ASME
SETTING THE STANDARD

ASME Report Cover Page & Vehicle Description Form

Human Powered Vehicle Challenge

Competition Location: Lansing, Michigan
Competition Date: April 5th – 7th, 2019

This required document for all teams is to be incorporated in to your Design Report.
Please Observe Your Due Dates; see the ASME HPVC website and rules for due dates.

Vehicle Description

University name: FAMU-FSU College of Engineering
Vehicle name: T-Bone
Vehicle number: 38
Vehicle configuration:
Upright ______ Semi-recumbent X
Prone ______ Other (specify) ______
Frame material: Low Carbon Steel
Fairing material(s): N/A
Number of wheels: 3
Vehicle Dimensions (m)
Length: 2.13 m
Width: 1.08 m
Height: 1.29 m
Wheelbase: 1.07 m
Weight Distribution (kg)
Front: 18.1 kg
Rear: 13.6 kg
Total Weight (kg): 31.7 kg
Wheel Size (m)
Front: 0.508 m
Rear: 0.6604 m
Frontal area (m^2): 0.81 m^2
Steering (Front or Rear): Front
Braking (Front, Rear, or Both): Front
Estimated Coefficient of Drag: 0.8

Vehicle history (e.g., has it competed before? where? when?):

T-Bone is a legacy project inherited from the 2017-2018 Senior Design team. It has not competed in the ASME HPVC before.

FAMU-FSU College of Engineering

2019 ASME North HPVC

Design Report

FAMU-FSU Human Powered Vehicle Team

T-Bone

#38

Contact Information

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Team Members

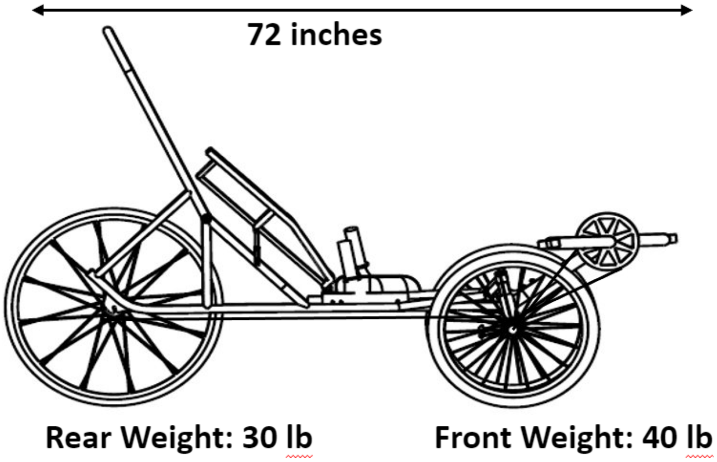
Tyler Schilf

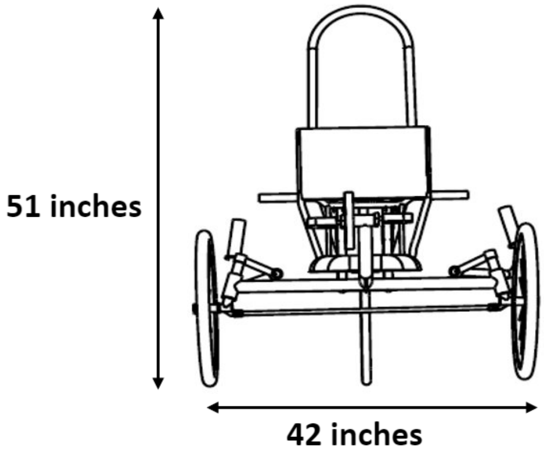
Kyler Marchetta

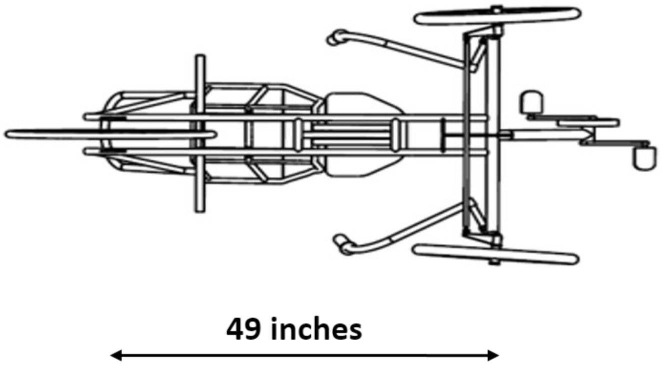
Jacob Thomas

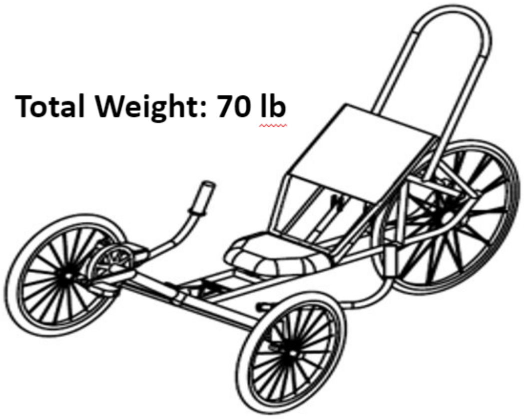
Tristan Enriquez

3-View Drawing









Abstract

The American Society of Mechanical Engineers hosts the Human Powered Vehicle Challenge every year. Human-powered transport is often the only available transport for underdeveloped parts of the world. Traveling to work and buying groceries are general tasks for people in these regions. The Florida Agricultural and Mechanical University – Florida State University College of Engineering's Team 512 produces a means of transport for the challenge that is sustainable and useful for every day. The team develops T-Bone with engineering design principles in mind. To solve this problem our team split the design into four parts (drivetrain, steering, frame, safety). The team explores different ways the design choices apply to the challenge and global impact.

Through analysis, the design choices for T-Bone are as follows. The drivetrain gearing ratios help the rider power through hills and reach high speeds. The rider uses direct steering handlebars for simplicity while maneuvering around obstacles and turns. Disk brakes on the front wheels also help the rider stop quicker and maneuver around corners. Using low carbon steel for material, the frame mimics a recline-seating trike to lessen drag on the rider. Testing the strength of our frame using computer-aided design shows how safe T-Bone is during crashes. Space is readily available on the frame to hold personal belongings of the rider. The roll protection, which needs a continuous hoop over the rider, provides protection for rollovers. The team tests the design to meet targets for the challenge and real-world applications. The final integration of the four parts on T-Bone carries out a sustainable design for everyday use. The cost for using human-powered transport is cheap and maintainable. Giving this research and design to people of underdeveloped regions can help some of their hardships in life.

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1. Design

1.1 Objective

Design and construct a human powered vehicle that:

- *Turns in a radius of 6 meters*
- *Maintains a straight path (deviation of 4 feet maximum) for 30 meters without driver input*
- *Comes to a complete stop in 6 meters from a speed of 25 kilometers per hour*
- *Contains a frame that can support loads mentioned in the 2019 ASME HPVC Rulebook*
- *Restricts the rider's head and shoulders from contacting the ground during a rollover*
- *Successfully completes all events at the competition*

1.2 Background

The drivetrain, frame, steering/braking, and ergonomic engineers performed research on different configurations for their systems and concepts. Each engineer developed a brief description of the research performed in their study.

1.2.1 Drivetrain

Being the sole "power source" of the vehicle, it was detrimental to design and implement a drivetrain system that translated optimal and maximum power to the vehicle from the driver. Since the vehicle's drivetrain is responsible not only for the motion of the vehicle but for the cease of motion of the vehicle, an effective braking system was needed.

It was decided that the HPV would model a tadpole recumbent tricycle. The HPV would implement a rear wheel driven drivetrain. A rider would input force with their legs to the pedals which would drive a chain routed underneath the driver seat to stimulate motion of the rear wheel. Also disc brakes actuated from controls on the steering handles would be implemented. A gear shifter along with derailleur would be utilized so that the driver may switch to appropriate gear sets when driving.

Figure 1: Example of Recumbent Tricycle with Rear Wheel Driven Drivetrain (https://www.basicallybicycles.com/product/sun-seeker-eco-tad-sx-1694.htm)

1.2.2 Frame

The human powered vehicle was modeled after a tadpole recumbent tricycle. A tadpole tricycle is designed so that there is one rear wheel and two front wheels. Deviating from a two wheeled vehicle, the reasoning for a tadpole model is to lower the center of gravity. This improves handling and encourages a lighter design. In order to abide by the ASME HPVC 2019 rulebook, an overhead roll protection system was required. To maximize the vehicle's efficiency and protectiveness during competition, an ideal frame would be lightweight and aerodynamic while also offering sufficient protection. It was also reasoned to include a five-point harness restraint to secure the rider to the seat to provide additional safety.

1.2.3 Steering

Many methods of steering geometry were researched for T-Bone. Direct and indirect steering, remote under and over seat steering, and side stick steering were among these types being researched. Their overall effect on the turning radius, and applications to global use were heavily weighted in the concept selection. Analyzing the Ackermann geometry for each configuration shows the different values the turning radius reaches. The overall complexity and moving parts in the geometry will determine how well the configuration could be maintained by underdeveloped countries. If a certain configuration had a complex design that needed mechanical expertise to fix, then it might not be consumer friendly to the poorer nations people. Some other determinants for our steering are the angles created by the geometry that influence caster and camber of the wheels. Typically, most cyclists have positive caster on the front wheel to help with straight line stability. Negative caster creates an unstable wobbling effect like that of wheels on a shopping cart. The camber is of lesser concern but still observed to see the effects on the steering. The camber angles could be adjusted to help with traction in cornering, preventing slip in the wheel contact patches. The speeds at which this would be a necessary value to include are well above the average speeds of our design.

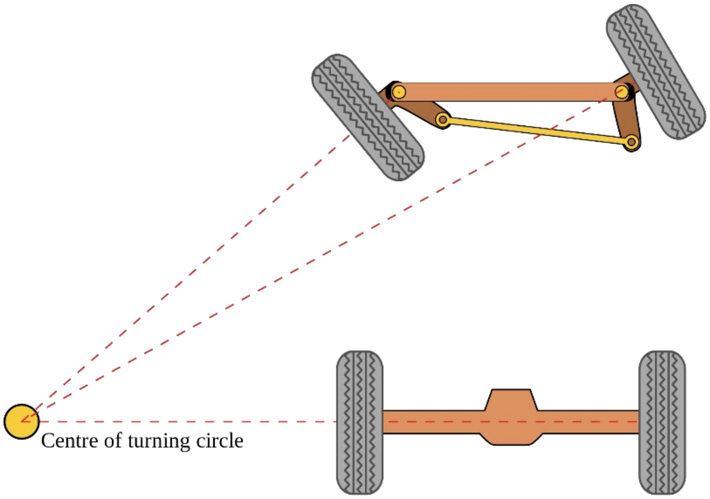


Figure 2: Ackermann Steering Geometry (https://en.wikipedia.org/wiki/Ackermann_steering_geometry)

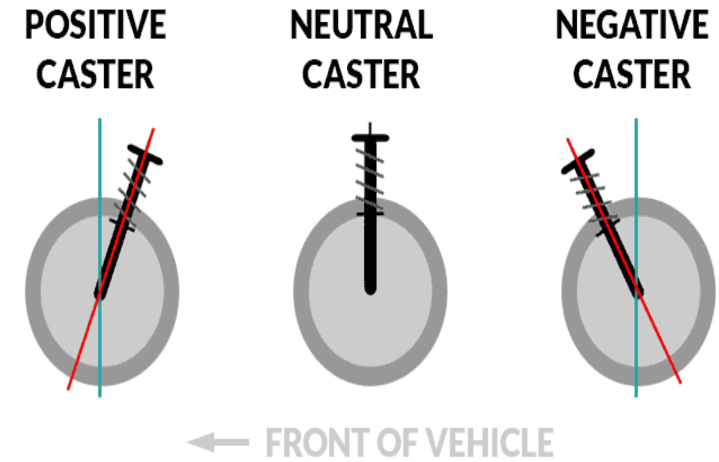


Figure 3: Example Caster Angles (https://www.comeanddriveit.com/suspension/camber-caster-toe)

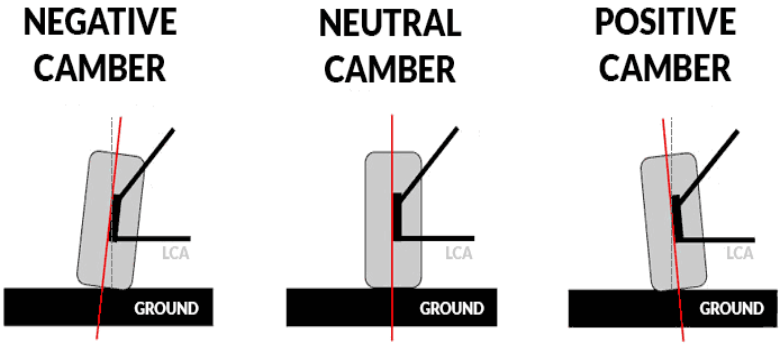


Figure 4: Example Camber Angles (https://www.comeanddriveit.com/suspension/camber-caster-toe)

The final design choice settled on direct steering to the wheels for its simplicity and achieving the desired turning angles. It features handlebars angled toward the rider's side coming from the stem of the wheel kingpins.

1.2.4 Ergonomics

In addition to ensuring all safety features are accounted for and present (e.g. helmet, harness, working with frame engineer for the RPS, reflectors, rearview mirror), important aspects that influence the comfort of the driver were taken into consideration. It was decided that a reclined seated position offers maximum comfort while allowing the driver to input the necessary forces to propel the vehicle. Decisions on how to limit the steering were considered as well. Instead of designing a limiter out of metal/aluminum, the driver's seat acts as the limiter. In the result of a collision there is no fear that the part would break and become a possible projectile. In addition, research found that the optimal handles to use were the grips and shifter combination commonly found on mountain bikes. The handles from the mountain bike used in last year's initial design were implemented. Also, two brake levers offer additional control and brake cable power transmission compared with using only a single lever with two cable pulls (this doubles the rider's force that they can input to stop the vehicle). Working with the frame engineer, it was determined that the optimal angle for the pedal-boom chain ring attachment was 45 degrees from horizontal. This allows for a pleasant rider configuration that maximizes comfort without limiting the power that the driver can input to the drivetrain.

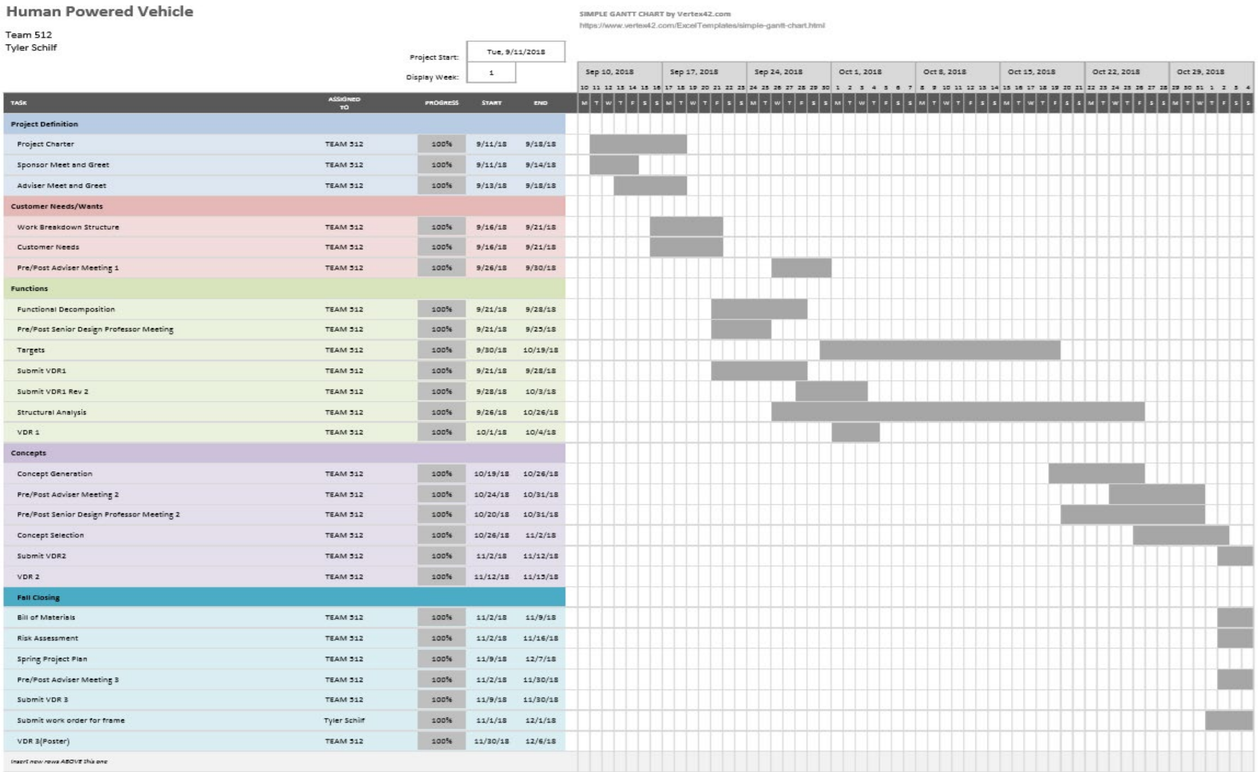
1.3 Prior Work

The team received a previously designed and built frame along with other biking components. These included a BMX bike and mountain bike frame with their parts. In addition to these parts, components such as a chain, derailleurs, seat, bike shifters, and chain rings were inherited. Below is the received frame with the seat, BMX wheels and mountain bike wheel.

Figure 5: Legacy Project Received From 2017 – 2018 Team

1.4 Timeline Structure

Figures 6, 7, and 8 below show a Gantt chart detailing Team 512's progression through the design of the HPV.



Human Powered Vehicle

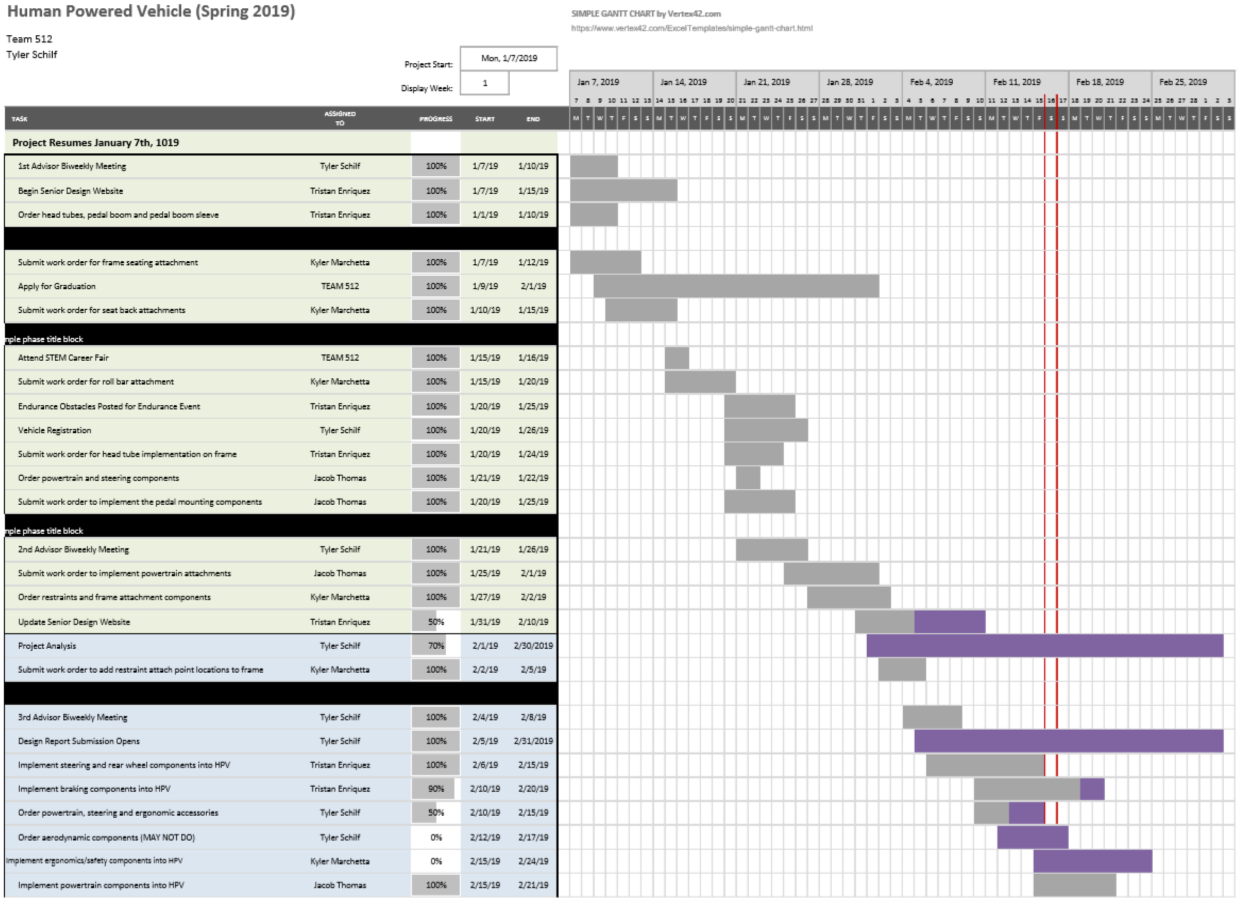
Team 512
Tyler Schiff

Project Start: Tue, 9/11/2018
Display Week: 1

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END
Project Definition				
Project Charter	TEAM 512	100%	9/11/18	9/18/18
Sponsor Meet and Greet	TEAM 512	100%	9/11/18	9/14/18
Adviser Meet and Greet	TEAM 512	100%	9/13/18	9/18/18
Customer Needs/Wants				
Work Breakdown Structure	TEAM 512	100%	9/16/18	9/21/18
Customer Needs	TEAM 512	100%	9/16/18	9/21/18
Pre/Post Adviser Meeting 1	TEAM 512	100%	9/26/18	9/30/18
Functions				
Functional Decomposition	TEAM 512	100%	9/21/18	9/28/18
Pre/Post Senior Design Professor Meeting	TEAM 512	100%	9/21/18	9/25/18
Targets	TEAM 512	100%	9/30/18	10/19/18
Submit VDR1	TEAM 512	100%	9/21/18	9/28/18
Submit VDR1 Rev 2	TEAM 512	100%	9/28/18	10/3/18
Structural Analysis	TEAM 512	100%	9/26/18	10/26/18
VDR 1	TEAM 512	100%	10/1/18	10/4/18
Concepts				
Concept Generation	TEAM 512	100%	10/19/18	10/26/18
Pre/Post Adviser Meeting 2	TEAM 512	100%	10/24/18	10/31/18
Pre/Post Senior Design Professor Meeting 2	TEAM 512	100%	10/20/18	10/31/18
Concept Selection	TEAM 512	100%	10/26/18	11/2/18
Submit VDR2	TEAM 512	100%	11/2/18	11/12/18
VDR 2	TEAM 512	100%	11/12/18	11/15/18
Fall Closing				
Bill of Materials	TEAM 512	100%	11/2/18	11/9/18
Risk Assessment	TEAM 512	100%	11/2/18	11/16/18
Spring Project Plan	TEAM 512	100%	11/9/18	12/7/18
Pre/Post Adviser Meeting 3	TEAM 512	100%	11/2/18	11/30/18
Submit VDR 3	TEAM 512	100%	11/9/18	11/30/18
Submit work order for frame	Tyler Schiff	100%	11/1/18	12/1/18
VDR 3(Poster)	TEAM 512	100%	11/30/18	12/6/18
Insert new rows ABOVE this one				

Figure 6: Gantt Chart Detailing Progress September 2018-October 2018



Human Powered Vehicle (Spring 2019)

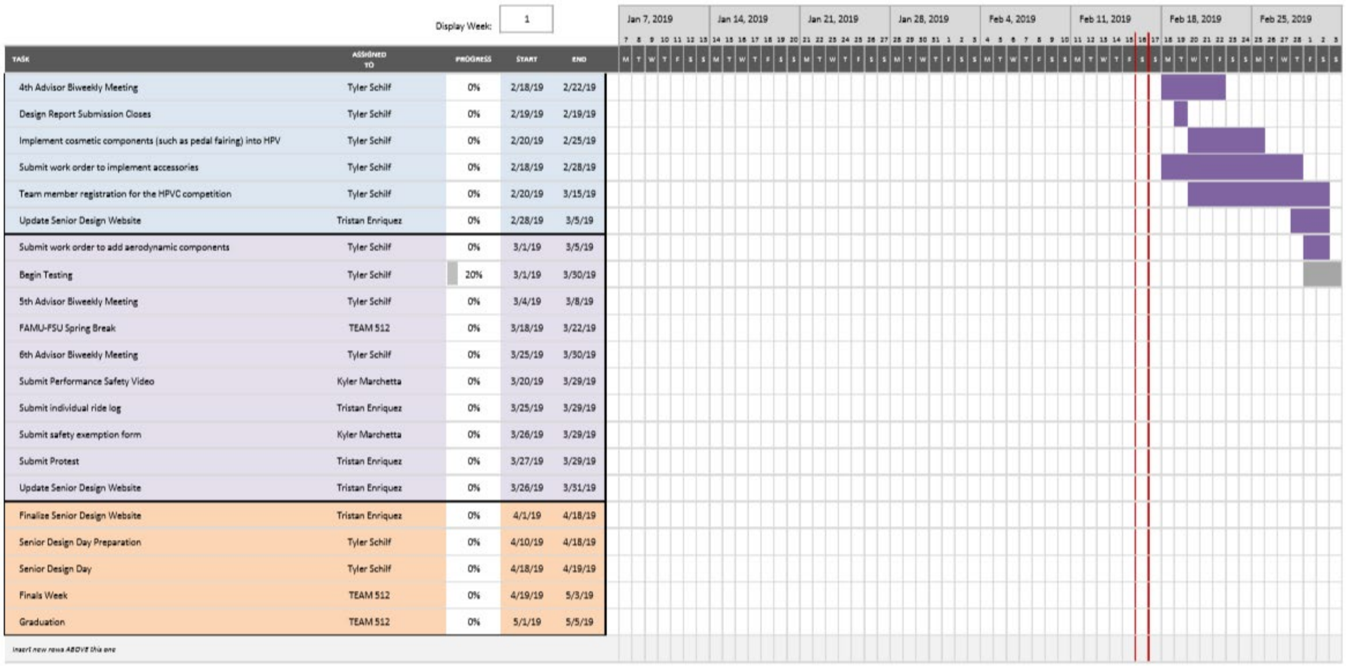
Team 512
Tyler Schilf

Project Start: Mon, 1/7/2019
Display Week: 1

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

TASK	ASSIGNED TO	PROGRESS	START	END
Project Resumes January 7th, 1019				
1st Advisor Biweekly Meeting	Tyler Schilf	100%	1/7/19	1/10/19
Begin Senior Design Website	Tristan Enriquez	100%	1/7/19	1/15/19
Order head tubes, pedal boom and pedal boom sleeve	Tristan Enriquez	100%	1/1/19	1/10/19
Submit work order for frame seating attachment	Kyler Marchetta	100%	1/7/19	1/12/19
Apply for Graduation	TEAM 512	100%	1/9/19	2/1/19
Submit work order for seat back attachments	Kyler Marchetta	100%	1/10/19	1/15/19
nple phase title block				
Attend STEM Career Fair	TEAM 512	100%	1/15/19	1/16/19
Submit work order for roll bar attachment	Kyler Marchetta	100%	1/15/19	1/20/19
Endurance Obstacles Posted for Endurance Event	Tristan Enriquez	100%	1/20/19	1/25/19
Vehicle Registration	Tyler Schilf	100%	1/20/19	1/26/19
Submit work order for head tube implementation on frame	Tristan Enriquez	100%	1/20/19	1/24/19
Order powertrain and steering components	Jacob Thomas	100%	1/21/19	1/22/19
Submit work order to implement the pedal mounting components	Jacob Thomas	100%	1/20/19	1/25/19
nple phase title block				
2nd Advisor Biweekly Meeting	Tyler Schilf	100%	1/21/19	1/26/19
Submit work order to implement powertrain attachments	Jacob Thomas	100%	1/25/19	2/1/19
Order restraints and frame attachment components	Kyler Marchetta	100%	1/27/19	2/2/19
Update Senior Design Website	Tristan Enriquez	50%	1/31/19	2/10/19
Project Analysis	Tyler Schilf	70%	2/1/19	2/30/2019
Submit work order to add restraint attach point locations to frame	Kyler Marchetta	100%	2/2/19	2/5/19
3rd Advisor Biweekly Meeting	Tyler Schilf	100%	2/4/19	2/8/19
Design Report Submission Opens	Tyler Schilf	100%	2/5/19	2/31/2019
Implement steering and rear wheel components into HPV	Tristan Enriquez	100%	2/6/19	2/15/19
Implement braking components into HPV	Tristan Enriquez	90%	2/10/19	2/20/19
Order powertrain, steering and ergonomic accessories	Tyler Schilf	50%	2/10/19	2/15/19
Order aerodynamic components (MAY NOT DO)	Tyler Schilf	0%	2/12/19	2/17/19
Implement ergonomics/safety components into HPV	Kyler Marchetta	0%	2/15/19	2/24/19
Implement powertrain components into HPV	Jacob Thomas	100%	2/15/19	2/21/19

Figure 7: Gantt Chart Detailing Progress January 2019-February 2019



TASK	ASSIGNED TO	PROGRESS	START	END
4th Advisor Biweekly Meeting	Tyler Schilf	0%	2/18/19	2/22/19
Design Report Submission Closes	Tyler Schilf	0%	2/19/19	2/19/19
Implement cosmetic components (such as pedal fairing) into HPV	Tyler Schilf	0%	2/20/19	2/25/19
Submit work order to implement accessories	Tyler Schilf	0%	2/18/19	2/28/19
Team member registration for the HPVC competition	Tyler Schilf	0%	2/20/19	3/15/19
Update Senior Design Website	Tristan Enriquez	0%	2/28/19	3/5/19
Submit work order to add aerodynamic components	Tyler Schilf	0%	3/1/19	3/5/19
Begin Testing	Tyler Schilf	20%	3/1/19	3/30/19
5th Advisor Biweekly Meeting	Tyler Schilf	0%	3/4/19	3/8/19
FAMU-FSU Spring Break	TEAM 512	0%	3/18/19	3/22/19
6th Advisor Biweekly Meeting	Tyler Schilf	0%	3/25/19	3/30/19
Submit Performance Safety Video	Kyler Marchetta	0%	3/20/19	3/29/19
Submit individual ride log	Tristan Enriquez	0%	3/25/19	3/29/19
Submit safety exemption form	Kyler Marchetta	0%	3/26/19	3/29/19
Submit Protest	Tristan Enriquez	0%	3/27/19	3/29/19
Update Senior Design Website	Tristan Enriquez	0%	3/26/19	3/31/19
Finalize Senior Design Website	Tristan Enriquez	0%	4/1/19	4/18/19
Senior Design Day Preparation	Tyler Schilf	0%	4/10/19	4/18/19
Senior Design Day	Tyler Schilf	0%	4/18/19	4/19/19
Finals Week	TEAM 512	0%	4/19/19	5/3/19
Graduation	TEAM 512	0%	5/1/19	5/5/19

Insert new rows ABOVE this one

Figure 8: Gantt Chart Detailing Progress February 2019-Current

1.5 Design Specifications

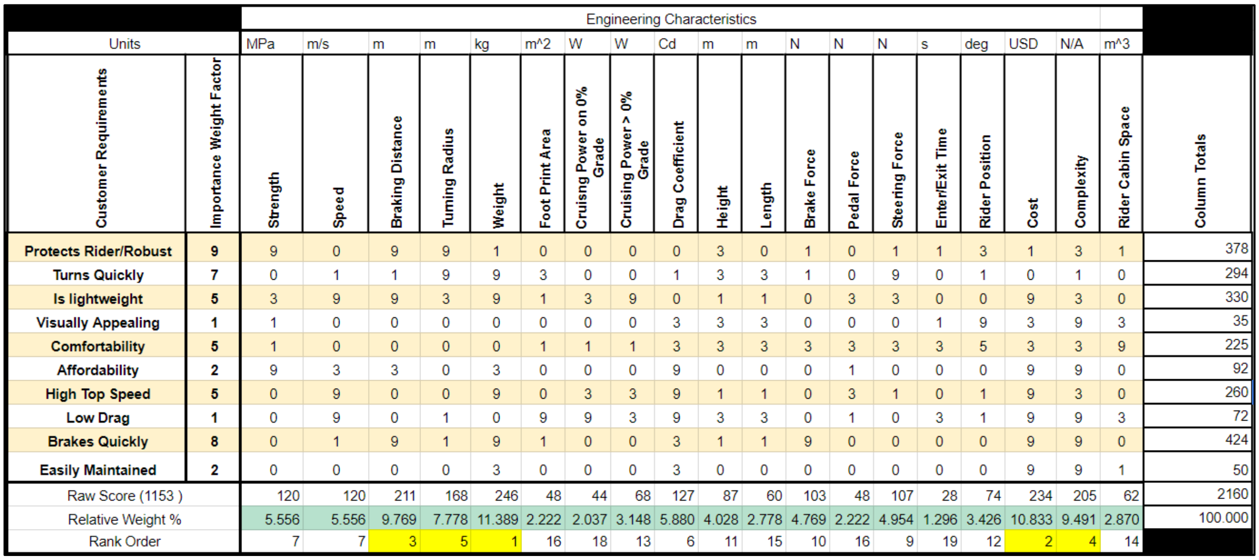
Table 1 contains the constraints created to help aid in the design and construction of T-Bone.

Table 1: Design Constraints and Justifications

Constraint	**Reasoning**
Minimum 6 meter turning radius	Comply with and exceed HPVC rules
Maximum stopping distance of 19.5 ft at 15.5 mph	Comply with HPVC rules
Maximum total vehicle weight of 60 lbs	Improved acceleration/less inertia to overcome

1.6 Concept Development and Selection Methods

The team generated over 100 concepts to choose from for the final design. Different systems for drivetrain (e.g. chain ring powered by feet, chain ring powered by hands, number of wheels that receive power) as well as different steering mechanisms (e.g. use of tie rod with rack and pinion or direct steer, use of handles to provide the input force for steering or a steering wheel) were considered. In addition, multiple ideas for rider position, types of brakes (e.g. hydraulic, magnetic, cable) as well as fairing options were considered. The total combination of possible ideas totaled to be well over 100. To limit redundant and repetitive designs, the team's four members performed a vote. Concepts with three yes votes passed on to the next phase. Eventually only 6 of the concepts were voted through. A Pugh matrix was created to compare the concepts against a datum to see how each faired against an actual performance model. The performance model chosen was a Green Speed GT20, a competitive commercial product. Seen below in Figure 9 is the streamlined House of Quality matrix that was used to assign, and weigh, engineering characteristics based upon their importance to the needs of customer. By using the top 5 weighted engineering characteristics from the House of Quality chart, the Pugh matrices helped to separate concepts that did not match up to the Green Speed GT20 datum. After a few iterations of the Pugh matrices, an Analytical Hierarchy Process (AHP) was followed to select the final concept. The final concepts to be compared were concept #24 and concept #85. Figure 9 shows the result of the AHP (math and additional matrices excluded for the sake of keeping the document within page limit). This resulted in concept #85 being the model to move forward with.



		Engineering Characteristics																			
Units		MPa	m/s	m	m	kg	m^2	W	W	Cd	m	m	N	N	N	s	deg	USD	N/A	m^3	
Customer Requirements	Importance Weight Factor	Strength	Speed	Braking Distance	Turning Radius	Weight	Foot Print Area	Cruisng Power on 0% Grade	Cruising Power > 0% Grade	Drag Coefficient	Height	Length	Brake Force	Pedal Force	Steering Force	Enter/Exit Time	Rider Position	Cost	Complexity	Rider Cabin Space	Column Totals
Protects Rider/Robust	**9**	9	0	9	9	1	0	0	0	0	3	0	1	0	1	1	3	1	3	1	378
Turns Quickly	**7**	0	1	1	9	9	3	0	0	1	3	3	1	0	9	0	1	0	1	0	294
Is lightweight	**5**	3	9	9	3	9	1	3	9	0	1	1	0	3	3	0	0	9	3	0	330
Visually Appealing	**1**	1	0	0	0	0	0	0	0	3	3	3	0	0	0	1	9	3	9	3	35
Comfortability	**5**	1	0	0	0	0	1	1	1	3	3	3	3	3	3	3	5	3	3	9	225
Affordability	**2**	9	3	3	0	3	0	0	0	9	0	0	0	1	0	0	0	9	9	0	92
High Top Speed	**5**	0	9	0	0	9	0	3	3	9	1	1	0	3	1	0	1	9	3	0	260
Low Drag	**1**	0	9	0	1	0	9	9	3	9	3	3	0	1	0	3	1	9	9	3	72
Brakes Quickly	**8**	0	1	9	1	9	1	0	0	3	1	1	9	0	0	0	0	9	9	0	424
Easily Maintained	**2**	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	9	9	1	50
Raw Score (1153)		120	120	211	168	246	48	44	68	127	87	60	103	48	107	28	74	234	205	62	2160
Relative Weight %		5.556	5.556	9.769	7.778	11.389	2.222	2.037	3.148	5.880	4.028	2.778	4.769	2.222	4.954	1.296	3.426	10.833	9.491	2.870	100.000
Rank Order		7	7	3	5	1	16	18	13	6	11	15	10	16	9	19	12	2	4	14	

Figure 9: House of Quality Matrix

2. **Analysis**

2.1 RPS Analysis

An analysis was performed on the HPV's role protection system to test the quality of the safety it provides. This is done not only to ensure the frame stands in accordance of the guidelines outlined in the rulebook, but to ensure the frame itself is a safe and reliable design. Figure 10 is a CAD model image of the designed HPV frame.

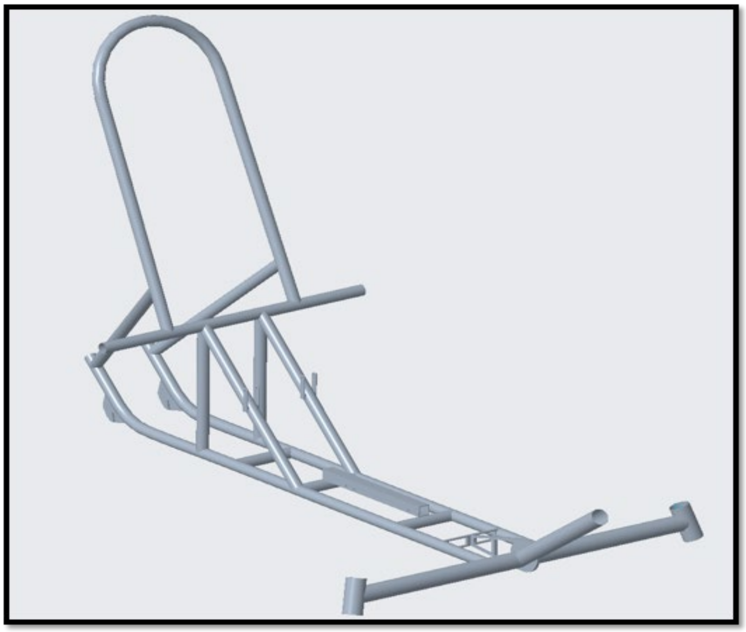


Figure 10: CAD Model of HPV Frame

2.1.1 Top Load

Figure 11 displays the results of a Finite Element Analysis (FEA) performed on a CAD model of the HPV. This was done to ensure the frame stands in accordance of the rulebook and simulates how the frame would behave if a top load was applied. A load of 2670 N was applied to the roll bar at an angle of twelve degrees from the vertical y-direction toward the rear of the frame. The scale on the right presents the von Mises stress concentrations in the frame due to this applied load. The simulation determined a max stress of approximately 392 MPa. This concentration occurs on the roll bar just above the two tubes that protrude from where the rear wheel is mounted and into the lower part of the roll bar.

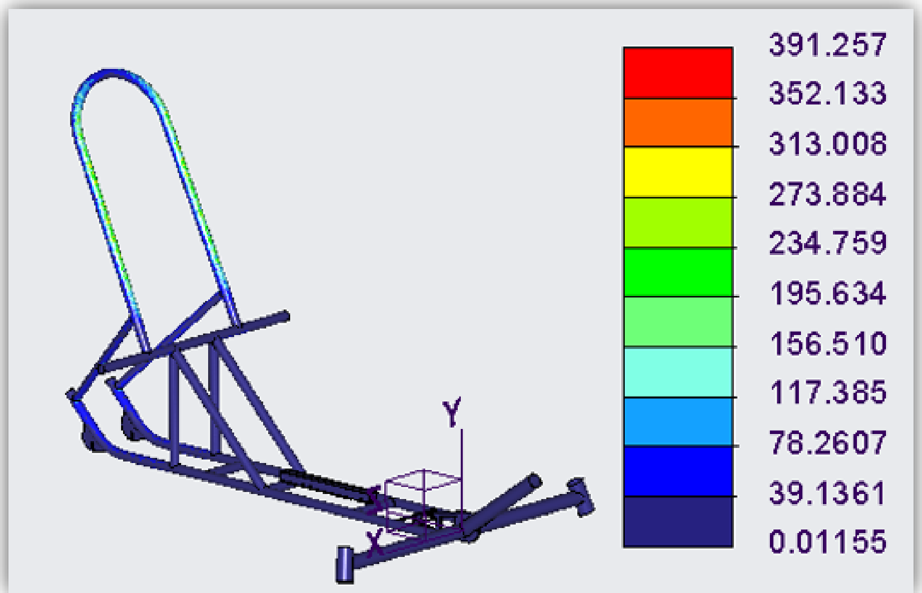


Figure 11: FEA of HPV Frame withstanding a Top Load

2.1.2 Side Load

Figure 12 displays the results of an FEA performed on a CAD model of the HPV. This was done to ensure the frame stands in accordance of the rulebook and simulates how the frame would behave if a side load was applied. A load of 1330 N of force is applied to the side of the roll protection system in the x-direction. The scale on the right side in the figure is in units of MPa and presents the von Mises stresses in the frame structure. A maximum stress of approximately 134 MPa was determined through this simulation. This stress is below the yield strength of the material used for the frame.

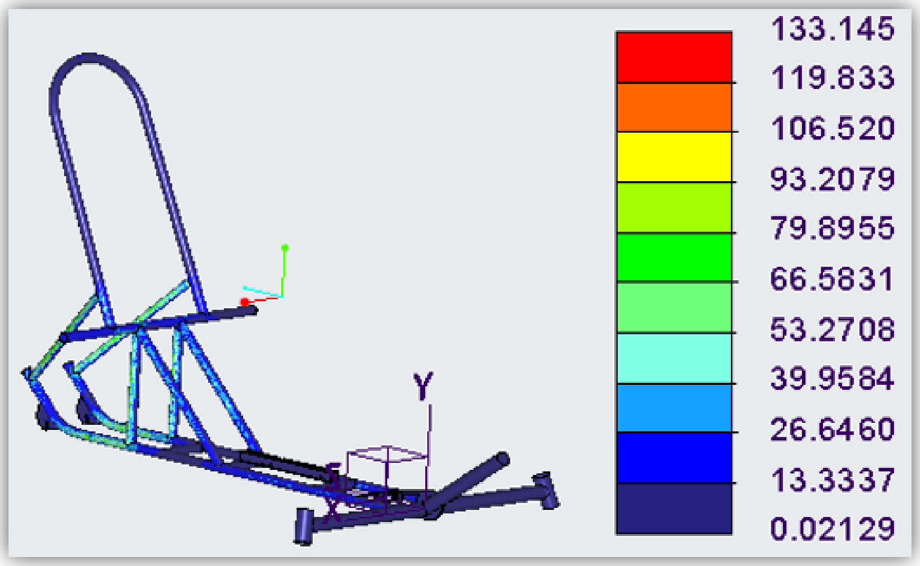


Figure 12: FEA of HPV Frame withstanding a Side Load

2.2 Aerodynamic Analysis

Table 2: Process of Aerodynamic Analysis

Item	**Description**
Objective	Analyze the aerodynamic drag experienced by T-Bone and determine if the gains from reducing the drag is worth the investment of resources.
Assumptions	Steady-state air flow, constant density in air
Methods	Use drag equation, supplemental research from other studies
Results	Reducing frontal area yields a lower drag on T-Bone

The full assembly model of T-Bone was created in Creo Parametric 4.0. The inclusion of a fairing to increase performance was excluded due to the cost of having it included. There are no aerodynamic devices either to help reduce drag on the vehicle. The goal was to analyze data of drag on the vehicle and determine whether the inclusion of a fairing is worth future investment. Due to this constraint, supplemental research from other organizations was used with our assumptions and methods to determine results. The future use of CFD on the frame would be necessary to properly determine the drag experienced on the vehicle without a fairing and compare to results with a fairing. The use of equation 1 for drag was the basis for our assumptions.

$$D = Cd \times \frac{\rho \times V^2}{2} \times A$$

Equation 1

Reducing the frontal area of the vehicle would yield a lower drag experienced by the vehicle, this was what we assumed. Modeling the air diverting around the front area through CFD analysis yields better data for drag calculations however. Following an aerodynamic study done by RMIT University of Melbourne, we were able to analyze data of how recumbent trikes experience drag in wind tunnel tests. They used nine different types of recumbent trikes for their tests, with and without fairings. Their results concluded that the inclusion of fairings on a vehicle often led to better results at competition due to the gains from reducing drag.

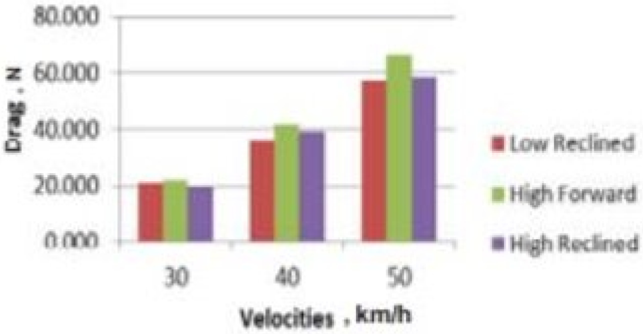


Figure 13: Drag Force Based on Changing Seat Position, No Fairing
(https://www.sciencedirect.com/science/article/pii/S1877705812016165)

The Figure 13 was RMIT's wind tunnel test on trikes with varying seat heights. The low reclined seating position was the most desirable for reducing drag at higher speeds. This is because of the total area experiencing drag has been reduced. Our design uses this seating position to provide some drag reduction.

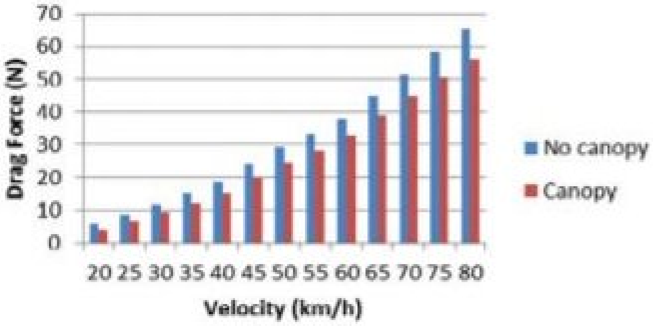


Figure 14: Drag of HPV with Full Faring
(https://www.sciencedirect.com/science/article/pii/S1877705812016165)

Figure 14 from RMIT was the wind tunnel test of the "industry leading vehicle" Glyde provided by Greenspeed. It had a full fairing around the trike and wheel covers to decrease the aerodynamic drag on them. When compared to the drag values experienced by the other vehicles, the full fairing is an exceptional choice. Across all the tested wind tunnel speeds, the Glyde outperformed them all. This takes proper specifications in the design of course but can be implemented into future iterations of our vehicle.
The results of our findings are mediocre at best for our own design. To improve this, the future team would need utilize a CFD analysis of the designed vehicle. Using an expected inlet speed around 35-45 mph as seen from other tests performed by other teams competing in the HPVC would suffice. Also showing the drag vs speed of the vehicle would properly show the advantages of having a fairing at higher speeds.

2.3 Cost Analysis

Team 512 was allotted a budget of $2,000 to design and build an HPV. This budget was also expected to help cover competition costs including entrance fees, travel, and lodging. In efforts to save money, materials purchased for last year's design were reused and materials used for the previous bike frame were recycled. The FAMU-FSU College of Engineering's Machine Shop provided free labor for the assembly of various parts of the current HPV design.

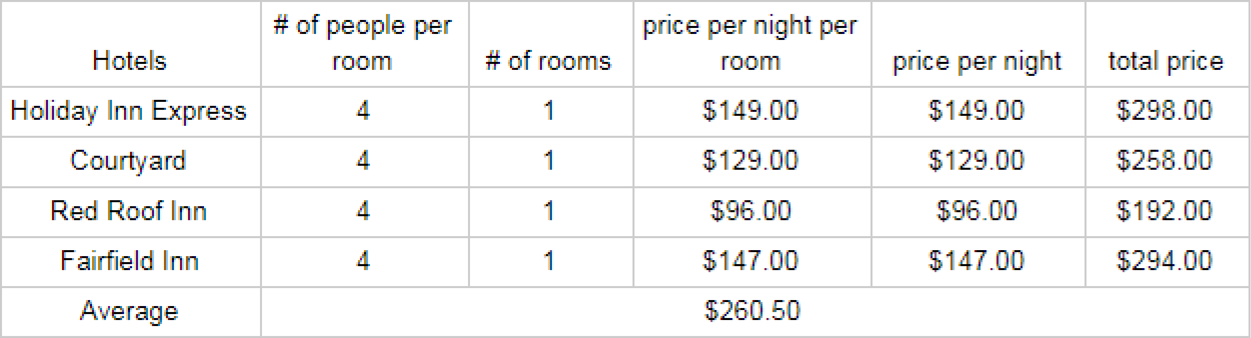
Team 512 collaborated with another senior design team from the FAMU-FSU College of Engineering that was also traveling to East Lansing, Michigan for a separate ASME competition. Since both teams were traveling to East Lansing, hotel accommodations and travel could be split. This was done in effort to save additional money that would be better allocated elsewhere.

Table 3: Bill of Materials for Parts

	Cost	**Quantity**	**Total Cost**
Pedal Mount Steel	$20.00	1	$20.00
Bottom Bracket Steel	$10.00	1	$10.00
Pedal Boom Steel	$20.00	1	$20.00
Headtube Steel	$15.00	1	$15.00
Steering Knuckle	$40.00	2	$80.00
20 Inch Wheel	$100.00	2	$200.00
Headsets	$60.00	1	$60.00
Brake Cable Mounts	$0.20	10	$2.00
Spray Paint	$5.00	3	$15.00
Disc Brakes	$60.00	1	$60.00
Vehicle Registration	$50.00	1	$50
			$532.00

Below are the truck rental and hotel costs for travel. The FAMU-FSU College of Engineering requires that the members do not travel over 500 miles in one day so the team must stay in Bowling Green, KY, the approximate halfway point between Lansing, MI and Tallahassee, FL. In addition to the costs below, $300 is set aside for fuel expenses.

Table 4: Cost of Hotels – Lansing, MI



Hotels	# of people per room	# of rooms	price per night per room	price per night	total price
Holiday Inn Express	4	1	$149.00	$149.00	$298.00
Courtyard	4	1	$129.00	$129.00	$258.00
Red Roof Inn	4	1	$96.00	$96.00	$192.00
Fairfield Inn	4	1	$147.00	$147.00	$294.00
Average	$260.50				

Table 5: Cost of Hotels – Bowling Green, KY

Hotels	# of people per room	# of rooms	price per night per room	price per night	total price
La Quinta Inn	4	1	$109.00	$109.00	$218.00
Country Inn	4	1	$109.00	$109.00	$218.00
Red Roof Inn	4	1	$85.00	$85.00	$170.00
Microtel Inn	4	1	$95.00	$95.00	$190.00
Holiday Inn	4	1	$132.50	$132.50	$265.00
Average	$212.20				

Table 6: Cost for Truck Rental

Truck	People	Mileage	Gas Cost	Rental Cost per week	Total Cost
Enterprise Nissan Frontier	4	20	$2.19	$510.52	$510.52

2.4 Other Analysis

2.4.1 Gear Ratio Analysis

Table 7: Mechanical advantage of bicycle at various gear settings

	Low gear	**Mid gear**	**High gear**
1st gear	0.301	0.340	0.529
2nd gear	0.261	0.295	0.459
3rd gear	0.241	0.272	0.423
4th gear	0.218	0.246	0.382
5th gear	0.194	0.219	0.341
6th gear	0.174	0.197	0.305
7th gear	0.15	0.170	0.265

Table 7 represents the mechanical advantage of the rider to the vehicle at its various gear settings. A higher gear setting produces ideal mechanical advantage for travel on steeper terrains. However, during competition, it would advantageous to stay in a lower gear setting in order to maximize power output for quicker accelerations. Due to the use of standard mountain bike parts, these mechanical advantage values are like that of a standard mountain bike.

3. Testing

3.1 Developmental Testing

3.1.1 Drivetrain Testing

Idlers were utilized to redirect the chain from its angled position to feed underneath the seat. Another set of idlers at the rear of the frame redirect the chain to its derailleur and gear set at the center of the rear wheel. The team utilized previously acquired skateboard wheels as idlers due to ease of machining of the wheel and their lubricated bearings. The skateboard wheels were used as idlers in effort to save money on the design. In addition to redirecting the chain, these idlers provide the necessary tension needed to keep the chain from derailing at high speeds and when traveling over bumps.

Figure 15: Zoomed Image of Front Set of Skateboard Wheel Idlers on HPV Drivetrain

During initial testing of the HPV, the vehicle was driven in a straight line and accelerated to test the efficiency of the chain and gear powertrain system. The derailleur and handle gear shifters were tested as well. It was noted that the HPV accelerated easily and shifted gears smoothly.

Figure 16: Drivetrain Testing

3.1.2 Steering Testing

Testing was done to ensure that all core steering components maintained their design purpose. T-Bone was able to turn in a radius in less distance than the target specified when designing the vehicle.

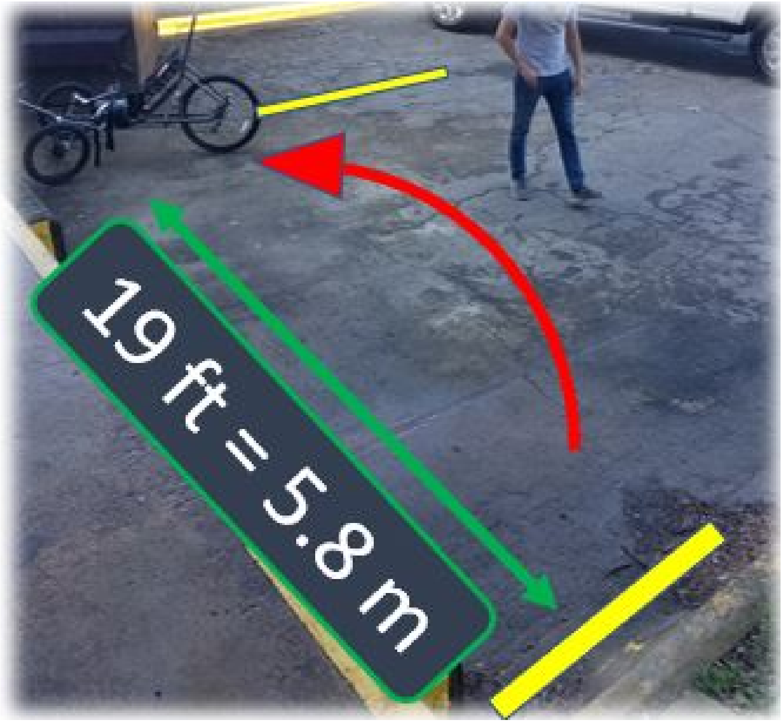


Figure 17: Testing Turn Radius

3.1.3 Braking Testing

Figure 18: Testing Braking Distance

T-Bone was accelerated to 15 mph (as specified by the rulebook) and then brought to 0 mph as quickly as possible. The disk brakes allowed T-Bone to come to a complete stop in exactly 10 feet.

4. Conclusion

4.1 Comparison

Table 8: Comparison of constraints from the design phase to final vehicle specifications

Constraints	**Outcome**
Minimum 6m turn radius	Turn radius is below 6m
Maximum stopping distance of 19.5ft at 15.5 mph	Reached a stopping distance of 10ft
Maximum total weight of 60lbs	Total weight went over the goal

4.2 Evaluation

During testing, T-Bone was able to create a 5.8 m radius turn. This turn remained 0.2 m shorter than the required radius. During a braking test, T-bone was able to slow from 15.5 mph to 0 mph over a distance of 10 feet. T-Bone's braking system stopped the vehicle nearly 10 feet shorter than the constraint. After construction and assembly, the vehicles weight was approximately 69.9 lbs. This near 10-pound overweight deviates from Team 512's initial goal over only a 60 pound maximum.

4.3 Recommendations

To improve T-Bone, Team 512 recommends future teams to focus on three features of the vehicle. These are aerodynamics, drivetrain, and frame. The use of a CFD analysis to calculate the drag coefficient of the vehicle and air flow patterns is highly recommended. The frontal area calculation through a CFD analysis is also recommended to improve aerodynamics. With the data obtained from these CFD results, a fairing can be designed to reduce these values and improve the performance of the vehicle. Drag ultimately increases fatigue on the rider during longer rides. Team 512 utilized existing mountain bike gear sets and pedal mounts. Future teams may find benefit from researching customized gear sets in order to improve mechanical advantage provided by the system. The current geometric design for the chain may also be improved, minimizing frictional elements. The frame uses two steel members going down the length of the vehicle and could be subject to high torsion forces bending the frame out of place. Redesigning this feature to be a singular steel tube with a larger radius can remove this possibility.

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