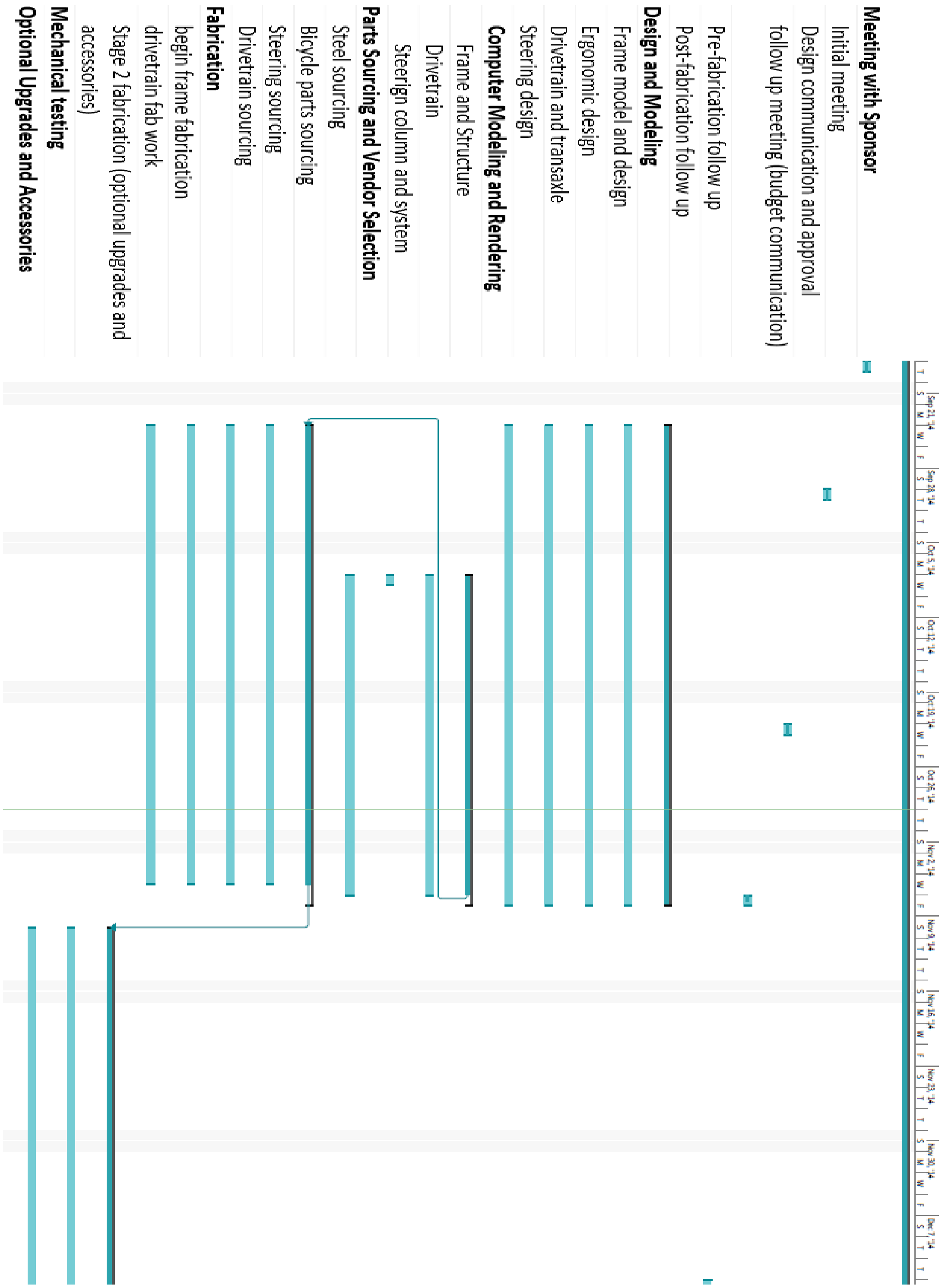
Pedibus 2.0 pre-operation checklist	**Task Completion (Initial)**
Check tire pressure (40psi)	
Check brake line for leaks	
Pump brake pedal to ensure proper bleed and function	
Check handbrake cable and proper brake engagement	
Inspect steering assembly for damaged/broken parts	
Check all 10 bicycle chains for lubrication, tension, and proper engagement	
Check that cranks are tighten onto bottom brackets	
Check battery charge status	
Check for burnt out bulbs in brake lights and turn signals	
Inspect frame for any corrosion of damage	
Inspect proper fastening of roof pins	
Check for damage to wood on benches (water damage)	

APPENDIX E

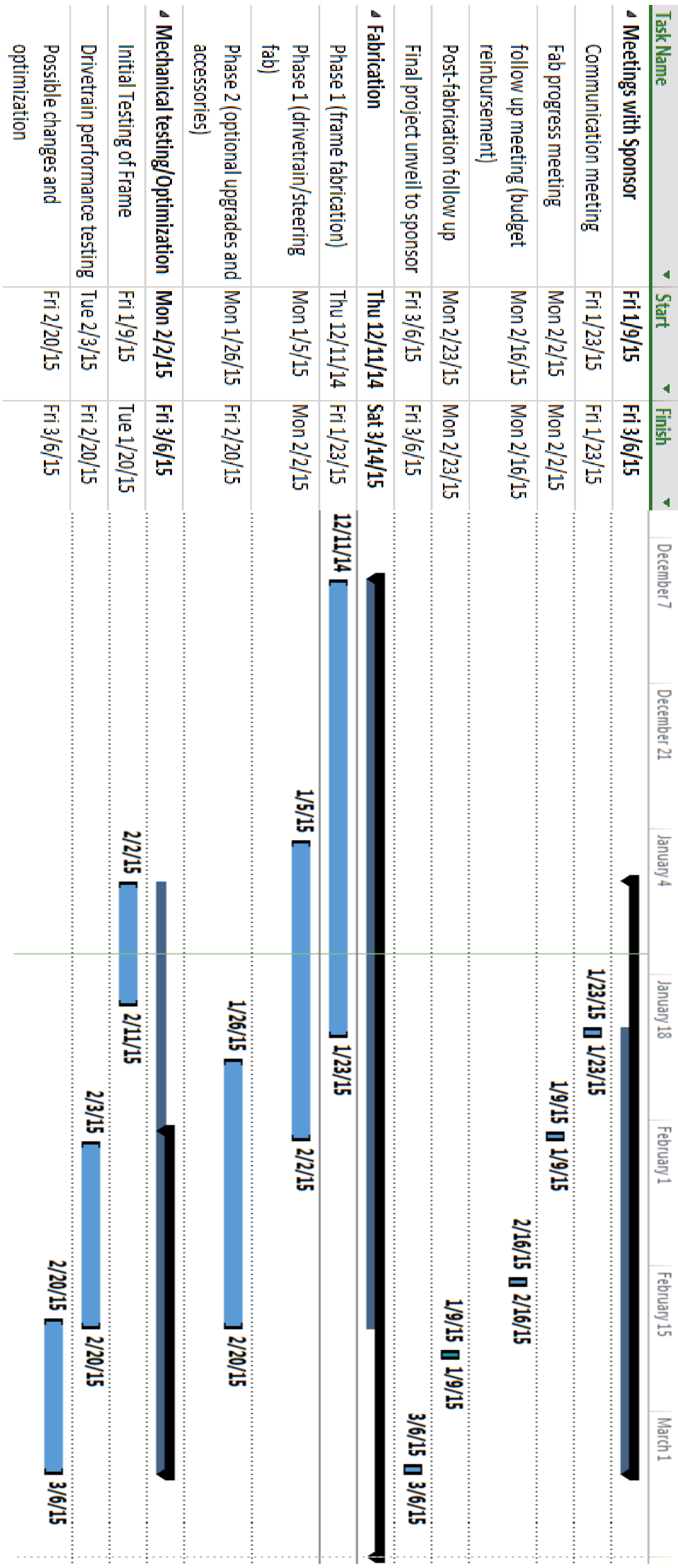
Depicted below are three Gantt charts generated by the team which dictate the schedule followed throughout the duration of the project. The first figure shows the Gantt chart for the entire year.



The following figure represents the Gantt chart for the fall semester only showing more details that lie within the span of the fall semester.



T[illegible]'[illegible]T[illegible] schedule includes meetings with sponsor as well as deadlines for the vehicle completion.



APPENDIX F

The following is a procurement list of all parts purchased for the fabrication of the Pedibus. This list includes: Part name, number, manufacturer and retailer.

Part	Brand	Manufacture Part #	In-Store/Online	Ordering Source	Source Part #	Quantity
2x4x1/8 Construction Box Steel (A500)	N/A	N/A	In-Store	Sabel	N/A	3
2x1x1/8 Construction Box Steel (A500)	N/A	N/A	In-Store	Sabel	N/A	8
6 Speed Transaxle	Peerless	820-040	Online		N/A	1
Floor Mount Brake Pedal	Wilwood	3401289	Online	Amazon.com	B003XVLGN8	1
1" Bore Master Brake Cylinder	Wilwood	2606766	Online	Amazon.com	B003XVJOHS	1
5-Hole Brake Drum	AL-KO	545LB3E	Online	Amazon.com	B001IN5KUI	2
10" Trailer Electric Drum Brake (Left & Right)	TruRyde	23158-C9	Online	Amazon.com	B0098M5LUK	2
Rubber Torsion Trailer Axle	Reliable	129287	Online	Amazon.com	B000F5861K	1
Trailer Spindle (#84)	Shadow	ST-SP20484F	Online	Amazon.com	B009COAXVQ	2
Spindle Bearings	Western Prime	BK-3500	Online	Amazon.com	B00MMSOZAO	2
10" Trailer Disc Brake	Kodiak	2/HRCM-10-DAC	Online	Amazon.com	B006UH5IMC	1
Bicycle Crank	Retrospec	3020M-10-48	Online	Amazon.com	B00FNT1BJ2	10
Bicycle Pedal	Coromose	N/A	Online	Amazon.com	B00LXQBXDS	10
Bicycle Bottom Bracket	Sunlite	N/A	Online	Amazon.com	B003COD29C	10
Bicycle Free Wheel	Shiamno	ISF120016	Online	Amazon.com	B001GSSIIG	10
Bicycle Chain	KMC	Z410 112L BLK	Online	Amazon.com	B0013C7M6E	12
Wheels/Tires			In-Store	Discount Tire		4
Freewheel Sprocket Adaptor	N/A	N/A	Online	Staton-Inc	N/A	10
Lawn Mower Idler	ICpower1	11634	Online	Amazon.com	B001V6OE1S	1
Pillow Block Mounted Bearing	Hub City	1001-07080	Online	Amazon.com	B00ECZZG7G	10
Spur Gear	Martin	6.9795E+11	Online	Amazon.com	B004BDO0EY	2
Bottom Bracket Shell	N/A	N/A	Online	Amazon.com	B001GSSL1A	10
1" Bore Diameter Sheave	TB Woods	BK231	Online	Amazon.com	B003N17P0Q	1
5/8" Bore Diameter Sheave	TB Woods	AK2458	Online	Amazon.com	B003N17JRU	1
Hitch Mount Receiver	PMD Products	18018	Online	Amazon.com	B00PB7UV1A	2
Trailer Swivel Mount Jack	Flagline	74410	Online	Amazon.com	B000CQOIVO	1
Husky Ball Coupler	Husky	87073	Online	Amazon.com	B004OK86O4	1
Towing Trailer Lights	ucostore		Online	Amazon.com	B0041AOHZ2	1
Driver Seat	Wise Economy	WD734PLS-711	Online	Amazon.com	B00LG7VIRU	1
Rear Axle Shaft	Dorman	630-300	Online	Amazon.com	B000C14QES	2
Rear Disc Brake Rotor	Dura International	BR53010	Online	Amazon.com	B00BLYZ9P0	2
30 mm Mounted Bearing	VXB	Kit7347	Online	Amazon.com	B002BBOF5W	2
5/8 Mounted Bearing	SKF	FYI 5/8FM	Online	Amazon.com	B00DBNPQ5M	2
Right Rear Disc Caliper	ARC	50-4376	Online	Amazon.com	B0001YFTXQ	1
Left Rear Disc Caliper	ARC	50-4377	Online	Amazon.com	B0001YFTYK	1
Seat Swivle	Springfield Marine	1100018	Online	Amazon.com	B000KKB811	1

Bench Seat Wood Planks (2x10x16)	ACQ Top Choice		In Store	Lowes		4
Bar Top Wood Planks			In Store	Lowes		4
Bench 3/8 by 2.5" Carriage	HM		In Store	Lowes		1
Bench 3/8" Washers (Box of 100)	HM		In Store	Lowes		1
Bench 3/8 Hex Nuts (Box of 100)	HM		In Store	Lowes		1
1-1/4" x 3ft 12 GA Bench Brackets			In Store	Lowes		6
1-1/4" x 6ft 12 GA Bench Brackets			In Store	Lowes		2
^^LOWES TAX AMOUNT						1
1/8 X 8ft Sheet Metal			In Store	Kelly Sheet Metal		1
1" Round Driveshaft Steel (20')			In Store	Sabel Steel		2
3/4" Round Steering Column Steel (20')			In Store	Sabel Steel		1
2" x 1/4" Square Tubing			In Store	Sabel Steel		1
1/4" Coil Plate (for mounting brackets)			In Store	Sabel Steel		1
Steering 3/4"-10x5.5" Hex Cap Screw			Online	Fastenal.com	13374	2
Steering 3/4"-10 Nylon Nut			Online	Fastenal.com	169783	4
3/8"-16x2"x7" U Bolts (with nuts and washers)			Online	Fastenal.com	156516	4
^^FASTENAL TAX AMOUNT						1
Steering Rack & Pinion		HEXSR2	Online	Summitracing.com	HFM-HEXSR2	1
Steering Wheel		270-8675	Online	Summitracing.com	REB-270-8675	1
U Joint		8052510	Online	Summitracing.com	UIS-8052510	2
Rear Brake Pads	Dura Int	BP881C	Online	Amazon.com	B001UCGPVU	1
Sheave	TB Woods	AK2534	Online	Amazon.com	B003N17JU2	1
McMaster Order (**see invoice**)			Online	McMaster.com		
Chain Tensioners	Razor		Online	Amazon.com	B008BPNIVY	10
McMaster Order (**see invoice**)			Online	McMaster.com		
McMaster Order (**see invoice**)			Online	McMaster.com		
U-Joint, 9/16 In 26-Spline to 3/4 Round	Sweet Mfg	91032237	Online	Speedway.com	91032237	1
Fastenal Order (**see invoice-106648)			In Store	Fastenal		
Fastenal Order (**see invoice-106537)			In Store	Fastenal		
Cold Rolled 1" Shafts			In Store	Sabel Steel		
2 x 1 Rectangular tubing			In Store	Sabel Steel		
Lowes Order (**see invoice-02707)			In Store	Lowes		
Lowes Order (**see invoice-67005)			In Store	Lowes		