Vehicle Description Form (Form 6)

Human Powered Vehicle Challenge 2014
INDIA: Indian Institute of Technology – Delhi, India Jan 17- 19, 2014

Vehicle Description

Competition Location: IIT Delhi, India
School name: Maharishi Markandeshwar Engineering College
Vehicle name: Shelby
Vehicle number: 06

Vehicle configuration: Upright ______ Semi-recumbent √
Prone ______ Other (specify) ______
Frame material: AISI 4130 Steel
Fairing material(s): A-Glass Fibre
Number of wheels: 3
Vehicle Dimensions:
Length 76 in Width 32 in
Height 50.74 in Wheelbase 40 in

Weight Distribution: Front 54 kg Rear 36 kg
Wheel Size: Front 16 in Rear 24 in
Frontal area:

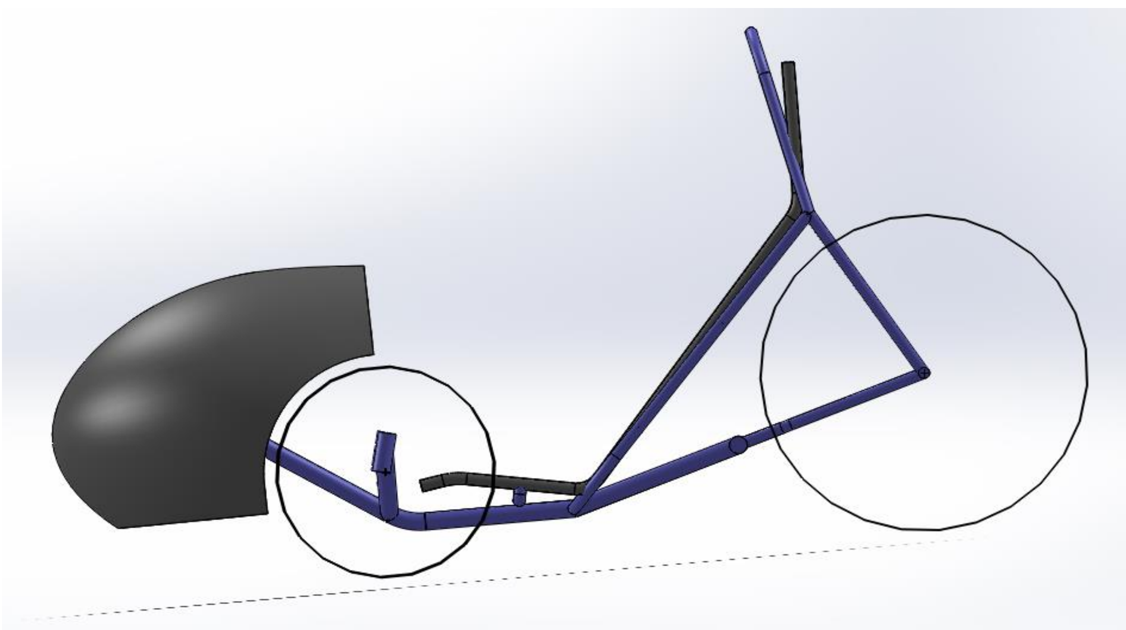
Steering: Front √ Rear ______
Braking: Front ______ Rear ______ Both √
Estimated C_d: 0.36

Vehicle history (e.g., has it competed before? where? When?) Shelby was designed, tested, and constructed for the 2014 HPVC competition by Maharishi Markandeshwar Engineering College Mullana-Ambala (Haryana)Human Powered Vehicle Team. This vehicle has not yet competed in any competition.

American Society of Mechanical Engineers
2014 Human Powered Vehicle Challenge
India

Maharishi Markandeshwar Engineering College
Human Powered Vehicle Team
Presents

Shelby

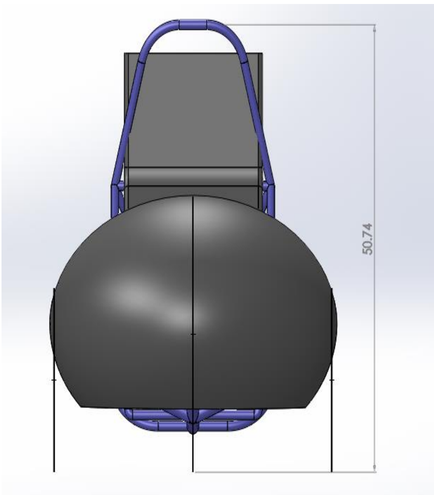


Team Leader: Deepak Raina

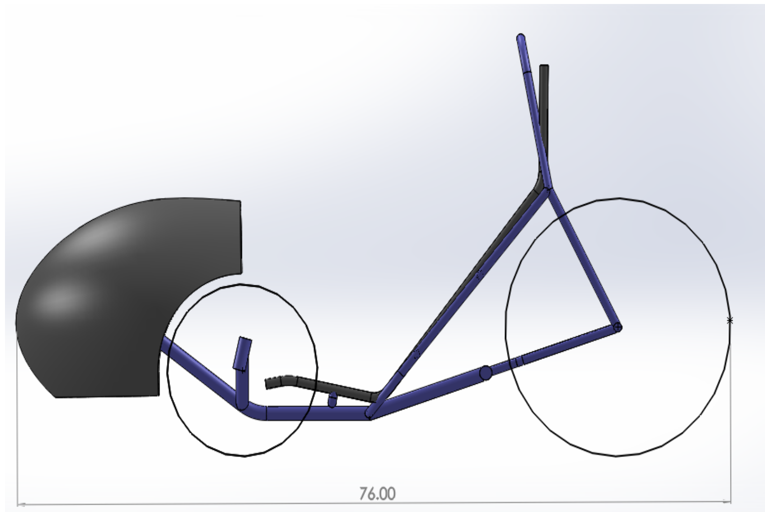
Team Members:

Aman Dagar
Aman Jain
Chirag Banga
Bhanu Goel
Krishna Mohan
Ishan Abeer
Ashish Dhull
Roushan Kumar

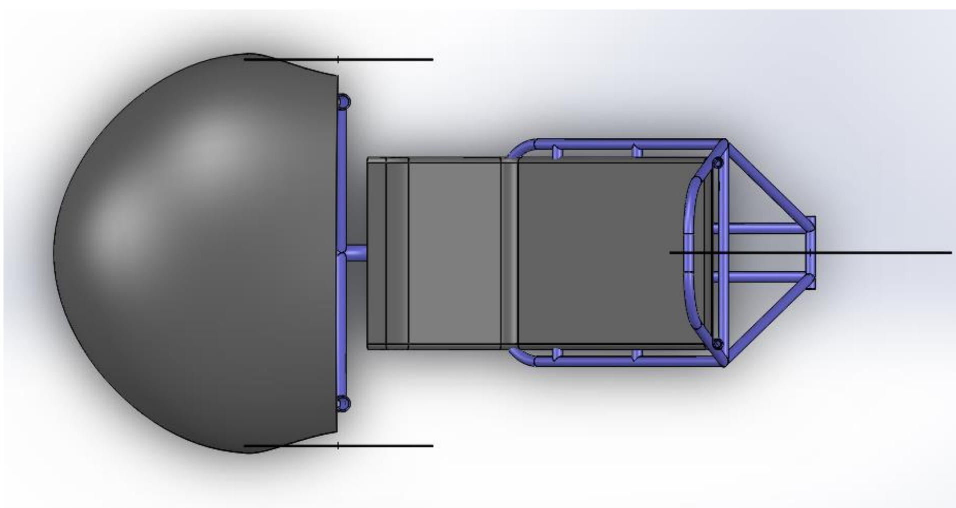
Vehicle 3D Drawing:



Front View



Left Side View



Top View

[All dimensions are in inches]

Table of Contents:

1. Abstract:

This Design report is submitted by Human Powered Vehicle team of Maharishi Markandeshwar University Mullana-Ambala (Haryana) in order to participate in ASME Human powered vehicle championship 2014 INDIA. For this competition, team will design and fabricate a partially faired, rear wheel drive, recumbent tadpole tricycle. The vehicle is all new and has not competed in any competition.

Mission Statement:

The aim of our team is to design and fabricate a Human Powered vehicle as per rules stated by ASME as well as to make it comfortable and easy to drive, allowing humans to cover longer distances with less effort.

Objectives:

- Win Endurance and drag event.
- Propel the vehicle up to a speed of 50 km/h.
- Utilize Design as aerodynamic advantage.
- Safe for riders as well as bystanders.
- Provide learning and working environment for students.
- Produce a vehicle that cost no more than INR 20,000.

In addition to meeting our objectives, the design, fabrication, and testing of our vehicle was also governed by a list of constraints. A primary concern is safety in all aspects of the project. The rules and guidelines of the ASME HPVC served as a governing document on all aspects of preparation for the Challenge.

After deciding mission, objectives and constraints, time was most important for our team in the busy schedule. Finally, the Team has designed a human powered vehicle that is low cost, environment friendly; making it beneficial for transportation and health of a rider.

The report given in the next pages explains the methodology and manufacturing processes that the team used for the production of Shelby HPV. The report is divided into description, design, analysis, testing safety and aesthetics sections that explain the well-defined approach taken towards the construction of the HPV.

2. Design:

Table 1: Summary of Design

Objective	Method	Result
To produce lightweight, reliable and stable human powered vehicle that can be used safely for everyday transportation.	Focused on keeping Center of Gravity as near as possible to the ground.	The tadpole configuration with RWD is accomplishing all the mentioned objectives.

While designing a human powered vehicle, our main area of focus is to minimize the weight of vehicle. Secondly, we focused on reliability and ease of use for driver. Third, we were concerned about the stability to the driver because stability is of utmost importance in Human powered vehicle.
To achieve the above mentioned objective, the team concentrated on following sections:

2.1 Frame Design:-

Before elaborating on the design overview, it is appropriate to offer some reasons why I prefer the two wheels front and one wheel rear design commonly referred to as the '**Tadpole**' configuration.
The most common tricycle design is the single wheel in front, two-wheel in rear configuration (1F2R) referred to as the '**Delta**' configuration. Although a well-designed Delta trike has many merits such as reduced cost, and complexity, it does not have the handling characteristics of a Tadpole design. Without going deep into physics to explain this comparison, I'll only mention that it has something to do with the Moment Of Inertia. In layman terms, a Tadpole trike front-end exhibits less acceleration (less G forces) than the rear end when turning. This allows the trike to negotiate corners at great speed and stability. On the other hand, a Delta trike exhibits the opposite condition; where the vehicle's front-end exhibits a higher degree of momentary acceleration in comparison to the rear. This condition results in over-steering and can compromise the handling performance of the vehicle. Although the overall handling characteristics are dependent on the actual design of the vehicle, the Tadpole design comes out as the winner as for handling.

Wheel Base and Track Width:-

The wheel base and track width of the trike decides the steering geometry which is one of the most important factors that is to be considered while designing. The longer the wheel base, the higher the high speed stability. But a much longer wheel base reduces the maneuverability. Therefore an optimum wheel base of 40 inches was chosen. The wider the track width, lesser is the susceptibility of vehicle to capsize during cornering. However, if too wide, the vehicle becomes impracticable on most track lanes. Therefore, an optimum track width of 32 inches has been chosen. As per the golden ratio in vehicles track width must be around 75% of wheelbase.

Wheelbase = 40

Track width = 32

Keeping the wheel base low will help me in increasing corning stability. Decreasing the wheel track or the overall width of the trike is an obvious way of reducing the frontal area of the trike. This will provide aero dynamical advantage to the HPV, that's why we have taken standard 32 inches track width.

Wheels:-

We discovered that smaller wheels in front allows for sharp turn, as the larger wheels tends to interfere with the rider. Since the rear tire is under less side loading, we were able to use 24-inch wheels that offered excellent rolling resistance and made the ride significantly smoother than a smaller diameter wheel. As we have discussed above that we are using a rear wheel drive mechanism so this is the actual reason for choosing a large diameter wheel. With the same angular velocity, larger diameter wheel will help me in increasing linear velocity. In mountain areas or in rough roads, we needed larger diameter wheels, as larger diameter wheels helps in reducing bumps and increases straight line stability. That's why, The Front Wheels are chosen smaller to provide better turning radius, to lower the center of gravity and reduce weight of the vehicle.

Front Wheel Diameter = 16

Rear Wheel Diameter = 24

2.2 Drive Train:-

One of the many questions while designing the recumbent trike was weather to make it front wheel drive or rear wheel drive. The choice was not clear cut as each of the type has its own pros and cons. So we found the best solution on the basis of the limitations, chainline, complexity etc. as follows:

Table 2: Comparison between FWD & RWD

Considerations	**Front Wheel Drive**	**Rear Wheel Drive**
Limitations	Steep Grades	-
PSI (Pedal Induced Steering)	Manageable	-
Chainline	Complex	Simple
Steering Behaviour	Oversteer	Understeer

Based on the above considered factors we chose Rear Wheel Drive for our trike. The details for these factors taken into account are as under:

Limitation:

The first and foremost significant limitation of FWD is their potential to loose traction on steep grades. We have a weight distribution of 60:40 in our trike. As the grade become steeper the weight distribution shifts to favour the rear wheel. So the more favorable drive for such terrain is RWD.

However on roads without slopes traction will become a limiting factor but that is not likely to affect the drive much.

PSI (Pedal Induced Steering):

One significant issue for FWD is the effect of pedal induced steering (PSI). Because the application of human power on pedals is not constant, the forces on the pedal create unbalanced turning forces on pivot. These unbalanced turning forces oscillate the pivot axis due to the shifting weight of the legs while pedaling, thus causing stability problems while pedaling.

Chainline:

Chainline is the alignment of the chain ring and the cog. A perfect chainline is one in which the chain ring and cog are in perfect alignment with each other and the chain takes a perfectly straight path from the chain ring to the cog.

The FWD requires a complex chain design to transfer the power to the front wheel. This is to be designed keeping in mind the steering while pedaling. The alignment of chain ring and cog is difficult to achieve for the front steering trike, whereas RWD is only constrained by the seat height. For a tadpole trike this is less of an issue than for a bike, in that you only have to route the chain under the seat.

Steering Behaviour:

How the steering behaves under power is dependent on the weight distribution and the friction coefficient of the tires. Steering behavior becomes more pronounced when the friction coefficient is low but this case is not applicable on road. Too much weight at the rear causes the rear to spin out (oversteer). Too much weight at the front causes the front wheels to understeer. Neutral handling is when the weight is evenly distributed between the front and rear, but generally slight understeer is considered safest. considering all these facts 65:35 weight distribution is best suited.

FWD trikes have a tendency to oversteer. The drivetrain pulls the front of the trike around the corner. It is only the friction of the rear wheels on the pavement that prevents the rear of the trike from spinning out that carries the risk that the rider may lose control. Too much oversteer will make a trike unstable and dangerous.

RWD trikes have a tendency to understeer. This is because the drive force is pushing the trike forward in a straight line, and the front wheels slip forward as they turn. It is only the friction of the front wheels on the pavement, not the driving force that turns the trike. The location of the optimal CG is also creating a weight distribution that favors understeer.

Moreover, another consideration is the effect of braking and accelerating turns. A braking turn tends to destabilize a single front wheel drive vehicle, whereas an accelerating turn tends to destabilize a single rear wheel drive vehicle. Because braking forces can reach greater magnitudes than acceleration forces, the rear wheel drive design has the advantage on this count.

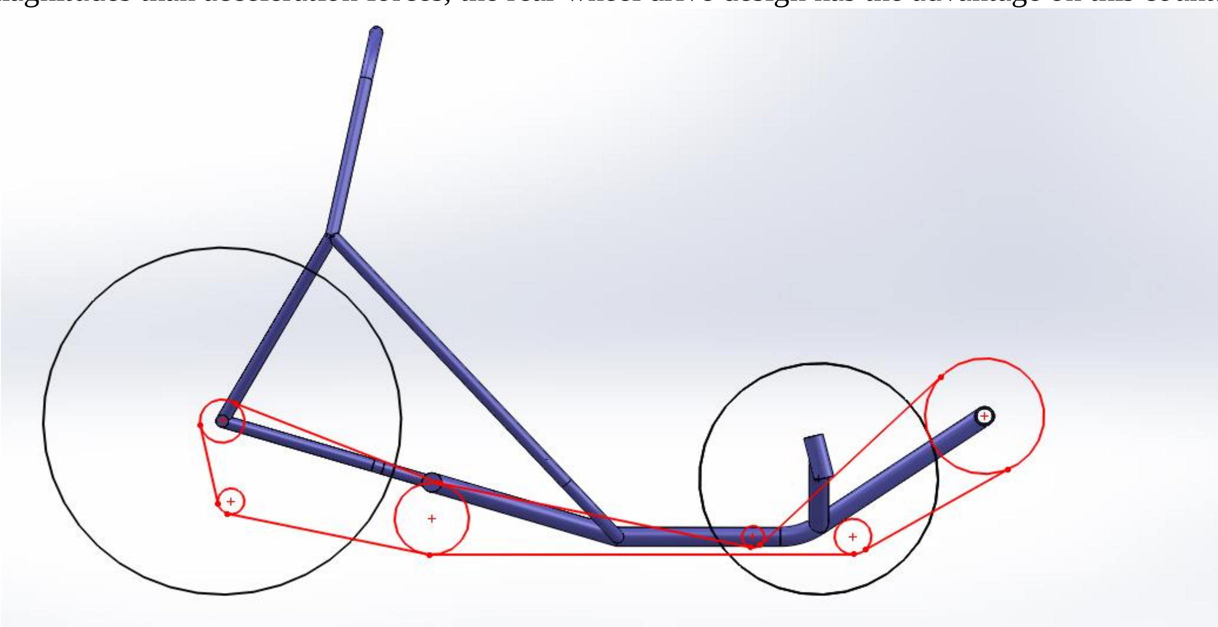


Figure 1: Drive Train Design

Gear Ratio Design

Our target top speed for the bicycle is approximately 50 Km/h. In order to pick gear ratios, we created a spreadsheet that predicts the bicycle speed given the sprocket sizes, drive wheel size, and rider cadences.

We referenced the power vs. cadence revolutions per minute curve in *Bicycling Science (by DJ Wilson)* to obtain the maximum cadence for forward pedaling. The maximum occurs at approximately 80 rpm. Then the power output is approx. 300 watt. Since the Torque produced by the human is about 35 N at the crank.

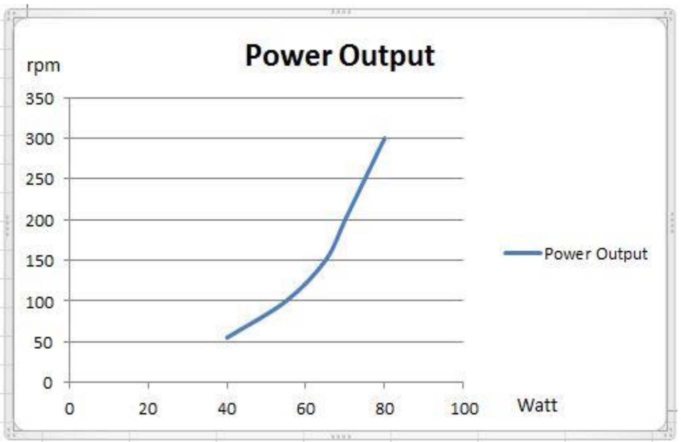


Figure2: Graph Power output Vs. Speed of Cadence

We chose to use a standard driver sprocket combined with the crank having the diameter of 8.6 inch and the no. of teeth is 55 and for driven we are using standard 8-speed cassette and a 20T to 18T interchange combination in order to minimize the height our chain path adds to the bicycle. Based on these constraints, we picked a ratio for the first reduction to achieve our design goal. We wanted to be sure that our cassette has a fine resolution of gears in the high range so that we will be able to optimize our rider cadence at speed.

DRIVETRAIN	SPECIFICATION	CASSETTE	Ratio	LOW SPEED (km/h)	MID SPEED (km/h)	HIGH SPEED (km/h)
Chain Ring	55 teeth	55 T	1.94	16.48	20.45	24.06
Interchange 1	18 teeth	26 T	2.23	19.44	23.61	27.75
Interchange 2	22 teeth	23 T	2.53	22.03	26.67	31.37
Wheel Diameter	24 inch	20 T	2.92	25.26	30.67	36.09
Crank Length	160 mm	17 T	3.43	29.72	36.09	42.46
Low Cadence	74.38 rpm	15 T	3.89	33.68	40.89	48.11
Medium Cadence	90.31 rpm	13 T	4.48	38.86	47.2	55.59
High Cadence	106.3 rpm	11 T	5.3	45.93	55.77	59.61

Table 3: Relative speeds (in mph) for each gear in the cassette.

Selection of Gear Sprocket:-

We are using the gear sprocket having the 10 cassette hub because 7 and 8-speed systems use a relatively wide, and almost identical, spacing between sprockets, and the same tried-and-true chain. 8 or more speeds require a longer rear axle. Rear-wheels get weaker as dishing becomes more extreme. Cornering clearance is reduced and tread width ("Q factor") increases. With 9-speed systems -- even more, 10-speed -- index shifting becomes finicky as sprockets crowd closer together. Each new generation of chain is narrower, weaker and harder to service. Certainly, most bicycles with 7-speed cassettes can be upgraded to 8, 9 or 10 speeds.

2.3 Fairing Design:-

Table 4: Summary of Fairing Design

Objective	Method	Result
To minimize the drag force, so that there will be less effort applied by the driver to maintain its max speed.	Use of appropriate shape to minimize its Drag.	Half –fairing is used to minimize the effect of drag forces.

As it takes power to move a vehicle through the air, this power is required to overcome the aerodynamic forces on the vehicle opposite to its velocity vector. Any reduction in this force “known as drag” represents either a direct saving in fuel or an increase in performance. Aero Wing components take the aerodynamics of recumbent riding to the next level of performance. Though body position is enough for many riders – more and more riders are taking the next step with the aid of fairings - front, rear or both. A fairing is the most influential component a rider can install on any human-powered vehicle. Yes - fairings are expensive but so are carbon fiber disc wheels that cost more but give back less in performance comparatively.

We cyclist have been cultured into the way of thinking. We believe removing weight seems to be the only way for improvement in quest of performance. That may be true at some point of view.

Note: - We are not saying weight isn’t an important factor for any human-powered vehicle – however, many times the added weight of a fairing generally returns dividends big-time to offset the added weight.

A few partial fairings for bikes are available today. They can be purchased easily, are made to mount on most recumbent and results in an astonishing performance improvement. Although it covers only the front 25% of the bike, it cuts drag by half, resulting in a speed improvement of 20%. The reason for the popularity of this fairing is its relatively low price, low weight and the fact that it is available on test-ride bikes where a prospective buyer can feel the advantage first hand.

The basic fact is that under ideal conditions an increase in streamlining of a vehicle always resulted in a faster average speed on a complete hill cycle, even though the streamlined vehicle was always heavier and would be expected to go up the hill more slowly. In fact, the fairing (even a partial fairing) increased the speed under all conditions so the weight never resulted in a decrease in speed on any part of the hill. In these cases the energy expended by the rider will also be considered, because even if a more streamlined bike takes longer to get somewhere it will still have an advantage for some riders if it takes less effort to do so.

Advantages of half fairing over full fairing:

1. Full fairing adds a considerable amount of weight to a trike whereas our chosen half fairing serves the 80% usage as full fairing with a lower weight then it.
2. Usually full fairing makes getting in and out of the seat much more difficult, while no such difficulties are faced with half fairing.
3. Full fairing generally mess up the driving as the driver has a limited visibility angle whereas half fairing gives a full viewing angle on the sides thus less interference to driving.

3. Technology Innovation:

3.1 Energy Regeneration:-

Dynamo:-

Bicycle Dynamos are alternators equipped with permanent magnets. They are typically claw-pole generators and deliver energy at rather low rpm.

Most bicycle dynamos are rated 3W (that is 500mA at 6V). For sure, the power of a dynamo light system depends somewhat on the speed. In a standard light system, the power is zero at standstill, at moderate speed it's 3W and at very high speed, it's just a little bit more than 3W. When team finalized to use the energy conservation mechanism in the vehicle, the team decided to use the dynamo mechanism to conserve the vehicle’s kinetic energy. In this, electrical energy is formed using the dynamo which is used to drive the electric motor with the help of energy storage devices. With an analysis on the energy storage devices, we decided to use the electric double layer capacitors (super capacitors) as they have maximum electrostatic charge capacity. The type of dynamo used in the vehicle is Dymotec6 as it has the best mechanical design of all tested dynamos. It doesn't suffer any noticeable deterioration after running at 50 km/h. Bearings and their lubrication suffer from the high internal temperature, resulting in rapid wear. As the dynamo runs for extended periods of time, its temperature increases. This test runs the B+M Dymotec6 at 50 km/h and 23ºC ambient temperature. After around 20 minutes, the dynamo output power has decreased from an initial 100% to 80%. For another 10 minutes, it doesn't drop any further and its characteristics are shown here:

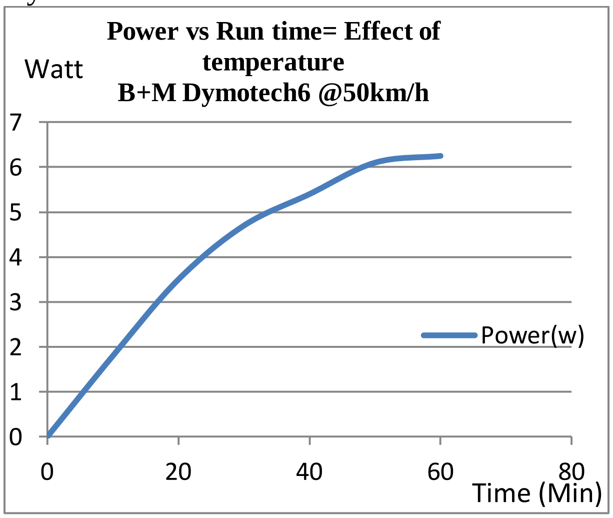


Figure 3: Graph Power vs. Runtime

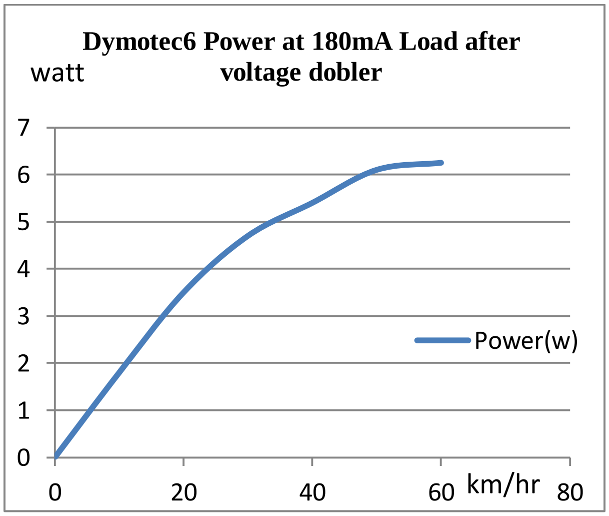


Figure 4: Graph Power vs. Speed

The most important point was that at what ambient power of the dynamo the vehicle would attain maximum speed. It is obvious that as the power would increase the vehicle speed would also increase and these characteristics shows this well enough:
The B&M dymotec6 is the dynamo which is used our vehicle as it has the best mechanics. It runs very well on the road. The Dymotec 6 is very reliable and a good choice for riders with a short commute or limited budget. It is available for either right or left side mounting. Dymotec 6 comes with a rubber roller, 185cm dual strand wire and connectors. For riding in the rain, I recommend using the wire roller which as available as a small part. It attaches to the Dymotec 6 easily in a few seconds, just remove the rubber roller and install the wire roller.
The team has used high energy density 'super capacitors' to drive a 250w mid drive motor which is rated 12v. These capacitors can store such large charge density that they can assist the driver in driving the vehicle. The ELDC capacitors are preferred over batteries as the use of super capacitors over batteries concluded:

- high energy density compared to rechargeable batteries
- reduced vehicle weight
- reduced charging time as capacitors charge very frequently in comparison with batteries
- Driver can be assisted using capacitor output in very short span of time.
- Long operation life of capacitors so they do not need replacing.
- they can produce high peak power
- they are ecofriendly as no heavy metal is used in their composition
- easily detachable

The capacitor is chosen depending on the input required to drive the mid drive motor and on the dc output of the dynamo. The calculations carried on determining the dc output of the dynamo will help in determining the rating of the super capacitors. In order to meet the rated voltage of the capacitors a number of same capacitors can be arranged either in series or in parallel and thus their collective output is used to drive the mid drive motor during the discharging period of the capacitor.

Type of Motor Used:

With the analysis on what type of motor should be used to drive the vehicle, the team came up with the conclusion of using the mid drive motors over hub motors. The differences between the two types of motor are actually quite substantial and can be placed into three categories: (1) performance; (2) safety; and (3) maintenance.

1. Performance:

When it comes to performance, mid-drive motors are capable of doing more with less. A mid-drive motor takes advantage of the existing gearing mechanism that comes on every bike to enable it to go as fast as possible and climb hills with ease. With a hub motor, on the other hand, the motor drives and the wheel does not take advantage of the bicycle gears.

2. Safety:

From the perspective of safety, it’s important to consider how the position of the motor on the vehicle affects handling and balance of the vehicle.

By their very nature, hub motors must be installed on either the front or the rear wheel. If installed on the rear wheel, the motor makes the vehicle very rear-heavy, affecting the balance. However, if the motor is installed in the front wheel, the vehicle will lack traction going up hills and the wheel might spin in wet weather. A mid-drive motor solves these problems. Its positioning in the lowest possible point of the bicycle frame maintains a low center of gravity and reduces the effect of the additional weight on the bike’s handling.

3. Maintenance

If you consider investing in a vehicle, it’s obvious to think about the maintenance of vehicle parts on the road. A hub motor usually needs to be secured in the frame to prevent breakage, and a flat tire usually means removal of the wheel plus the motor to accomplish this is difficult. Hub motors can result in more flat tires overall, due to the extra weight which can decrease the shock-absorbing capability of the tire.

A mid-drive motor, on the other hand, is pretty much independent from all of the other bicycle components. Fixing a flat tire is just as easy as on a regular bike. Removing or swapping the electrical components can usually be done in a matter of minutes with no complications.

Figure 5: Mid-Drive Motor

A 250w mid drive motor has been used in our vehicle and this power is sufficient to assist the driver in driving the vehicle. The 250 watts of power we use is multiplied in transition through the crank and, as a result, generates more torque and power than a traditional 500 watt hub motor. So it can be said that a 250w of mid drive motor is more efficient than a 500w of hub motor

Calculation:

Let the maximum velocity attained by the vehicle =45km/h

V=12.5m/s

Since the dynamo is connected at the top of the tyre so the velocity by which the wheel of dynamo rotates is =2V
$V_d = 2V$
$V_d = 25 m/s$
The radius of the dynamo wheel R= 1.5 inch=0.0381m
Calculating, Angular Velocity:
$\omega = \frac{V_d}{R}$
$\omega = \frac{25}{0.0381} = 656.17$ rad/sec
So, $N = \frac{60\times\omega}{2\pi} = \frac{60\times656.17}{2\pi}$
N= 6269.14 rpm
Output voltage for a dynamo:
E=0.1Nφ
(where E=voltage produced, N=rpm, φ=flux density of a dynamo in Weber)
So E=0.1 X 6269.14 X 0.05
E=31.34 V
Now we use this o/p voltage of the dynamo to charge the EDLC (super capacitors) which assist the mid drive motor in driving. A no. of capacitors can be used depending on their rated voltage and can be connected in series and parallel to meet the input voltage conditions required to drive the mid drive motor.

3.2 Communication:

For long distance trips, a rider might lose direction of the route. To overcome this problem, we integrated into the trike's frame a spot to place a smartphone to act as a GPS navigator which is placed directly in front of the rider so that it is easy to access and does not hinder the viewing during driving. This smartphone can also be used for communicating with the pit crew.

4. Analysis:

4.1 Rollover Protection System:

Table 5: Summary of RPS

Objective	Method	Results
To prove that the Roll Over Protection System is designed as per HPVC rules	Analyzed two static cases of loading with ANSYS workbench 14.	Total elastic deformation are calculated as: Top Load Deformation=0.02in Side Load Deformation= 0.3in The above values are much less than the allowable 1.5 inch deformation standard set by HPVC rules

4.1.1 Top Load:

The First loading Case is 600 lbs load applied to the top of the roll bar, directed downward and aft (towards the rear of the vehicle) at an angle of 12° from the vertical. The Result of the Analysis is shown in figure below:

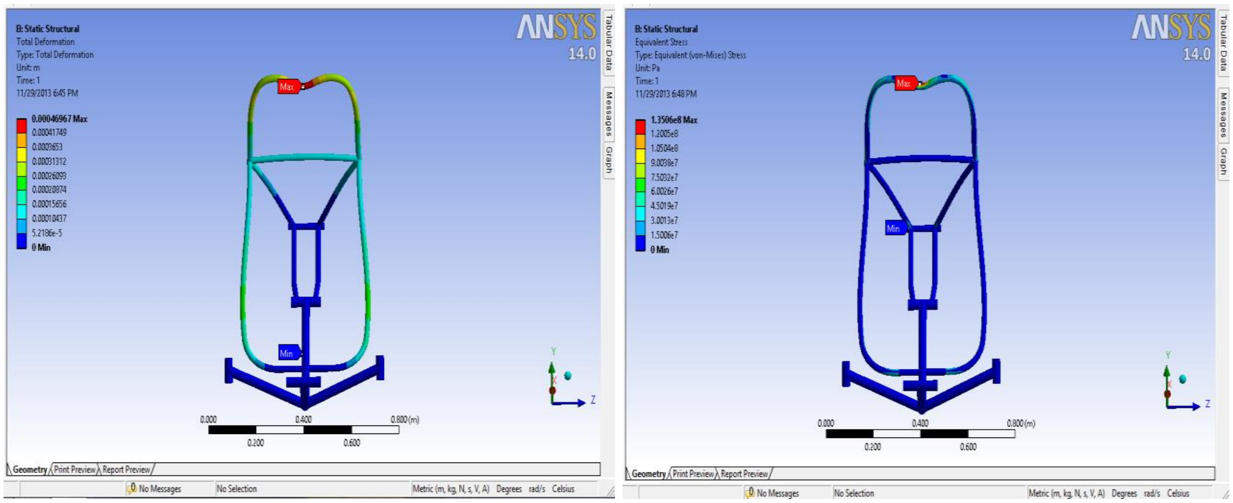


Figure 6: Deflection and Equivalent Stress due to 600 lbs. top load

Form this analysis, the team analyzed that the maximum Von-Mises Stress acting upon the RPS was 135.06 MPa. When it is compared to the yield strength of AISI 4130 Steel (460 MPa), a Safety factor of 3.4 is calculated and assures the rider that if the bike were to flip over, the rollover protection system would not fail and keep the rider safe. In addition, the total elastic deformation due to the vertical loading was calculated to be 0.02 inches, which is much less than the allowable 1.5 inch deformation standard set by HPVC rules.

4.1.2 Side Load

The Second loading case is 300 lbs load applied horizontally to the side of the roll bar at shoulder height. The Result of the analysis is shown in Figure Below:

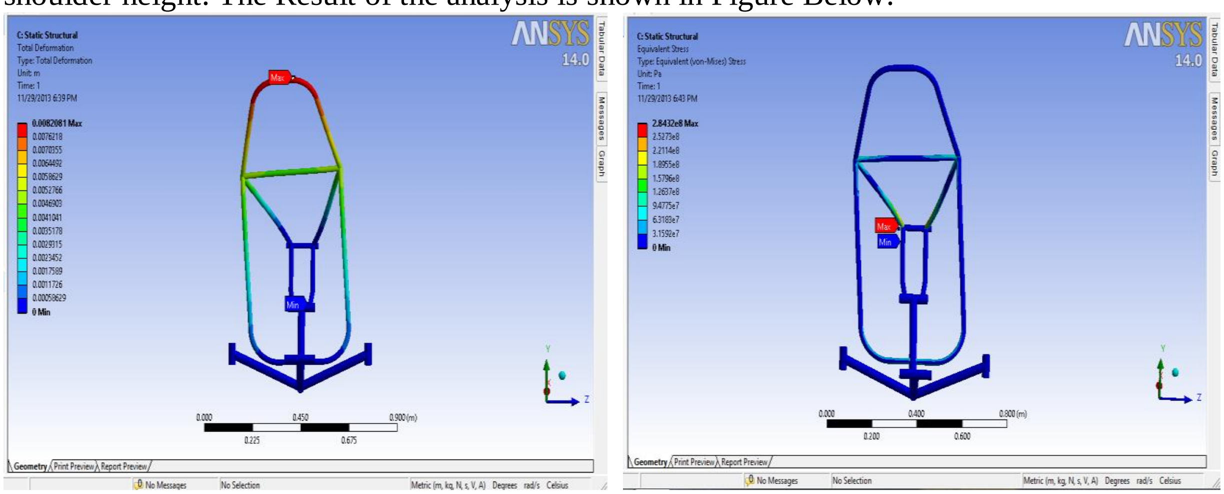


Figure 7: Deflection and Equivalent Stress due to 300 lbs. side load

From this analysis, the design team found that the maximum Normal stress acting upon the right shoulder side of the roll cage was 284.32 MPa. When compared to the yield strength of AISI 4130 Steel (460 MPa), a safety factor of 1.6 is calculated and assures the rider that a side crash would not cause the rollover protection system to fail. In addition, the total elastic deformation due to the horizontal loading was calculated to be 0.3 inches, which is much less than the allowable 1.5 inch deformation standard set by HPVC rules.

This ensures the design team that in the event of the vehicle flipping, the rollover protection system will not deform such that contact with the driver's helmet, head, or body will occur. Therefore, the design team is confident that the rollover protection system will meet the safety rating and protect the rider in the event that the vehicle flips over.

4.2 Frame:

4.2.1 Mid Frame:

In order to analyze the structural strength of the frame, the design team wanted to confirm that the frame geometry would be able to withstand the weight of the team's heaviest rider, which weighs in at close to 180 lbs. Using ANSYS Workbench 14, the design team simulated the resulting stress that the bike would experience under a 180 lbs load acting on the spine of the frame where the bottom of the seat would attach to the frame. For the highest level of accuracy, the design team used fixed constraints where both the front and rear tire would attach to the frame. The results of this analysis can be seen in the figure below:

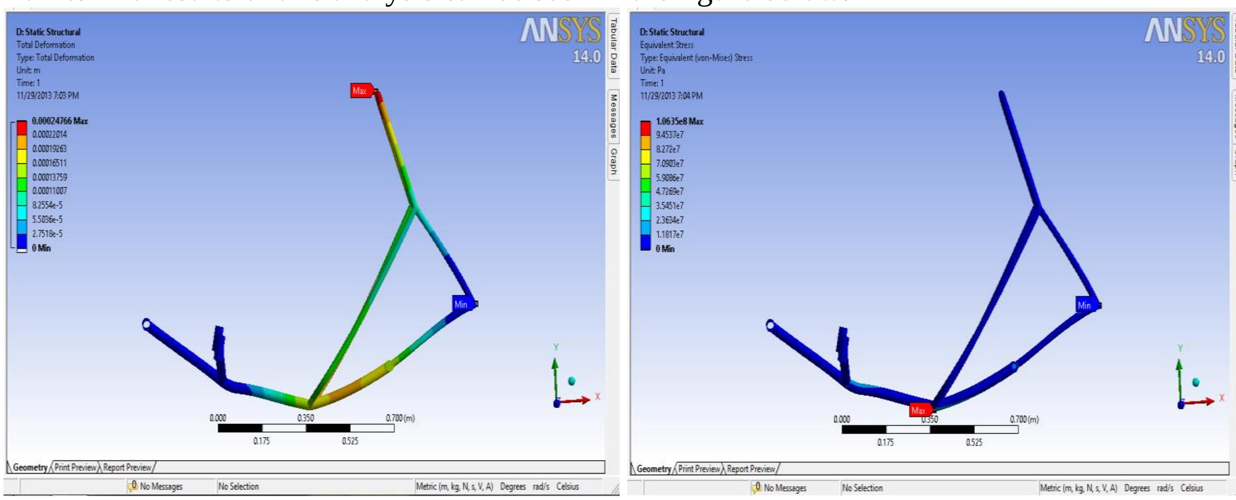


Figure 8: Deflection and Equivalent Stress due to 180 lbs. load at mid frame

From this analysis, the design team found that the maximum von-Mises equivalent stress acting upon the frame of the vehicle was 106.35 MPa . When compared to the yield strength of AISI 4130 Steel (460 MPa), a safety factor of 4.3 is calculated. With such a high safety factor, the design team is assured that the frame will be more than capable to withstand the weight of each member of the team that will ride the vehicle during the competition.

4.2.2 Frontal Impact:

The second test has a 600 N force applied from the front which will be testing vehicle in case of frontal impact during accident.

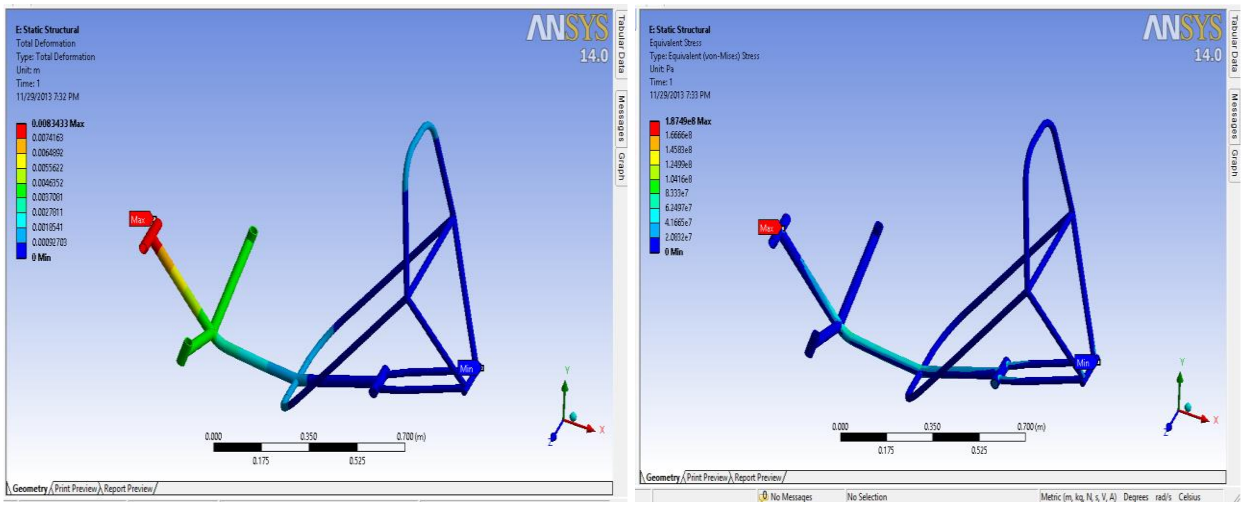


Figure 9: Deflection and Equivalent Stress due to frontal impact

From this analysis, the design team found that the maximum von-Mises equivalent stress acting upon the frame of the vehicle was 187.49 MPa. When compared to the yield strength of AISI 4130 Steel (460 MPa), a safety factor of 2.45 is calculated.

4.3 Aerodynamics:

Table 5: Summary of Aerodynamics

Objective	Method	Result
Use a fairing to get aerodynamic advantage	Measurement of Drag Forces Using SolidWorks Flow Simulation 2013	Coefficient of Drag comes out to be C_d = 0.36 at 40 km/h

4.3.1 Manual Calculations:

Nomenclature:
F_f-Drag force due to skin friction
C_f-Skin friction coefficient (It is a function of Reynolds no.)
S_w-Wetted area
Q-Dynamic pressure
F_d-Drag force due to pressure
C_d-Drag coefficient
A-Frontal area
F_h- Drag force produced by head
C_h-Coefficient of drag in circular section
F_t-Drag force produced by tyres
C_tA-Drag area for tyres
F_r-Resultant manual drag force
R_L-Reynolds number
All the calculations are done considering velocity of vehicle v=11.1 m/s
There are basically two types of major drag that we should consider while designing:-
1) Skin friction drag: - This drag is usually caused by the wetted area in design due to its roughness.

As we all know,

$R_L = \frac{\rho v L}{\mu}$

ρ =1.2 {density of air at standard temperature (25°)}

v =11.1m/s (40km/hr.)

L = assumed as flat plate of 1m

μ =dynamic viscosity

Calculation for skin friction coefficient

$R_L = \frac{1.2\times11.1\times1}{1.81\times10^{-5}}$

$R_L = 7.69\times10^5$

$C_f = 0.074[R_L]^{-1/5}$ *[Source: Book of Aerodynamics by Barnes W. McCormick]*

$C_f = 0.074\times[7.79\times10^5]^{-1/5}$

$C_f = 0.0049$

Skin friction drag:

$F_f = \frac{C_F\times\rho v^2\times S_W(wetted\ area)}{2}$ $[Q = \frac{\rho v^2}{2}]$

$F_f = \frac{0.0049\times1.2\times11.1^2\times1.7}{2}$ *[wetted area is calculated in solid works=2839in^2=1.7m^2]*

F_f=0.615 N

Drag produced by head of a driver:

As the head of the driver is in direct contact with the air, this will definitely going to produce some drag which is not calculated in the solid works. So we are going to calculate that drag manually:-

Assumption- Considering the head of a driver as a circular section

$F_h = C_h\times Q\times$cross-sectional area

$F_h = 0.6\times73.9\times0.036$

F_h=1.59 N

Drag produced by tyres:

Through our detailed research in our library we come to our conclusion that drag area of tyre is 0.013m^2 when it is moving with 11.1m/s.

By substituting values for C_tA=0.013m^2

F_t=1.04 N

And for two tyres it will be 2.08 N

F_t=2.08 N

Calculation for drag coefficient:-

Pressure Drag: As a fluid stream flows around a body, it tends to adhere to the surface for a portion of the length of the body. Then at a certain point, the thin boundary layer separates from the surface, causing a turbulent wake to be formed. The pressure in the wake is significantly lower than that at the stagnation point at the front of the body. A net force is thus created that acts in a direction opposite to that of the motion. This force is the pressure drag. The pressure drag force is calculated by:-

From the flow simulation in solid works we have calculated that the drag comes out to be 10.31 N when our tricycle is moving with 11.1m/s velocity considering no cross wind.

So the calculations of drag coefficient can be done very easily.

$F_d = C_d \times Q \times frontal\ area$ $\left[Q = \frac{\rho v^2}{2}\right]$

$8.31 = C_d \times 73.9 \times 0.31$ [frontal area was calculated in solid works that is $482.2 in^2 = 0.31 m^2$]

$C_d = 0.36$

Table 6: Results of Drag Calculation manually

Drag Forces calculated manually including all phenomenon
$F_r = F_d + F_f + F_t + F_h$ $F_r = 8.31 + 0.615 + 2.08 + 1.59$ $F_r = 12.59$ N

4.3.2 SolidWorks Flow Simulation:

In order to verify that our fairing design will reduce drag forces, SolidWorks Flow Simulation 2013 was used to perform CFD analysis and calculate the drag forces that the fairing would experience at different speeds.

By performing the flow simulation at 10, 20, 30 and 40 km/h, the full range of bicycle operation could be considered and evaluated against the option of not having a fairing or aerodynamic device. The Table below includes the results of the eight flow simulations mentioned above. At each speed, the drag force was set as a global goal for the simulation so that it would quantify the global drag force experienced on the bike

Table 7: Drag calculated by solid works assuming tyre width zero and no air striking the head of a driver

Speed (Km/h)	Without Fairing		With Fairing	
	Drag Force (N)	C_dA (m^2)	Drag Force (N)	C_dA (m^2)
10	1.06	0.24	1.008	0.23
20	4.69	0.25	4.30	0.23
30	7.98	0.19	6.90	0.16
40	16.03	0.21	8.31	0.12

It can be seen that the fairing effectively reduces the drag force experienced by approximately 50% at high speed. As the speed increases, that 50% reduction becomes more and more significant, while at low speeds it becomes unimportant.

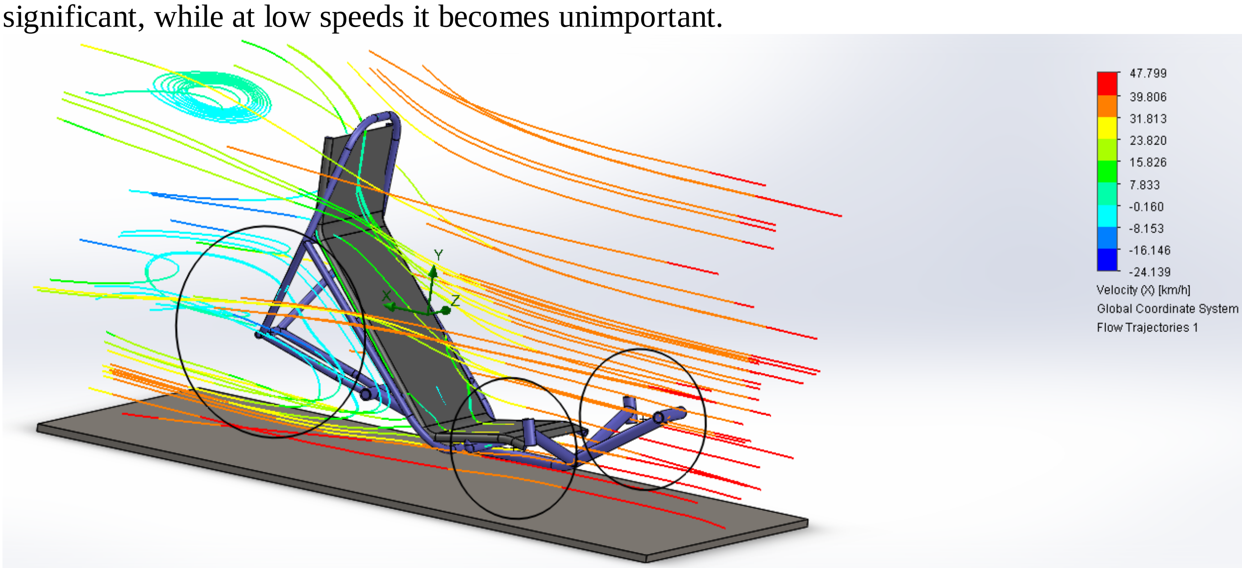


Figure 10: Flow Trajectories without fairing at 40 km/h

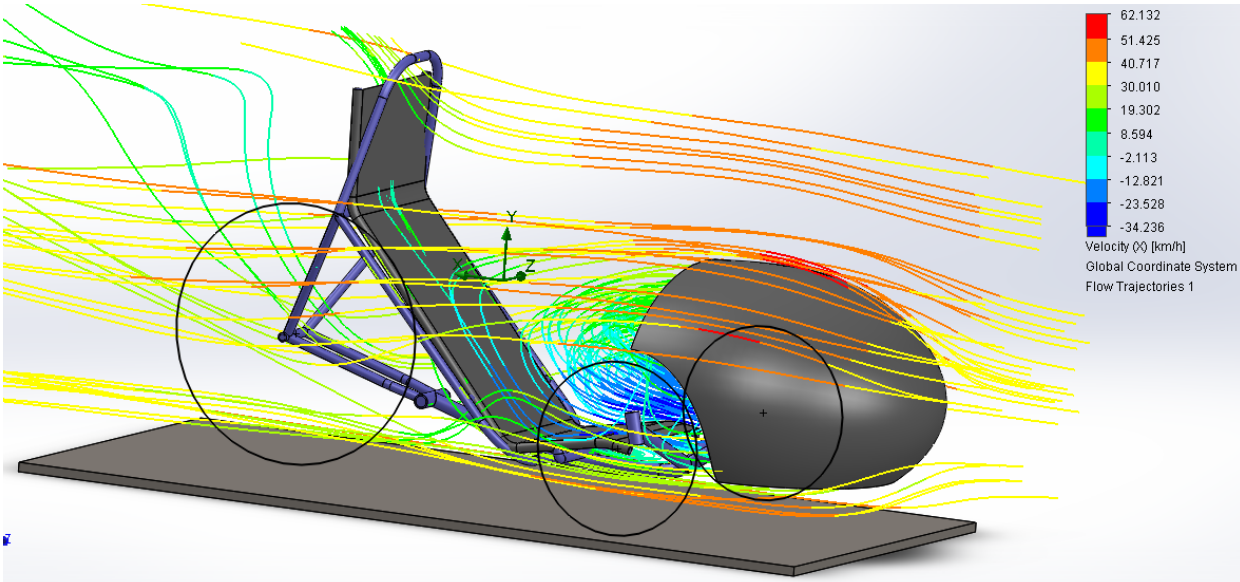


Figure 11: Flow Trajectories with fairing at 40 km/h

Conclusion:-

This study has proven that a well-designed fairing will be faster in all of the cases analyzed, under the assumptions made. It is expected that application of power during riding can be optimized to provide the greatest speed with the least effort. Power utilized in overcoming the drag at U=11.1m/s comes out to be 111 watt.

4.4 Stability:-

4.4.1 Steering:-

Table 9: Summary of Steering

Objective	Method	Result
To provide a stable steering system which allows the vehicle to turn in 25 ft. radius	Extensive research on different types of steering along with analytical calculation of turning radius	All of the objectives were reached by using direct knuckle steering.

The discussion for steering selection for vehicle was long and tiring but the team came through with the direct knuckle steering. In this type of steering the king pin is attached to the knuckle which is in turn attached to the tire. Vehicle in this case is steered by pushing the rods attached to king pin sideways. It is a 1:1 steering which means that the angle through which the rods are pushed sideways is equal to the angle of shifting of the steering tires. Unlike the rotational Movement used by other steering systems, this type is described as a left to right motion. Consequently, it is not as intuitive as other steering systems. Also as there is no connection of steering with track rod so there is no stress in tie rod and chance of its breakdown is very less. As everything in the universe the direct knuckle steering system has its pros and cons.

Pros:

- Simple and inexpensive implementation uses single tie-rod system.
- Provides comfortable support for arms.
- Gives the rider support during high G turn, precludes the use of lateral seat support.

Cons:

- Side to Side motion is counter intuitive to some.
- Increases the Frontal Area making the trike less aerodynamic.
- Requires ample room for U bar clearance that may compromise wheel track or seat width.

Steering Geometry:-

Table 10: Geometry of Steering

Kingpin	Camber	Caster	Scrub radius
22°	0°	14°	0.5'

Turning Radius:-

As we know that the turning radius of a vehicle is given by:

R= $\sqrt{a^2 + l^2(\cot\delta)^2}$

Where

R= Turning radius

a= Distance of center of gravity from rear axle = $\frac{2l}{3}$

l= Wheel base

$\cot\delta = \frac{1}{2}(\cot\delta_o + \cot\delta_i)$

Also, $\cot\delta o - \cot\delta i = \frac{w}{l}$

Where, w = Track width

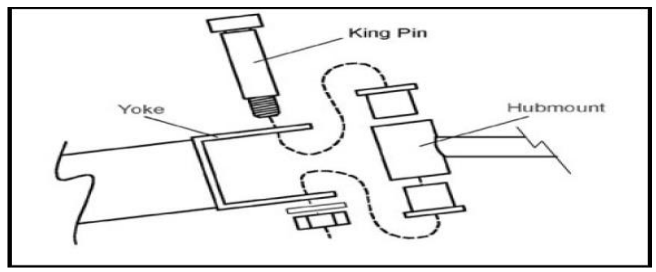


Figure 12: Attachment of steering with knuckle

Calculation for Turning Radius:-

For sake of calculation,

Assume:

$\delta_i = 21°$

w = 2.6 ft

l = 3.33 ft

We know that,

$\frac{w}{l} = \cot\delta_o - \cot\delta_i$

(Putting the values of the given in the equation)

$\frac{2.65}{3.33} = \cot\delta_o - \cot 21°$

$0.79 + \cot 21 = \cot\delta_o$

$\delta_o = \tan^{-1}\frac{1}{3.395}$

$\delta_o = 16.41°$

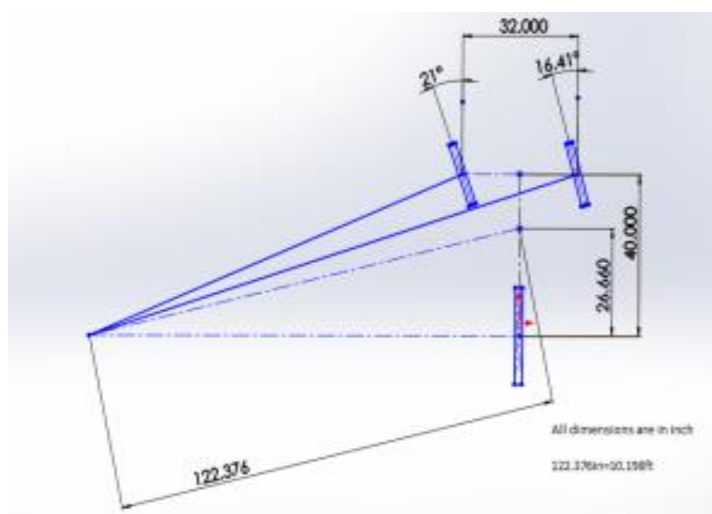


Figure 13: Steering Geometry

Now we know that,

$R = l\sqrt{[\frac{4}{9} + (cot\delta)^2]}$

Putting the values
l = 3.33 ft.
$\cot\delta = 2.99$
We get
$R = 3.33\sqrt{0.44 + 8.9401} = 3.33\times3.062$
R= 10.198 feet.
Now we see that if the inner wheel of the vehicle turns by an angle of 21° ; the outer wheel of the vehicle is turned by an angle of 16.41° . Under these conditions the turning radius of our vehicle turns out to be 10.198 feet. Similarly turning radius was calculated using different values of δ_i and a graph was plotted the following table shows the value of radius and corresponding values of δ_o ,δ_i & δ

Table 11: Turning Radius Calculation

Turning Radius (ft.)	δ_o	δ_i	δ
22	8.17°	9.20°	8.68°
15	11.67°	13.83°	12.75°
10 (minimum)	16.41°	21°	18.705°

4.4.2 Braking:

Table 12: Summary of Braking

Objective	Method	Result
Vehicle must demonstrate that it can come to a stop from a speed of 24 km/h in a distance of 6 meters or less.	Extensive research on different types of braking along with analytical calculation of Braking Distance.	Vehicle can come to a stop from a speed of 24 km/h in a distance of 5.67 meters.

In any bicycle, not only does the driver need to accelerate the vehicle, but he must also apply force to stop it. There are many different ways to slow a rolling wheel, and there are many different types of brakes that can be bought off the shelf, normally used in bicycles. In our model we are going with the Hydraulic Disc Brakes.
Hydraulic Disc Brakes are one of the types of Disc Brakes**,** which feature a closed system of hoses and reservoirs containing special hydraulic fluid to operate the breaks. When the lever is activated, a plunger pushes the fluid through the hoses and into the caliper where the pads are pushed onto the rotor, stopping the bike.
The Advantage of hydraulic systems is being sealed so the water, dirt or debris can't compromise the brakes, making them very maintenance free once they have been properly installed. Also, hydraulic brakes have a silky smooth feel at the lever and incredible gripping power at the business end.
For drawbacks, hydraulic brakes must withstand extremely high pressure, so expert set up and frequent inspections are essential. The smallest air bubble or leak in the hydraulic brakes can cause a loss of power or complete failure. The process of removing the bubble is known as Bleeding.
We will use a dual lever hydraulic disc brake for front tyres which will be controlled by the right handle of the tadpole trike. The left handle will control the braking of rear wheels.

Calculation of Braking Distance:
Following calculation is done to check whether vehicle moving with velocity of 24Km/hr. or 6.67 m/s comes to halt within 6 meters when brakes are applied.
Using Work Energy principle Equation to determine stopping distances, which is given by

$$D = \frac{v^2}{2\mu g}$$

where V= 24 km/hr. (6.67 m/s)
μ= 0.4 and g=9.8 m/s^2
Then D= 5.67 m
The stopping distance is calculated at various velocities by using above mentioned equation. The result is shown in the Table below:-

Table 13: Braking Distance at various velocities at various velocities

Velocity (km/hr.)	Distance (m)
8	0.62
16	2.52
24	5.67
32	10.09
40	15.75

4.5 Cost Analysis:-

Table 14: Summary of Cost

Objective	Method	Results
To determine the cost of producing Shelby, as presented for the competition and estimated cost for a production run based on 10 vehicles per month.	Market Research	Cost of presented vehicle is INR 20,875.00

The detailed breakdown of production run cost estimate including the capital investment, tooling, parts and materials, labour, and overhead cost is given in the table below:

Table 15: Brief Cost Report

Category	Presented Vehicle (INR)	Production Run (Per Vehicle) (INR)	Production Run (360 Vehicles) (INR)
Capital Investment	0.00	19500.00	7,200,000.00
Parts and Materials	20,875.00	20,875.00	7,515,000.00
Labour	0.00	4500.00	1,620,000.00
Overhead	0.00	2600.00	9,36,000.00
Total	20,875.00	47,975.00	17,271,000.00

The estimate for Shelby HPV includes the costs of one vehicle. The Whole amount of money is funded by team members and no money is received from sources. Additional funds like travel, however, are not included as they do not affect the vehicle. A detailed analysis of the Cost Analysis is included as Appendix 1.

5. Testing:

5.1 Ergonomics:

The aim of this profession is to optimize human well-being and overall system performance. This discipline is our main area of consideration while designing a Human-Powered Vehicle. Therefore, great care is made to provide more ergonomic frame and handlebar design.

5.1.1 Rider Position:

First of all, we have to decide the Position of Rider. To determine the most ergonomic rider position, a variety of rider positions were considered. They are as follows:

1. **Semi-Recumbent:**

   Advantages:

- Most comfortable, as it doesn't cause any stress on hands, wrists and spine.
- Most stable, as it has low centre of gravity.
- Better aerodynamic design, as smallest frontal area provides fastest designs.
- Increases power, as gluteal muscles of our butt gets a better workout.
- Easier for rider to learn
- Visibility is increased, by keeping the oncoming road in vision.

  Disadvantages:

- This position does not allow for peak power production.
- The rider will not get sustained aerobic performances.

2. **Upright:**

   Advantages:

- Riders can apply their maximum power.
- Power transmission is very simple.
- Simple Design and easy to manufacture.

  Disadvantages:

- Uncomfortable, as it causes stress on hands, wrists and spine.
- Aerodynamic Disadvantage, due to the increased frontal area
- Less stable, as it has high centre of gravity
- Decreases Power, as gluteal muscles of our butt doesn't get a same workout.

On further study, we have found that the fastest human powered vehicle, Cheetah (110.6 km/h), has used Recumbent Rider position with slight variations. Even Vector (101 km/h) and Gold Rush (105.9 km/h), has used this configuration. As per the requirements of the events in HPVC India, the vehicle must have minimum air drag, so we choose Semi-Recumbent Rider position over Upright Position. In the next step, we tried to overcome the limitations of semi-recumbent configuration.

5.1.2 Recumbent Configuration:

Recumbent bikes show variation in configuration depending upon the designs. The recumbent cycling position has become common for high-performance human-powered vehicles; questions still remain as to the influence of familiarity on recumbent cycling, the optimal riding position, and how recumbent cycling positions compare to the standard cycling position (SCP). Two of our team members had done a test comparing 5 recumbent positions as well as the SCP. For the recumbent positions, hip orientation was maintained at 10° below the bottom bracket while the backrest was altered to investigate body configuration angle (BCA: the angle between the bottom bracket, hip, and a marker at mid-torso) changes from 100° to 140° in 10 increments. Therefore both groups were combined for further analysis. Whole-group peak power (14.6 W/kg body mass) and average power (9.9 and 9.8 W/kg body mass, respectively) were greatest in the 120° and 140° BCA positions, with power dropping off as BCA decreased through 100° (peak = 12.4 W/kg body mass; avg. = 9.0 W/kg body mass). Power output in the SCP (peak = 14.6 W/kg body mass; avg. = 9.7 W/kg body mass) was similar to that produced in the 120° and 140° recumbent BCA. These findings suggest us that BCA is the major determinant of power output. So we have taken 120° BCA into consideration to fulfill the criteria for visibility of 15°

5.1.3 Human Model:

Further, to get accurate configuration, a human model was required. The dimension of driver was to be similar to an average driver so that a correct paddling motion and design is obtained.
For this, we designed a human model to achieve all these requirements. First, the general dimensions of the most average of our team members were tabbed and a model was constructed based on them.

On the basis of all the above mentioned tests, the following configuration is considered:

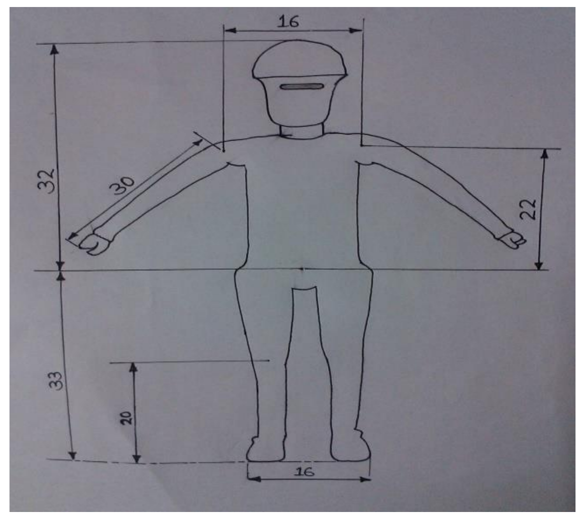


Figure 14: Human Model

Table 16: Rider Position Geometry

Torso Angle	50°
Hip orientation Angle	10°
Visibility Angle	15°
Torso Length	22 in
Length between bracket & hip point	25 in
Bottom Bracket Height	12.66 in
Hip Height	8 in
Crank Length	160 mm
Q-Factor	140 mm

5.2 Power required to drive at different velocity:

<table>
<tr><th>Theoretically observed</th><th>Practically observed</th></tr>
<tr><td>There is a well-known equation that gives the power required to push a bike and rider through the air and to overcome the friction of the drive train:
$\mathbf{P=g.m.V_g(K_1+S)+K_2.V_a^2V_g}$
[Source: Wikipedia; Human Power Requirement]

P is power in watts,
g is Earth's gravity,
$\mathbf{V_g}$ is ground speed (m/s),
m is bike/rider mass in kg,
s is the grade,
$\mathbf{V_a}$ is the speed of wind (m/s),
$\mathbf{K_1}$ is a lumped constant for all frictional losses (tires, bearings, chain), and is generally reported with a value of 0.0053,
$\mathbf{K_2}$ is a lumped constant for aerodynamic drag and is generally reported with a value of 0.185 kg/m.
If there is no wind, $\mathbf{V_g=V_a}$ then
$\mathbf{P=g.m.V_g(K_1+S)+K_2V_g^3}$
$P=110\times11.1(0.0053)+0.185(11.1)^3$
P=259.4 watts
Table 17: Power required at different velocity:
<table>
<tr><th>Velocity (m/s)</th><th>Power (watts)</th></tr>
<tr><td>6.94</td><td>65.8</td></tr>
<tr><td>9.00</td><td>143.0</td></tr>
<tr><td>11.1</td><td>259.4</td></tr>
</table>
</td><td>Device which is usually used to measure the power is cycle power meter.so we used this device to measure power output of one of our rider
• 175 W for a 90 kg bike + rider to go 9 m/s (20 mph or 32 km/h) on the flat (76% of effort to overcome aerodynamic drag), or 2.6 m/s (5.8 mph or 9.4 km/h) on a 7% grade (2.1% of effort to overcome aerodynamic drag).
• 290 W for a 90 kg bike + rider at 11 m/s (25 mph or 40 km/h) on the flat (83% of effort to overcome aerodynamic drag) or 4.3 m/s (9.5 mph or 15 km/h) on a 7% grade (4.2% of effort to overcome aerodynamic drag).</td></tr>
</table>

Note that the power required overcoming friction and gravity is proportional only to rider weight and ground speed. The aerodynamic drag is roughly proportional to the square of the relative velocity of the air and the bike. Being that the total power requirement to propel the bike forward is a sum of these two variables multiplied by speed, the degree of proportionality between power requirement and speed varies according to their relative magnitude, in an interval between the linear and cube; at higher speeds (riding fast on a flat road) power required will be close to being a cube function of speed; at lower speeds (climbing a steep hill) it will be close to being a linear function of speed

6. **Safety:**

1. **Vehicle layout: -** The decision for a recombinant three wheeled tadpole layout was based on the superior stability at slow and high speeds it offered. The layout also allows for the center of gravity to lie very low which helps prevent turnovers at high speed turns. A 4in ground

clearance means that we will still be able to climb standard speed bumps without issue by making the vehicle difficult to turn over.

2. **Materials: -** The Team is using AISI 4130 Steel in the construction of Tadpole. This Material is resistant to scaling and oxidation and has a clean, smooth finish both on the outside and inside of the tubing.
3. **Visibility: -** The seat of our tadpole Trike is inclined at 40 degrees to the horizontal axis of tadpole for a better and comfortable visibility of the driver. Our energy storage system which is powered by the moving wheels includes both break lights and a head light both of which will stay lit. All of these elements combined with traditional bike reflectors have been added for the safety of the rider and of bystanders.
4. **Seatbelt: -** Seat belt is basically used in vehicle for rider to exit the vehicle quickly. If the rider is incapacitated, emergency personnel can also easily remove the harness. In the case of a crash, protecting the rider inside. It is secured by two latches: one on each side of the rider. These latches are accessible from the seat of the trike as well, to access the rider if they become incapacitated.
5. **Rollover Protection System: -** It protects the rider from injury during crashes. It also protects riders by keeping shoulders and elbows from contacting the ground and getting road-rash. Although this system does slow entrance, the protection provided is very beneficial to riders. This should be fully covered by a curved rod from one end to on other end of seat.
6. **Helmet: -** A helmet protects the head from injuries. Helmets are one of the many safety features employed by the team. The typical bicycle helmet is designed to crush to reduce the rate at which the skull and brain are accelerated. Recent studies indicate that “helmets provide a 63 – 88% reduction in the risk of head, brain and severe brain injury for all ages of riders.
7. **Braking system: -** In the event that a crash does occur, our vehicle is also constructed to protect the rider from injury. In dangerous situation we upgraded from a single calliper brake on the front wheel to dual disc brakes.
8. **Manufacturing Safety: -** Manufacturing safety was observed by the entire team throughout the development Stages. Manufacturing did not begin until a complete design and manufacturing process had been developed. These plans included things like tool and cutting speed selection, budgeting time to avoid human fatigue, and using the proper skin protection when assembling the tadpole. All manufacturing was done in a machine workshop that was complete with all precautionary Safety measures such as a fume hood, fire extinguishers, first aid kits and fire blanket.

Moreover the Driver of the Vehicle has been given proper training regarding safety measures during the event.

7. Aesthetics:

The most successful bicycle design is one which is functional, comfortable, and is of aesthetics intersect. The aesthetics of a tricycle are crucial in the enjoyment of the overall riding experience. We consider "aesthetically pleasing vehicles" which is extremely subjective, probably even more than comfort and functionality. Aesthetics is how appealing or attractive people find the vehicle to be. It is about people enjoying looking at it. We feel compelled to touch it, to ride it. It is about an emotional response for the beauty of a tricycle. The fairing over the bike provides a sporty look to the vehicle which people do enjoy looking at. The seat of the vehicle is designed in recumbent position which is comfortable and attractive. People love vehicles that are functional, comfortable and aesthetic. The graceful sweep of a loop frame is not only visually pleasing, but allows easy step-through. Frame is designed using certain long tubes rather than short tubes providing the vehicle a clean look reducing the number of welds and unavoidable weld sections are finished and painted properly. All the vehicle controls are designed near the handlebar which increases the ease of driving and keep the control and cables centralized. Special attention is also paid in painting the roll cage to make it look attractive. Internal components are treated with special care and are kept clean to appear clean to attractive.

8. References:-

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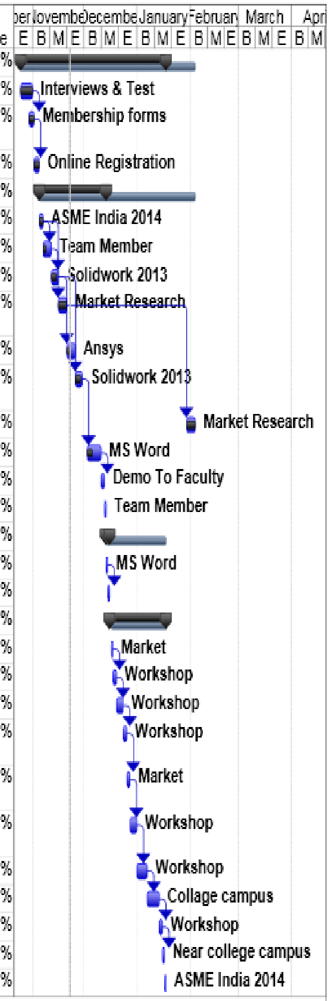
9. Appendices:
Appendix 1: Cost Report

S.No.	Componant	Specification	Quantity	Cost of Presented Vehicle (INR)	Production Run (Per Vehicle) INR	Production Run (Per 360 Vehicle) INR
1	Capital Investment					
	Machines and Tools	.....	....	Rs. 0.00	Rs. 14,500.00	Rs. 5,220,000.00
	Transportations	.....	......	Rs. 0.00	Rs. 5,500.00	Rs. 1,980,000.00
2	Parts And Materials					
	Transmission System					
	Chain	Stander size (As Required)	2	Rs. 300.00	Rs. 300.00	Rs. 108,000.00
	Sprocket (Driver , Driven)	Designed	3	Rs. 200.00	Rs. 200.00	Rs. 72,000.00
	Shaft(transmition)	Small Size	1	Rs. 100.00	Rs. 100.00	Rs. 36,000.00
	Bearing	Market	3	Rs. 300.00	Rs. 300.00	Rs. 108,000.00
	Tyres and tube (Front & Rear)	Tube and	3	Rs. 975.00	Rs. 975.00	Rs. 351,000.00
	Rims with Hub (Front & Rear)	...	3	Rs. 750.00	Rs. 750.00	Rs. 270,000.00
	Derailleur ,Gear Wire	Standered Size	1	Rs. 1,200.00	Rs. 1,200.00	Rs. 432,000.00
	Cassette Sprocket	18 speed Sprocket	1	Rs. 800.00	Rs. 800.00	Rs. 288,000.00
	Crank and Pedal	crank 160 mm	2	Rs. 300.00	Rs. 300.00	Rs. 108,000.00
	Steering system					
	Tie -Rod	Design	2	Rs. 200.00	Rs. 200.00	Rs. 72,000.00
	Ball Joint	Market	2	Rs. 150.00	Rs. 150.00	Rs. 54,000.00
	Clamper	Market	1	Rs. 100.00	Rs. 100.00	Rs. 36,000.00
	Bearing	Market	1	Rs. 100.00	Rs. 100.00	Rs. 36,000.00
	Braking system					
	Disc hub	Design	2	Rs. 150.00	Rs. 150.00	Rs. 54,000.00
	Disc Rotor	Bicycle standard size	2	Rs. 250.00	Rs. 250.00	Rs. 90,000.00
	Brake caliper	Bicycle standard size	2	Rs. 600.00	Rs. 600.00	Rs. 216,000.00
	Single cylinder	Bicycle standard size	1	Rs. 500.00	Rs. 500.00	Rs. 180,000.00
	Hand lever	Market	1	Rs. 100.00	Rs. 100.00	Rs. 36,000.00
	Brake Fluid	DOT 5	.....	.....	.....	
	Frame					
	Rollcage	AISI 4130	1	Rs. 3,000.00	Rs. 3,000.00	Rs. 1,080,000.00
	Seat	Recombent position	1	Rs. 800.00	Rs. 800.00	Rs. 288,000.00
	Mounts	As required	.....	Rs. 1,000.00	Rs. 1,000.00	Rs. 360,000.00
	Seat Belt	Market	1	Rs. 400.00	Rs. 400.00	Rs. 144,000.00
	Fairing	fiber Glass Sheet	......	Rs. 3,000.00	Rs. 3,000.00	Rs. 1,080,000.00
	Others					
	Fasteners	As required	.....	Rs. 600.00	Rs. 600.00	Rs. 216,000.00
	Electrical System	Back light , Horn	1	Rs. 250.00	Rs. 250.00	Rs. 90,000.00
	Innovation					
	Sprocket (Driver)	Standard Size	1	Rs. 100.00	Rs. 100.00	Rs. 36,000.00
	Dynamo	Market (As required)	2	Rs. 1,500.00	Rs. 1,500.00	Rs. 540,000.00
	Motor	Mid drive Motor	1	Rs. 3,000.00	Rs. 3,000.00	Rs. 1,080,000.00
	Chain	Market (As required)	1	Rs. 150.00	Rs. 150.00	Rs. 54,000.00
3	Labour					
	Labour Cost (Man & Hours)	....	....	Rs. 0.00	Rs. 4,500.00	Rs. 1,620,000.00
4	Overhead Cost					
	Insurance	....	....	Rs. 0.00	Rs. 1,100.00	Rs. 396,000.00
	Facilities	....	...	Rs. 0.00	Rs. 1,500.00	Rs. 540,000.00
	Total			Rs. 20,875.00	Rs. 47,975.00	Rs. 17,271,000.00

Figure 15: Cost Report

Appendix 2: Project Plan

ID		Task Name	Duration	Start	Finish	Predecess	Resource Names	% Work Complete
1		Human Powered Vechile 2014	65 days	Fri 10/25/13	Fri 1/17/14		ASME India 2014	44%
2	✓	Team member selection	5 days	Fri 10/25/13	Thu 10/31/13		Interviews & Test	100%
3	✓	MMEC Human Powered colligate club	3 days	Wed 10/30/13	Fri 11/1/13	2	Membership forms	100%
4	✓	Team Member Registration	1 day?	Sat 11/2/13	Mon 11/4/13	3	Online Registration	100%
5		Preliminary Design	29 days	Tue 11/5/13	Fri 12/13/13			36%
6	✓	Benchmarking	2 days	Tue 11/5/13	Wed 11/6/13		ASME India 2014	100%
7		Free Hand Sketches	3 days	Thu 11/7/13	Mon 11/11/13	6	Team Member	67%
8		Design Of Roll cage	4 days	Tue 11/12/13	Fri 11/15/13	7	Solidwork 2013	75%
9	✓	Selection Of Other Components	3 days	Sat 11/16/13	Wed 11/20/13	6	Market Research	100%
10		Analysis Of Roll cage	3 days	Thu 11/21/13	Mon 11/25/13	8	Ansys	67%
11		Design and Analysis of Casing	4 days	Tue 11/26/13	Fri 11/29/13	8	Solidwork 2013	75%
12	✓	Approximate Cost Report	3 days	Thu 1/30/14	Mon 2/3/14	9	Market Research	100%
13		Report Prepration	6 days	Tue 12/3/13	Tue 12/10/13	11	MS Word	50%
14		Final Presentation	2 days	Wed 12/11/13	Thu 12/12/13	13	Demo To Faculty	0%
15		Report Submition	1 day?	Fri 12/13/13	Fri 12/13/13		Team Member	0%
16		Update in Report	2 days	Sat 12/14/13	Sun 12/15/13			0%
17		Changing in the Report	1 day	Sat 12/14/13	Sat 12/14/13		MS Word	0%
18		Final Report	1 day?	Sun 12/15/13	Sun 12/15/13	17		0%
19		Fabrication	27 days	Mon 12/16/13	Fri 1/17/14			0%
20		Raw Material	1 day	Tue 12/17/13	Tue 12/17/13		Market	0%
21		Cutting Of Material	2 days	Wed 12/18/13	Thu 12/19/13	20	Workshop	0%
22		Welding	3 days	Fri 12/20/13	Mon 12/23/13	21	Workshop	0%
23		Finishing of Roll cage	2 days	Tue 12/24/13	Wed 12/25/13	22	Workshop	0%
24		Purchasing of other components	2 days	Thu 12/26/13	Fri 12/27/13	23	Market	0%
25		Assembly of different components	3 days	Sat 12/28/13	Tue 12/31/13	24	Workshop	0%
26		Final assembly	4 days	Wed 1/1/14	Mon 1/6/14	25	Workshop	0%
27		Testing of vehicle	5 days	Tue 1/7/14	Mon 1/13/14	26	Collage campus	0%
28		Problem solving	2 days	Tue 1/14/14	Wed 1/15/14	27	Workshop	0%
29		Final testing	1 day	Thu 1/16/14	Thu 1/16/14	28	Near college campus	0%
30		Final Event	1 day?	Fri 1/17/14	Fri 1/17/14		ASME India 2014	0%



Project: Project planning
Date: Sat 11/23/13

Task		External Milestone		Manual Summary Rollup	
Split		Inactive Task		Manual Summary	
Milestone		Inactive Milestone		Start-only	
Summary		Inactive Summary		Finish-only	
Project Summary		Manual Task		Progress	
External Tasks		Duration-only		Deadline	

Page 1

Figure 16: Project timeline (Gantt chart)