NEW YORK CITY
COLLEGE OF TECHNOLOGY
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Try-Unique Cycle

MECH 4850 Senior Design Project

Mechanical Engineering Department, Fall 2015

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Chapter 1.Design Problem

1.1 Introduction

The intent is to design and build a functional tricycle for use in the Human Powered Vehicle Challenge (HPVC). Human-powered transport is often the only type available in underdeveloped countries and other inaccessible parts of the world. If well designed, it can be an increasingly viable form of sustainable transportation for a majority of people. A project plan will be developed and submitted to the project Sponsor for approval. The project plan will include: scope statement; schedule; cost estimate; budget; and provisions for scope, resource, schedule, communications, quality, risk, procurement, and project control. The challenge is to develop a vehicle that is capable of satisfying all the rules yet preform efficiently and well enough for the scored obstacles in the event. Our design will entail a different approach than many other teams. With minimal funding, resources and teammates, compared to other teams, we will design our human powered vehicle accordingly. Our product will be able to accommodate riders up to 250lbs from 5 feet to 6’2” tall and be capable of being brought on a commercial airline for traveling.

1.2 Problem Statement

The purpose of the ASME Human Powered Vehicle Competition is to provide opportunity for students to design and build a human powered vehicle to demonstrate its goal of discovery and transmission of knowledge. As mentioned in the rule book, the objective for this competition is to “provide an opportunity for engineering students to demonstrate application of sound engineering principles toward the development of fast, efficient, sustainable, and practical human-powered vehicles.” The team will be scored on the design of the human powered vehicle, innovation in the area of human-powered transport, reliability of performance, speed, and practicality of the overall design on the day of the competition.

Most recreational cycling achieves health enhancing levels but is more likely to be an intermittent choice of activity. It can be a health benefit when cycling is used to get to and from places, including riding to work, to shops, to visit friends locally, or for other regular short trips. Utilitarian cycling is likely to be a more regular or habitual form of physical activity than gym-based or recreational cycling. (13 Pucher)

Human-scale urban environments that support cycling and walking and discourage car use can improve social interactions and increase community attachment, livability, and amenity. Cycling, as a zero-emission form of transportation, offers a currently untapped potential to lower emissions in the passenger transportation sector. Unlike a number of high-tech options, human-powered vehicles are an equitable, off-the-shelf option that can be deployed immediately. (23 Pucher).

Our team will introduce a new tricycle in the recumbent bicycle market. Our product will provide comfort and safety for the user, especially in the case of long distance travel. We will gain the awareness of the consumers who are enthusiastic about exercise and attain an interest of human-powered vehicles. The trike will be used for leisure and commuting to a destination.

1.3 Bench Marking

In this section we observe concepts that were proposed by team members and create a decision matrix displaying the grading of each concept and its effectiveness in each category. Out of the categories chosen, 'Cost' is the one that resonates with the consumers' budget. If the price of the product is too high, it limits the customer base and the amount of retailers that would be willing to hold a floor model with the hope to eventually sell. Due to this element 'Marketability' had to be included in the category listing. This not only factors in price but also quality, features, and other major points about such a trike in its class. 'Durability' was placed to take note of how long the product stays in great working condition, as well as how it deteriorates over time with use. We don't want to sell an expensive product that has to be completely replaced frequently. It has to be able to withstand the wear it will be subjected to in its use. 'Safety' is included to touch upon retaining the wellbeing of the customer, even in the event that something happens to disable the trike; the rider needs to be kept safe and protected. 'Mobility' is really important in this product, because a bike is supposed to be one of the freeing methods of traveling or transportation in terms of being able to move at whatever pace you feel comfortable with. The rider is the engine and heart of this product. The teams' motive is to sell a lifelong investment that enriches the user's life, not a costly expense that does not reap a benefit.

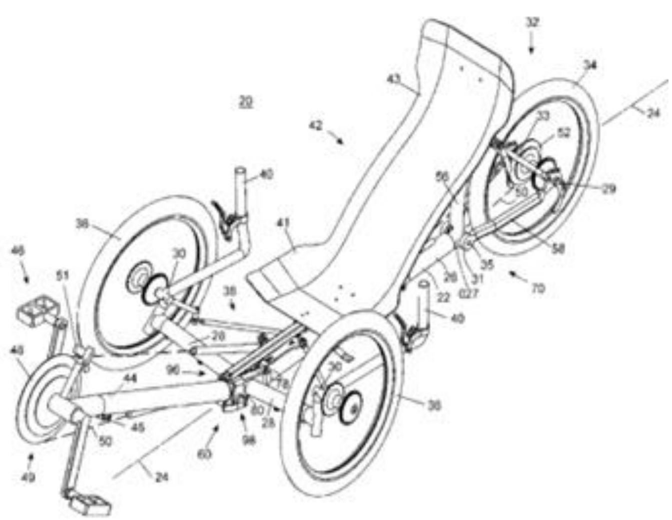
Figure 1 First Concept: Delta

The delta is easier to design then our other alternatives. Unlike Tadpole trikes, it has two rear wheels and one front wheel. Its front wheel is used to steer the vehicle. It requires a lower cost to manufacture because it uses standard bicycle components giving it a rating of cost at **7**(good).However, braking is comprised by a single front wheel which must provide the majority of braking for the vehicle, establishing a rating of mobility at **5**(fair). The *over the seat* steering system makes it easy to get in and out and creates a very comfortable seating position. One-wheel drive delta trikes pull to one side when accelerating and climbing. These trikes tend to be large and not foldable which makes them hard to store and transport.

Figure 2 Second Concept: Tadpole

Tadpole Trikes are versatile, fashionable and practical. The new and inventive way to the road comes from its two front wheels that guide when the trike is in motion. Much like a traditional bicycle, its rear wheel is driven by pedals. Getting in and out of the vehicle might be bit of work because of its low seating position. These are great vehicles to be used in long and fun journeys. Two wheels in front provide better overall braking. The two wheel configuration also offers excellent handling when applying the Ackermann steering system, giving the design a rating of mobility at **8** (Good).

Figure 3 Third Concept: Tilt/one handle bar



The one-handle bar used for steering creates a more distinct riding experience because it allows steering in complex obstacles. However this feature is not favorable for the structural support of the trike because one handlebar used for steering can increase wear in the bearings. Manufacturing a steering system with one handle bar would also influence the design of the steering axle.

Figure 4 Fourth Concept: Folded

The folded design would require extensive design iterations to determine the exact position of the fold. Also research will have to be conducted on the sizing of hinges and joints so that the chassis can fold into the desired position. A folded trike has a high marketability, because this feature makes it easier for consumers to transport their trike to off-road trips and in public transportation. The high marketability gives a rating of **9**.

Figure 5 Fifth Concept: Hand-cycle

The hand-cycle design appeals to handicap people. A person with disabilities can use their hands to propel the tricycle. This consumer group creates an incentive to add health diagnostic equipment to the bike such as a heart rate monitor. It can also be marketed in this aspect, giving it a marketability rating of **8(**good). Unlike a bicycle rider, a hand cycle rider lacks the ability to use body weight to gain a torque advantage. Therefore a low (under drive) gear is necessary and will be considered in order to climb hills or start moving from an idle position. The hand-cycle can be equipped with an electric assist motor for climbing up steep inclines and or resting tired muscles.

Our rating scale is from Unsatisfactory (0) to Excellent (10). Each category will have a grade for each of the designs that will be considered in this project.

Rating scale 1:10

Excellent 9-10

Good 7-8

Fair 5-6

Poor 3-4

Unsatisfactory 0-2

Table 1 Decision Matrix

Design	**Cost**	**Safety**	**Marketability**	**Durability**	**Mobility**	**Total**
Tilt/one handlebar	5	8	3	6	4	26
Tadpole	5	8	9	7	8	37
Hand-cycle	3	6	8	6	6	35
Folded	2	4	9	4	8	32
Delta	7	8	7	8	5	35

Table 2 Summary of Pros and Cons

Design	**Pros**	**Cons**
Tilt/one handlebar	Different dynamic behavior	Stresses applied to handlebar
Tadpole	Intuitive, easy to learn, provides stability	Rear wheel carry excessive weight
Hand-cycle	Used by handicap	Not applicable to all consumers
Folded	Easy to transport	Raises design complexities
Delta	Simple to manufacture	Difficult to steer

1.4 Identifying Customer Requirements and Needs

1.4.1 Purposes and Market

The target market for this project are people that have some knowledge about bicycles and enjoy customizing their ride. These riders are most likely weekend explorers that are looking for a fun way to adventure and exercise. The most expected users are middle aged road cyclists that are looking for a change in their riding position and a different way to cycle. Before we start building the vehicle, we research the information on materials, components, steering concepts, wheel sizes, and rider ergonomics.

Recumbent tadpole trikes are specialty products. Although they cost more than regular bikes, they have a gone through development and a lot of companies and stores are dedicated to this exact market. They are more comfortable than regular bikes, and are great for people with back or neck pain, or for people who just want a more comfortable ride. There can be room for storage behind the seat, and can be sold with an optional electrical motor. They are great for commuting or for long range riding. These wouldn't sell so well in the city, but they are great for suburban areas, where there is more space and less cars on the roads. Unlike other designs out there, our design will feature roll bars and a harness. This not only protects the rider, but also makes the trike higher and more visible to cars, which is a safety concern with low trikes. The trike will meet all New York safety standards for a human powered vehicle.

Most recumbent tadpole trikes sell for upwards of $1400. If we keep costs down without compromising the quality, this trike could potentially sell very well. The marketability is high given the rise of outdoor related activities and more people taking extended trips in non-motorized vehicles. Such would be the markets that this recumbent trike would be marketed to: outdoor enthusiasts, adventurers, and people with recumbent tricycles. The cost of the trike itself will cost considerably less than a rigid trike based off of raw material costs, and manufacturing costs. The benefits to the user are high. The user has a complete aerodynamic device that cuts down on wind resistance, increases their efficiency, shields them from the environmental elements and reduces the amount of overall gear necessary to pack. With the trend to buy products that have lower environmental impacts and more people using bicycles for transportation, recumbent trikes have a high market potential.

1.4.2 Functions and Requirements

Since this product is being made with the intent to participate in the next available Human Powered Vehicle Challenge (HPVC), it only makes sense to meet the standards placed for the competition as well as those for a customer if/when we get the support to produce the product for the market. The following is an excerpt from the September 20, 2015 Rev. 1 of the 2016 HPVC Rules document titled RULES FOR THE 2016 HUMAN POWERED VEHICLE CHALLENGE.

General Rules of Competition

A) Minimum Number of Vehicles to Compete: There is no requirement for a minimum number of vehicles. However, should the number of vehicles entered be more than one but less than four, the number of awards granted for overall placement in that event shall be one less than the number of competing vehicles. To be eligible for overall 1st, 2nd, or 3rd place winner, a vehicle must compete and score in all four competitions. In the endurance event, a vehicle must complete at least 10 kilometers in order to meet this requirement.

B) Events of the Competition:

▪ Design Event: Teams are scored on their application of sound engineering principles and practices toward a vehicle design. This event includes a written report, a technical presentation, and static judging of their design.

▪ Men's and Women's Speed Event: Teams are scored on the speed of their vehicles, either in a flying start 100 meter sprint or a head-to-head drag race from a standing start. The ASME HPVC Committee will announce which event will be held well in advance of the competition. Separate scores for men and women are recorded for this event.

▪ Innovation Event: Teams are scored on the design and demonstration of a technical innovation related to their vehicle.

▪ Endurance Event: Teams are scored on speed, practicality, performance and reliability of their vehicles in a road race format with urban transportation obstacles and challenges.

C) Modification of Vehicles: Modifications to the vehicle are allowed between events, as long as safety is not compromised. Vehicles must retain their main frame and general drivetrain configuration. Any vehicle deemed to have undergone changes in excess of this allowance will be permitted to compete if it does not present a safety risk; however, any scores achieved will not be credited to the original entry. Vehicles in which the basis of design involves changes to the main frame or drive train configuration for various racing events must submit a request for a waiver prior to the report due date.

D) Aerodynamic Devices: Vehicles may include components, devices, or systems engineered specifically to reduce aerodynamic drag. Front fairings, tail sections, full fairings and other such devices are encouraged. The effectiveness of aerodynamic devices must be substantiated in the design report in order to receive credit for the design scores regarding aerodynamics.

E) Vehicle Number and Logos ASME will assign each vehicle a number. The number "1" will be assigned to the overall winner from the prior year's competition. All other numbers will be assigned by ASME. At its discretion, ASME may consider requests for specific vehicle numbers, but no zero or triple digit numbers will be allowed.

School Name – All vehicles should display their school name or initials on each side of the vehicle in characters at least 10cm high in a color that contrasts with the background.

F) Fairness of Competition: All participating teams will be assured an equal opportunity and a fair competition. Any participating team that, in the reasoned opinion of the judges, seeks to exert an unfair advantage over other competitors will be subject to a penalty in performance points or disqualification from the competition.

G) Protests: Protests must be announced to a member of the judging staff either at the time of the incident or within a 15 minute period following the announcement of results of the event. Following the announcement of the intent to protest, a written protest must be presented within 30 minutes unless otherwise allowed by the Head Judge. Oral protests will not be recognized.

Protests must be specific in nature and must include a factual account of the event being protested and the specific rules infraction, or the perceived error in the scoring of an event. ASME HPVC Form 7 may be used to file a protest. This form is available in the appendix of the rules. Protests will be examined and resolved by the judges at their earliest convenience during the competition. Their decision will be final and without further appeal.

H) Event Scoring: Scoring for each event and the overall scores will be based on a points system. The team with the most points wins the event.

I) Energy Storage Device: Vehicles may employ the use of energy storage devices for purposes of accelerating and improving performance of their HPVs, but by no means are they required. If energy storage is used energy must be stored while the vehicle is in motion, with human power as the sole external source of energy. Prior to each race, each team must demonstrate that their storage device has no initial energy stored. Combustion engines are excluded from the competition. Energy storage devices are permitted in the Technology Innovation event, and all energy storage devices should be compatible with the spirit of the competition with respect to energy conservation and environmental stewardship.

During the safety inspection the team must be prepared to discuss the safety of the storage device, especially during a high-speed incident. Teams whose vehicles present an unacceptable risk in the perception of the judges will not be allowed to utilize the energy storage device in the competition. Stored energy used to power non-motive systems (does not impart momentum to the vehicle) is allowed and may be stored prior to the beginning of the race.

J) Report Publication After the completion of the events for a particular HPVC all team’s design and innovation reports will be published to a shared site.

If a team does not want their design and/or innovation reports posted publically the team must submit a request, in writing, to the event Head Judge no later than the report due date. The request must convincingly outline the grounds (such as active NDAs, or submission for intellectual property) for which the request is being made, and teams must be prepared to present an alternative submission omitting any specific sections in question. Requests will be granted or denied by the judging committee, and their decision will be final and without appeal.

K) Readiness to Compete Teams must show up ready to compete and repair facilities will only be provided if the host school offers. The host is not responsible for assistance with vehicle repairs.

[1] RULES FOR THE 2016 HUMAN POWERED VEHICLE CHALLENGE, https://community.asme.org/hpvc/m/default.aspx#_ga=1.195434028.1490881909.1445380531

1.5 Corporate Constraints

1.5.1Time to market

The product should be ready by December 15. By the end of October we should have the CAD drawings done, all the materials on hand, and some of the assembly started. Midway through November we should be finishing up the assembly. After that we would need to run tests and do some finishing up on the assembly. Afterwards we would just need to make adjustments, and finish up the reports.

The key process requirements for rapid time-to-market are:

- Clear understanding of customer needs at the start of the project and stability in product requirements or specifications;
- A characterized, optimized product development process;
- A realistic project plan based on this process;
- Availability of needed resources to support the project and use of full-time, dedicated personnel;
- Early involvement and rapid staffing build-up to support the parallel design of product and process;
- Virtual product development including digital assembly modeling and early analysis and simulation to minimize time consuming physical mock-ups and testing
- Design, re-use and standardization to minimize the design content of a project
- Simplicity – the areas that are complex should be evaluated and reviewed to make sure it is feasible to create the part(s)/system(s) and that they can be tested and approved for use.

1.5.2 Financial Performance

$$Q = N \times A \times P$$

Q = Quantity of the product expected to be sold during a time period

N = number of (annual) purchases

A = Fraction of potential customers or purchases for which the product is available and the costumer is aware of the product

* A = awareness x availability *

P = probability of purchase (surveyed)

$$= C_{definitely} \times F_{definitely} + C_{probably} \times F_{probably}$$

$F_{definitely}$ is the fraction of survey respondents indicating in the concept test survey that they would definitely purchase the product

$F_{probably}$ is the fraction of survey respondents indicating in the concept test survey that they would probably purchase the product

$C_{definitely}$ and $C_{probably}$ is calibration constants usually established based on the experience of company with similar products in the past.

$$0.10 < C_{definitely} < 0.50 \qquad 0 < C_{probably} < 0.25$$

This is assuming that the trikes are sold into the market at a rate of 15,000 units per year.

Our company will be selling the product through a single distributor that accounts for 45 percent of the sales within the same category. Results from a concept test with factory managers responsible for purchasing transportation devices responsible for purchasing transportation device indicate a definitely-would-buy fraction of 0.60 and probably-would-buy fraction of 0.35

- N = current device sales to factories (15,000)
- A = 0.45 (single distributor's share)
- P = 0.4 x *top-box* + 0.2 x *second-box*
- Q = 15,000 x 0.45 x [0.4 x 0.6 + 0.2 x 0.35]

  = 2092.5 units/yr

1.6 Social, Political and Legal Requirements

Hard braking mixed with a yank on the handlebars can spell disaster on recumbent trike. This is a true fact, a rider can brake hard or swerve, but not at the same time. Trikes are different, because you can put force into a turn without leaning the bike, a trike is much more capable of maneuvering around sudden road danger. If you try this your life will be in grave danger! It is NOT safe to swerve and brake at the same time. For those who believe a trike won't roll over, think about the national campaigns warning of SUVs doing so in the past. They were heavier and had a wider wheel base than a trike. A swerve is NOT a turn. Please DO NOT attempt applying brakes during a swerve. You can apply brakes immediately before or after a swerve. Just separate them. The laws of physics involved do not discriminate based on luck, experience, or the number of accident-free miles ridden. Understanding the limits of the Trike, the environment and the Rider – and staying within them is the key to reducing the inherent risk involved in riding a trike.

The following are mechanical requirements established in *The Code of Federal Regulations*.
Sharp edges. There shall be no unfinished sheared metal edges or other sharp parts on assembled bicycles that are, or may be, exposed to hands or legs; sheared metal edges that are not rolled shall be finished so as to remove any feathering of edges, or any burrs or spurs caused during the shearing process. (The Code of Federal Regulations §1512.4 Mechanical requirements)

Braking system. Bicycles shall be equipped with front- and rear-wheel brakes or rear-wheel brakes only. (The Code of Federal Regulations §1512.5 Requirements for braking system)

Crank differential. The differential between the drive and brake positions of the crank shall be not more than 60° with the crank held against each position under a torque of no less than 13.6 N-m (10 ft-lb). (The Code of Federal Regulations §1512.5 Requirements for braking system)

Independent operation. The brake mechanism shall function independently of any drive-gear positions or adjustments. (The Code of Federal Regulations §1512.5 Requirements for braking system)

Construction. Pedals shall have right-hand/left-hand symmetry. The tread surface shall be present on both top and bottom surfaces of the pedal except that if the pedal has a definite preferred position, the tread surface need only be on the surface presented to the rider's foot. The Code of Federal Regulations §1512.7 Requirements for pedals)

1.7 Evaluating Customer Requirements an Needs

To evaluate our audience, a questionnaire was created. A series of questions highlight customer requirements that are specific to the mobility and quality of the product. The results of the survey will help to screen design concepts that will ultimately become a physical product. The results will also provide solutions that can help to improve the design of trike.

Product Questionnaire

Please pick one of the designs and answer the following question to the related project idea and decision making.

Questions

1. Which design do you prefer and why?
    - A. Delta
    - B. Tadpole
    - C. Hand-cycle
    - D. Tilt/one handlebar
    - E. Folded

2. What kind of feature/mechanics do you prefer?

3. How important is it to transport the trike in your vehicle? (Rate 1.Not too important -5.Very Important)

4. How important is it to travel with your bike? (Rate 1.Not too important -5.Very Important)

5. Does price affect the design selection? (Rate 1.Not too important -5.Very Important)

6. Does the quality and durability affect your selection? (Rate 1.Not too important -5.Very Important)

Chapter 2. Design Proposal

2.1 Concept Selection

Based on our decision matrix, we narrowed our design to two types of three wheeled vehicles; Delta and Tadpole. Let's see the differences in these two types of design. Within this section we compare the perspective cost analysis of each type of design.

Table 3 Estimated cost analysis for Delta Trikes

Delta Trikes			
Parts	**Quantity**	**Unit Price**	**Total**
Aluminum square beams	3	$10	$30
Chain	3	$10	$30
Pedal	1	$12	$12
Crankset	1	$20.57	$20.57
Seat/Hardware	1	$10	$10
Rear derailleur	1	$9.47	$9.47
Rear-Wheel (20x1.5 Inch)	2	$34.32	$68.64
Front- wheel(26X1.5 Inch)	1	$24.99	$24.99
Tube	1	$3.30	$3.30
Tire	3	$22.03	$66.09
Chain housing guide	2	$15	30
Brake Cable	1	$12.97	$12.97
			Total= $318.03

Table 4 Estimated Cost analysis for Tadpole Trikes

Tadpole Trikes			
Parts	**Quantity**	**Unit Price**	**Total**
Aluminum square beams	3	$10	$30
Chain	3	$10	$30
Pedal	1	$12	$12
Crankset	1	$20.57	$20.57
Seat/Hardware	1	$10	$10
Rear derailleur	1	$9.47	$9.47
Rear-Wheel (26x1.5 Inch)	1	$34.32	$34.32
Front- wheel(20X1.5 Inch)	2	$24.99	$49.98
Tube	1	$3.30	$3.30
Tire	3	$22.03	$66.09
Chain housing guide	2	$15	30
Brake Cable	1	$12.97	$12.97
			Total= $308.70

2.2 Functional Analysis

Based on our decision matrix, we narrowed our design to two types of three wheeled vehicles; Delta and Tadpole. In our decision-making process we will also analyze other features such as stability, braking, and turning; we analyze how each design holds up in these features.

Dynamic Stability

When talking about dynamic stability in a vehicle it is meant that it reacts safely and predictably under various driving conditions. To choose the right design for the chassis, we can relate this to how a car reacts when turning too fast. One of the two things will happen, either the car wheels will slip relative to the ground, or the vehicle will tip over. Obviously, slipping is the desired outcome. Why do we want slipping? The answer is simple, when the car does slip out of control on a fast turn, we can design it in such a way that we know the front or the back will slip first. If the rear wheels slip first, the vehicle runs the risk of spinning out of control (oversteer). If the front wheels slip first (understeer), you won't spin out and it is easier to regain control. Understeer is considered a safe dynamic response to slipping in a turn and is designed into all commercial cars.

The problem for delta vehicles is how to distribute their weight and control their weight transfer during a turn to avoid undesirable outcomes. If you design the weight distribution for a heavy front bias to achieve understeer, you increase the risk of tipping over. If you increase the weight distribution on the rear tires, the vehicle will oversteer in hard turns. The following is an image of a Delta type vehicle known as the Reliant Robin doing a regular left turn.

Figure 6 Example of Weight distribution – car in image, Reliant Robin.

Concept Selection Winner: Tadpole
Here is why.

Braking

The front wheels on any vehicle provide the majority of your stopping power (60%-70%). The delta is at a disadvantage considering the weight distribution and the fact that it has one less front tire to brake on.

The steering system for a tadpole is definitely easier to design for the delta. No special considerations need to be taken into account to avoid lateral wheel slipping on turns. Front suspension design is a common feature on the delta. The best choice is the telescopic fork.

Center of Gravity (COG)

For any tadpole trike, the center of gravity of the rider is low, and located ahead of the forward tipping axis so it would tip forward under a 1g braking force. With modern caliper brakes, this would have a tendency to lift the rear wheel. On a downward slope the tipping manifest would be even less. Now many customers will have this question on their mind "Why not position the front wheels further forward" Well there are some issues with it such as; the cross member will get in the way of the cyclists calves, the seat will become more difficult to stand up out and the riders feet will be located are too far forward.

The COG for Delta rider's is unusually high for a trike, and it is located behind the forward tipping axis so it will be far more stable under a 1g braking force. Although the delta trike exacerbates problems when riding up an unusually steep grade, the trike could easily lift the front wheel if enough force was applied to the pedals in a low gear. But in normal riding conditions it will be an unlike problem.

Turning:
Delta Trike

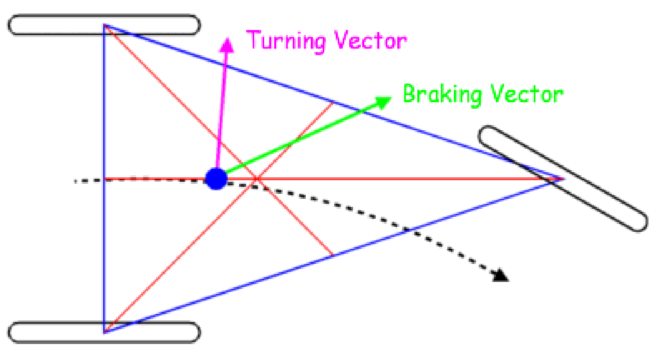


Figure 7 Turning Forces in Delta Configuration

As demonstrated in Fig.7, while under turning forces the delta rider's COG is well placed under combined turning and braking forces. The long wheel base of the delta decreases the twitchiness of the steering, improving high speed steering control and precision. Even though with such a well-placed COG, delta trikes can still roll over. Though the rearward weight distribution favors oversteer, the trike would tend to spin out as a result if the wheels loose traction on loose gravel.

Tadpole Trike

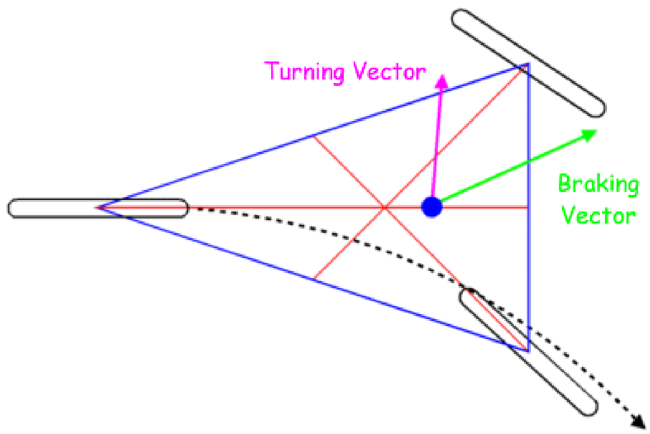


Figure 8 Turning forces in Tadpole configuration

Tadpole riders experience well placed COG under turning forces; this is due to a low seat, which makes it more stable than the delta. Yet under combined turning and braking forces there is a possibility of tipping forward. Although the forward COG placement, it will still take some effort to get the tadpole to tip forward.

Aerodynamics

The tadpole design lends itself better to the aerodynamics compared to the delta. The tadpole tear drop length/width ratio is higher than the delta. The image below shows how poorly the correct shape fits the delta design. Plus, you would have to encase more empty space with the delta design.

Figure 9 Tear drop length/width ratio

Powertrain

The delta design has more disadvantages when selecting your drive wheel. If you go with front wheel drive, you risk putting too much weight at the front of the vehicle. If you choose the back, you need to add a differential gear to the rear wheels. In each configuration you have a disincentive to have too much weight on the front driving wheel, so you miss out on potential traction. A tadpole with one rear wheel drive gets the best of both worlds. No differential is necessary and you can keep 30% of the vehicle weight on the drive wheel to maintain good traction.

2.3 Project Variables

2.3 a Goals and Objectives

The goal and objectives of the project generate a clear target for the entire project.

Goals	**Objectives**
To create and distribute a working tricycle for use in the Human Powered Vehicle Challenge in the time frame of three months.	1. Form teams to help move the work load. 2. Conduct extensive research to create a concept of the design 3. Move forward with a two-step process of elimination to determine the selection that will ultimately drive the project. 4. Test the concept – Structural Analysis and Forecasting of Sales before introduced to the market. 5. Trike Architecture 6. Design for Environment & Design for Manufacturing 7. Building of Trike 8. Analysis and Testing

2.3 b Project Deliverables

Milestone	**Deliverable**
1. Assignment of Teams	• Organization of Workforce
2. First Draft/ Template of the HPVC Report	• A starting point to build off of
3. Periodic Collection of Data from teams	• Words &/ CAD files from designers that have drafted/ created parts • A view on current progress with build of trike • Periodic updates to the document
4. Fully Built trike	• The physical product, fully working
5. Final Presentation	• A new vehicle that will be registered to participate in the competition.

2.3 c Project Milestones

Project Milestone	**Date Estimate**	**Deliverable(s) Included**	**Confidence Level**
Assignment of Teams	[09/08/2015]	[Organization of Workforce]	[High/**<u>Medium</u>**/Low]
First Draft/ Template of the HPVC Report	[09/29/2015]	[A starting point to build off of]	[**<u>High</u>**/Medium/Low]
Generate Drawings	[09/08/15] – [11/24/15]	[Words &/ CAD files from persons that have drafted/ created parts] [Periodic updates to the document]	[High/**<u>Medium</u>**/Low]
Safety/failure analysis	[11/12/15]	[A view on current progress with build of trike]	[High/**<u>Medium</u>**/Low]
Final Presentation	[12/15/2015]	[Final Design Report]	[**<u>High</u>**/Medium/Low]

2.3.1 Project Assumptions

We begin the project with a set of assumptions that need to be verified during the course of the project. If these assumptions turn out to be incorrect; in effect, the team has to adjust behaviors and assignments that need to be altered in accordance. It is important that we do not hold any one of the following assumptions true without further investigation.

- Group members will attend meetings outside of class hours.

- Group members in specific roles will do the tasks assigned to them.

- The budget we work with will not be enough for our project.

- All group members are working on a similar time-frame with a similar availability.

- We may have to outsource to professionals with manufacturing experience.

- The group does not have an efficient and reliable means of communications.

- This project, with all the rules and specifications, may not be completed in the allotted time-frame.

- We have a reliable source for scrap bike parts.

- We have access to necessary equipment for construction.

- We understand the rules of the competition.

- There may be a delay in the obtaining of some of the parts for construction.

- A lot of time may be spent in the research process.

2.3.2 Project Risks

The Project Risk table provides information of the risks that could happen during the performance of the project. Determining risks helps the team to avoid them in the project and also assist in the development of a solution. This discussion will also prepare the team for upcoming problems and help the team to prepare for the worst. Risks that are important are the processes that are the most time-consuming which include, obtaining parts and the manufacturing of the tike. In order to prevent so, the team must prepare and plan ahead the tasks that need to be done.

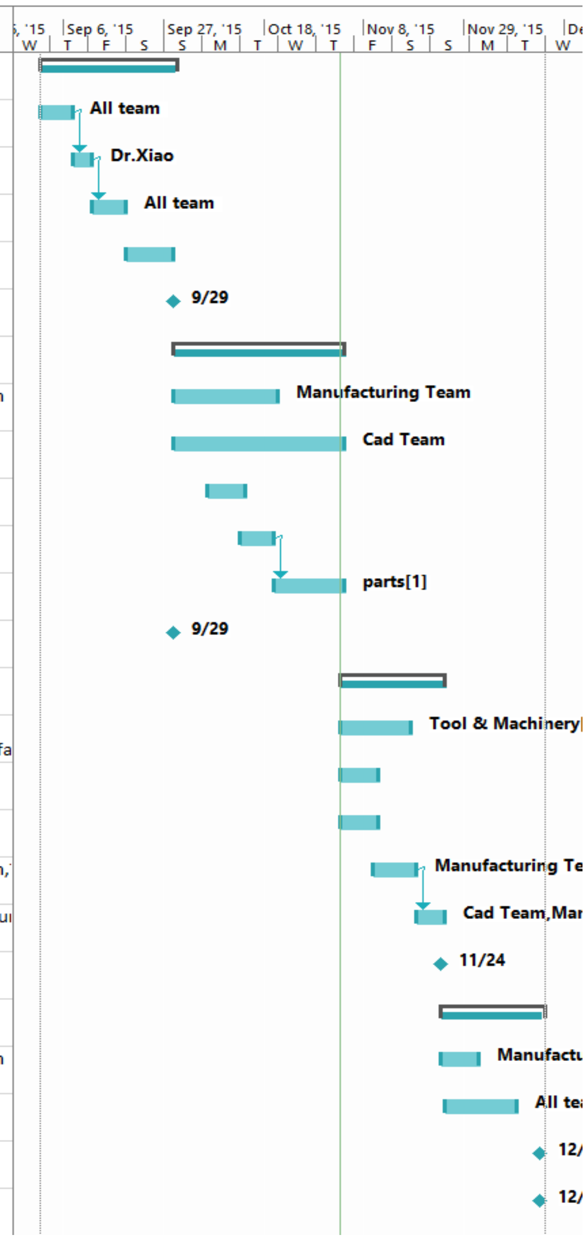
#	Risk Area	Likelihood	Risk Owner	Project Impact-Mitigation Plan
1	[Obtaining parts may be time consuming]	**[High]**	Manufacturing Team	[What other parts can we use instead?]
2	[Completion of First Draft]	[Low]	Group	[Follow through with everything we need accordingly and in a timely manner.]
3	[Building the Trike]	**[High]**	Group	[Do we have all the parts?] Find out about the parts for the trike, and check against a plan. [Is there enough funding to acquire all the things we need?] We will borrow the Managers line of credit, if that is not enough – we can petition to other resources or sponsors. [Are there enough parts to use?] If we are able to obtain a bit more as to not worry if anything breaks or not the exact fit, that would be very favorable. [Will the parts fit and work together?] We will be consistent in the measurement system of the parts. Using ASME Y14.5-2009 Dimensioning and Tolerance standards and International Organization of Standards (ISO) [Do we have the right tools for the job?] Specialty equipment can be borrowed.

2.4 Project Schedule

A Gantt chart is commonly used in project management. It is a useful way of showing our activities displayed against time. On the left side of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration, and end date of the activity. In the chart, our team starts with the preliminary design phase which consists of research and decision making. As time moves forward, we monitor the progress of our project throughout the report. During the intermediate design phase, the drawings are generated and finalized by the end of October. While the drawing is undergoing, the manufacturing team will generate a manufacturing plan based on research of similar trike projects. The process which proceeds is the comprehensive design phase which consists of the manufacturing of the trike. In this phase the teams will coordinate to re-iterate designs and use safety and failure testing to ensure quality in the product.

Table 5 Gantt Chart

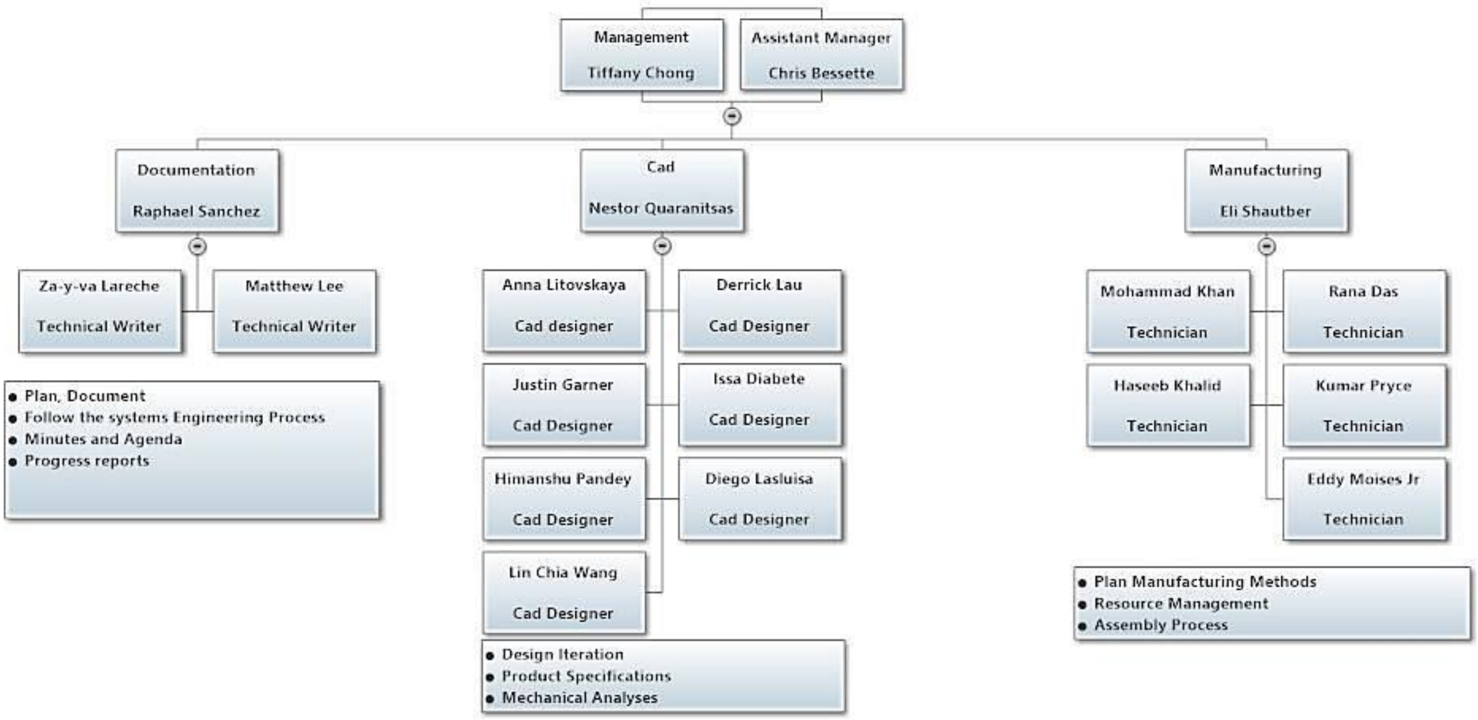
ID				Duration	Start	Finish	Resource Names
1	1		**Preliminary Design phase**	**21 days**	**Tue 9/1/15**	**Tue 9/29/15**	
2	1.1		Proposal	5 days	Tue 9/1/15	Mon 9/7/15	All team
3	1.2		Design proposal review	4 days	Tue 9/8/15	Fri 9/11/15	Dr.Xiao
4	1.3		Design decision	6 days	Sat 9/12/15	Fri 9/18/15	All team
5	1.4		Resource management plan	7 days	Sat 9/19/15	Mon 9/28/15	
6	1.5		preliminary design repor	0 days	Tue 9/29/15	Tue 9/29/15	
7	2		**Intermediate Design phase**	**26 days**	**Tue 9/29/15**	**Tue 11/3/15**	
8	2.1		Manufacturing plan	16 days	Tue 9/29/15	Tue 10/20/15	Manufacturing Team
9	2.2		Generate Drawings	26 days	Tue 9/29/15	Tue 11/3/15	Cad Team
10	2.3		Finite Element Analysis	6 days	Tue 10/6/15	Tue 10/13/15	
11	2.4		Material Selection	5 days	Tue 10/13/15	Mon 10/19/15	
12	2.5		purchase of raw material	11 days	Tue 10/20/15	Tue 11/3/15	parts[1]
13	2.6		Intermediate design report	0 days	Tue 9/29/15	Tue 9/29/15	
14	3		**comprehensive Design phase**	**16 days**	**Tue 11/3/15**	**Tue 11/24/15**	
15	3.1		Major component welding: chassis	11 days	Tue 11/3/15	Tue 11/17/15	Tool & Machinery[1],Manufa
16	3.2		Seat Fabrication	6 days	Tue 11/3/15	Tue 11/10/15	
17	3.3		Spindle Fabrication	6 days	Tue 11/3/15	Tue 11/10/15	
18	3.4		sub-component assembl	7 days	Tue 11/10/15	Wed 11/18/15	Manufacturing Team,
19	3.5		safety/failure Testing	4 days	Thu 11/19/15	Tue 11/24/15	Cad Team,Manufactu
20	3.6		comprehensive design report	0 days	Tue 11/24/15	Tue 11/24/15	
21	4		**final design phase**	**16 days**	**Tue 11/24/15**	**Tue 12/15/15**	
22	4.1		Trike redesign	6 days	Tue 11/24/15	Tue 12/1/15	Manufacturing Team
23	4.2		Prep for Presentation	11 days	Wed 11/25/15	Wed 12/9/15	All team
24	4.3		Final design report	0 days	Tue 12/15/15	Tue 12/15/15	
25	4.4		Final Presentation	0 days	Tue 12/15/15	Tue 12/15/15	



2.5 Team Structure and Resource Management

2.5.1 Team Structure

In the structure we have the entire class broken up into teams. The teams are arranged by their profession, such as management, documentation, CAD, and manufacturing. Underneath each team, is a brief description of the tasks that the team hold responsible. The team structure helps us to know where to find a member of a particular group when in need of assistance. The structure is also flexible when the workload is high. If there is a need for members to help out with activities temporarily in a different group; it can be accommodated if they are available.



2.6 Resources

2.6.1 Resource Management Plan

Table 6 Resource Management Plan

Resource	Role	Sep-15	Oct-15	Nov-15	Dec-15
Tiffany Chong	Project Manager				
Chris Bessette	Assistant Project Manager				
Raphael Sanchez	Writer / Editor				
Za-y-va Lareche	Documentation Specialist				
Eli Shzauber	Manufacturing Lead				
Kumar Pryce	Manufacturing				
Haseeb Khalid	Manufacturing				
Mohammad Khan	Manufacturing				
Rana Das	Manufacturing				
Eddy Moises Jr.	Manufacturing				
Nestor Ouranitsas	CAD Lead				
Justen Garner	CAD				
Himanshu Pandey	CAD				
Issa Diabate	CAD				
Derrick Lau	CAD				
Anna Litovskaya	CAD				
Diego Lasluisa	CAD				
Lin Chia Wang	CAD				

2.6.2 Material Purchase

Table 7 Material Purchase

Number	Product	Quantity	Price	Sub Total
1	*Zinc-Plated Grade 5 Steel Hex Coupling Nut, 3/8"-24 Thread Size*	**2**	$4.77	$9.54
2	*ASTM A193 Grade B7 Steel Threaded Rod, 3/8"-24 Thread, 4 ft Long, Fully Threaded*	**2**	$13.60	$27.20
3	*Steel Ball Joint Rod End, 3/8"-24 Right-Hand Female Shank, 3/8" Ball ID, 13/16" L Thread*	**4**	$3.78	$15.12
4	*Medium-Strength Grade 5 Zinc-Plated Steel Cap Screw, 5/8"-18 Thread, 3-1/2" Long, packs of 5*	**1**	$9.22	$9.22
5	*Medium-Strength Grade 5 Zinc-Plated Steel Cap Screw, 3/8"-16 Thread, 4-1/2" Long, packs of 10*	**1**	$6.44	$6.44
6	*Low-Carbon Steel Rectangular Bar, 3/16" Thick, 2" Width, 3' Length*	**1**	$11.66	$11.66
7	*Clamping U-Bolt with Screw Threads, Zinc Plated Steel, 5/16"-18 Thread Size, 1-3/4" ID*	**6**	$1.75	$10.50
8	*Low-Carbon Steel Tubing, 1.125" OD, .625" ID, .250" Wall Thickness, 1' L*	**1**	$16.16	$16.16
9	*Low-Carbon Steel Bar, 1/4" Thick, 2" Width, 2' Length*	**1**	$16.15	$16.15
10	*Extended-Life Adjustable Roller Chain Tensioner, 3" Long, 2-11/16" Wide*	**1**	$55.32	$55.32
11	*Galvanized Low-Carbon Steel 90 Degree Angle, 2" X 2" Legs, 1/4" Thickness, 1' Length*	**2**	$17.20	$34.40
12	*Galvanized Low-Carbon Steel 90 Degree Angle, Perforated, 1-1/2" X 2-1/4" Legs, 5/64" Thickness, 3' L*	**2**	$11.65	$23.30
13	*High-Strength A514 Alloy Steel, 1/4" Thick, 6" X12"*	**1**	$52.33	$52.33
14	*Light Duty Plastic White Solid Surface 4 '25" Diameter*	**1**	$7.16	$7.16
15	*Steel Bar Bearing*	**2**	$8.23	$16.46
16	*Stainless Steel Flat Head Philip Machine Screw*	**1**	$5.01	$5.01
17	*Shimano Brake Cable and Housing Set*	**1**	$12.55	$12.55
18	*Koch Roller Chain Connector Link -4 packs*	**1**	$6.38	$6.38
19	*Brake Lever Sunlt Dual Cable for F&R ALY*	**1**	$11.15	$11.15
20	*Spindle Sets and Components*	**1**	$45.93	$45.93
21	*2 inches EMT pipe*	**2**	$13.00	$26.00
22	*Bicycle Miscellaneous Parts*	**1**	$21.78	$21.78
		Total		**$439.76**

2.6.3 Machinery and Equipment

- Johnson® Horizontal BandSaw
- Powermatic®-Drill Press
- Cincinnati®-Surface Grinder
- Bridgeport®-Vertical mill
- Clausing®-Vertical Mill
- Clausing®-Horizontal lather
- Powermatic® -Vertical Bandsaw
- Dimension® sst -3s BP machine
- Miller®-AC/DC Arc welder
- Fortus® 400mc-3D BP machine

2.7 Specifications

Table 8 Design Specifications

Customer requirements	Design specifications	Component Design
Steering	Can turn within an 8m radius, and demonstrate stability by traveling for 30m in a straight line at a speed of 5 to 8 km/hr	Steering arms connected to front wheels to pivot the front wheels and a steering crossbar to maintain proper alignment.
Rollover protection system (RPS)	Functionally, the RPS must: Absorb sufficient energy in a severe accident to minimize risk of injury.	Adjustable support seat frames. Wide distance between two front wheels for stability.
Acceleration system	Can accelerate to 25 km/hr	Using a derailleur to change gears.
Light-weight	Can be lifted by rider for transport	The use of steel tubes and fittings provides a very stiff and lightweight frame
Long-term use	Able to last for several years without component failure	Using tough material and applying appropriate welds
Braking system	Each vehicle must demonstrate that it can come to a stop from a speed of 25 km/hr in a distance of 6.0 m	Disc brakes operated by movable brake levers mounted to steering arms
Aerodynamic drag	Vehicles may include components, devices, or systems engineered specifically to reduce aerodynamic drag. Front fairings, tail sections, full fairings and other such devices are encouraged	Front fairing

2.7 QFD

Quality function deployment is a method used to organize the customer requirements and compare them to the functional requirements of the trike. We analyze the relationship between the functional requirements by assigning a positive or negative correlation in the diagonal column above the chart. The chart also establishes the strength of the relationship between the customer and functional requirements by aligning the rows and columns to display a value. After completing the QFD, we make the observation that the drive train is an important functional requirements since it shares a strong relationship with steering, acceleration, and cost. This observation lead us to prioritize this specific functional requirement in our design. The QFD chart also displays the values in which we rate our competitor's performance in reaching the customer requirements. Based on these values we can make a prediction on how we will succeed in the future of the project.

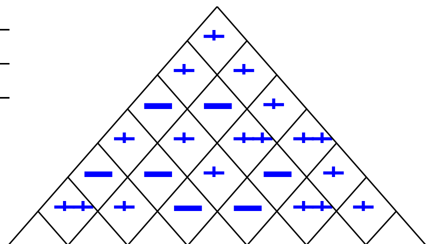
Title: HPVC Trike 2015

Author: Senior Design Documentation

Date: 10/20/2015

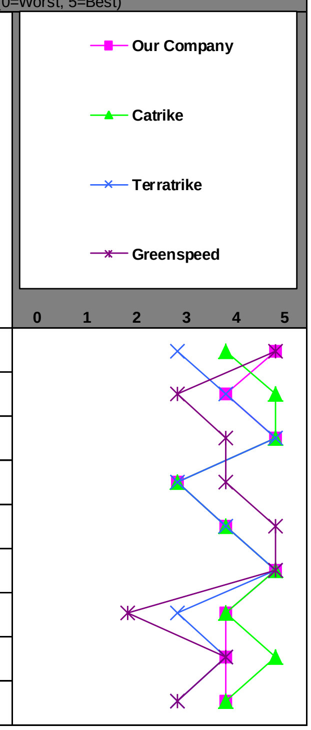
Notes: Analysis of Customer Requirements and there relationships to the functional requirements

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Chassis Structure	Suspension	Steering Axle	Adjustable Seat	Drive Train	Wheel size	Weight Limit	Our Company	Catrike	Terratrike	Greenspeed
				Column #	1	2	3	4	5	6	7				
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▼	▼	▲	▲	▲	▲				
1	9	14.7	5.0	Steering	O	Θ	Θ	O	Θ	Θ	Θ	5	4	3	5
2	9	8.8	3.0	Comfort	O	Θ	O	Θ	O	▲	Θ	4	5	4	3
3	9	8.8	3.0	Acceleration	▲	O	▲	▲	Θ	Θ	Θ	5	5	5	4
4	9	11.8	4.0	Light-w eight	Θ	▲	▲	O	O	O	O	3	3	3	4
5	9	14.7	5.0	Long-term use	O	Θ	O	O	Θ	▲	▲	4	4	4	5
6	9	14.7	5.0	Braking System	O	▲	Θ	▲	Θ	Θ	O	5	5	5	5
7	9	5.9	2.0	Aerodynamic drag	Θ	Θ	O	O	▲	O	Θ	4	4	3	2
8	9	8.8	3.0	Storage	O	▲	▲	Θ	▲	Θ	▲	4	5	4	4
9	9	11.8	4.0	Cost	Θ	O	O	O	Θ	O	▲	4	4	3	3
				Target or Limit Value	7	8	9	8	7	9	6				
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	8	5	7	6	5	4	3				
				Max Relationship Value in Column	9	9	9	9	9	9	9				
				Weight / Importance	458.8	494.1	417.6	358.8	658.8	535.3	458.8				
				Relative Weight	13.6	14.6	12.3	10.6	19.5	15.8	13.6				

Competitive Analysis (0=Worst, 5=Best)



Chapter 3. Detailed Product Design

3.1 Preliminary Sketches

This section displays the collection of hand sketches made by the team. Some of the sketches were initial designs while other sketches were used to illustrate different configurations of the trike's system.

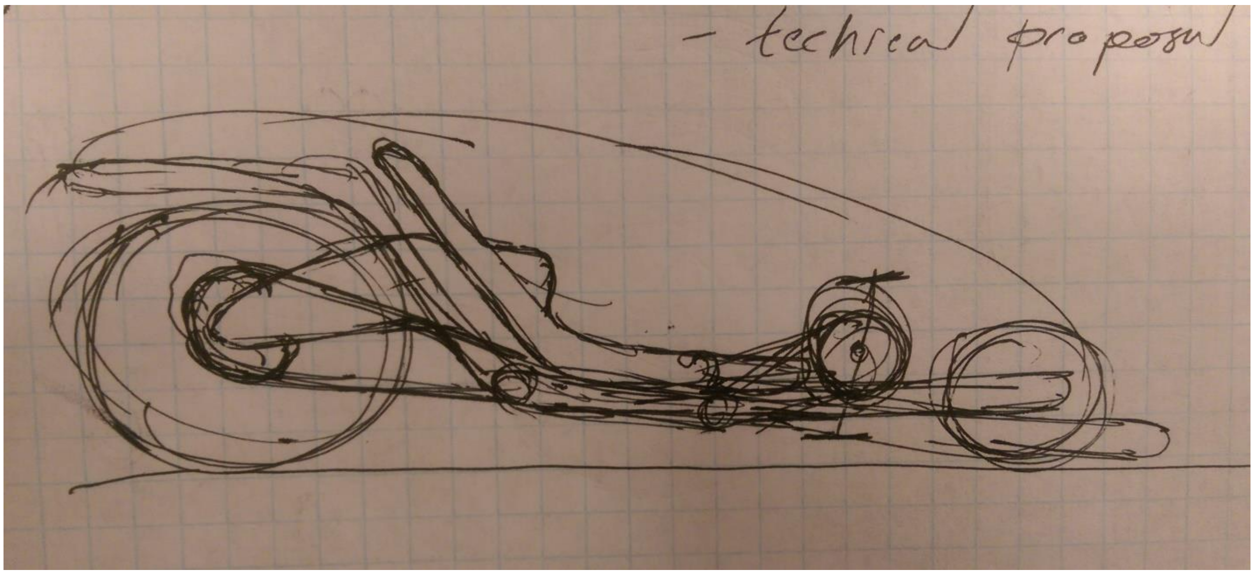


Figure 10 Trike Orientation sketch

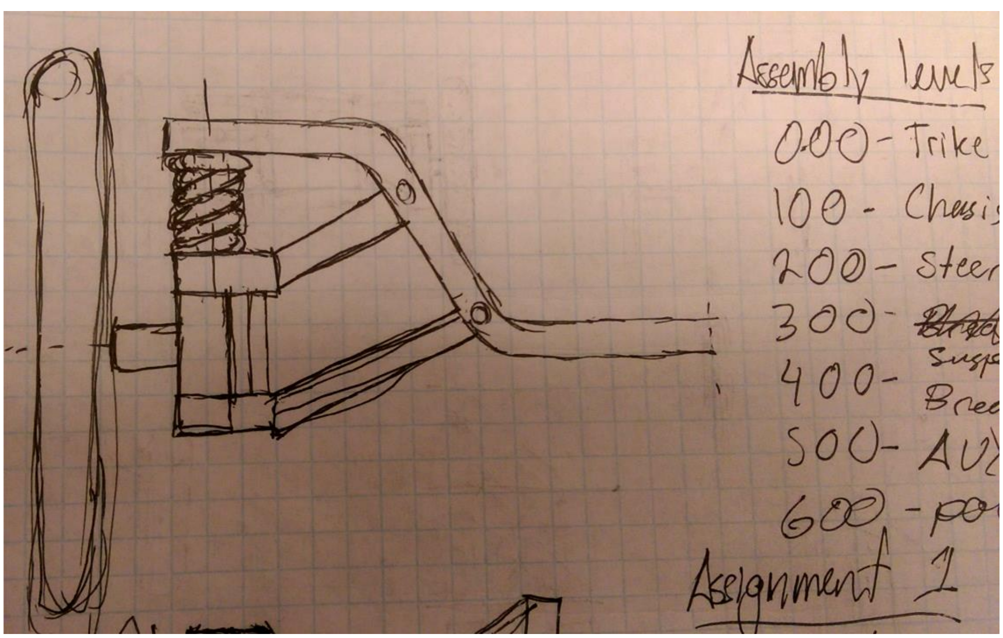


Figure 11 Suspension sketch

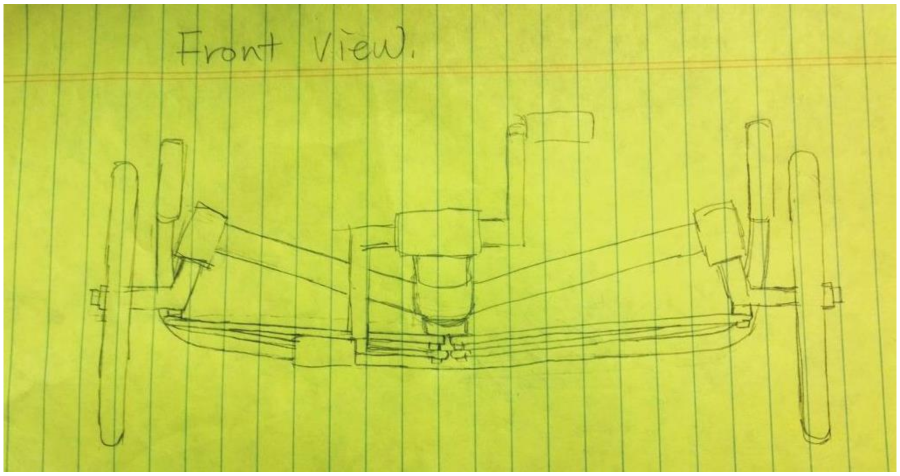


Figure 12 Steering system sketch

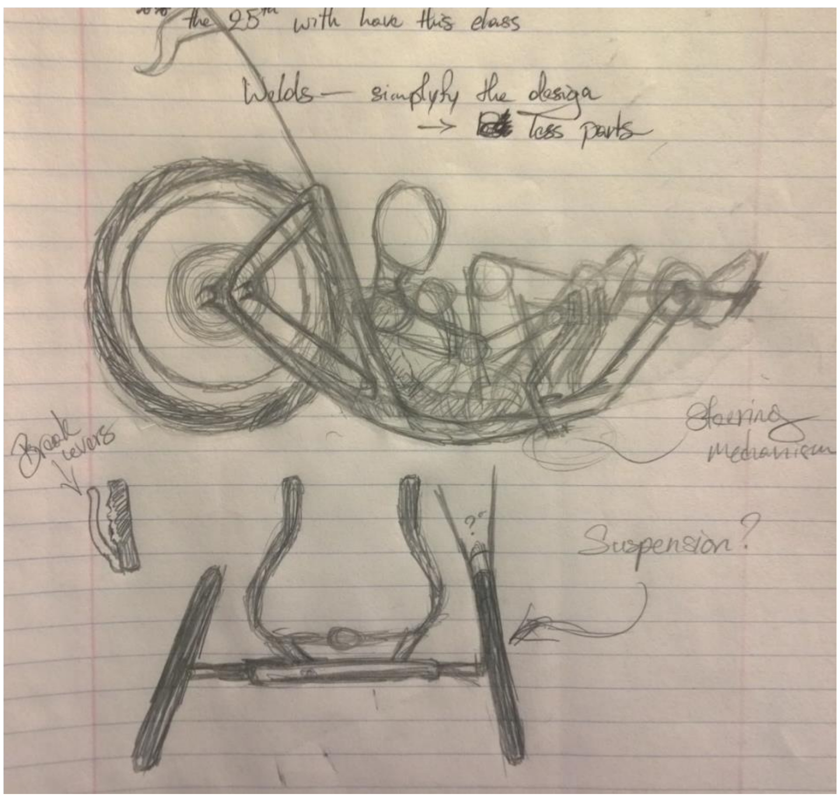


Figure 13 Rider position sketch

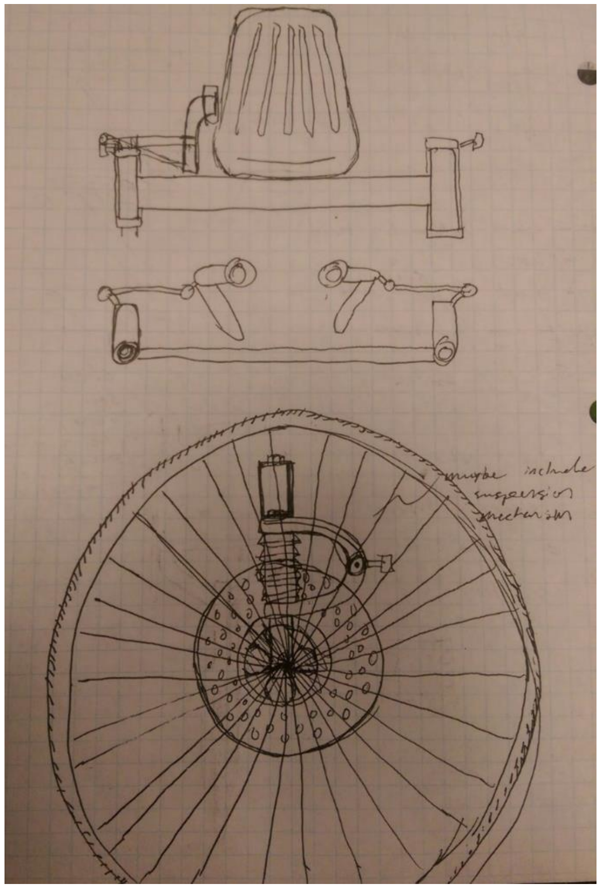


Figure 14 Steering and spindle sketch

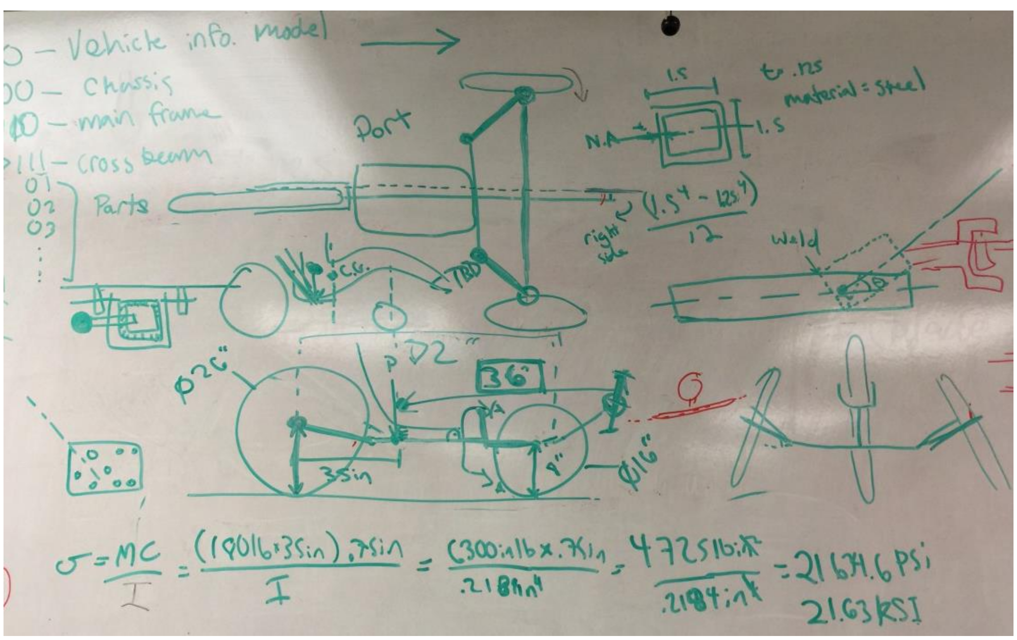


Figure 15 Frame sketch

3.2 Functional Requirements

3.2.1 Chassis

This is the skeleton of the trike. All the other components in some way or another are attached to this frame. The curvature of the spin and the height above the ground will determine where the center gravity of the trike will be. Refer to Figure 16.

3.2.2 Rear Wheel Triangle

This area of the frame supports the back wheel of the trike and assists in the weight distribution of both the trike and rider's weight. The support contains dropouts, which are horizontal slots for the wheel axle to slide into. The dropouts allow the wheel to be positioned properly. Besides providing lateral rigidity, this bridge provides a mounting point for rear brakes, fenders, and racks. The seat stays themselves may also be fitted with brake mounts. Refer to Figure 17.

3.2.3 Power Train

Arguably, the most important component in the human powered trike is the power train. The front power transmission system is composed of the sprocket gearing assembly, two cranks, two pedals and T bar connection. In designing and building the power train, it is important to take a few things into consideration.

The foot pedals are located at the very front of the bike, while the drive wheel is located at the very back of the bike. Because of this, it is crucial to have a smooth and efficient support system to transmit the power through. Another important design element that will have to be addressed is the sprocket and the gear shifting system. A well designed power transmission system will allow for easy motion.

The sprockets are used to transmit rotary motion. The sprocket present on the recumbent trike will have a pedal shaft which carries a large sprocket-wheel which drives a chain. In turn the large sprocket will drive a small sprocket on the axle of the rear wheel. Creating at least seven variable speeds which will allow the rider to start moving and then build speed. The rear derailleur placement requires precision placement to reduce chain slippage.

The T bar connection will ease the assembly of the power transmission system to the main chassis. The main function of the front power transmission is to allow the rider to provide motion by exerting force against on the pedals. Refer to figure 18-22

3.2.4 Chain Tensioner

A tensioner is a device that applies a force to create and or maintain tension. The chain tensioners are usually installed either on near the stays of the bike or near the chain rings, it takes up slack in a chain by an arm with a jockey wheel (for fluid movement of the chain) set at an angle or is spring loaded so that it reacts to vibrations taken by the trike during use. When riding a bike you want your bike's chain to have enough tension so that it does not fall off the cog/gear/chain ring. In other words, the chain tensioner provides enough tension to prevent slack. Refer to Figure 25.

3.2.5 Derailleur

The derailleur is the mechanical part that shifts the gears by guiding the chain from one gear to the next. There are usually two on a modern multi geared bike. There is one in the front guiding the chain over the chain rings, and one near the rear wheel cassette, controlling the chain for the cog shifting. For the purpose of this project our trike will be using only the rear derailleur with a 5 speed cassette. It is cable-operated using a shift control on the handlebar or the front of the frame near the handlebar. The derailleur allows the rider to choose the ease of pedaling, for example, for hill climbing or a downhill run. For those who take things a bit more seriously, gearing allows the rider to maintain the most economical pedaling rate regardless of minor changes in terrain. Refer to Figure 26.

3.2.6 Brakes

The Brakes provide deceleration when the trike is in motion. The lever located on the handlebars allow for the rider to increase tension to brake slightly or to come to a full stop. These brake levers are connected to the calipers on the bike by cables. On the calipers are brake pads, aligned to match with the rim of the wheel(s). When the levers are pulled, the cable is tensioned – causing the calipers to pull the pads against the rim of the wheel(s). The friction from the pad slows the wheel(s) down, with enough tension – the wheel will stop rotating. Refer to figure 27 and 28.

3.2.7 Steering

Changing the trajectory of the trike is a manual input from the rider. The handle bars aid in this effort by giving leverage and ease of control over the angle at which the wheels are directed. Slowing down of the bike is another manual input, by using the braking system. Refer to Figure 29 and 30.

3.2.8 Suspension

The suspension in a bike reacts to vibrations taken in from the bike in motion. Through the use of the spring, the vibrations are lessened if not completely defused to give the rider a smoother and more comfortable ride. Refer to Figure 34.

3.2.9 Trike Assembly

The complete trike with all the parts together working seamlessly. The fruit of our labor – this trike. Refer to figure 35.

3.3 Cad Drawings

This section contains a library of the parts that the trike consists of, in addition to where they are in each assembly.

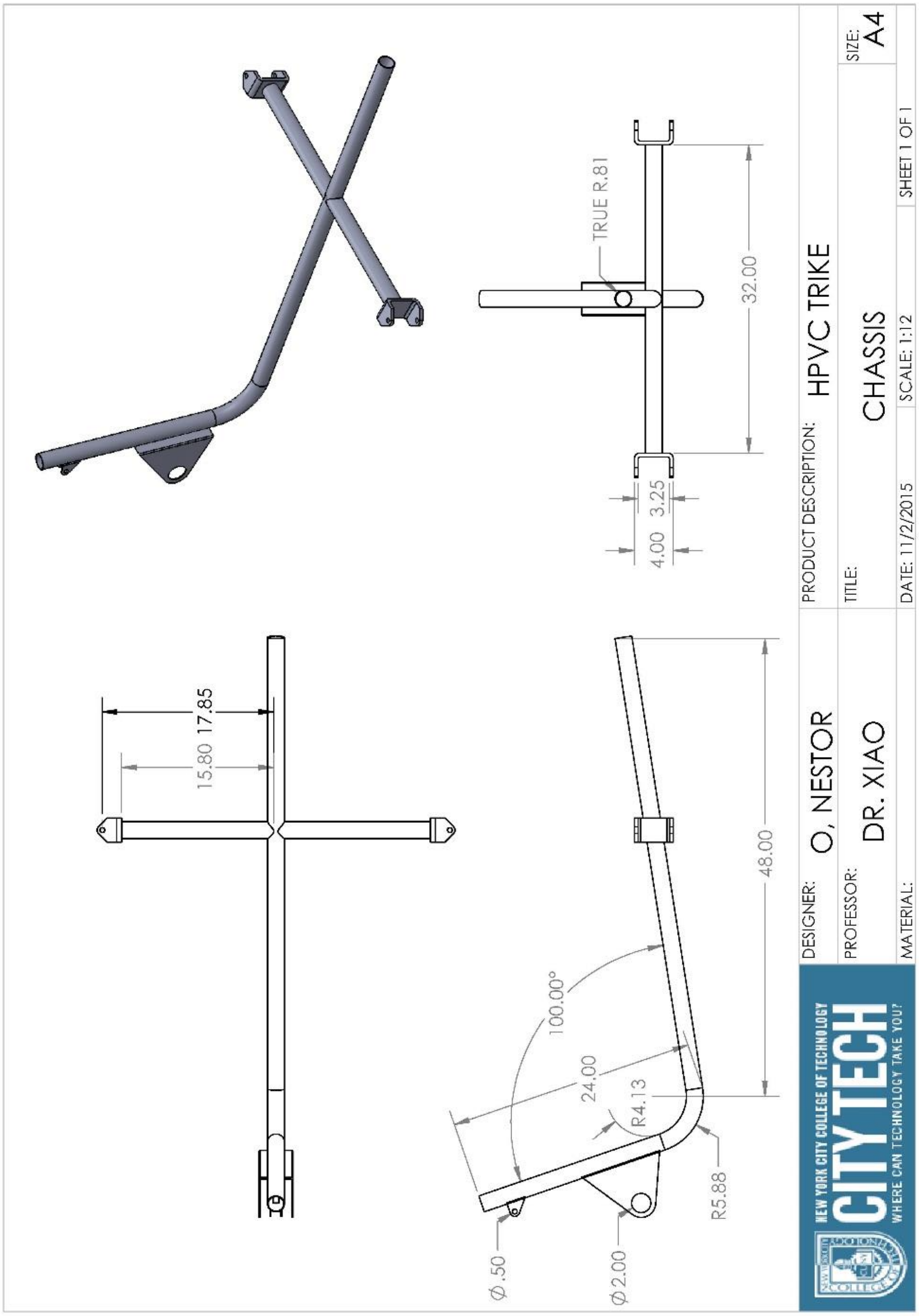


Figure 16 Chassis

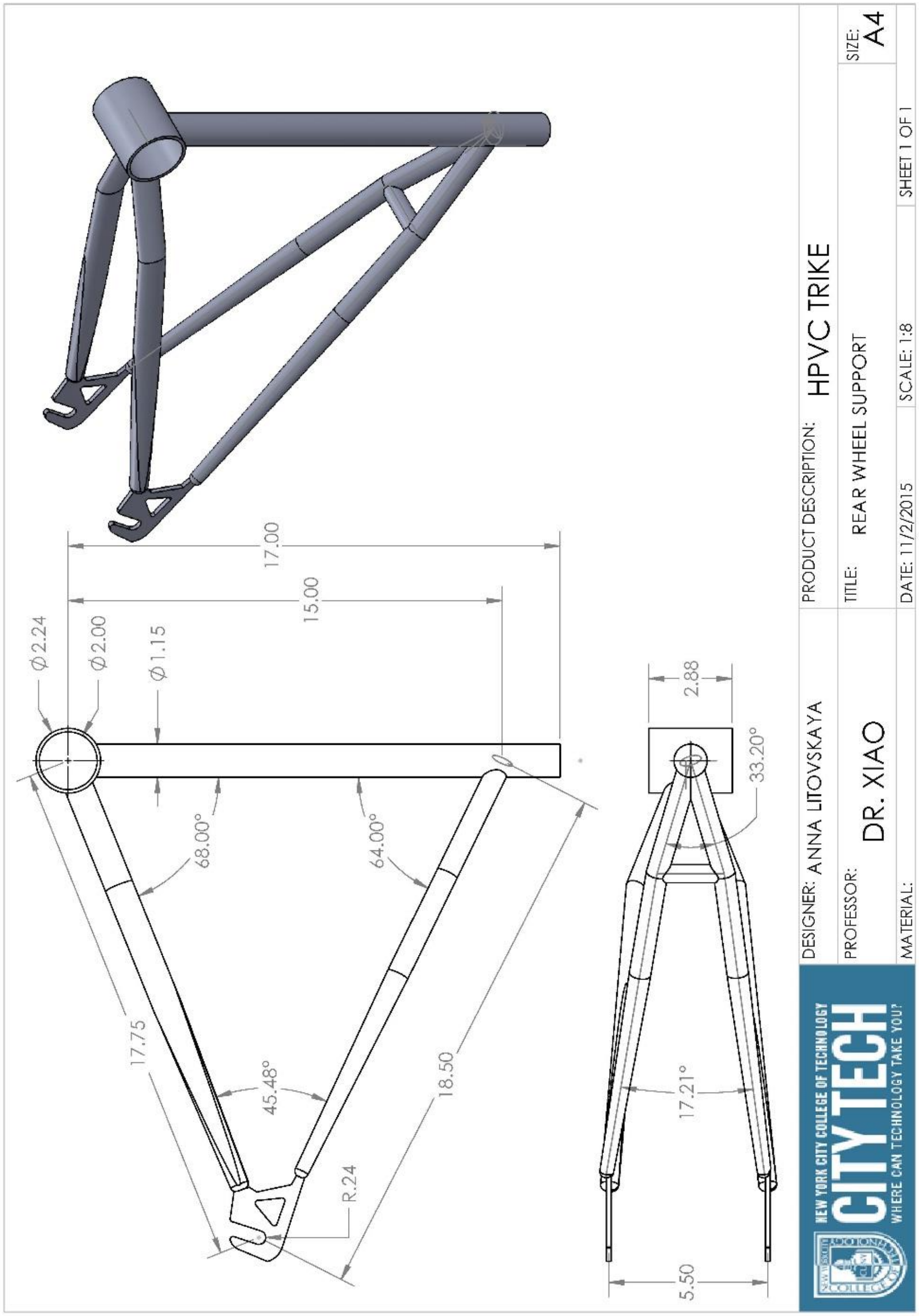


Figure 17 Rear Wheel support

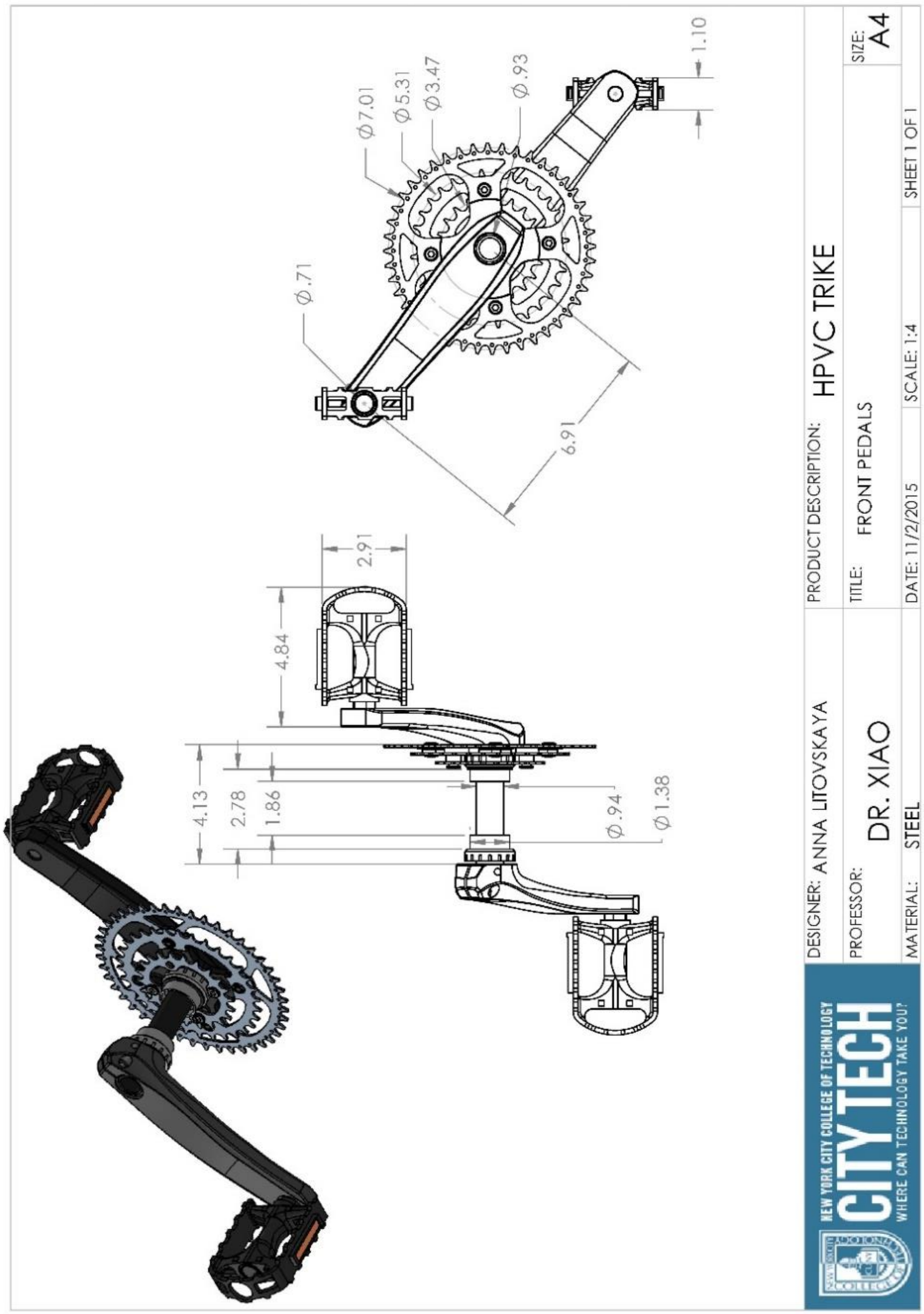


Figure 18 Front Pedals

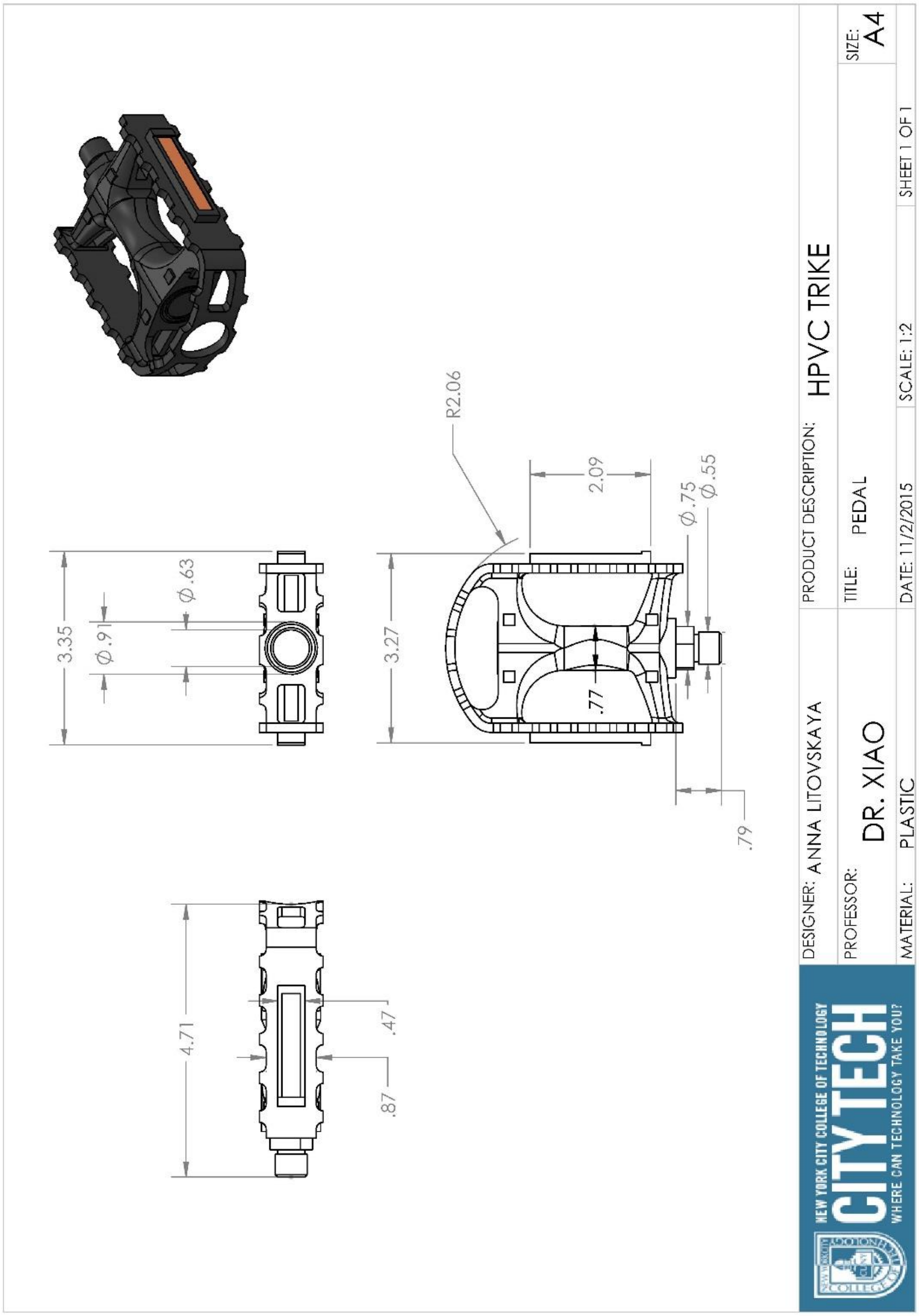


Figure 19 Pedal

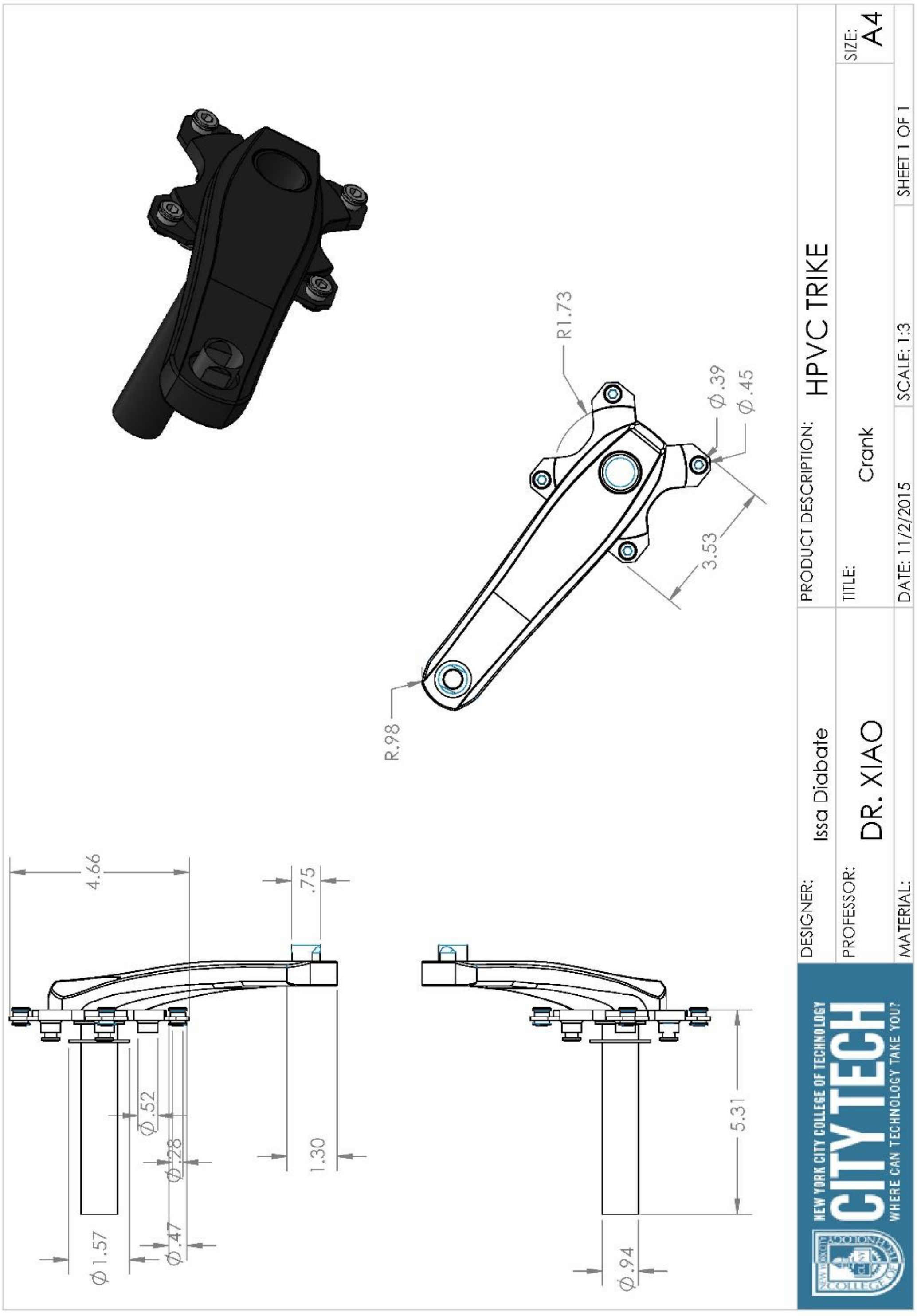


Figure 20 Crank Arm

Figure 21 Crank Arm

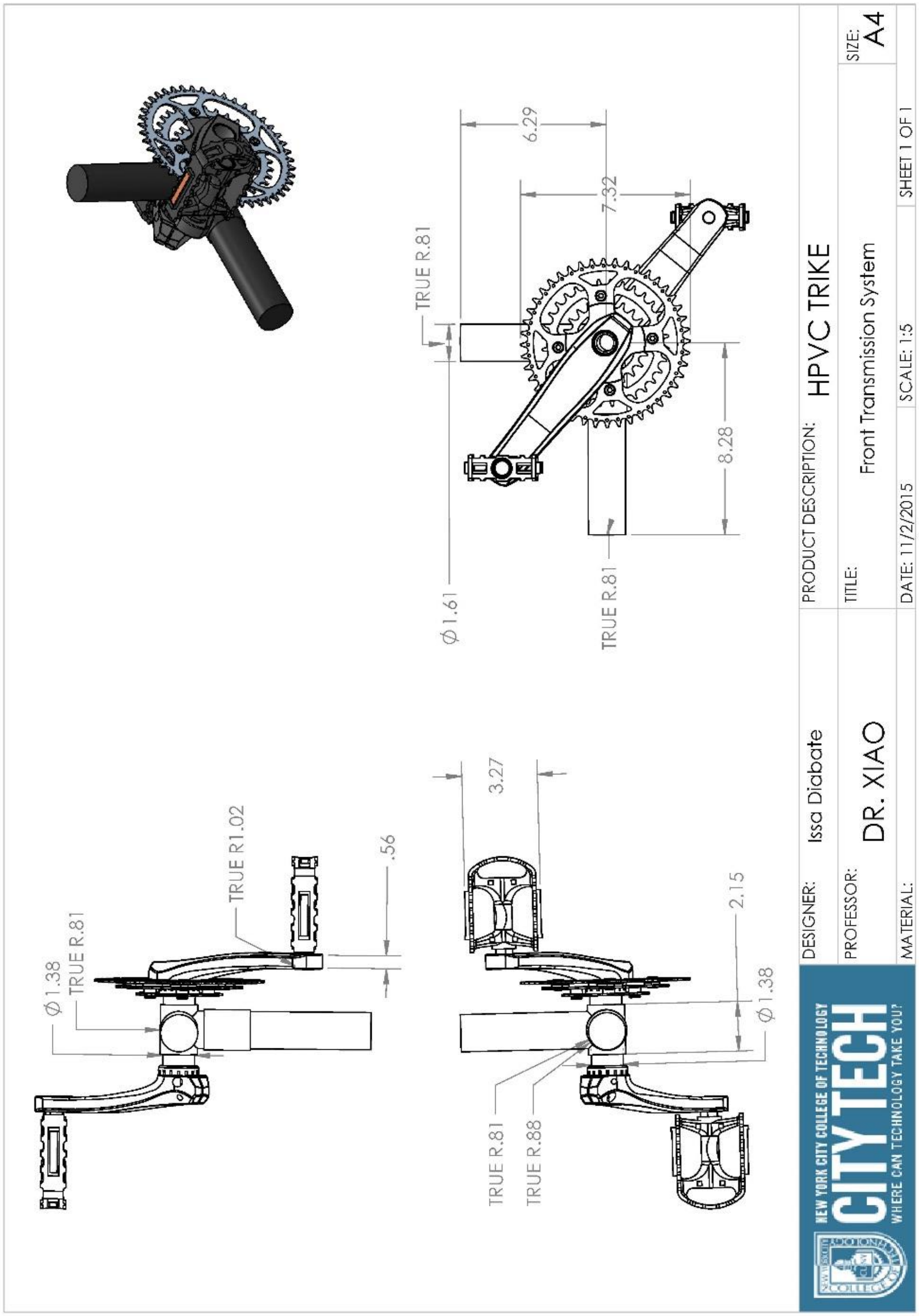


Figure 22 Front Power Transmission system

Figure 23 Gears

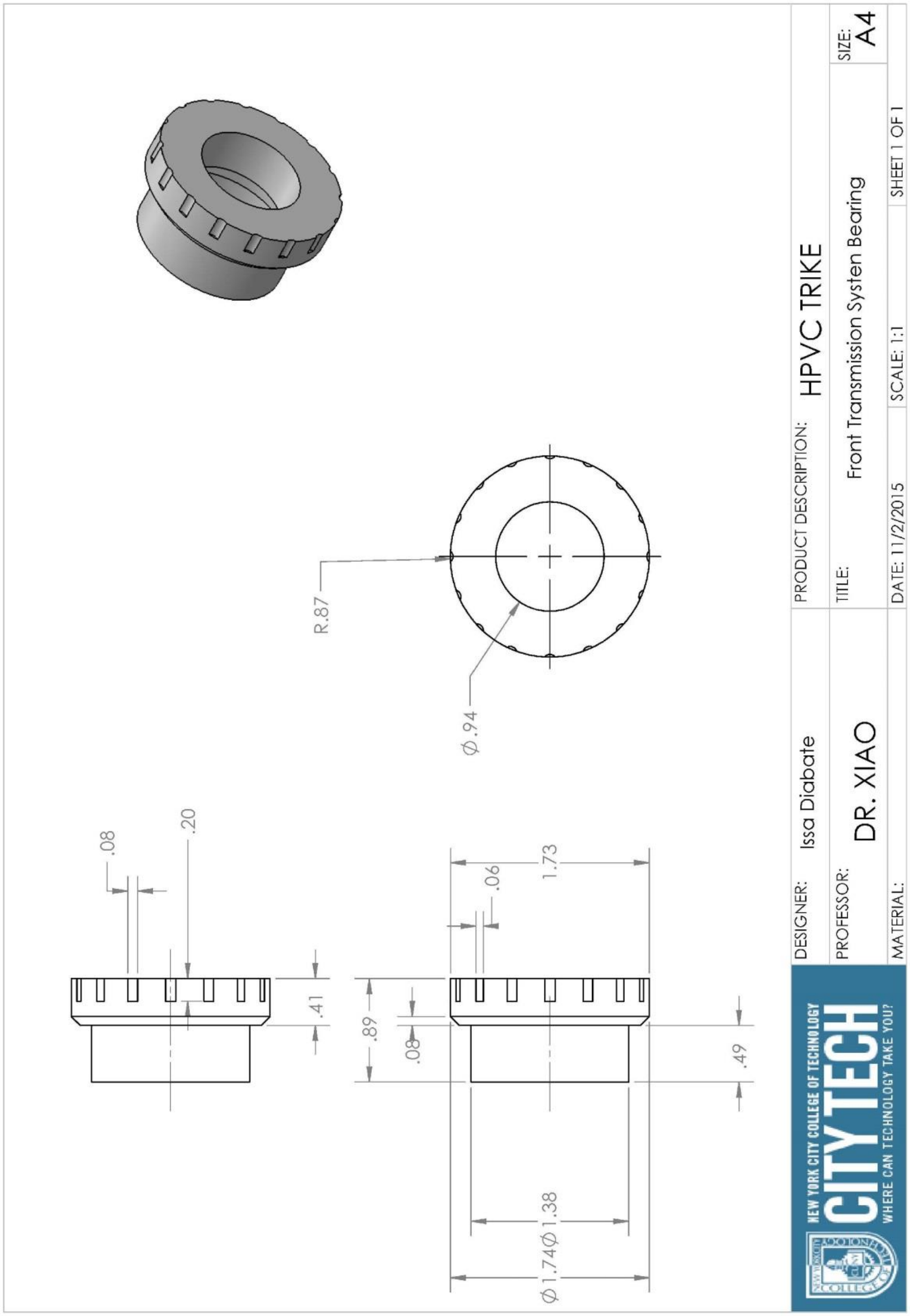


Figure 24 Front Transmission System Bearing

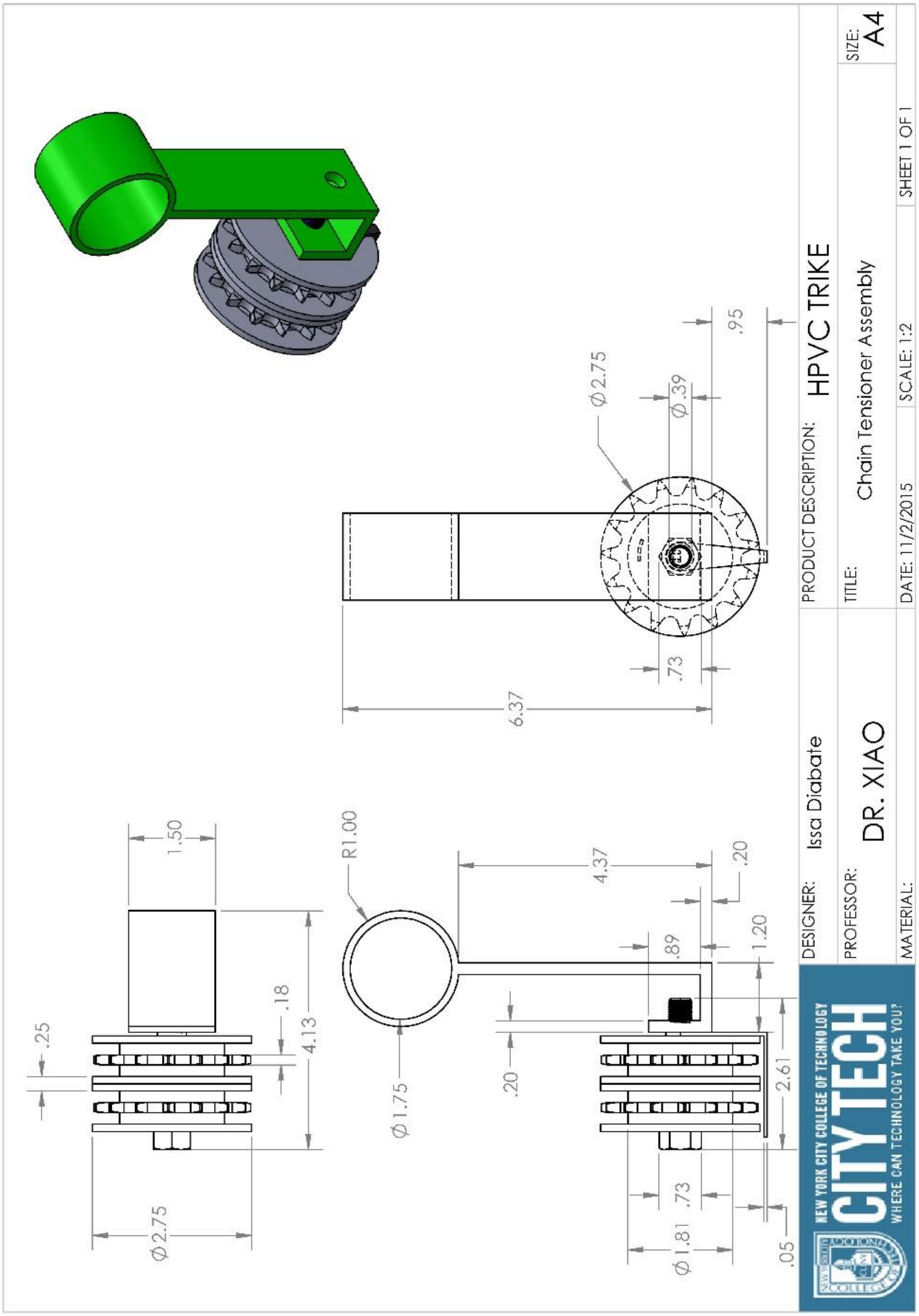


Figure 25 Chain Tensioner Assembly

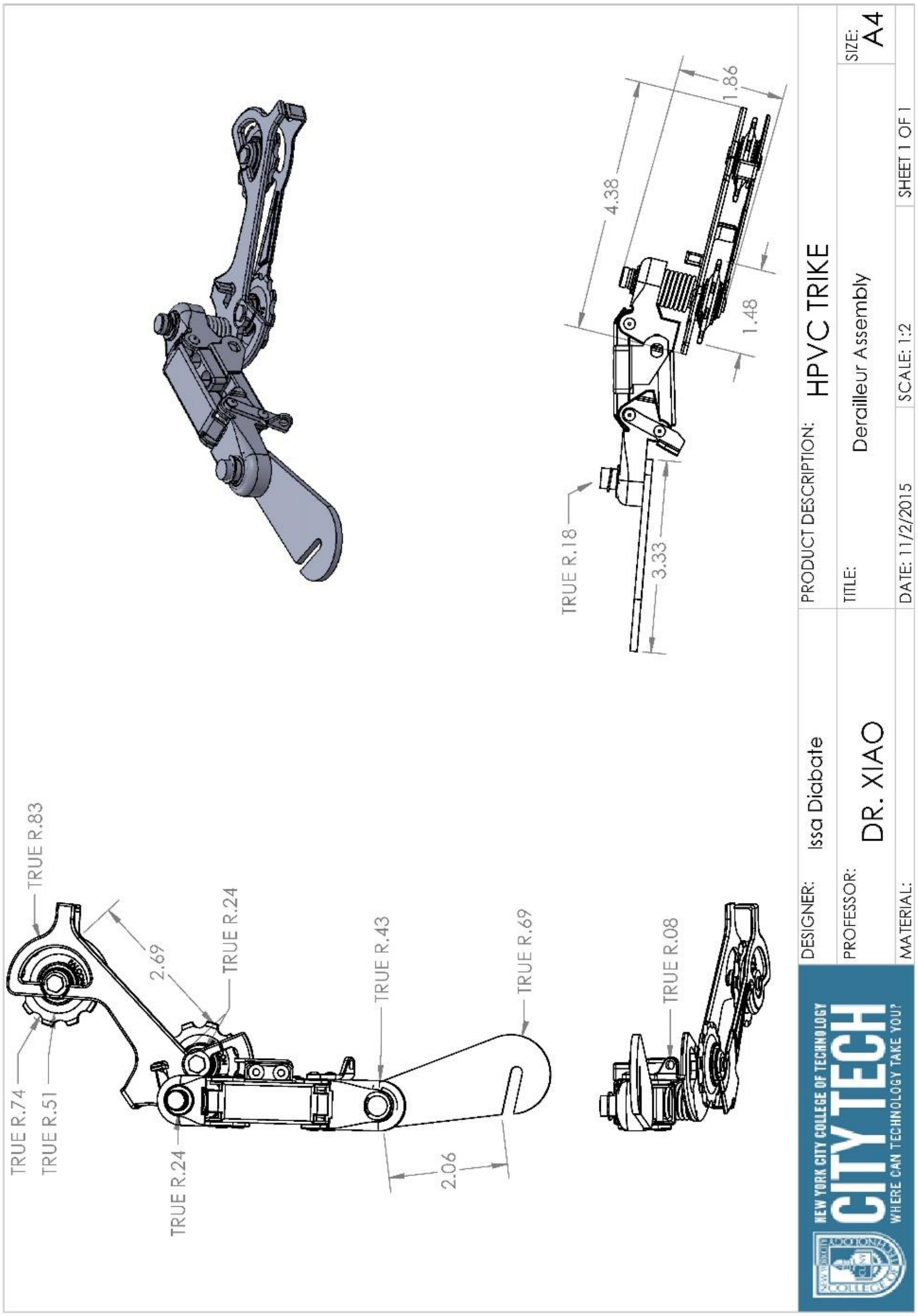


Figure 26 Derailleur assembly

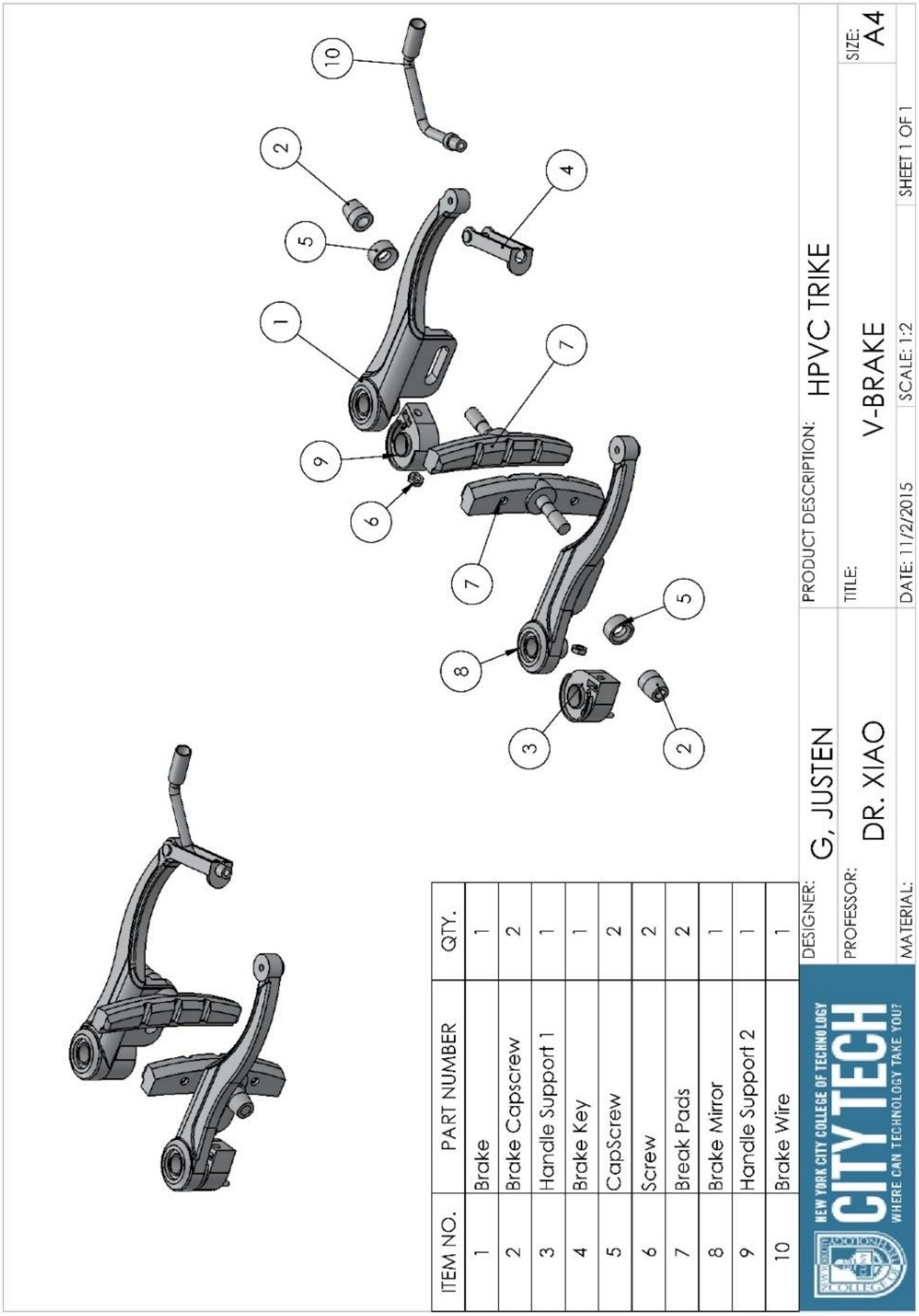


Figure 27 V-Brake

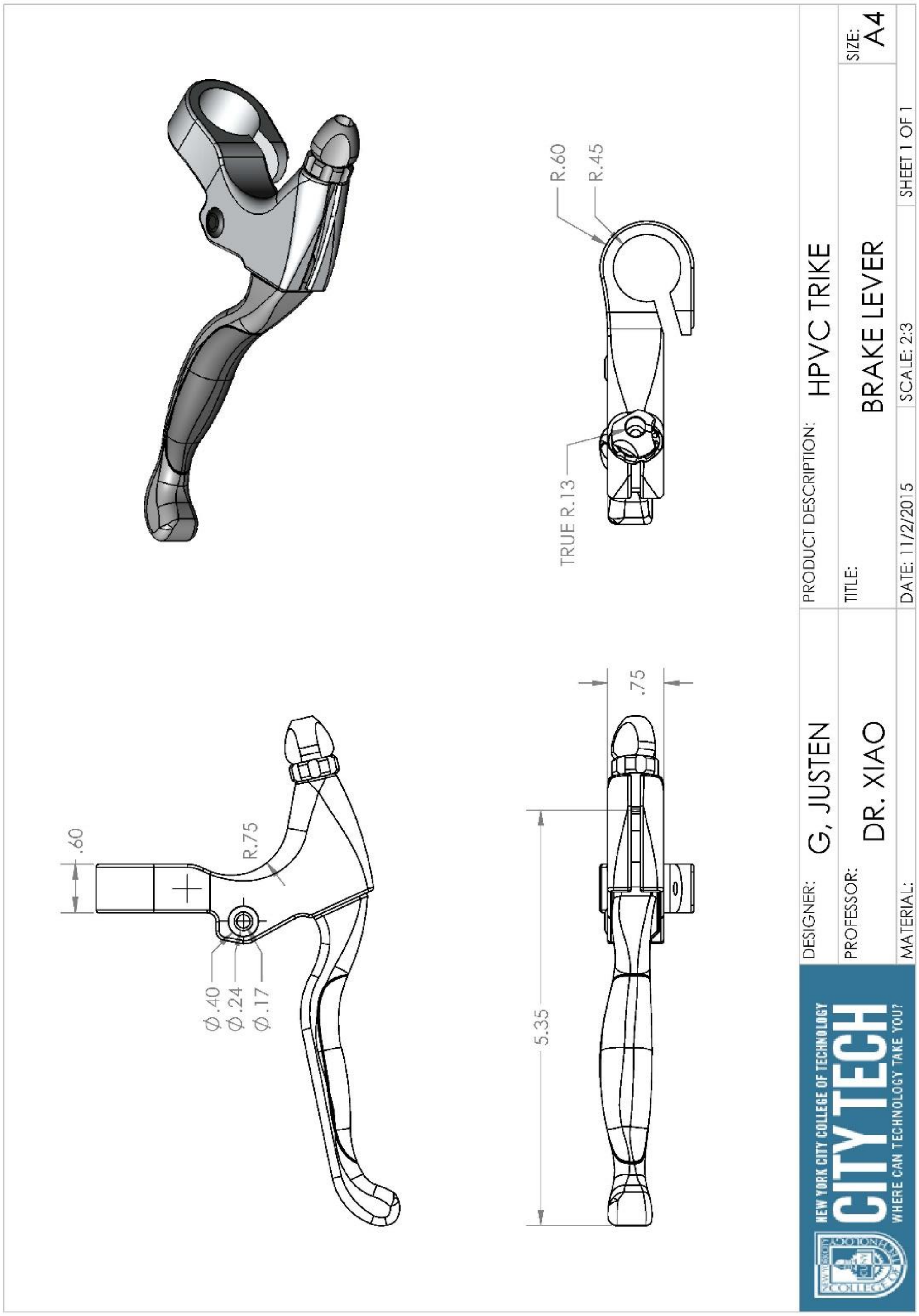


Figure 28 Brake Lever

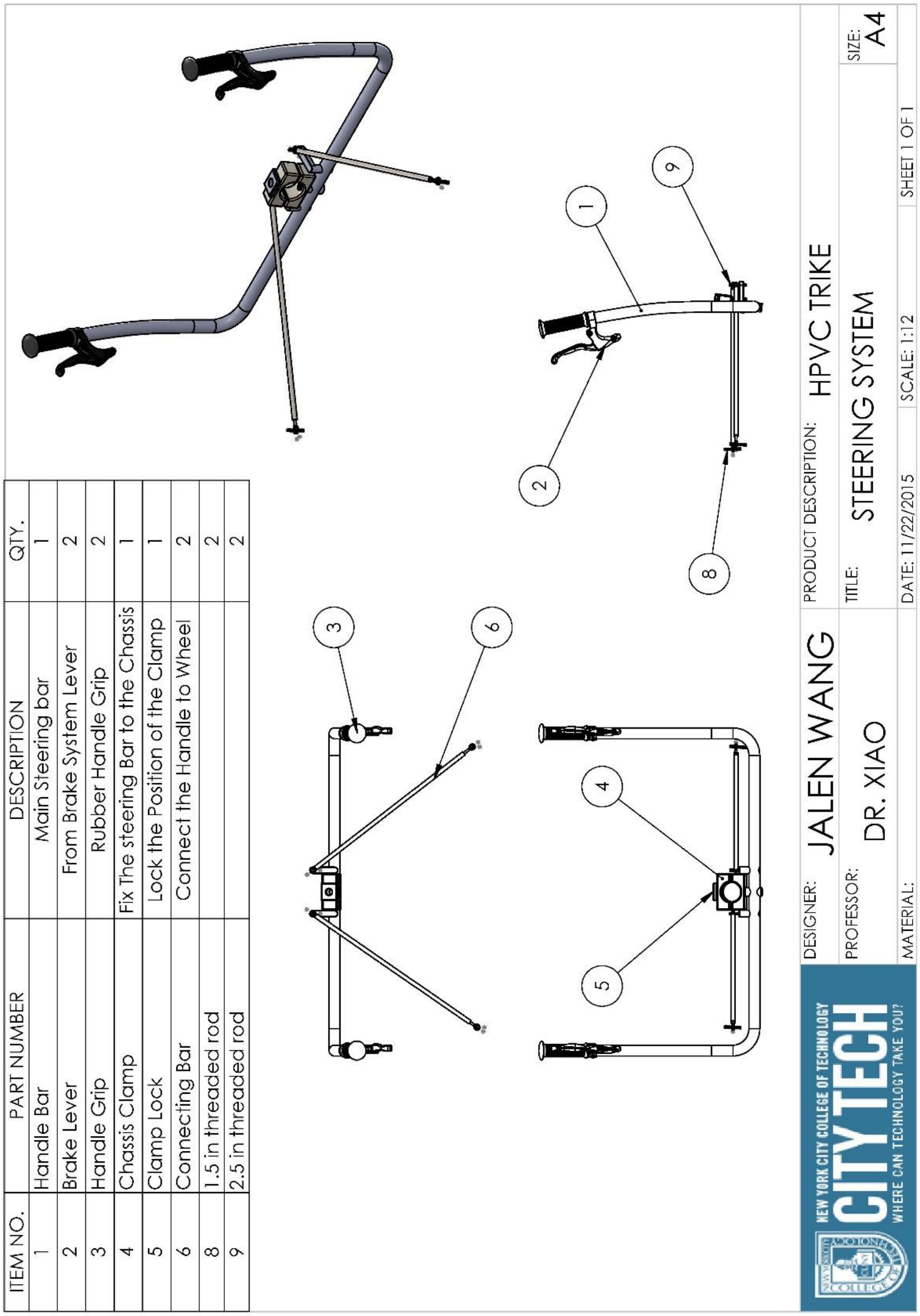


Figure 29 Steering Assembly

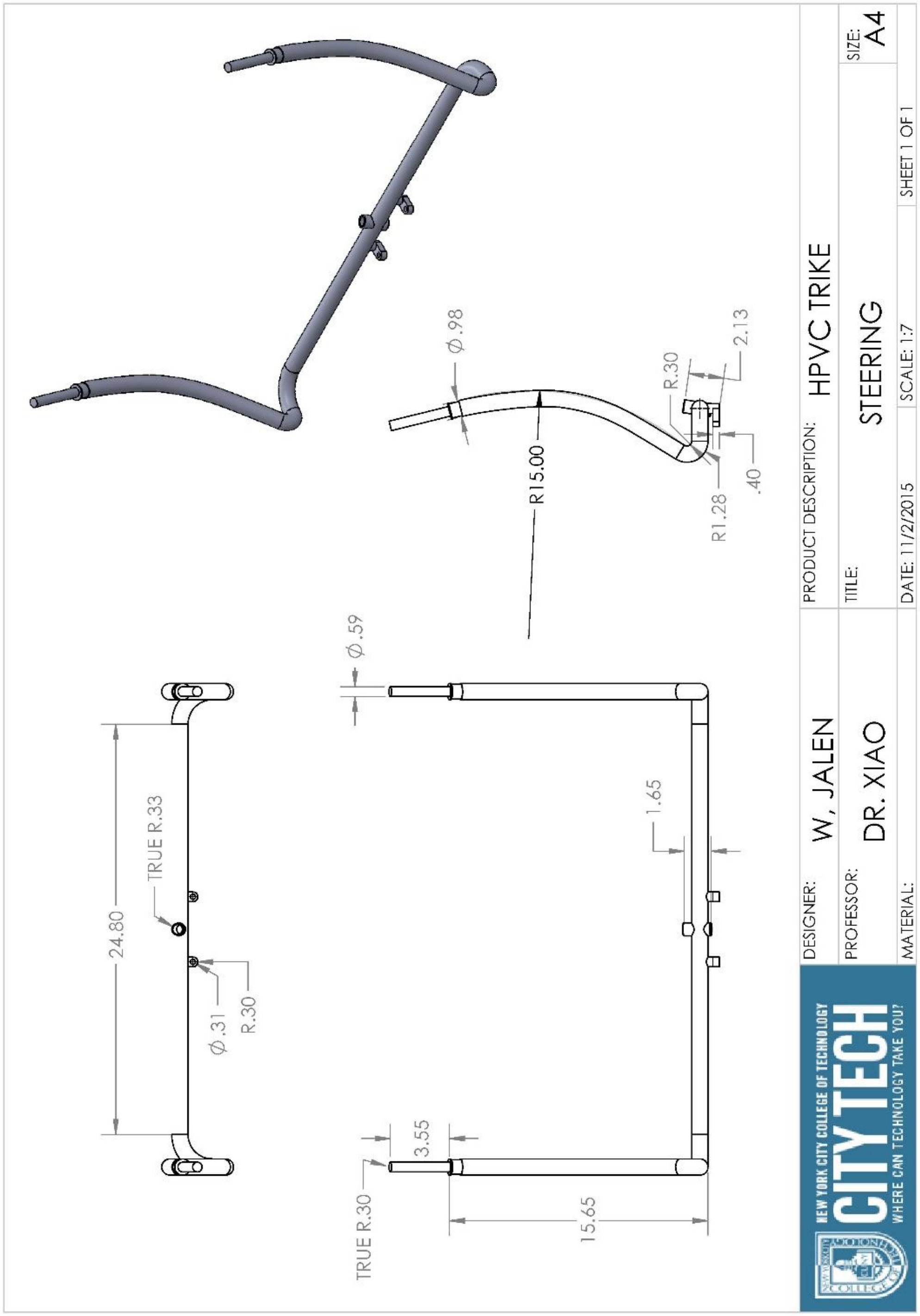


Figure 30 Steering Handle Bar

Figure 31 Handle

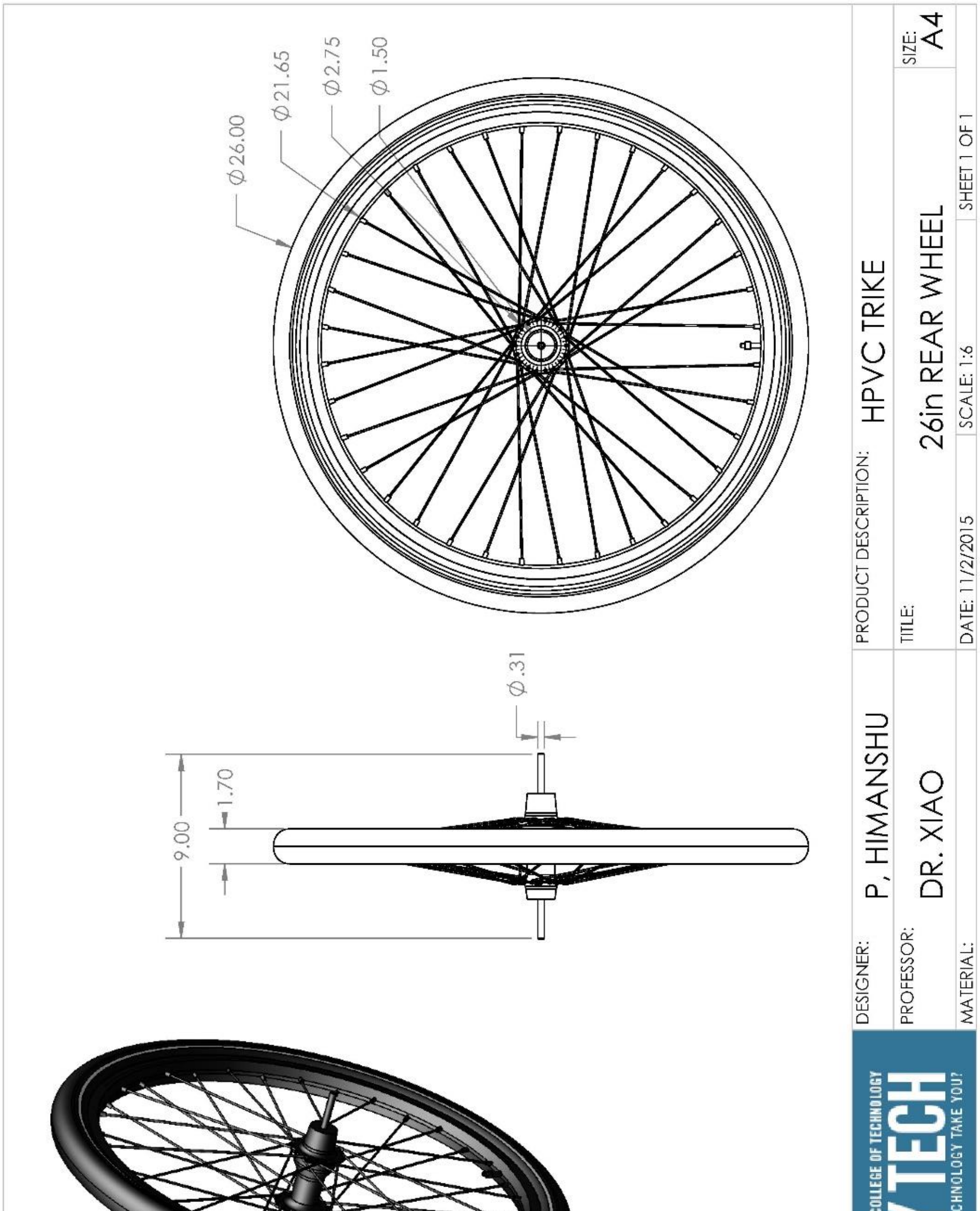


Figure 32 Rear Wheel

Figure 33 Seat

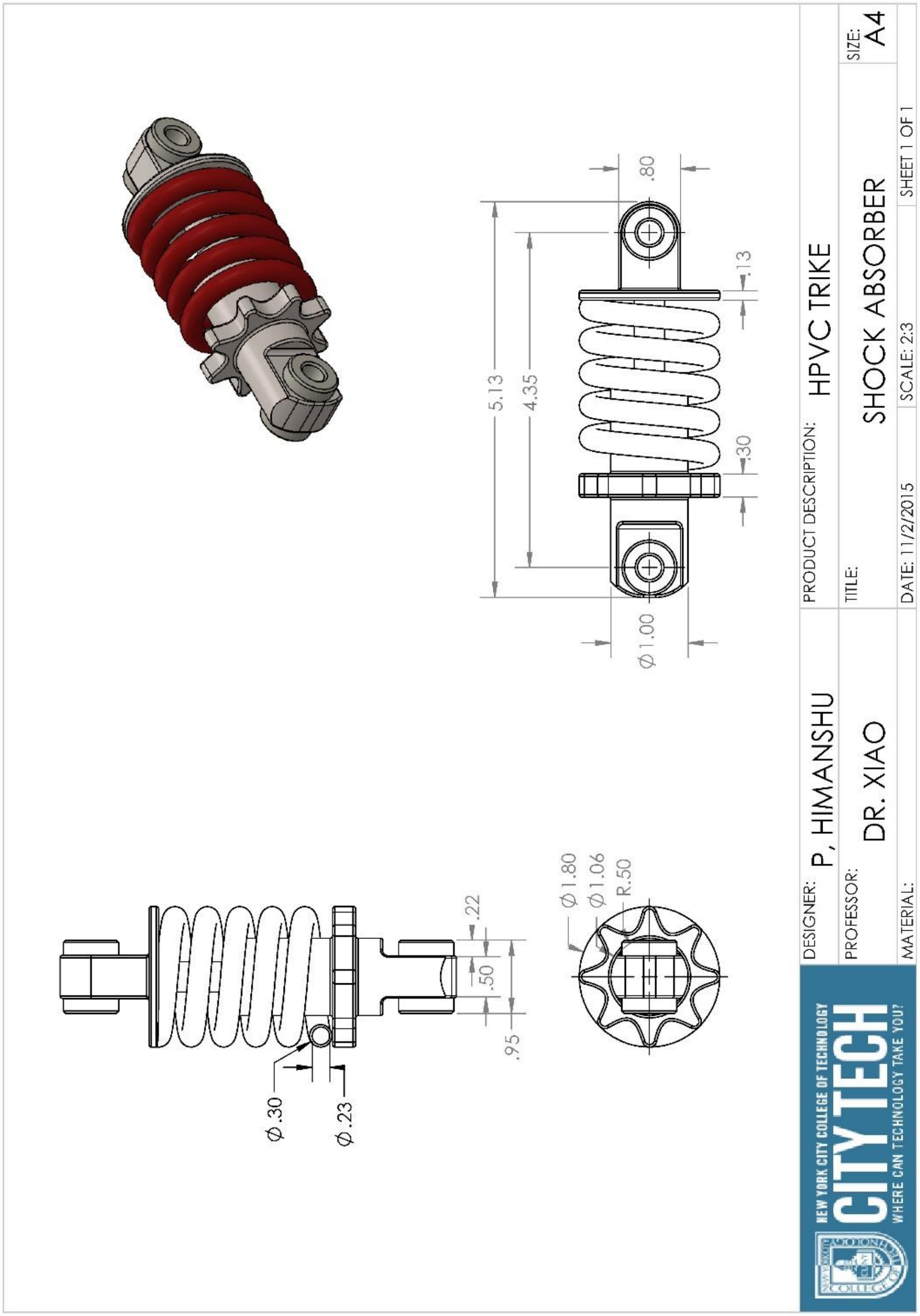
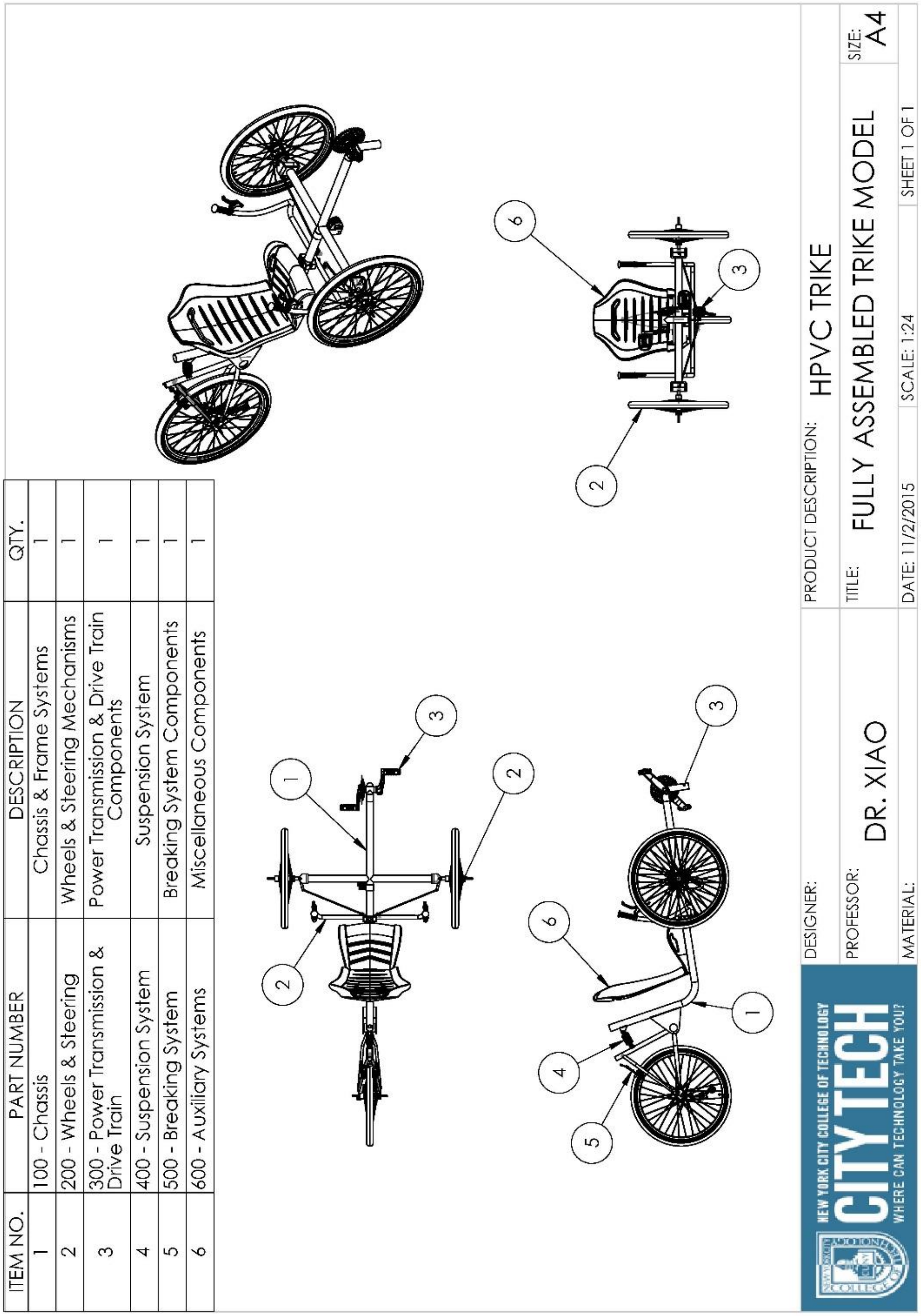


Figure 34 Shock Absorber



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	100 - Chassis	Chassis & Frame Systems	1
2	200 - Wheels & Steering	Wheels & Steering Mechanisms	1
3	300 - Power Transmission & Drive Train	Power Transmission & Drive Train Components	1
4	400 - Suspension System	Suspension System	1
5	500 - Breaking System	Breaking System Components	1
6	600 - Auxiliary Systems	Miscellaneous Components	1

Figure 35 Trike Assembly

3.3.1 Trike Rendering

Figure 36 Trike Rendering

3.4 Motion Analysis

The motion analysis of the trike displays the range of motion for the steering. While in motion, the rider can steer left and right using the handlebars to control the amount of the wheels rotation and in effect changing the curvature of the trike's trajectory. The relationship is controlled by geometry in the design of the steering system.

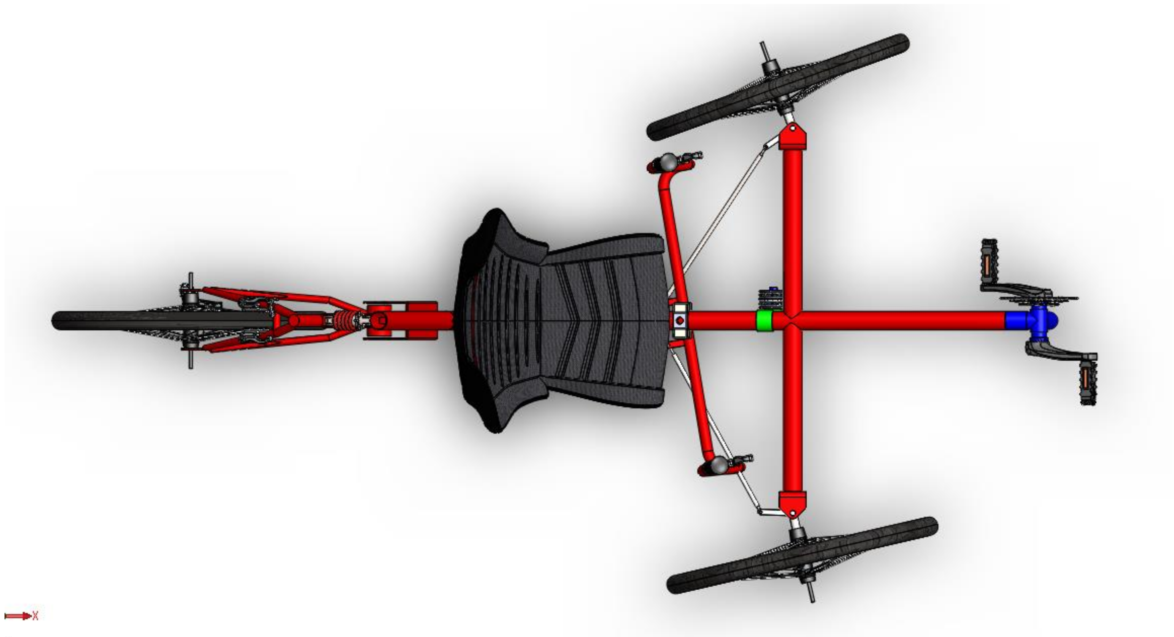


Figure 37 Left Turn

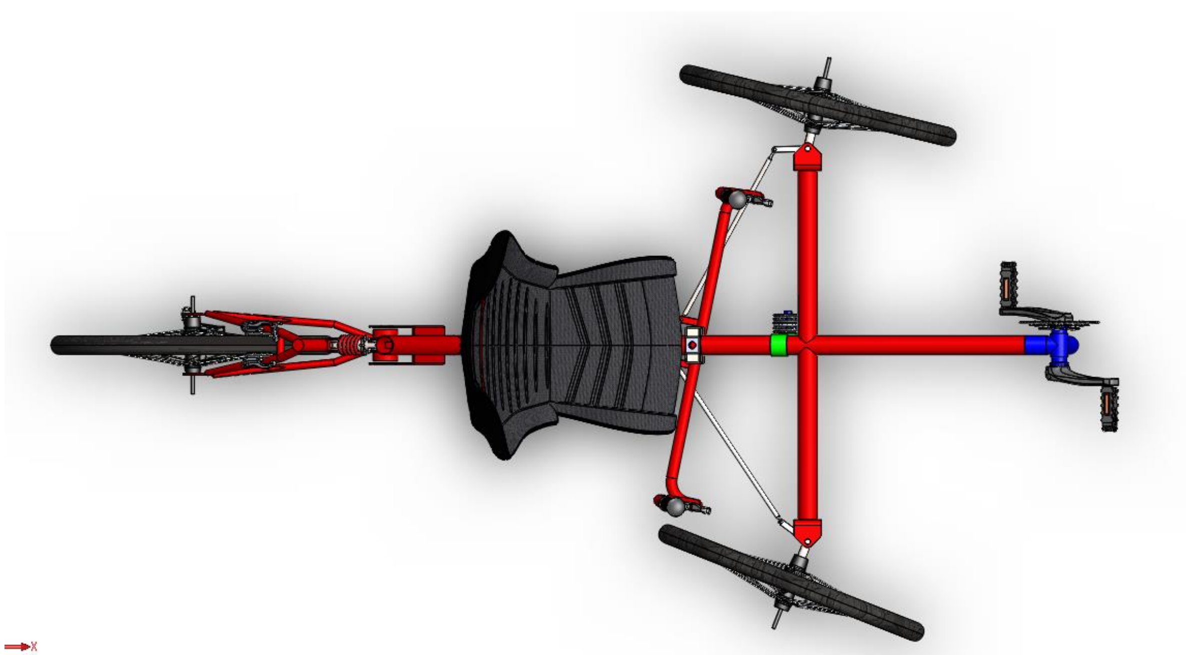


Figure 38 Right Turn

Chapter 4. Manufacturing Plan

4.1 Material Selection

For the chassis, we considered the functional requirements and accessed a list of potential materials. Our group discussion considered the mechanical properties and the cost for the standard lengths available for purchase.

Table 9 Material Selection

Material	Yield Strength (ksi)	Modulus of Elasticity (psi)	Cost 1 ½’’ diameter
6061 Aluminum	35	10.1 psi	$52.98 6ft
2024 Aluminum	42	10.6	$62.54 6ft
Steel conduit(304)	74	28	$23.75 10ft

Values from textbook *Mechanics of Materials* Ferdinand Beer ... [et al.]. — 6th ed.

After comparing the material properties and cost we observed that the steel conduit was the most exceptional material because it has the highest yield strength, compared to other materials analyzed. The characteristic of yield strength denotes the maximum load that the material can withstand before failure. The steel conduit is also favorable because it has the lowest cost. Steel is also a recyclable material as stated by the Steel Recycling Institute (SRI) “steel is the world’s most recycled material.” (steeltubeinstitute.org)

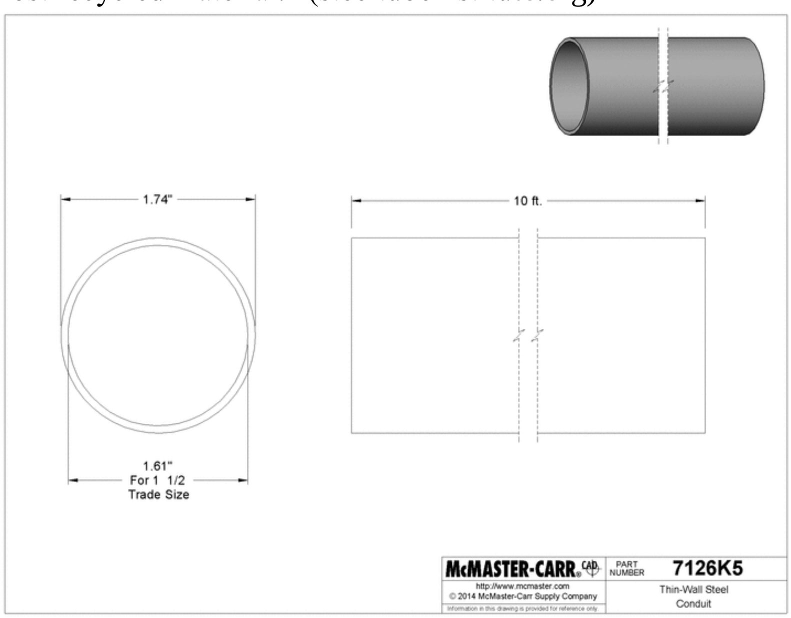


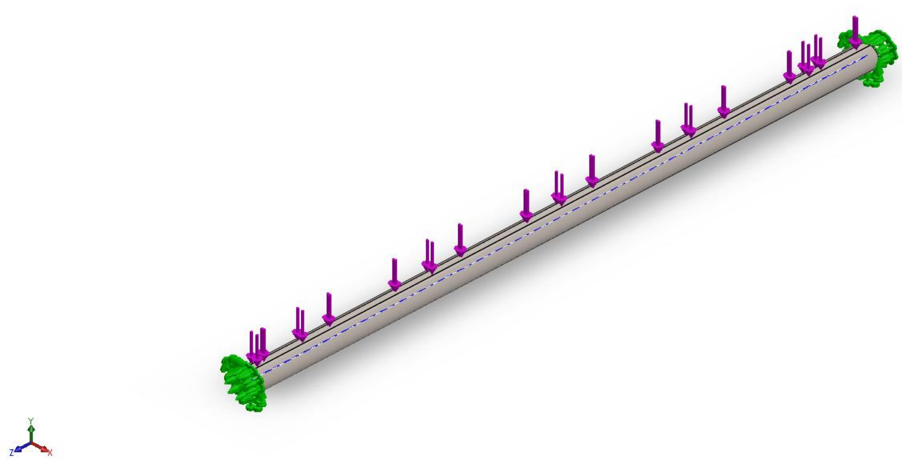
Figure 39 Thin-walled Steel Conduit

4.2 Finite Element Analysis

4.2.1 Description

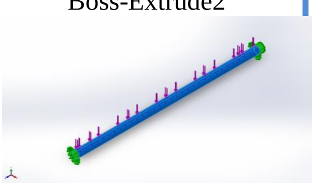
Before the Senior Project Team can begin manufacturing, the conceptual design for the project finite element analysis (FEA) testing must be done. FEA is a computer based method of simulating and analyzing the behavior of engineering structures and components under a variety of conditions. It is an advanced engineering tool that is used in design to augment experimental testing. Real world forces will be applied to the material. During the group discussion of the material to be used for the chassis of the trike, the manufacturing team leader suggested to use $\mathbf{1\frac{1}{2}}$" diameter and 6' steel EMT pipe for the chassis. Once, everybody was in agreement with the material, the team ran an analysis using the engineering tool known as SolidWorks. SolidWorks is a computer-aided design (CAD) program that helps engineers design and conduct simulations on parts. The functional requirements proposed that the chassis should withstand a load (force) of 71.4 pounds per foot (lbf). After the load was given, the FEA team observed how the pipe would react to the static load.

4.2.2 Model Information

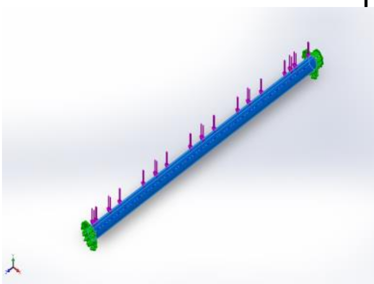


Model name: pipe
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude2 	Solid Body	**Mass:1.71043 kg** **Volume:0.000222134 m^3** **Density:7700 kg/m^3** **Weight:16.7622 N**	**F:\Senior Design\jpg\Manufacturing Results\pipe.SLDPRT** Oct 13 19:16:08 2015

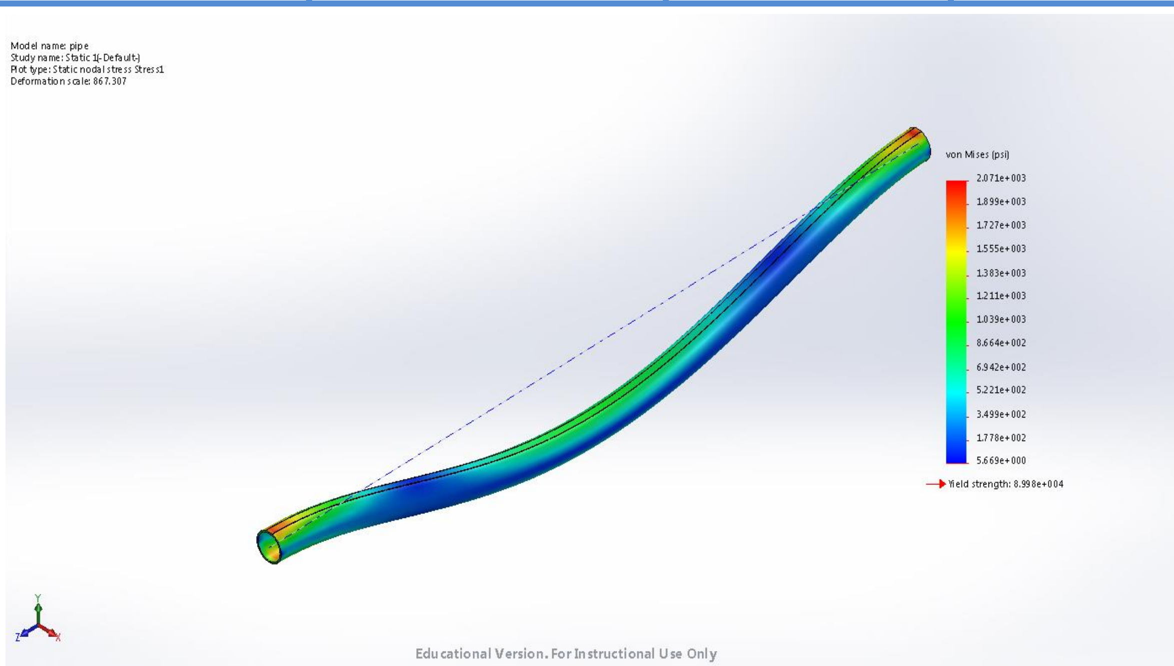
4.2.3 Material Properties

Model Reference	Properties	Components
	**Name:** Alloy Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 6.20422e+008 N/m^2 **Tensile strength:** 7.23826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7700 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Boss-Extrude2)(pipe)
Curve Data:N/A		

4.2.5 Study Results

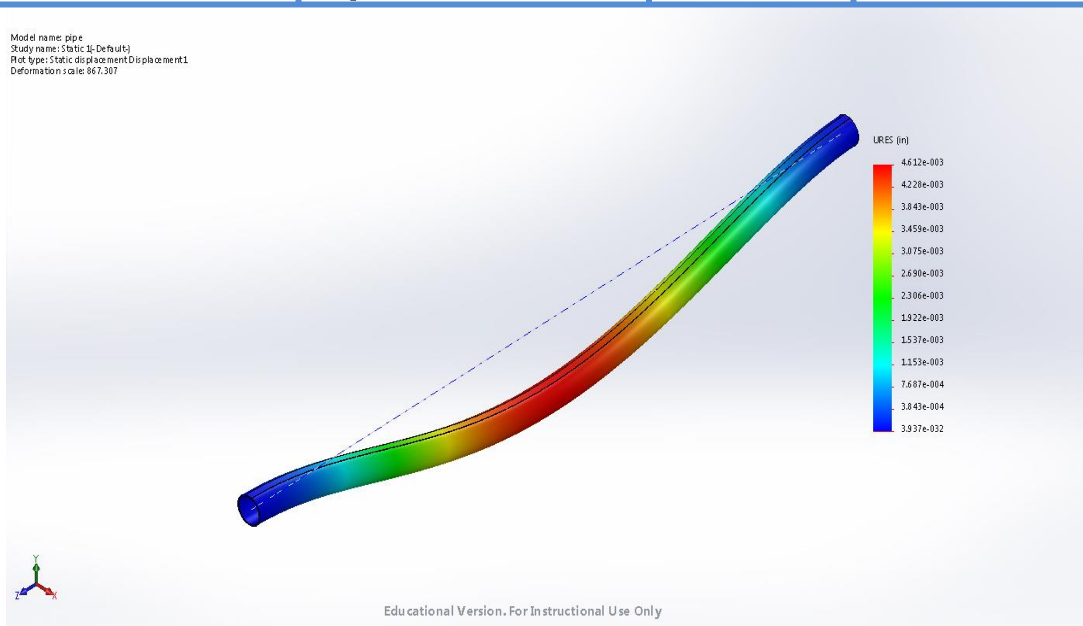
The results show that the stress as an effect of load, did not exceed the material's maximum yield strength (2071.34 psi < 74 ksi). This statement verifies our use of the materials and also confirmed that the suggested dimension for the chassis are safe to use.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	5.66892 psi Node: 14597	2071.34 psi Node: 2895



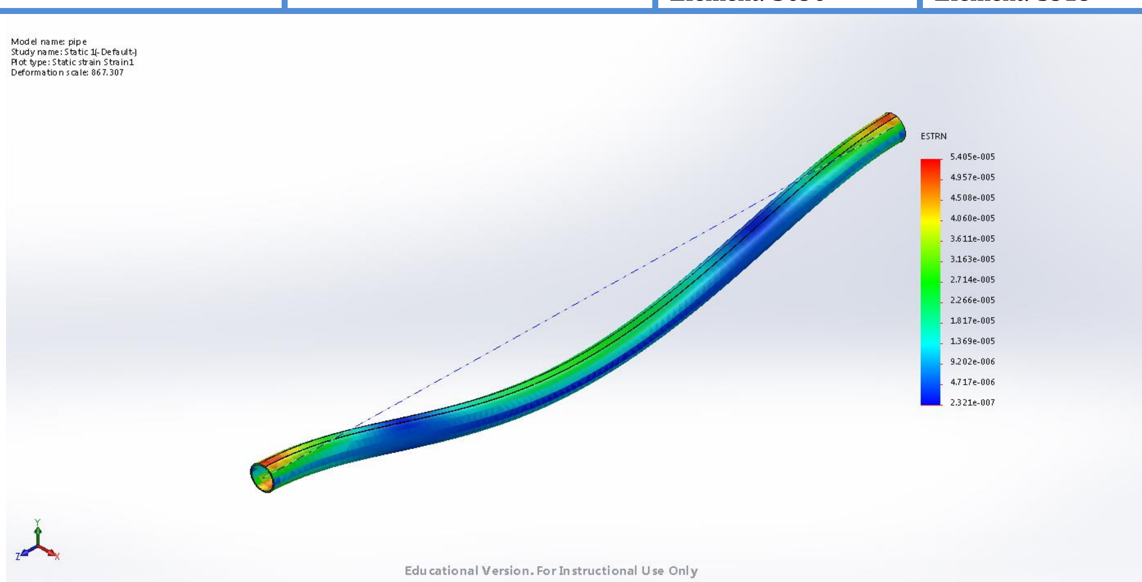
pipe-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 1	0.00461198 in Node: 2373



pipe-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.32074e-007 Element: 3696	5.40538e-005 Element: 3918



pipe-Static 1-Strain-Strain1

4.3 Manufacturing Process

4.3.1 Main Frame Assembly

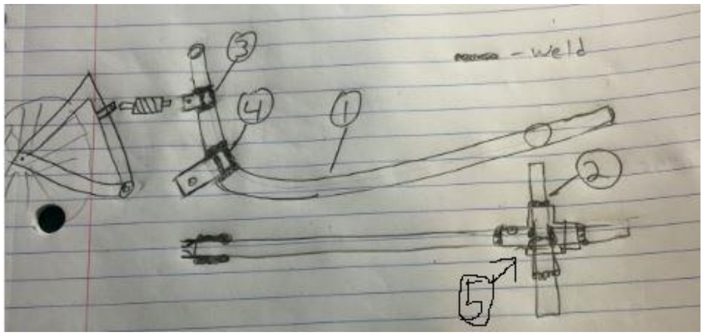


Figure 40 Main Frame Assembly Sketch

<u>Parts List</u>

1. Main Frame - Allied Tube & Conduit 1-1/2 in. x 10 ft. Electric Metallic Tube Conduit
2. Crossmembers x 2 - Allied Tube & Conduit 1-1/2 in. x 2 ft. Electric Metallic Tube Conduit
3. Pivot Bracket - Low-Carbon Steel Rectangular Bar 3/16" Thick, 2" Width, 10" Length
4. Suspension Bracket - Low-Carbon Steel Rectangular Bar 3/16" Thick, 2" Width, 8" Length
5. Frame support - Low-Carbon Steel Sheet, 1/8" Thick, 12" x 12", Ground Finish

<u>Assembly</u>

1. Bend the main frame.
2. Cut the crossmember beams to size and cut 1-5/8" half circle into the very end of the beam. This will let it sit securely on the main frame. Weld to frame.
3. Make some relief cuts halfway through the thickness of the metal. Wrap the bracket around the frame. Weld around the top and bottom all the way around. - Fig 37.
4. Cut a square sheet of metal and wrap it around the crossmembers and the frame. This will tie them together and provide extra support.-Fig 38

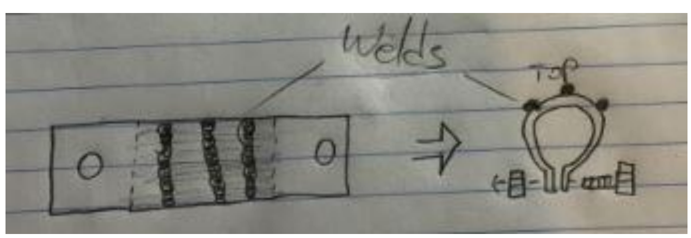


Figure 41 Weld Bracket Sketch

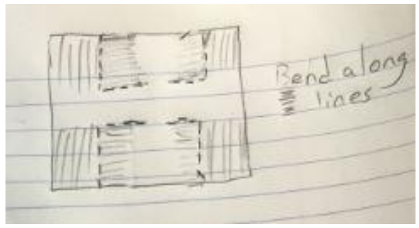


Figure 42 Cross members weld sketch

4.3.2 Spindles Assembly

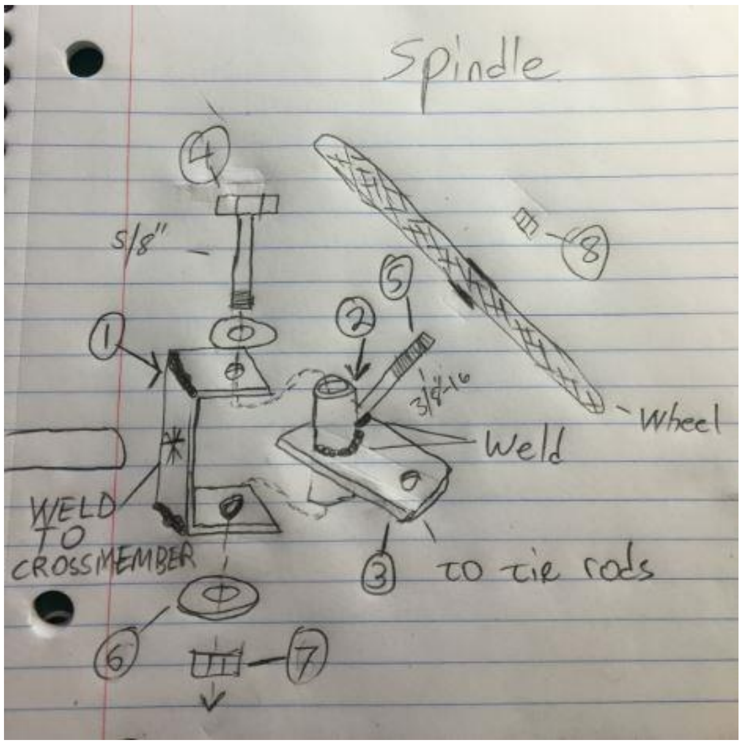


Figure 43 Spindle Assembly Sketch

<u>Parts List</u>

1. Spindle Bracket - Low-Carbon Steel Bar 1/4" Thick, 2" Width, 7" Length
2. Spindle Body - Low-Carbon Steel Tubing 1.125" OD, .625" ID, .250" Wall Thickness, 2-1/2" L
3. Steering Arm - Low-Carbon Steel Rectangular Bar 3/16" Thick, 2" Width, 4" Length
4. Medium-Strg Grade 5 Zinc-Pltd STL Cap Screw 5/8"-18 Thread, 3-1/2" Long
5. Medium-Strg Grade 5 Zinc-Pltd STL Cap Screw 3/8"-16 Thread, 4-1/2" Long
6. 2 x Grade 5 Steel Hex Nut, Zinc Plated, 5/8"-18 Thread Size, 15/16" Wide, 35/64" High
7. Grade 5 Steel Hex Nut, Zinc Plated, 3/8"-16 Thread Size, 9/16" Wide, 21/64" High
8. 2 x Type 18-8 Stainless Steel Flat Washer, 5/8" Screw Size, 0.688" ID, 1.500" OD

Assembly

1. Bend the spindle bracket. Two 90 degree bends two inches from both ends. Since the bar is very thick, it will need to be cut about halfway through the depth before bending. Afterwards the outer corners will be welded.
2. Put a .875" hole near one end for the steering body, and smaller hole on the other side, to connect to the tie rod end.
3. Place the spindle body into the hole in the steering arm and weld the hole on both sides.
4. Cut the head off the 3/8" bolt and weld it the spindle body and to the steering arm.
5. Assemble the spindle.

4.3.3 Pedal and crankset installation

Crankset

1. We will lightly grease the threads of both pedals. If we are to install “11” pedals we will be using anti-seize on the titanium spindle threads
2. Starting by hand, we will install the left pedal (groove in flange) into the left crank arm.
3. Following with turning the spindle a few turns to engage the threads. Note: Be careful not to cross thread! If difficult to turn, either the wrong pedal is being installed, or the crank arm threads will need to be changed tap and cleaned out.
4. Insert the hex through the backside of the crank arm and into the socket of the pedal spindle. (See diagram).
5. Continue turning the spindle counterclockwise until the spindle flange makes contact with the crank arm.
6. Using a torque wrench, tighten the pedal spindle.
7. Repeat the process for the right pedal. Note the right pedal (no groove in flange) has right hand threads (slopes up to right) so the spindle installs clockwise into the crank arm.

Pedal Installation

1. Determine the left and right pedal spindles. Left pedals have a small groove on the spindle flange and right pedals have no special markings (see diagram).
2. Lightly grease the threads of both pedals.
3. Starting by hand, install the left pedal (groove in flange) into the left crank arm. This pedal has a left hand thread (slopes up to the left) so the spindle installs counterclockwise into the crank arm.
4. Turn the spindle a few turns to engage the threads.
5. Insert the hex through the backside of the crank arm and into the socket of the pedal spindle.
6. Continue turning the spindle counterclockwise until the spindle flange makes contact with the crank arm.
7. Using a torque wrench, tighten the pedal spindle.

Rear-Derailleur Installation

1. Apply a small amount of grease to the derailleur’s mounting bolt. Select the appropriate tool for the mounting bolt.(83 Zinn)
2. Tighten the mounting bolt until the derailleur fits snuggle against the hanger.(83 Zinn)
3. Route the chain through the jockey wheels and connect it.(83 Zinn)
4. Install the cables and housings.(83 Zinn)

4.3.4 Seat Assembly

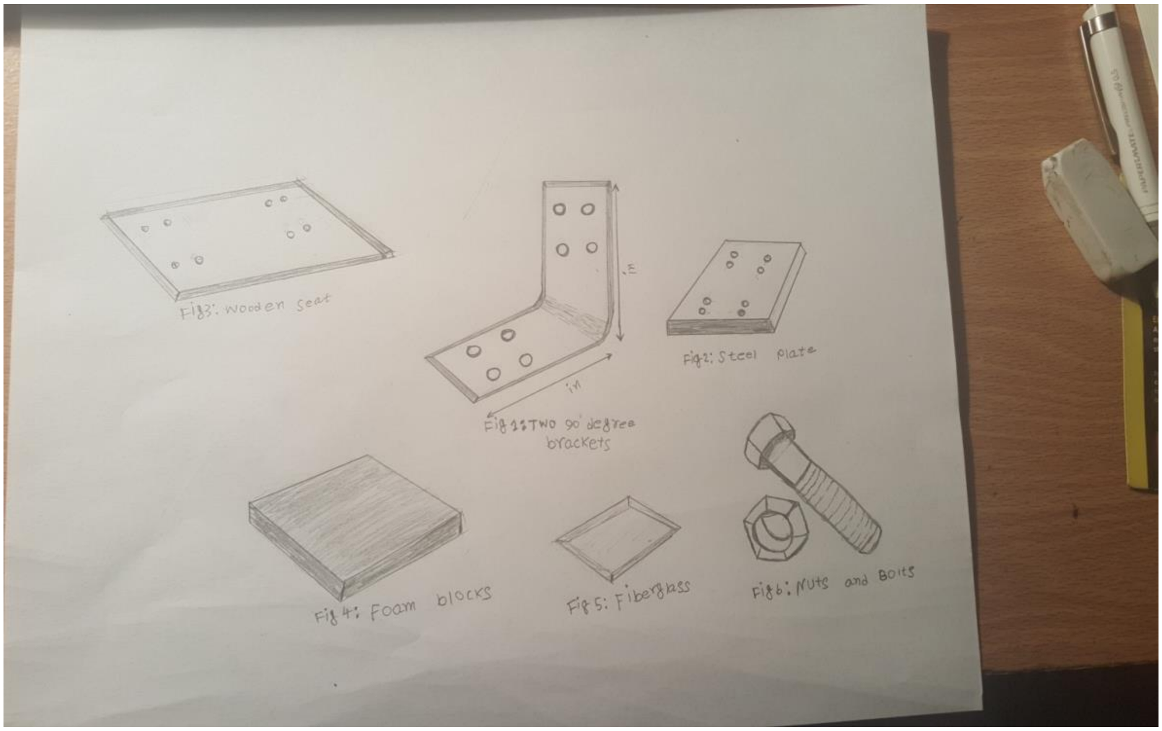


Figure 44 Seat Assembly Sketch

Parts List

1. Two Steel 90 degree brackets.
2. 16 in x 16 in Square steel plate ½ in Thick
3. 16 in x 16 in Square Wooden Seat
4. Foam blocks
5. Fiberglass

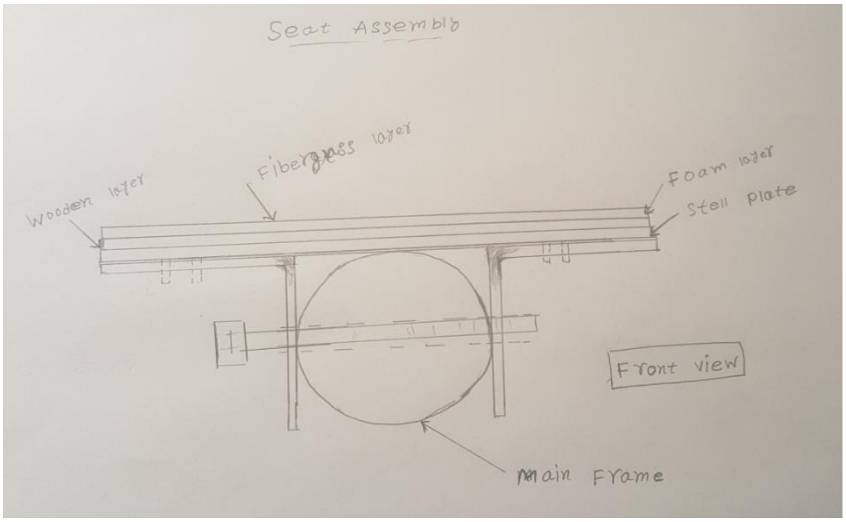


Figure 45 Seat Connection Sketch

<u>Assembly Procedure</u>

Step 1: 16 in x 16 in square steel plate will be welded with two 90 degree steel brackets.
Step 2: Wooden square cardboard will be placed on top of the steel plate and be secured by nuts and bolts.
Step 3: Foam block will be then placed on top of the wooden seat.
Step 4: Fiberglass will be put on top of the foam layer to give the seat a final shape.
Step 5: Finally, the seat will be secure with the Trike's main frame using same two 90 degree steel brackets and a long bolt though the tube that tightens it.

4.3.5 Brake System

The brakes consist of a few components.

- Brake levers
- Brake cable
- Brake - either rim, disc or drum

The handlebars of the trike will be placed vertically. The best setup for the brake levers would be under the handgrips with the lever being pressed with the middle, ring and pinky fingers. This will make it easy to use, and easy to install since the cable is going in that direction already. The left side will need a dual cable lever since there are two front brakes.

The cables will run down the handlebars and split to front and back. Make sure to leave enough slack so it does not impede the steering. Can be attached to the frame and handlebars with Velcro straps which are cheap, lightweight, and are easy to adjust.

The rear will have a rim brake. The will be very easy to do since it can be placed in the original factory mounting spot. The front however, will have disc brakes that are mounted in the center of the brake. The disk bolts onto the hub of the wheel, and the caliper will need to be mounted directly above it.

Figure 46 Orientation of Handlebars

Figure 47 Dual Cable Lever

Figure 48 Mounting of brakes

4.3.6 Shifter and brake installation and adjustments

Shifter Selection

To switch gears there will be a twist style gear shifter on the right handlebar. It will be placed right above the brake lever. A twist selector is great because it is easy to use, and easy to install since it is in-line with the cable. A rear derailleur will be used to move the chain through the gears. It will be mounted to the original factory mounting points.

Derailleur Adjustment

One of the immense things about modern derailleur drive trains is that they're easily fine-tuned should the need arise. How do you know? Usually, the warning sign that alerts you that adjustment is needed is hesitation during shifts. You click the shifter but the chain doesn't quite engage the next gear the way it used to. The most likely cause for this is a shift cable that has stretched slightly, which happens to all cables. When the cable stretches, it does not move the derailleur far enough when you click the shift lever. Here's how to adjust the derailleur so it shifts perfectly again

Derailleur designers provide a simple way for you to dial in shifting. To adjust the derailleur, look at the point where the cable enters the rear derailleur (photo above). The black round knob-like piece where the arrow is pointing is called a barrel adjuster. It is used to tune the derailleur adjustment. Standing behind the bike, the barrel adjuster is turned either counter-clockwise or clockwise in half-turn increments until the shifting hesitation is cured. Which way to turn, depends on what type of hesitation you're experiencing. The most common problem is slow shifting into easier gears (toward the spokes) due to the cable stretching. But, it's possible that you're experiencing the opposite.

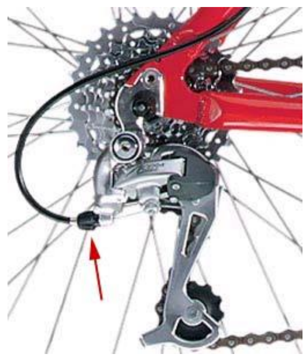


Figure 49 Derailleur Adjustment

This rule will help you remember which way to turn it: If the derailleur is hesitating when shifting toward the spokes (the more common problem), turn the barrel toward the spokes (counter-clockwise); and if it hesitates shifting away from the spokes, turn the adjuster away (clockwise) from the spokes. (Always turn it only a half turn, shift multiple times to check the adjustment, and repeat as needed to cure all hesitation.)

4.4 Manufacturing Schedule

The manufacturing schedule is organized by the different assemblies involved in the building of the trike. The order in which they are performed is organized on the manufacturing complexity and the teams' expectation on the duration of each assembly. It is favorable to begin with the construction of the frame and steering system so that once accomplished, it can facilitate the assemblies of other systems. Our extensive inventory of recycled bicycle parts has led to minimal dependence on the time to purchase materials and therefore a low probability of causing and extension in the duration of the tasks.

Table 10 Manufacturing schedule

Manufacturing Schedule				
Step	Assembly	Tasks	Start Time	End Time
1	Frame	Welding frame, supports and cross member. ES	11/3/15	11/17/15
2	Spindles	-Create the spindles using a brake and arc welder - Once it is done, it will be welded to the frame.	11/13/15	11/10/15
3	Steering	-Bend the steering bars and mount them on the frame. -Connect tie rods to spindles	11/3/15	11/10/15
4	Pedal and Crankset	-Mount the pedals onto the frame. -Put the chains together and mount it on the bike.	11/10/15	11/24/15
5	Chain and guide assembly	-Mount the chain guide -Put the chains together and mount it on the bike	11/10/15	11/24/15
6	Seat assembly	-Mount the fiberglass seat to the frame.	11/13/15	11/24/15
7	Brake system	-Mount the brakes	11/24/15	12/1/15
8	Shifter installation	-Mount the brake lever and gear shifter on the handlebars.	11/24/15	12/1/15
9	Fairings, mud guards, and accessories	-Install the accessories	12/1/15	12/9/15

Chapter 5. Failure Mode and Effect Analysis

Failure modes and effects analysis is a "bottom up" analysis. It begins by focusing upon each basic component – one at a time - and tries to determine every way in which that component might fail. Specifically, we look at the following things:

- Ways each part may fail (failure mode).
- Severity of each potential failure.
- Determine the defects that cause each failure mode and the likelihood of the mode occurring.
- Determine procedures or tests that could catch these defects in future design processes.
- Determine corrective action to either reduce the failure mode or eliminate the defect.

The FMEA method estimates the performance of the product in its lifetime. The method is initialized by thinking about potential failures. Each of the failures are categorized into physical failures, process failures, and coordination failures. Physical failures in the model include, bending or shear in the chassis; deformation of the seat; and malfunction in the parts of the subassemblies. Another category of failures involve errors in team coordination such as absence of communication.

In deriving and categorizing these failures we simultaneously think about what would cause these failures to occur. This process lead us to critically observe our model and verify that each of the functional requirements are met. The next step in the FMEA method consists of reflecting on the potential failure modes individually and determining what actions can be taken to eliminate the failures or minimize the severity of the consequence of failure.

A Risk Priority Number is used to aid in going through and revising any areas that need to be reviewed. This rating is used to assess the risks of a failure in three areas:

- Severity rating (SR)
- Occurrence rating (OR)
- Detection rating (DR)

Each rating is between 1 and 10 with 1 posing the lowest risk possible verses 10 requiring an overhaul. Here is the formula that is used to derive the Risk Priority Number (RPN) rating.

$$RPN = (SR)x(OR)x(DR)$$

Table 5.1a Risk Priority Rating Legend

Rating	Severity of Effect	Likelihood of Occurrence	Ability to Detect
10	Hazardous without warning	Very high: Failure is almost inevitable	Cannot detect
9	Hazardous with warning		Very remote chance of detection
8	Loss of primary function	High: Repeated failures	Remote chance of detection
7	Reduced primary function performance		Very low chance of detection
6	Loss of secondary function	Moderate: Occasional failures	Low chance of detection
5	Reduced secondary function performance		Moderate chance of detection
4	Minor defect noticed by most customers		Moderately high chance of detection
3	Minor defect noticed by some customers	Low: Relatively few failures	High chance of detection
2	Minor defect noticed by discriminating customers		Very high chance of detection
1	No effect	Remote: Failure is unlikely	Almost certain detection

Here is a brief run through of the (10) ten steps in this process.

10 Step FMEA Method

Step 1 - Determine failure modes

How does part function? What information is already available?
Take this moment to list items/ parts, take a look at industry standards available and if possible, any other information you can find in regards to dealing with any problem you can think of.

Step 2 - Determine effects of each failure mode

What will occur in each situation of failure?
Describe what happens to the part, try to be specific. Feel free to list different scenarios.

Step 3 - Select a severity rating

How do you rate this? Reflect its importance in the rating you choose to give.

Step 4 - Determine causes for each failure mode

List every possibility to increase the chance to eliminate the concern.

Step 5 - Select occurrence rating

Choose your ‘flavor’: Very high/ High/ Moderate/ Low/ Remote

Step 6 - Determine controls

What test or inspections could be used to find failures?

Step 7 - Select a detection rating

Refer to the Risk Priority Rating Legend for the appropriate

Step 8 - Compute RPN for each failure mode

Step 9 - Recommend and take action

Step 10 – Re-compute RPN after some action taken

In the next few pages you will find what items were observed and a few ways we took precautions to get rid of hazards.

5.1.2 Analysis of Failures Mode

Chain failure

The principal failures that can affect a chain installed on the trike are the following:

- Chain to come off the sprocket
- Chain jams
- Chains falls off
- Chain suck
- Chain breakage
- Chain skips or run rough

In order to avoid these types of failure on a chain, the manufacturing team should make sure that the derailleur is aligned with the sprocket. After assembling, we should check that chain and sprocket are in very good condition, and none of these have any crack or wear. In order to avoid the chain from coming off the inner chain wheel, we can install a chain deflector. We can also add spokes protector behind the gearbox to prevent the chain to fall between the sprocket and the spokes.

Derailleur failure

The derailleur failure can cause major chain jams. When a derailleur is bent inward, it can be the cause of chain jam. In order to prevent the derailleur from bending, a device can be installed next to the derailleur so it remains straight and aligned with the sprocket. The derailleur effectiveness depends also on the shift cable. A broken shifter or shifter cable can cause a derailleur to malfunction or even to break.

The braking system failure

One common problem with the braking system is the squealing when pressing the pads against the rim so that the trike can stop. One way to prevent this situation from happening is by purchasing high quality brake pads. If the brakes were to break or malfunction it would cause the rider to collide unintentionally unto objects or bystanders and potentially cause an accident. This provides a severity of (10).Most braking systems use reliable hardware so the probability of failure is very low indicating a rating of occurrence of (2).

Sprockets

The sprocket should be checked for any wear. The parts of the sprocket affected by wear are the teeth. The sprockets' teeth can change form over the time. The sprocket tends to creep under load. Because of the creep and wear, the sprocket may lose one or many teeth, and they can go unnoticed. Therefore, a careful visual inspection should be done. In addition, a trike made for competition purpose should have a proper sprocket. For these reasons, we recommend a ceramic type bearing because it will require less effort to rotate and make the trike accelerate faster.

Chassis

The chassis serves as the structural component of the trike. Its importance to other sub-assemblies makes it a high priority. Failure in bending or shear can cause catastrophic damage in the structural integrity of the bike. A potential failure can cause injury to the rider. A cause of this failure is due to loading over a period of time. High deflections in the chassis can be detected easily establishing a detection of (4).

Welding Failure

Welding is used is a primary joining method in the assembly of the trike. If cracks occur, it will occur in various components and not in the same time. Cracks in weld are microscopic in size and difficult to detect establish a detection rating of (9).Distortions in welding can cause damage if the welded components become detached. Assessing a severity of (4).

Team Coordination

Coordination involves the distribution of design ideas and the teamwork to accomplish tasks. Communication between the manufacturing and design team is conducted to re-iterate designs that accompany a manufacturing process. Communication is also conducted in the subject of functional requirements and manufacturing constraints. If this coordination is not present, parts can be manufactured without considering assemblies and in effect leading to dysfunctional components. This failure contains a high RPN value because of the high severity that this failure poses.

Table 11 FMEA table

Item	Functional Requirements(s)	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Occurrence	Potential Causes	Detection	RPN	Recommended Actions
Brake System	Decelerate the trike	Brakes will not work	Accident	10	2	Hardware	1	20	Purchase Reliable hardware
Chain	Deliver power to wheel	Chain will brake	Come to a stop, moving links can hit pedestrians	6	6	Loose fitting of chain links	4	144	Install a chain deflector.
Chassis	Support of rider	Chassis will bend or shear	Worst possible case, cause accident	9	7	Excessive loading	1	63	Use FEA on frame to determine weak points & reinforce/redesign frame
Seat	Adjusted to riders body	Seat will break due to riders' weight	Rider will experience injury	9	2	Deformation in Polymer	2	36	Use a large factor of safety on seat components (N=3.5-4), also include weight limit hazard sticker
Tires	Maintain traction, dissipate vibrations	Flat tires	Bike will be unable to travel, rider is stranded at location	5	10	The tires	4	200	Add a pouch or storage compartment with a patch kit, or use solid rubber tires (not recommended)
Weld(s)	Used in the manufacturing of chassis	Fatigue in welding	Crack in weld	4	5	Welding practices	9	180	Do NDT on welds during quality assurance testing, also heat treat frame/welded components to relieve stress
Team Coordination	Exchange Design Ideas between manufacturing and CAD	Parts manufactured with different dimension then drawings	The sub-assembly components will not be able to be assembled	7	6	Lack of consensus on design and major assembly	4	168	Post Ideas and design suggestion on Openlab.®
Management	Organize team agenda	The management will not provide necessary tasks	The objectives will not be met.	4	3	Disrupted communication with team members	3	36	Update the Agenda weekly and consult with team leaders for necessary tasks.

Weather protection	Protect the Trike from rain in outdoor use	Trike components will not be protected against weather	Rust and corrosion in parts			Rain in outdoor use			Use rust proof paint on components.

5.1.3 Corrective actions

Welding Methods

In our welding method we will be using electric arc welding which uses a consumable electrode that melts and becomes part of the weld metal that is deposited. One of the factors influencing joint integrity is the type of metals being weld. The mechanical and physical properties of the metal must be considered when designing a dissimilar metal joint .If there is mutual solubility of the two metals the join can usually be made successfully. In dissimilar metal welding the filler metal must alloy readily with the base metals to produce a weld metal that has continuous ductile matrix phase. (280 Campbell, F.C.)

To insure the selection of the filler metal, we reviewed our selection of the filler electrodes by comparing two electrodes in the table and chose AWS E6011 to use in the welding because it creates a stronger weld.

Table 12 Electrode Selection

Type of Electrode	AWS E6011	AWS E7018
Metal Classification	Mild Steel	Mild Steel
Rod Diameter	3/32’’	1/8”
Current Range	40-85 Amps	110-165
Melting Point	2500-2730 Fahrenheit	2500-2730 Fahrenheit
Tensile Strength	60,000 Psi	60,000 psi

The components that are being welded will be placed on a jig so that the manufacturing team member will have ease of directing the welding tool, insuring a uniform weld. Also welded parts are measured with a magnetic protractor to ensure that the angle of the welded pars meets the design dimensions.

Safety Testing

After the Trike is fully assembled the team will ride the trike to test its performance and verify that the assemblies are working properly. The test will include accelerating and decelerating to check to see if the braking system is functioning. The test will also include a series of right and left turns to verify that the steering system establishes the desired motion of turning. If flaws our present from the safety test the team will record them and prioritize the redesign of the failed components.

Rider Safety

To reduces the severity of an accident. We will consult the United States consumer Products Safety commission guidelines for our end users by stating the urgency of wearing a helmet when riding the trike. “Wearing a bicycle helmet while cycling can reduce the risk of head injury. A bicycle helmet should have a snug but comfortable fit on the rider's head. If a parent is buying a helmet for a child, CPSC recommends that the child accompany the parent so that the helmet can be tested for a good fit”. (U.S. CPSC Publication 5002 009608 062013)

To minimize the occurrence of an accident we installed headlights and taillights so that the rider is noticed by pedestrians and vehicles when riding on the street. We also install wheel reflectors so that the trike is visible in a nighttime setting

Chapter.6 Product Redesign

6.1 Redesign of steering

The manufacturing of the original designed steering system was unsuccessful because the hardware that was proposed in the cad design such as steering bracket was not available for purchase and could not be recycled from standard bicycle components. Also the measurements of the connecting bar exceeded the current built dimension of the width of the trike. From these observations the team came to a consensus to redesign the steering. A small-scale model made up of 3d printed parts was proposed by team members. This was not possible to achieve because small scale representations of the tie roads and spindles would be too small to model. A prototype was created with Legos. It represented how the steering related to the wheel spindles. The prototype also helped to evaluate if our redesign was capable of being manufactured. The redesigned parts also implemented DFA (design for assembly) techniques because they are removable in case of a maintenance operation.

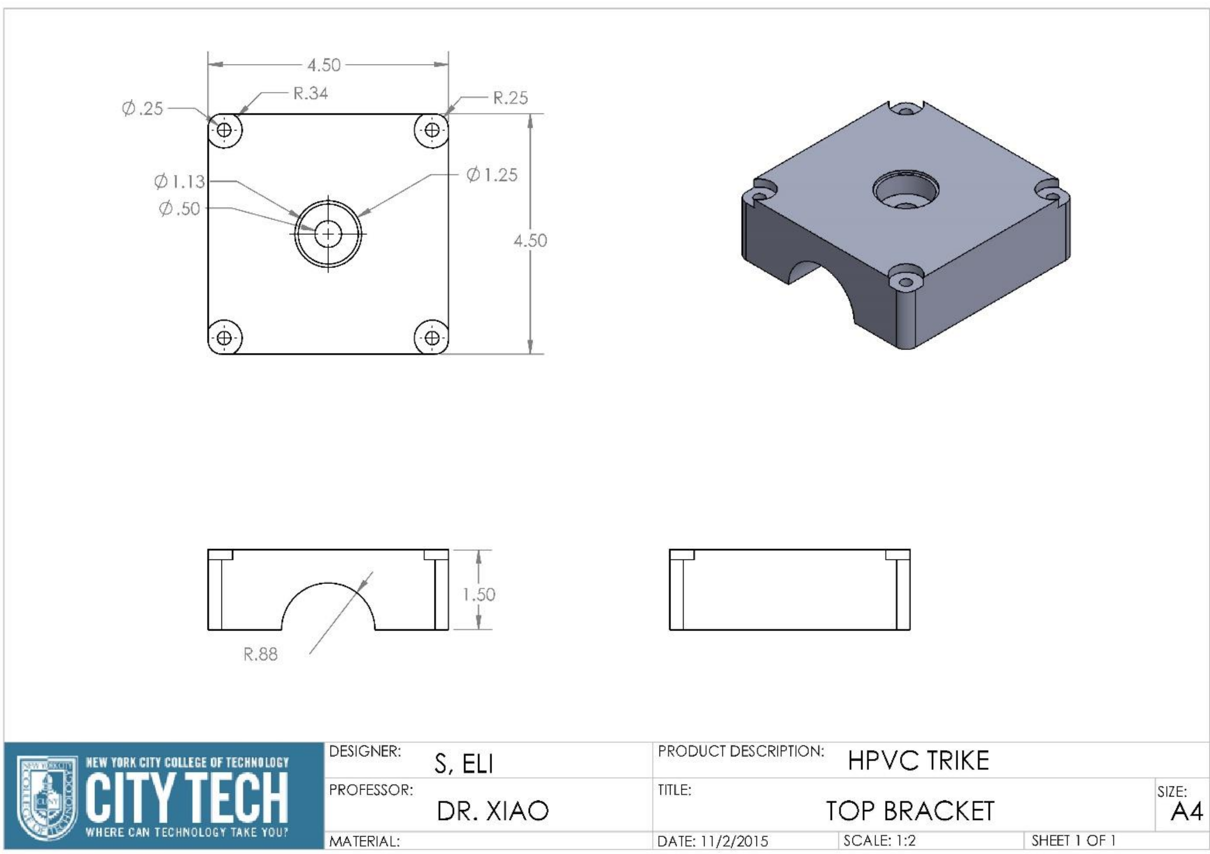


Figure 50 Top Bracket

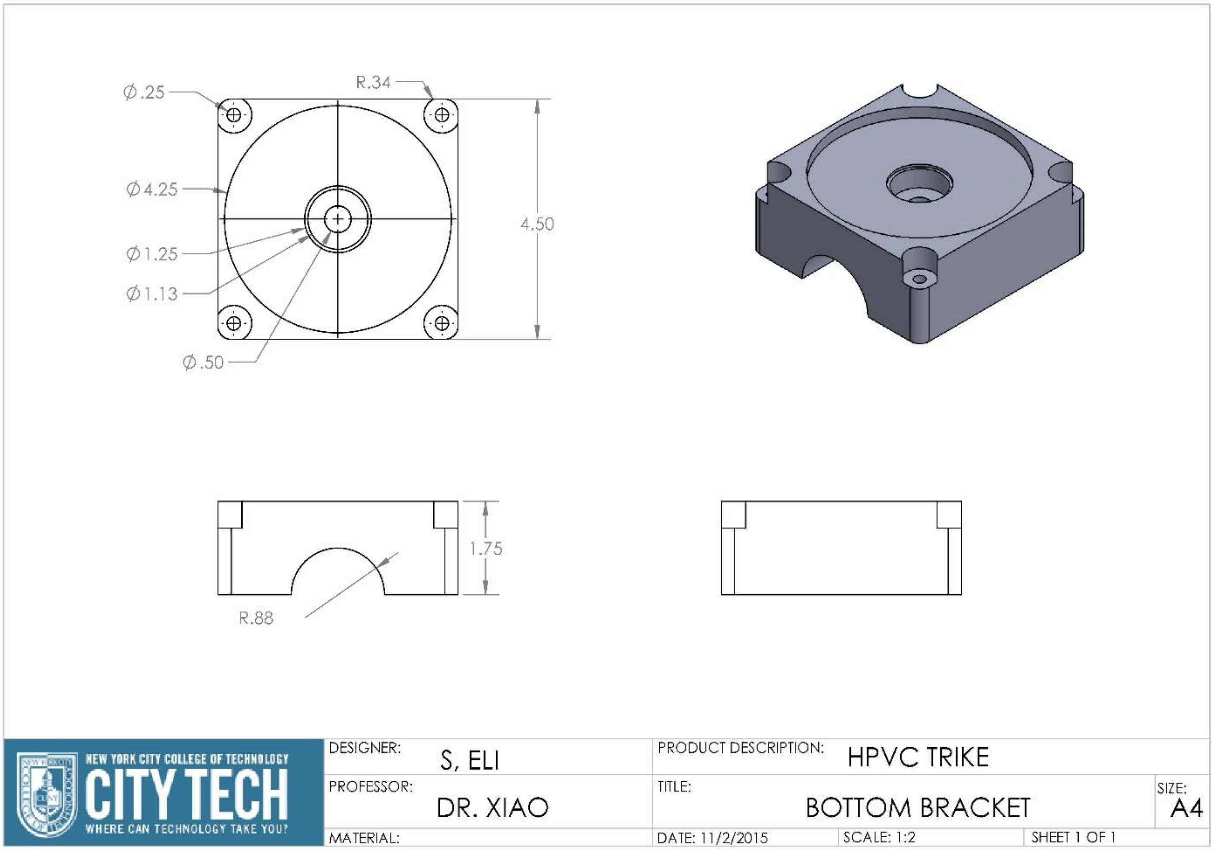


Figure 51 Bottom Bracket

New manufacturing Process to accompany the redesigned steering system

1. Weld the spindles, making sure that they are oriented at a 10 degree angle
2. Add linkages to accommodate Ackermann steering
3. Cut the threaded rod to the length of specifications
4. Add tie rod ends to the threaded rod
5. 3d print the Brackets
6. Add bearings to the brackets
7. Add the steering column to the Bearings
8. Weld two metal plates
9. Bend the metal plates to keep them at the same angle as the steering arms
10. Cut the steering column into a rectangular shape to fit into the slot of an angle Iron
11. Weld the set screw collar on to the angle Iron to set it into place.

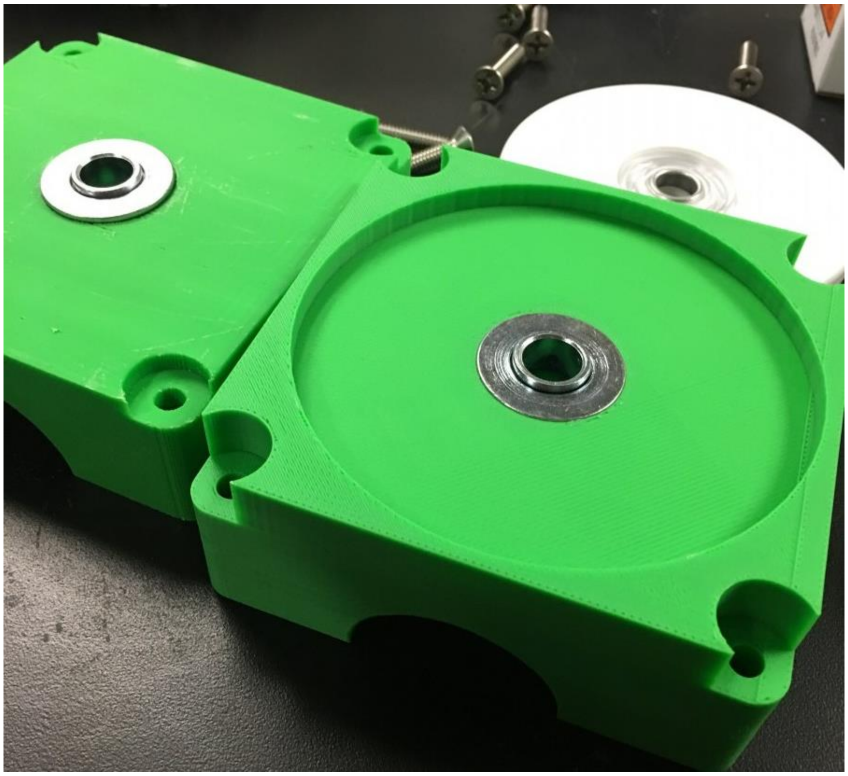


Figure 52 3d Printed Brackets

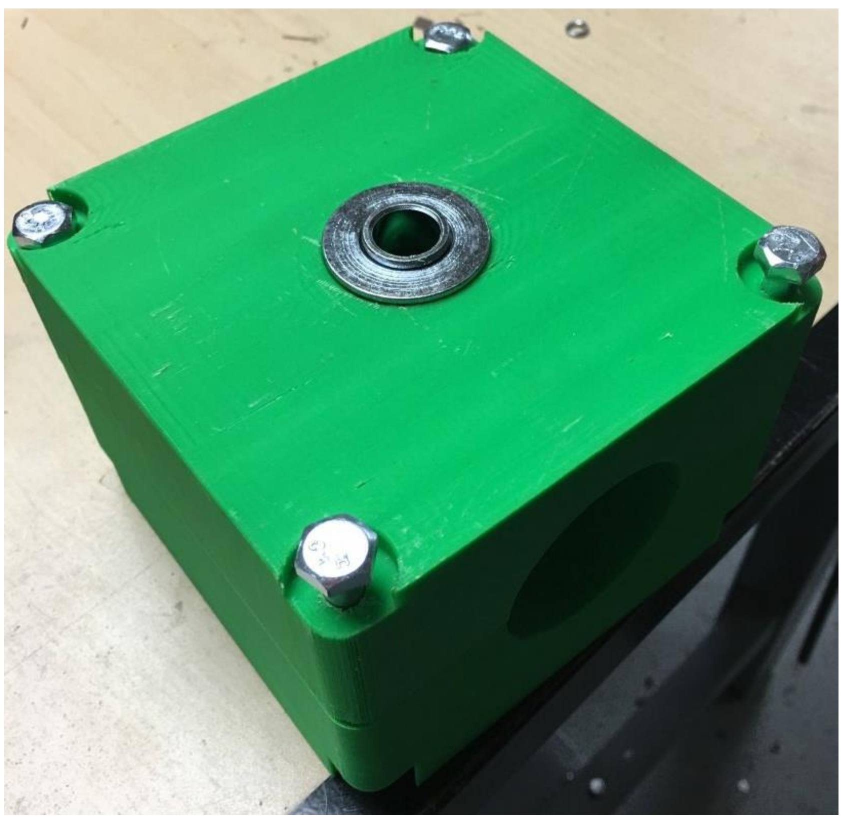


Figure 53 Assembly of 3d Printed Brackets

6.2 Redesign of Seat Mount

After the Assembly of the crank Arm., we noticed that the riders of different heights had difficulty reaching the pedals. To help accommodate the riders, we redesigned the seat mount so that that the seat bottom can incline at an angle, providing leg support. The team also added an extension to the back support so that the rider has a more comfortable seating position and easier reach to the pedals.

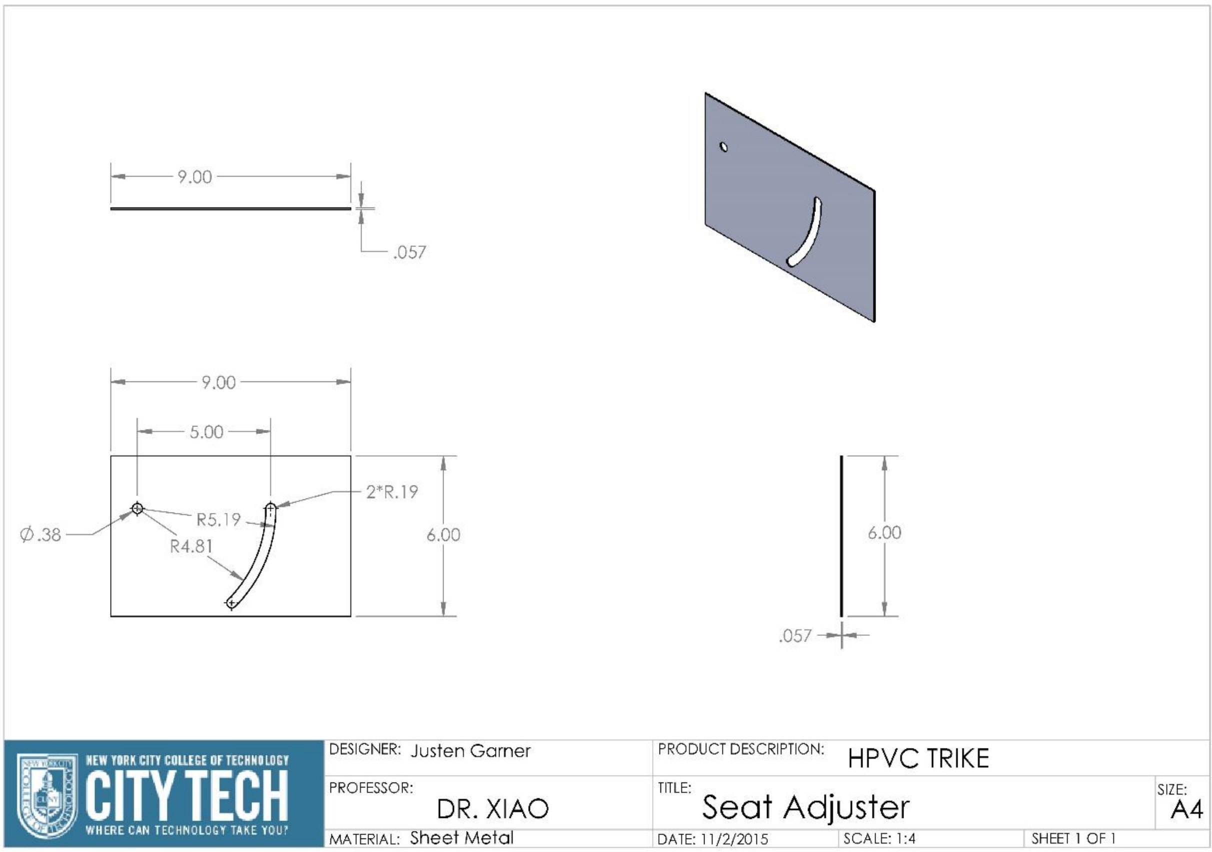


Figure 54 Seat Adjuster

The manufacturing process conceived make the seat mount required the use of a CNC mill .The. CNC code was developed by the team members and involved the setting of specific machine tools.

Conclusion

Our performance was measured by teamwork and organizations of tasks. The organization involved thinking about how the design affected manufacturing methods. It also involved the resources that we depended on to fulfill our manufacturing.

We learned that we can use to the full extent our engineering knowledge to find solutions to design problems. The importance of analytical methods such as the QFD method helped us to think analytically of our product.

Figure 55 Final Product

Resources and References

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