Designing a Human Powered Vehicle

Team #20 Midterm Report

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Chapter One: EML 4551C

1.1 Project Scope

The Human Powered Vehicle Challenge is an ASME competition in which students design and build an eco-friendly, fast, and safe mode of transportation. The goals of the project are to achieve top marks in the Design and Innovation challenges at the Official ASME HPVC. The team will build a prototype and attempt to obtain a high ranking in the racing portion of the competition as well. The main market for this human power vehicle is mega cities where alternative solutions for current highway vehicles are needed. The team will produce a prototype for the competition and assuming time and budget allows, will produce a fully functional vehicle.

1.2 Customer Needs

Knowing that our project is a competition, the rules in the competition are spelled out very strictly and we need to adhere to them. After meeting with Dr. McConomy, we decided that that we need to focus on 3 specific aspects of the challenge; Design Challenge, Innovation Challenge and Women's Speed Challenge. Each of these challenges have to follow the following main rules and guidelines for the event which are shown below.

The requirements of the American Society of Mechanical Engineering's Human Powered Vehicle Challenge are as follows:

- Roll protection system capable of withstanding specified top and side loads indicated in the 2018 HPVC Rules document.

- Roll protection system that is structurally attached and braced to the vehicle frame or fairing.
- Rigidly mounted and structurally sound seat and properly affixed safety harness.
- Safety harnesses attached to the RPS or a structural member in the RPS and may not be attached to the seat unless it is structurally integrated into the RPS.
- Come to a stop from a speed of 25 km/hr in 6.0 m (19.7 ft)
- Turn radius within an 8.0m (26.2 ft)
- Capability of driving for 30 m (98.4 ft) in a straight line at a speed of 5 to 8 km/hr
- Braking system with properly designed brakes on the front most wheel of the vehicle at a minimum; must have at least front wheel brakes (if more than 1 front wheel)
- Appropriate guards fitted for all drivetrain components, steering components, and wheels if within reach of the rider and must be designed and constructed so that they will not injure the rider in the event of an accident.
- Properly fitting helmets with fastened straps that meet CPSC Safety Standard for bicycle helmets (16 CFR Part 1203)
- Forward-facing field of view of at least 180° wide for the driver.
- Submit a short video (maximum 2 minutes) showing their HPVs completing the three performance safety requirement tests (Section III.B). Video files must be less than 500MB, in mp4 format, and submitted at least one week before the race.
- Written report, technical presentation, and performance safety video for the vehicle

Our team feels that these points below should be implemented in the project:

- Be compact
- Design and demonstrate technical innovation related to their vehicle.
- Display school name or initials on each side of the vehicle in characters at least 10 cm high in a color that contrasts with the background

After discussing with Dr. McConomy, we feel that it would be nice to:

- Win the challenges
- Utilize ultracapacitors
- Incorporate a CVT

1.3 Functional Decomposition

The human powered vehicle's functions are to:

- Use human input to create mechanical energy
- Transport operator by rolling on wheels
- Transport operator safely
- Enable operator to travel on government maintained roads
- Enable operator to steer vehicle in desired direction
- Enable operator to detect upcoming obstacles
- Enable operator to alter vehicle's longitudinal acceleration

1.4 Target Summary

The targets of the Human Powered Vehicle are made up of velocities, accelerations and decelerations, and numbers of components. Some of the targets were found from benchmarking other human powered vehicles as well as from the official ASME HPVC rules. The first target is to use human input to create mechanical energy. The rules of the competition are that the vehicle must use only human power to propel the vehicle down a track. The human input should be able to pedal the vehicle at least 142.8 RPMs to get the vehicle to 40mph. To achieve this speed, we will use a gear ratio of 3.25:1 on the standard bicycle gear train that can be implemented in this vehicle. The calculations are shown in the table below:

Target Speed (mph)	Speed (ft/s)	Tire Diameter (in)	Tire Diameter (ft)	Tire circumference (ft)	Tire angular velocity (rev/s)	Max Gear Ratio	Input angular velocity (rev/s)
40	58.67	29	2.42	7.59	7.73	3.25	2.38
Vehicle operator would have to pedal			**2.38**	**revolutions per second to achieve**		**40**	**mph**

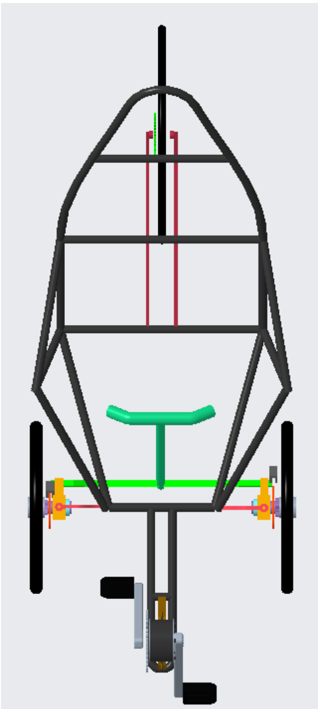
Figure 1. Calculations for the Tire Size

The second target is to transport the operator on rolling wheels. We have this target so that the vehicle can be used to move the driver from one place to another. This will be done using 700c bike tires. Which equate out to 29 inches in diameter, as shown in the speed calculation table above. We will aim to use at least 2 wheels but no more than 4 total.

The following targets are designated to keeping the operator of the vehicle safe, to be able to maneuver it adequately and to be able to operate the vehicle on government maintained roads. This is because, if the vehicle is ever actually marketed to the public, these are important for both appealing to customers as well as getting the permits needed for production. This is done by being able to stop the vehicle from 25km/hr in less than 6 meters. Having a Roll Protection System in place is also going to keep the operator safe and must withstand a top load and side load of 2630 N and 1330 N respectively. Maneuvering the vehicle should come with ease and it should have a turn radius of less than 24.6ft, while the operator has at least a 180-degree field of view.

1.5 Concept Generation

Tadpole Trike Configuration



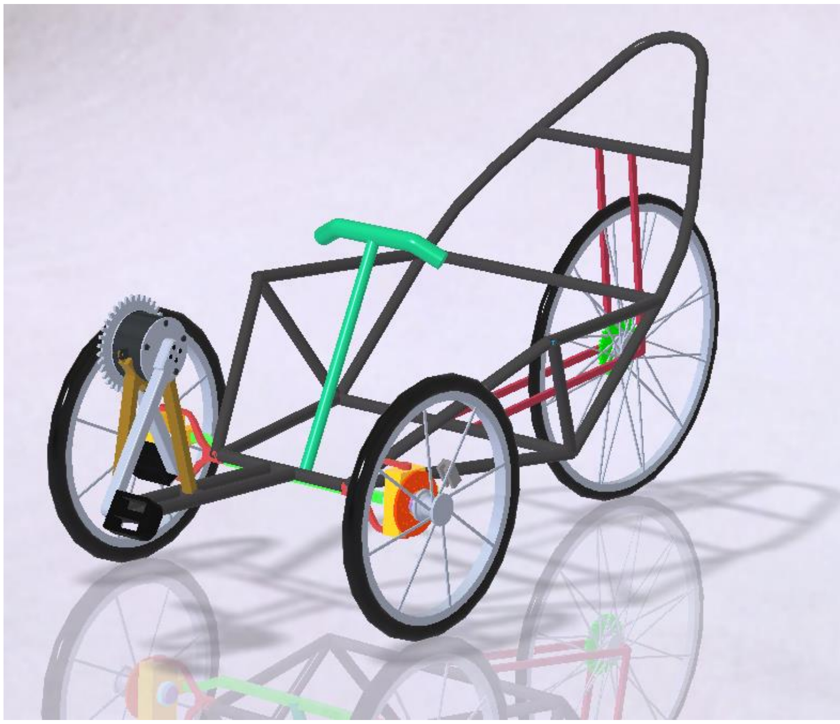


Figure 3a. Isometric View *Figure 3b.Top View*

Tadpole Trike Configuration Features

- 20” kid’s mountain bike tires (thick tires to better withstand lateral forces) in front
- 26” tire in rear
- Chain runs from front to rear
- Steering: 15 degrees with 48” wheelbase gets about a 16-foot turning radius
- Drivetrain will include derailleur and multiple gears or a cvt system along with the HANScycle gear system

- Steering involves a linkage still to be determined; two configurations include laterally moving steering wheel to rotate wheels or a linkage or steering rack that rotates wheels when the steering wheel is rotated
- RPS completely protects driver during operation and protects them in both the vertical load and side load crash conditions
- Brakes rotors and calipers are located on both front wheels of the vehicle

Bicycle Configuration

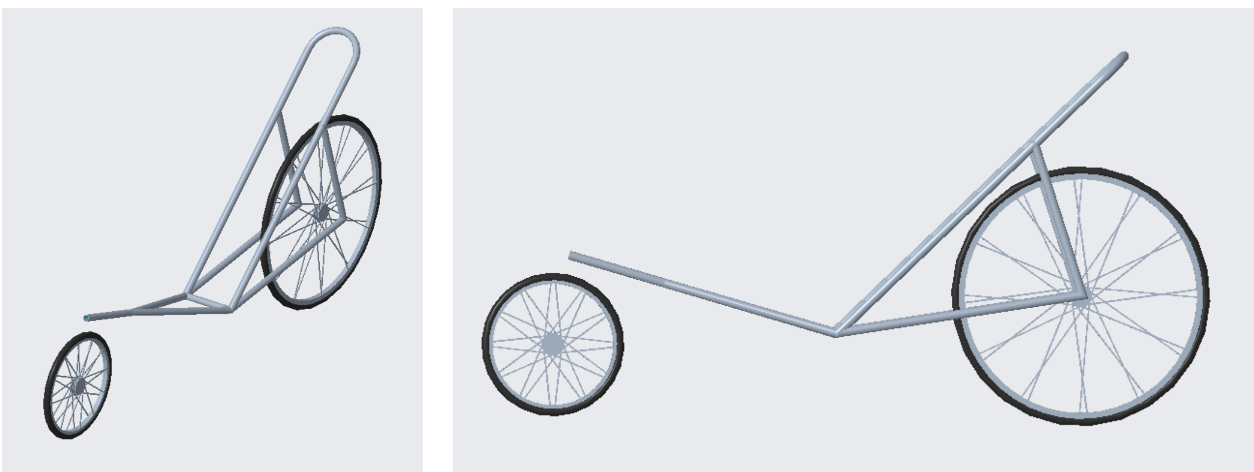


Figure 3. Bicycle Configuration

- Large 29" wheel in the rear for more speed at same rpm.
- Chain runs from front to rear
- Very low and skinny orientation of the driver
- Steering: The ability to lean into the turn will reduce the chance of flipping and will allow for less turning from the handle bars. The steering will be exactly like a normal bicycle.

- Roll protection system will be made from the back rest of the vehicle. A roll cage will be made from a bar above the driver and a bar on each side of the driver.
- Brakes rotors and calipers are located on the front wheel of the vehicle

Table 1.

Breakdown of Concepts from each subsection.

System	Concepts
Aerodynamics	Full Fairing
Aerodynamics	Small Fairing
Aerodynamics	No Fairing
Drivetrain	Chain
Drivetrain	Rubber Belt
Drivetrain	Full Rotating Petals
Drivetrain	HANScycle
Drivetrain	Gear
Drivetrain	CVT
Drivetrain	2 Wheel
Drivetrain	3 Wheel
Drivetrain	Variable Wheel
Frame/Roll Protection System	Frame
Steering	Linkage
Steering	Bicycle Handlebar
Steering	Steering Rack
Energy Storage	Ultracapacitor

System 1. Aerodynamics

Full Fairing

A full fairing would be used to compensate for the air resistance caused by a non-streamlined design.

Small Fairing

A small fairing would be used as a windshield for the driver rather than for aerodynamic purposes. The fairing would help for rain avoidance.

No Fairing

A fairing would not be necessary if the increase in weight because of adding the fairing outweighs the aerodynamic benefit of having one. In other words, the addition of a fairing will increase the overall weight of the vehicle and therefore the force of friction acting on the tires would slow us down.

System 2. Drivetrain

Chain

A chain will provide an efficient and durable method of transferring human input into mechanical energy. Although a chain has very tight tolerances when installing, it can be repaired easily after it fails.

Rubber Belts

A rubber belt functions similarly to a chain; however, the rubber belt has a significantly greater tolerance and cannot be fixed once it fails.

Full Rotation Pedals

Full rotation pedals allow the user to pedal in a circular motion to convert their energy into mechanical energy and can be found on most bicycles.

HANScycle

The HANScycle system is a gearbox with pedals attached to it such that the user inputs a different motion with their feet than a standard bicycle. The user pushes their feet in and out in an oscillatory fashion on the pedals rather than a rotary motion. This allows the user a different experience when riding such that less stress in placed on the joints, primarily the knee joints, during operation. Implementing the HANScycle system in our Human Powered Vehicle design would set us apart from the other teams and provide us with an innovative advantage in the realm of relieving stress in the joint of the user and a more pleasing ride experience.

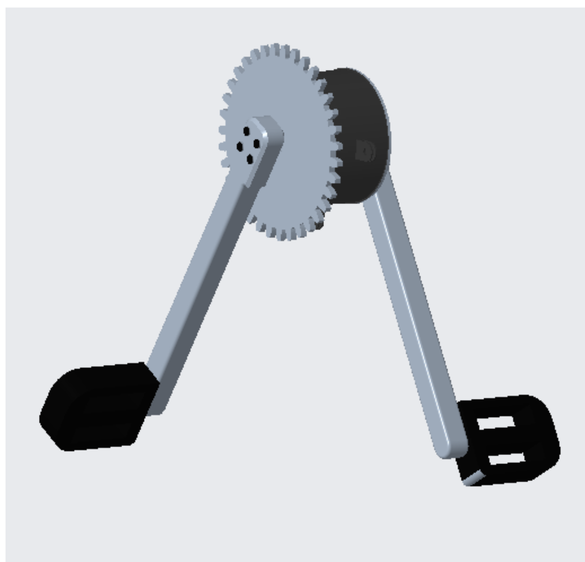


Figure 4. HANS cycle

Standard Bicycle Gears

Gears can be a very inexpensive way to increase the output speeds of wheels. Two gears on a chain give only one gear ration, but having multiple gears would add the multiple ratios.

CVT

The CVT is a rare technology when it comes to implementation on bicycles. It's not seen very often and it's a great option to explore since an infinite gear ratio between a certain range is available, giving the operator of the vehicle efficient acceleration capabilities. It can also make the acceleration process swifter as opposed to shifting through many different gear ratios as with a standard bicycle, giving us an advantage when it comes to accelerating.

2 Wheel

A two-wheeled vehicle would be utilized to reduce the weight and size of the vehicle. The vehicle would be made skinnier than a vehicle with more wheels, therefore it would have a smaller frontal area and make it more aerodynamic. This vehicle would also have less material, which would reduce the weight allowing it to travel faster. Two wheels would make it harder for the vehicle to flip in a turn because it could lean into also make it.

3 Wheel

A three-wheeled vehicle would be more stable than a two wheeled. The driver wouldn't have to worry about balance when coming to a stop or going slow threw turns.

Variable Wheel Size

The main reason for using a wheel that can change its size would be to change the moment of inertia of the wheel. A small wheel would have a small moment of inertia and would be easier to rotate. As the speed increases, the wheel size could manually be increased to allow for more distance per revolution of the wheel. The small wheel size would be great for acceleration while the large wheel size would be great for getting a higher top speed.

System 3. Frame/Roll Protection

Frame

The frame needs to be made very safe so the driver won't injure themselves. The frame will have a roll protection system such as a roll cage to protect the driver in the case of a crash or rollover.

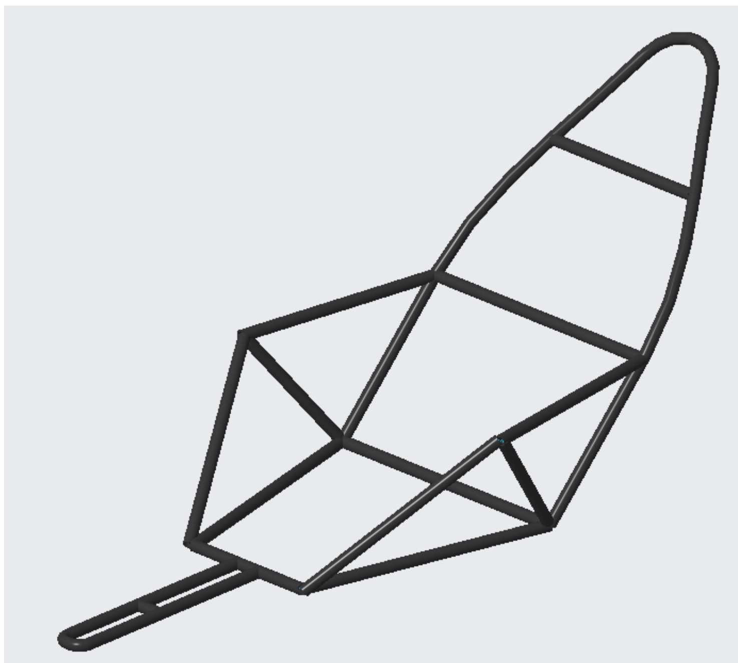


Figure 5. Frame

System 4. Steering

Linkage

A linkage could be used to move the axle side to side. This could be set up so that little movement between the legs would be necessary to turn the vehicle. The linkage only moving an inch or so to the right could turn the wheels far enough.

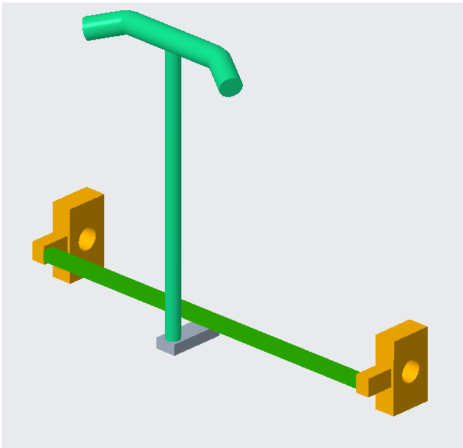


Figure 6. Steering Linkage

Bicycle Handlebar

The traditional bicycle handlebar is a compact and easy steering system to implement. It uses a one simple pin joint to rotate the tire.

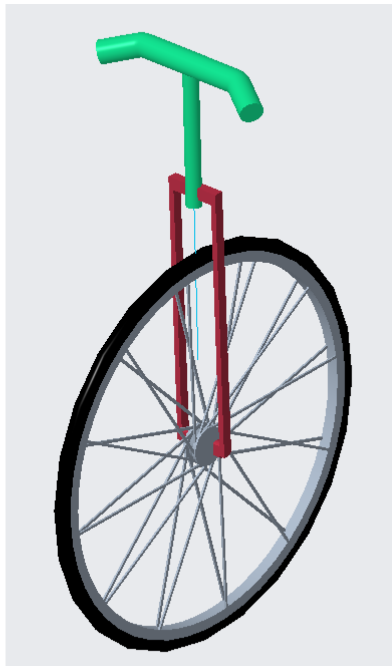


Figure 7. Bicycle Handle Bar

Steering Rack

A steering rack system could combine the bicycle and linkage system by having an axis that turns the wheel hubs and has a handle bar that rotates in a pin joint. A rack and pinion gear set is used to change the rotational movement into linear movement of the axis side to side.

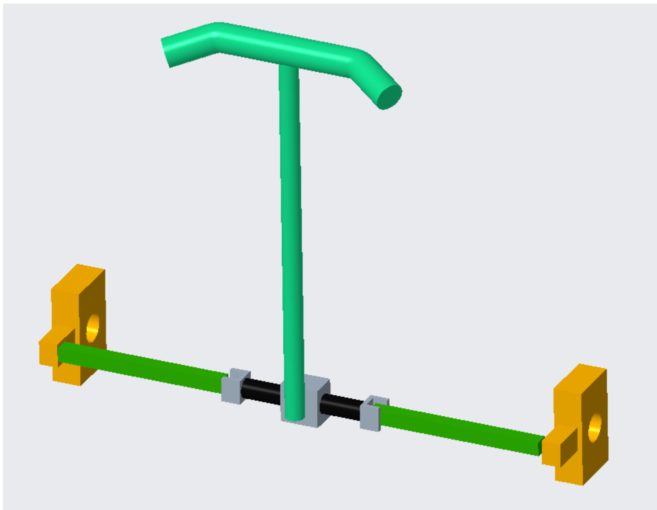


Figure 8. Steering Rack

System 5. Energy Storage

Ultracapacitors

These would be utilized to harness energy while operating the vehicle and use it later during situations where faster acceleration or max speed is desirable. Integration would involve placement near the pedals of the vehicle and the motion of the pedals would help create electrical energy within the ultra-capacitor.

1.6 Concept Selection

For the selection of concepts we used a Pugh Matrix to determine which concept would work best for our Human Powered Vehicle. We broke down our overall concepts into 8 different sections to thoroughly select the best designs. The first component of the vehicle that we analyzed was the Fairing.

When selecting which concept to implement, it was evident that the weight, aerodynamics, and cost of each concept needed to be evaluated to select the optimal concept. We decided that the weight of the fairing should be weighted as 0.35 since it as a large effect on the amount of work needed to move the vehicle from rest. Additionally, the aerodynamic benefits of the fairing were weighted as 0.2 because it would ultimately decide if higher speeds could be achieved. However, we decided cost was the most important factor which was weighted as 0.45 since the cost of fairings could be high depending on the material.

To determine if the aerodynamic benefits of a fairing were worth the additional cost and weight, a force analysis was performed on the force of friction of the tires and the drag force due to air. The force of drag is on an object is a function of the density of the fluid surrounding the object, the frontal area of the object, the drag coefficient, and the velocity squared. Therefore, the density of the fluid is air was assumed to be constant, the frontal area was approximated as 8 square-feet, and the drag coefficient was estimated as that of the Ariel Atom in figure 9 which was 0.4.

Figure 9: Ariel Atom

The only unknown was velocity which was varied and plotted on a force versus velocity curve. After benchmarking the previous human powered vehicles entered in the HPVC, we approximated the weight of our vehicle and rider as 190 lbs. Additionally, we found the kinetic coefficient of friction of bicycle tires on dry asphalt to be 0.75 and thus able to calculate the force of friction of the road on the tires. The two forces were plotted together and compared.

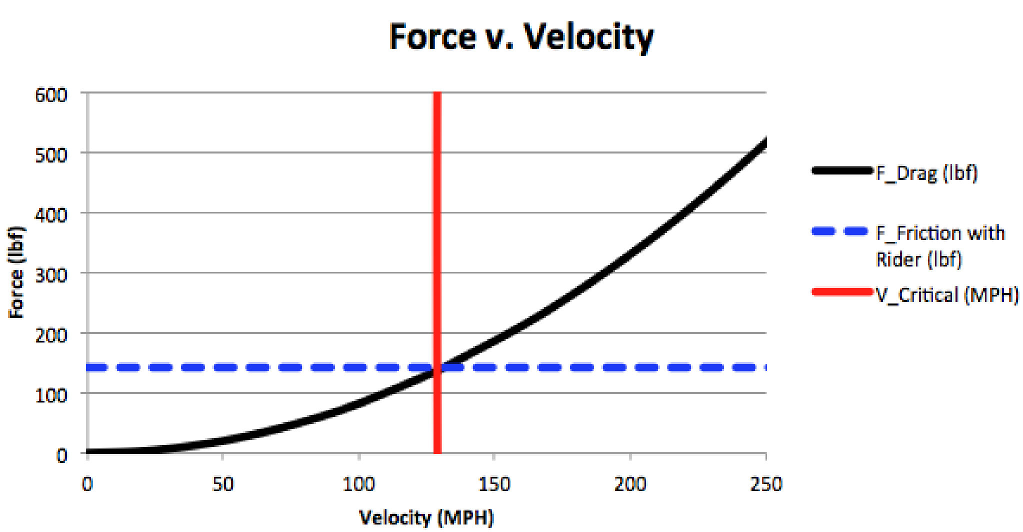


Figure 10: Force of friction plotted with Drag Force

We determined a critical velocity of 141 MPH at which the force of frag is equal to the force of friction on the tires. It is at this critical velocity where an aerodynamic fairing is required to decrease the drag force in order increase the vehicle's velocity; however, we do not intend on reaching a speed this high and therefore the aerodynamic benefits from a full fairing aren't that large. Considering that minimizing weight and cost had the highest weighting, it was obvious that we should choose the concept which did not utilize a fairing.

Fairings				
ECs	None	Partial	Full	Weighting
Weight	5	4	1	0.35
Aerodynamic	3	4	5	0.2
Cost	5	3	1	0.45
Score	4.6	3.55	1.8	

Table 2: *Faring Matrix*

The next component that we needed to analyze was the drivetrain of the vehicle. The durability of the drivetrain was determined to be the most important factor when considering how to transfer power to the wheels. The worst outcome from the drivetrain would be it breaking in the middle of a race, therefore, it was weighted the highest. Reparability and Cost are weighted lower because the cost of all the ideas are relatively low and we would like to be able to fix our drivetrain, but wouldn't be able to during the race. The chain was the best of our concepts mainly because of its reparability.

Drive Train			
ECs	Chain	Belt	Weighting
Durability	4	4	0.4
Variability of Size	5	3	0.2
Reparability	5	1	0.2
Cost	4	5	0.2
Score	4.4	1.8	

Table 3: *Drive Train Matrix*

Next, we analyzed which gear set we need to use to maximize our performance. The gear set will most likely be the most expensive component on the human powered vehicle. This resulted is cost being the most influential factor in determining the correct gear set to use. A CVT will be far more expensive than a derailleur which is why cost is the driving gear set factor. Reparability and ease of power transfer are very important with respect to which gear set is chosen, but if one of them is out of the potential cost range, then it cannot be chosen even if its performance is superior. Reparability and ease of transfer are somewhat interchangeable when it comes to importance.

Gearset			
ECs	CVT	Derailleur	Weighting
Ease of Transfer	5	4	0.3
Repairability	1	2	0.3
Cost	1	4	0.4
Score	2.2	3.4	

Table 4: *Gear Set Matrix*

The pedals were the next aspect that we analyzed. For the different pedal configurations, comfortability was determined to be the highest weighting factor. This human powered vehicle should be something that someone would want to buy. We can afford to make comfortability the highest factor because the cost and power output of all our options were very similar and optimal. The HANScycle won this section because it can get the same output power from a method that uses and easier motion.

Pedals			
ECs	Standard Petals	HANScycle	Weighting
Power Output	4	4	0.3
Comfortability	3.5	5	0.4
Cost	4	4	0.3
Score	3.8	4.4	

Table 5: *Pedals Matrix*

The wheels were analyzed next. As we are entering a race, weight is always an important factor. We decided that we would give weight a weighting of 0.3 for the wheels because the weight of a wheel is not quite large enough to be our top priority but is still enough to have to take it into consideration when deciding. For the weight, the 2 wheeled option is the best option with 4 wheels being the heaviest. The stability of the vehicle is extremely important in that the driver must be able to start the race without help from the team. Due to this, it was decided to give stability a rating of 0.4 which is the heaviest weighting for this section. For stability, the 4-wheeled design is the best because it has the most points of contact with the ground and 2 wheels being the worst with the least points of contact. The cost of the wheels is also something in which we needed to take into consideration. The overall cost of the vehicle is on a budget and it was therefore determined that it would receive a weighting of 0.3. For cost, the 2-wheeled design is the best because it will be the least numbers of wheels and therefore the least cost with 4 wheels being the worst. After all the weighting, the best number of wheels for our purposes ended up being 3 wheels.

Wheels				
ECs	2-wheels	3-wheels	4-wheels	Weighting
Weight	2	3	4	0.3
Stability	2	4	5	0.4
Cost	5	4	1	0.3
Score	2.9	3.7	3.5	

Table 6: *Wheels Matrix*

The Frame of our vehicle, which was analyzed next, can be made from many different options but we narrowed them down to four different materials: Aluminum, Steel, Stainless Steel, and Carbon Fiber Reinforced Polymer (CFRP). For deciding which material is the best for our purposes we decided to have weight of the material, strength of the material, and cost of the material be our focuses. We decided to give weight a weighting of 0.35 because the overall weight of the vehicle is quite important when it comes to racing so we wanted to be sure to take that into account. In terms of weight, CFRP was the best material for our frame with the two steels tying for worst. The strength of the material is also very important to our team to protect the driver in the event of a crash. For this reason, we gave it a weighting of 0.25. The best material in this aspect was CFRP again with Aluminum coming in last. Lastly, the cost of the material is important due to the fact of a strict budget on our vehicle. The cost was given a weighting of 0.4 due to the strictness of the budget. The best material in terms of cost was steel with CFRP coming in last. According to our weighting and decisions the best material for the frame ended up being CFRP with the highest score overall.

Frame					
ECs	Aluminum	Steel	Stainless Steel	CFRP	Weighting
Weight	4	2	4	5	0.35
Strength	3	3	4	5	0.25
Cost	3	5	3	1	0.4
Score	3.35	3.45	3.6	3.4	

Table 7: Frame *Matrix*

The next component, steering, is a component that needs to be very easy for the operator to use when driving the vehicle to ensure their safety. Therefore, ease of use was the most important factor chosen for the steering component of the car. If the driver is going to fast and cannot easily control the steering of the car, that puts the driver at the risk of crashing, and safety is the most important in a student competition. Cost and ease of installation are equally weighted below ease of use but are still both very important to the steering subsystem selection.

Steering				
ECs	Handlebars	Linkage	Steering Rack	Weighting
Ease of use	5	3	4	0.4
Ease of Installation	5	4	3	0.3
Cost	5	4	2	0.3
Weighting	5	3.6	3.1	

Table 8: Steering *Matrix*

The final component analyzed was energy storage. One of the major factors of all our concepts is cost. Energy Storage can be a very costly idea which is why it has a very high ranking is this area. The other most important factor is output power. We don't want to add a lot of weight or pour a bunch of money into this project if the addition is having very minimal effects. It was easily determined that compressed air was one of the worst concepts based on our factors. Tanks for compressed air would be bulky and are very inefficient for powering something of our magnitude. Ultracapacitors were the best from this section because they are like the rechargeable batteries, but each factor was slightly better. The only thing that makes the ultracapacitors worse would be cost. The cost would be more than the normal rechargeable batteries, but the other benefits outweigh this negative.

Energy Storage				
ECs	Batteries	Ultracapacitor	Compressed Air	Weighting
Weight	3	4	2	0.1
Capacity	4	5	3	0.1
Output Power	4	5	2	0.3
Charge Time	3	5	2	0.2
Cost	3	2	3	0.3
Weighting	3.4	4	2.4	

Table 9: Energy Storage *Matrix*

Appendix A: Code of Conduct

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Mission Statement

Team 21 is dedicated to making safe, ethical and thought-out decisions when performing engineering tasks. Anything produced by the team is intended to relay engineering knowledge and innovative ideas to the engineering community. Time management, teamwork, and discipline will allow the team to meet deadlines and efficiently create engineering designs, analyses and products.

Roles

Team Leader

The team leader will be the main point of contact for our team. They shall keep the team working in unity. If a problem in the team should arise, the team leader will keep the integrity of the project intact. The team leader will be the mediator in case of untimely indecision.

The team leader will be in charge of delegating tasks to members best suited for the job based on that team members strengths. Team leader will be responsible for keeping positivity among the group and act in the best interest of the project. They will develop a timeline for the project and use organizational skills to make plans come to life in a timely manner.

Financial Manager

The treasurer will be in charge of organizing finances for Team 21 and for the Human Powered Vehicle competition. The treasurers are responsible for reviewing all requests for purchases in order to decide whether the product is necessary or could be substituted. If the purchase is necessary, the treasurers will order the product and add the cost to their budget records.

Scribe

The scribe will be in charge of keeping minutes of every meeting as well as keeping track of where the team left off at previous meetings. In addition, the scribe will be responsible for keeping track of who attends meeting as well as send out emails containing their notes.

Design and Analysis Lead

The design and analysis lead will be in charge of leading efforts regarding designing and performing analyses for the vehicle. Consulting with school faculty will also be sought out regarding the validity and effectiveness of said analyses and designs.

All Team Members

All team members will communicate effectively while respecting others' roles and ideas. Additionally, team members will be assigned different projects and are expected to keep all commitments and deliver them before the designated due date. Members will be expected to treat all parts of the project with respect and commitment. Members will respect others' feedback of their portions of the project and will be respectful in giving feedback. Every person is expected to be an ambassador to the outside world for their own portions of the project and report back to the team at weekly meetings. Team members will show confidence in our team when any and all occasions to do so arise.

Communication

The team will have most of its communication in the meetings. If there are urgent matters that cannot wait until a meeting, there is a GroupMe group chat setup to allow for messaging us. The documents that are being made by the team will be stored on Google Drive which will eliminate the need for emailing them.

If a meeting time will need to be changed, the message must be sent out more than 4 hours before the meeting is supposed to start. If a meeting needs to be added, the message should be sent out 24 hours in advance. If a member cannot make it to a meeting, they need to let the team know 4 hours in advance. Multiple absences will result is meeting time changes and further absences will not be tolerated.

Team Dynamics

All members of our team are equal; every person's opinion will be not only considered but done so thoughtfully when it comes to every decision; each member of the team will keep all commitments by the due date; each member agrees to assess whether all members are honoring their commitments to the team. All communication between team members will be respectful; No team member will talk down to another; Team members will recognize contributions positively.

Ethics

The team members should practice the NSPE Engineering Code of ethics. Each team member must complete all work assigned to them and try to go above and beyond to help the rest of the team. Always keeping ethical practices in mind will allow the team to be successful.

Dress Code

Team meetings can be held in any socially appropriate attire. Sponsor meetings and group presentations will be held in business casual or formal dress that will depend on the event.

Weekly and Biweekly Tasks

There will be meetings held every Monday and Wednesday from 12:00 PM to 2:00 PM is a reserved conference room at the COE. If more meeting time is needed during the week, the team will use the unused time from Senior Design Class. If there are too many or not enough meeting times, the team will vote on how to change them. Meeting minutes will be taken by the team note taker.

Each week the team needs to make journal entry that explains everything that was accomplished that week and everything that needs attention the week coming up. At Least every other week, the sponsor/advisor will be updated on the team's progress.

Decision Making

All ideas and opinions will be taken into consideration during the decision making process. Members will make decisions by consensus, but majority rule will be used if a consensus can not be made in a timely manner; any and all conflicts will be resolved with the persons involved directly.

Conflict Resolution

All team members will make certain they have agreed on what and when to communicate; complaints about fellow team members will be addresses within the team first.

If a conflict cannot be resolved within the team, Professor McConomy will be contacted to help resolve it.

Statement of Understanding

By signing this document the members of Team 21 agree the all of the above and will abide by the code of conduct set forth by the group.

Name	Signature	Date
Peyton Lanier	[illegible]	9/20/17
Brady Bauer	[illegible]	9/20/17
Genevieve Macdonnell	[illegible]	9/20/17
Miguel Rodriguez	[illegible]	9/20/17
Edward Bohne	[illegible]	9/20/17

Appendix B: Functional Decomposition

The human powered vehicle's functions are to:

- Use human input to create mechanical energy
- Transport operator by rolling on wheels
- Transport operator safely
- Enable operator to travel on government maintained roads
- Enable operator to steer vehicle in desired direction
- Enable operator to detect upcoming obstacles
- Enable operator to alter vehicle's longitudinal acceleration

Appendix C: Target Catalog

1. Use human input to create mechanical energy
    a. How many RPMs?
        i. 600 RPMs
    b. What gear ratio if no CVT is used?
        i. 3.25:1 (standard bicycle gear train)
    c. What gear ratio can the CVT provide?
        i. 4.8:1 (NuVinci CVT)

2. Transport operator by rolling on wheels
    a. What size wheels?
        i. 700c (29”)
    b. How many wheels?
        i. 2
        ii. 3
        iii. 4

3. Transport operator safely
    a. How many meters does it take to stop it?
        i. <6 m from 25 km/hr
    b. How stable must the vehicle be while traveling?
        i. Must travel for 30 m (98.4 ft) in a straight line at a speed of 5 to 8 km/hr (fast paced walking speed).
    c. What kind of RPS (single post, or bar over head)?
        i. What kind of loads does it need to handle?
            1. (Single or bar) top load of at least 601 lbs (2670 N)
            2. (Single or bar) side load of at least 299 lbs (1330 N)
        ii. How will operator be secured in vehicle?
            1. Shoulder harness
        iii. How is driver positioned?
            1. Recumbent
        iv. How is the vehicle able to adapt to different sized riders?
            i. Seat adjustment

4. Enable operator to travel on government maintained roads
    a. Does it need lights, if so how many?
        i. >300 lumen white headlight
        ii. >10 lumen red taillight
    b. Does it need reflective material, if so how much?
        i. No reflective material required

5. Enable operator to steer vehicle in desired direction
    a. Turning radius
        i. 24.6 ft turn radius

6. Enable operator to alter vehicle’s longitudinal acceleration
    a. How many wheels have brakes?
        i. One brake per wheel on front most wheels

7. Enable operator to detect upcoming obstacles
    a. Field of view angle?
        i. >180 degrees

References

There are no sources in the current document.