ASME SETTING THE STANDARD	**Critical Design Review Report Cover Page &Vehicle Description Form** **Human Powered Vehicle Challenge Competition Location: <u>Digital</u>** **Competition Date:**
This required document for <u>all</u> teams is to be incorporated into your Critical Design Review Report. <u>Please Observe Your Due Dates</u>; see the ASME HPVC website and rules for due dates.	

<u>Vehicle Description:</u>

University name: <u>National Institute of Technology Patna</u>
Vehicle name: <u>QUARENTINO 2.0</u>
Vehicle number: <u>26</u> Vehicle configuration:

Upright: Semi-recumbent: X Prone: Other (specify):

Frame material: <u>Aluminum 6063 T6</u>
Fairing material(s): <u>Fiber Glass</u> Number of wheels: <u>2</u> Vehicle Dimensions(m):

Length: <u>2.27 m</u>
Width:<u>0.63m</u>
Height:<u>1.27m</u>
Wheelbase:<u>1.32m</u>

Weight Distribution(kg)
Front:<u>7.1kg</u>
Rear:<u>12kg</u>

TotalWeight:<u>19.1kg</u>

Wheel Size (m)
Front:<u>0.508m</u>
Rear:<u>0.6604m</u>

Frontal area: 0.56m^2
Steering (Front or Rear): <u>Front</u>
Braking (Front, Rear, or Both): <u>Both</u>
Estimated Coefficient of Drag: <u>0.109</u>

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

Quarentino 2.0 has been freshly designed in the current academic year and has never competed in any previous competition.

Human Powered Vehicle Challenge Asia Pacific'21

National Institute of Technology Patna

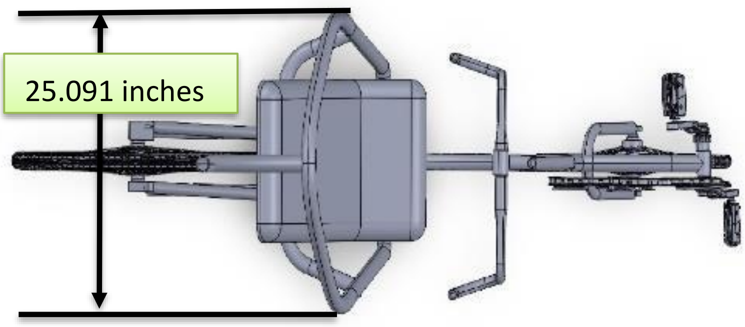
Team XLeration

Presents

QUARENTINO 2.0

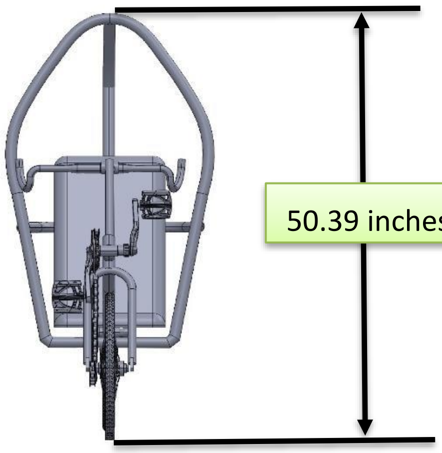
Vehicle Number: 26

Four View Drawing



Top View

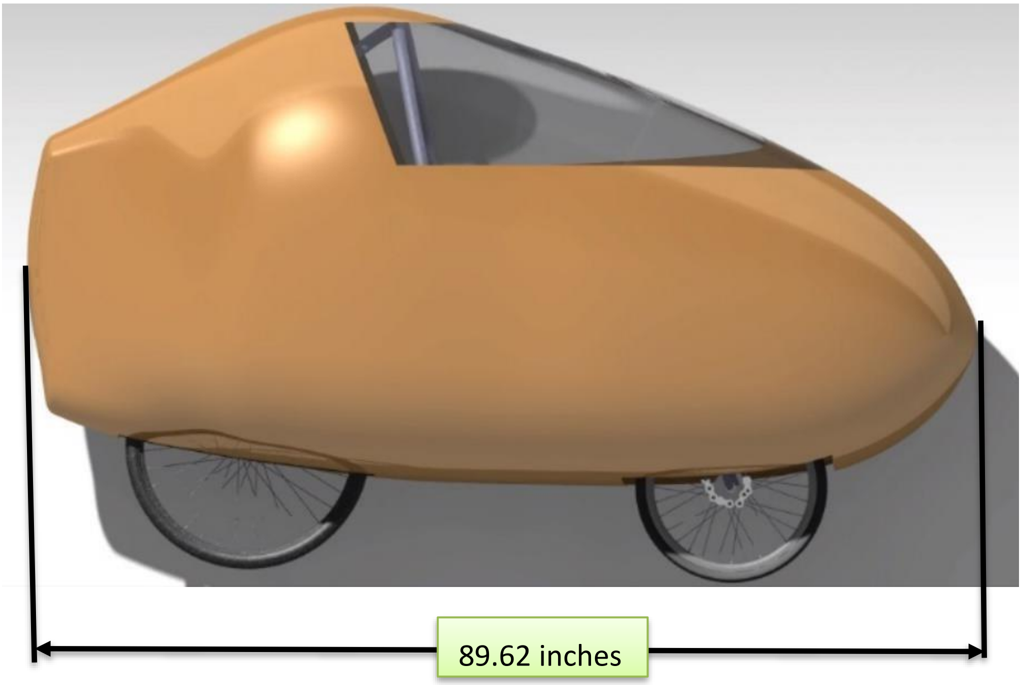
Isometric View



Front View

Side view

With Fairing



Abstract

In today's world when the advancement in technology is at its peak and the impact of these technologies over the human health has become a point of concern. Also, the demand for efficient mode of transport is quite high.

Human powered vehicles, such as the bicycle, are low cost, environmentally friendly, and benefit the health of the rider; making them attractive choices for transportation as well as leisure. The main reason that people do not prefer current version of HPVs like bicycle over motorized vehicle is their low speed, less comfort and cannot be used for long distance travel.

In order to meet this challenge team XLeration designed human powered vehicle recumbent bicycle with great ergonomics and aerodynamic performance making it efficient, safe, practical and affordable.

The whole design was focused on fabricating a lightweight, efficient and fast human powered vehicle without compromising the safety, comfort, aesthetics of the rider.

And at the same time can withstand all the conditions that are going to face by the vehicle in future. It is a single chain front wheel drive, semi-recumbent vehicle with small wheel base, lower ground clearance and shock absorbent suspension.
Material selected for main frame, RPS is a circular pipe of Aluminium6063-T6 having external diameter of 30mm and 3mm thickness. Circular cross-sectional pipe is selected over square pipe of previous year's model for main frame to reduce the number of excess welds, in order to give main frame, the desired shape.

We have improved the fairing after the previous year competition. Fiber Glass has been used as fairing material.

The CAD model of our vehicle was developed on CATIA V5 along with fairing. All the initial test of CAD model were performed on ANSYS is to determine the factors like stress concentration, optimum handle position, seat position, wheel base, air drag etc.

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VI. Design

VI.A. Objective

Team Xleration mainly focused on improving last year's error while designing the vehicle. Our main objective was to design an HPV that could be utilized by the masses. A largely acceptable design that would also change the way people look at Human Powered Vehicles. For this reason, the following design objectives were outlined, produce a human powered vehicle within compliance with the 2022 ASME HPVC rules, produce a vehicle weight of 40 kg or less, low Centre of gravity, driver safety and comfort, and high-speed stability.

VI.B. Background Research

In the American Society of Mechanical Engineers (ASME) Human Powered Vehicle Challenge (HPVC) the practicality aspect of the vehicle has become a more important focus. This year, with "Quarentino 2.0", our goal is to raise our overall level of performance in the ASME HPVC INDIA. As many options are available in market for a human powered vehicle, in order to compete with them our vehicle should be fast, comfortable and safe. So, we decided to design a front wheel driven recumbent bicycle having a good speed and being aerodynamically stable. We preferred the front wheel drive vehicle design due to its benefit in increasing the speed. We have also improved our fairing design to enhance speed, reducing the drag Also, we have included some new innovations in the vehicle.

VI.C. Prior Work

We have taken inspiration from our previous models (Quarentino, Vortex, Impulse). In order to improve on the shortcomings in the previous models, we have designed our vehicle Quarentino 2.0. It is a freshly designed vehicle and not the modification of the previous ones and all its parts, CAD models are developed on CATIA V5 and testing is done on ANSYS 20.1. No result is copied from previous year data. Freshly obtained results were used.

VI.D. Organizational Timeline

"An early start gives the better results." Keeping this in mind we started as early as possible to give our best. The following table shows the schedule of our work.

VI.E. Design Specification

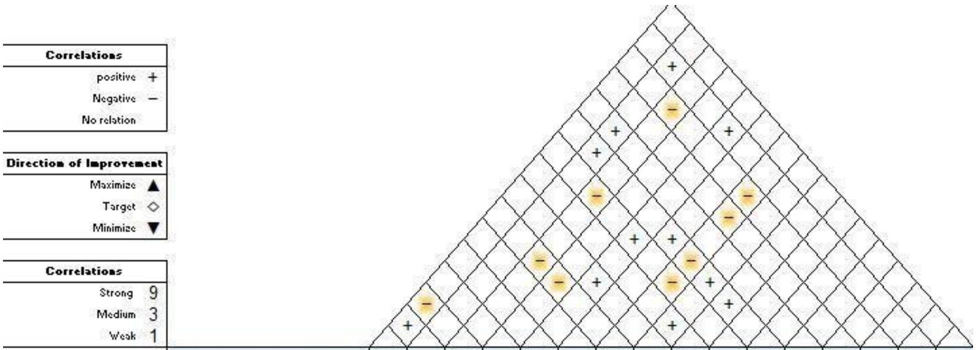
Some goals set by our team for the HPV design (taking consideration of HPVC 2022 rules) were as follows:

Parameters	Goals
Vehicle Safety	• It should have a maximum turning radius of 6m. • It should stop within a distance of 6m after applying brakes at a speed of 25kmph. • It should be able to drive in a straight line at low speed of 6kmph. • It should have a Factor of safety between 1.2 and 1.5 • It should have a minimum Field of View of 200 degrees.
Vehicle comfort	• It should have a RULA score less than 3. • Seat must be able to accommodate both the tallest and shortest rider.
Roll Over Protection	• The RPS must be able to support a top load of 2670N at an angle of 12degrees from vertical with maximum deformation not more than 5.1cm. • The RPS must be able to support a side load of 1330N with maximum deformation not more than 3.8cm. • It should prevent the body from ground contact in case of an accident.
Braking System	• It should have a front wheel braking system. • It must be able to start and stop without outside assistance.
Drive Train	• It should have a front drive train which is hassle-free while turning the vehicle.
Cost	• It should cost less than INR 35,000.

Weight	• To reach better speed and stability, it should have maximum weight of 20 kg.
Coefficient of Drag	• It should be aerodynamically advantageous with cod less than 0.2. • The fairing should be streamlined.
Wheelbase	• The wheel base must be about 1300mm to achieve the minimum turning radius.
Caster Angle	• To provide a better control and directional stability of the steering, it should have a caster angle between 12 to 14 degrees.

Table 1: Design Specification

VI.E.1. House of Quality:



Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Direction of Improvement	▼	▲	▼	▼	▲	▲	▼	▲	▲	▼	▲	▲	▼	▼	▲	▲
Demanded Qualities / Quality Characteristics	Dimensions	Balancing	Weight	Cost	Frame strength	RPS strength	Storage space	Drivetrain efficiency	Field of vision	Turning radius	Fairing strength	Rider comfort	Drag force	Energy consumption	Rolling resistance	Skidding resistance
Safety		3	3	1	9	9		3	9	3	1	3	1	3	3	3
Speed	3	3	3	3	3	1		9		3	9	1	3	1	3	3
Manueverability					3						3	3	1			
Manufacturability				3	3		1	1		1						
Repairability	3		3	1	1			3			3	3			1	1
Aesthetics				1			1		1		1	3		9		
Structure Complexity				1			1	1				1				
Repairability				1												
Visibility	1								9			9				
Durability			1	3		3	1	3	1	1			1		1	1
Vehicle Stability	1	9			3	3	1	1		3	1	9	1		3	1
Importance Rating	8	15	10	14	22	16	5	21	20	11	18	30	7	13	11	9

House of Quality

VI.F. Concept Development and Selection Method

Based on the design criteria and QFD the Pugh's concept selection technique was adopted. We have used a decision matrix with weighted average to select the various parameters for the design. The priority value has been assigned to each criterion and thus each entry gets a score. The entry with highest score got selected. We have used the following scoring criteria.

Score	Quality
5	Excellent
4	Good
3	Average
2	Poor
1	Very Poor

VI.F.1. Different vehicle configuration

When it comes to a human powered vehicle, we have many options available like upright, prone, recumbent, delta and tadpole. On the basis of decision matrix, we have selected recumbent as our model. The decision matrix is shown below:

Criteria	Weightage	Recumbent	Upright	Delta	Prone	Tadpole
Comfort	3	5	3	4	3	4
Safety	3	3	4	5	3	5
Design Simplicity	2	4	5	3	2	3
Manufacturability	2	5	5	3	3	3
Aerodynamics	1	4	2	4	5	4
Prior Experience	2	5	3	2	3	3
Cost	2	4	5	3	3	3
Total		61	59	53	45	55

Table 2: Vehicle Type Decision Matrix

VI.F.2. Drive Train

We have designed a front wheel drive HPV which is a single chained multi-geared drive train supported by pulleys to avoid chain derailment. For changing the gear front and rear derailleur and gear shifter are installed in the design. The major contradicting components for the drive train were:

Criteria	Weightage	Rear wheel drive	Front wheel drive
Complexity	3	5	3
Manufacturing ability	2	5	4

Efficiency	2	3	4
Cost	1	3	4
Speed	3	3	5
Total		43	44

Table 3: Rear wheel drive vs Front wheel drive

Criteria	Weightage	Single chain	Multiple chain
Durability	2	4	3
Stability	3	4	5
Manufacturability	3	5	3
Total		35	30

Table 4: Single chain vs Multi chain drive

Criteria	Weightage	Pulley	Idler
Weight	2	5	4
Chain Derailment	3	5	2
Cost	1	3	5
Durability	3	3	5
Total		37	34

Table 5: Pulley Vs Idler

VI.F.3. Material Selection

It was a hard nut to crack for our team to choose a material which should be cost effective, light in weight, strong and can be machined easily. The following table shows various materials considered and why the specific material (Al6063-T6) was chosen over other materials. It describes various important points which affect the working efficiency, speed and cost productiveness of the vehicle.

Criteria	Weightage	Al 6063-T6	Al 6061-T6	SS 304
Weight	3	5	4	3
Cost	2	2	3	4
Machinability	3	5	5	4

Weldability	2	3	3	4
Corrosion Resistance	1	5	4	3
Strength to weight ratio	3	5	4	3
Total		60	55	49

Table 6: Material comparison

VI.F.4 Cross-section of the main Frame

When it comes to machinability and weldability, cross-section also plays a vital role. In order to avoid multiple weld joints, we have selected a circular cross-section pipe for main frame.

Criteria	Weightage	Square pipe	Round pipe
Resistance to Torsional stress	3	3	5
Weight (per unit length)	2	3	4
Machinability	2	5	3
Total		25	29

Table 7: Comparison between cross-section of frame

VI.F.5. Fairing Configuration

Keeping out vehicle configuration type in mind and based on Pugh's selection criteria, we have decided to make a full fairing for our vehicle.

Criteria	Weightage	Full fairing	Partial fairing	No fairing
Aerodynamics	3	5	3	1
Weight	3	3	4	5
Cost	2	3	4	5
Total		30	29	28

Table 8: Fairing configuration

VI.G. Vehicle Description

VI.G.1 Main Frame

Our team has selected a recumbent position for our vehicle Quarentino 2.0 with front wheel drive. Aluminum alloy 6063 T6 with circular cross-section (external diameter 30mm, thickness 3mm) was selected for main frame. Like last year, we decided to choose a circular cross-section for main frame to avoid multiple welds in the main frame. After numerous iterations, this design was selected for main frame. The design was analyzed on ANSYS 20 and the main frame was developed on CATIA V5. The bottom bracket was

Figure 1: Main Frame

attached to the front end and the rear fork was pivoted at the rear end of the frame. This year we gave a supporting pipe at the rear fork which was attach to the RPS supporting pipe. The top most pedal point was kept lower than heart for cardiovascular benefits.

VI.G.2. Rollover Protection

The material for RPS was chosen same as the main frame i.e., Aluminum 6063 T6 as it was best according to our vehicle specifications; having external diameter 30mm and thickness of 3mm. The 4 point safety harnesses was attached to the RPS
It was attached to the main frame design by
(1) Top support and
(2) support (one from each side) to the second member of main frame. RPS was designed to fit our tallest as well as widest completely inside in case of fall or overturn.

Figure 2: RPS

VI.G.3. Drive Train

After analysis and numerous research our team have found that front wheel drive and also on the basis of our previous experience, chain derailment was a big problem due to long chain and pulley support. So, we decided to make a front wheel drive supported with pulleys instead of idlers. This design allows for a shorter, simpler chain line. We've used 48-38-28 teeth crank set, 2 pulley, a six speed freewheel with front derailleur, rear derailleur and gear shifter.

Figure 3: Drive Train

VI.G.4. Suspension


Figure 4: Suspension

Considering the condition of Indian roads, especially the village areas, and the requirements for offroading, suspension was a necessary component for our vehicle. Therefore, we decided to install a shock absorbent front fork and a suspension spring in the rear fork pivoted to the main frame, for providing the rider a comfortable ride while off-roading or riding on uneven roads. The problem with suspension is that it can cost us some efficiency. Instead of using all of your energy to push the bike forward, some of our energy compresses the suspension. So, we decided to install single suspension in the rear fork and suspension in the front fork to reduce the effective cost and the above problem.

VI.G.5. Wheels

We have used 20inch diameter front wheel and 26-inch diameter rear wheel. Front wheel is kept smaller than the rear wheel because it gives an extra edge to speed and also provide required area of vision for the rider. Wheel base is also kept small in order to take sharper turns.

VI.G.6. Steering

The system of steering is very similar to an upright bicycle with some simple modifications in order to make the rider’s position comfortable and safe. The steering has front and rear braking system levers and the gear shifter was fitted on the handle of the steering on both (one for front derailleur and other for rear derailleur).

VI.G.7. Aerodynamic Fairing

After some iterations and prior experience of our team had decided to design a full fairing for our vehicle Quarentino2.0. The fairing is designed in order to minimize the drag. The full fairing has also some extra advantage like, it protects the rider from sunlight, rain and wind. Our fairing is inspired from kingfisher bird also from fishes. We did some iterations, reduced the drag and also tried to get more streamlined structure. Fiber glass was selected for of our vehicle’s fairing as it is strong and cheaper than other potential options.

Figure 5: Fairing

VII. Innovation

VII.A. Purpose

Team Xleration always focused on the effectiveness of the vehicle in day-to-day life and also keep it cost effective so under the under the rules of HPVC 2022, we came up with an idea to innovate our HPV as an electric and human powered hybrid vehicle. Electric vehicles are considered as a potentially effective technological innovation to reduce carbon impacts. Our aim is to build sustainable, cheap and smart electric-pedal assisted HPV.

We often see that people do not prefer electric vehicles in India due to charging issues. Batteries are stuck to the vehicle and cannot be charged we cannot get a e vehicle charging spot everywhere but if we can remove the battery then we can charge it easily anywhere.

VII.B. Concept evaluation:

As per Indian rules and regulations, safety requirements for electric bicycles are; •
One or more electric motor with power less then 250W

- Maximum speed should be 25km per hour.
- Vehicles which comply the above requirements are not categorized as motor vehicles. Hence the transport rules are not eligible for them (insurance, taxes etc.). So, we decided to be under the above given rules.

Components required:

1. 36V 250W hub motor
2. Microcontroller
3. Brakes
4. PAS
5. Battery and charger
6. LCD Display

Component selection:

Motor

Hub motor was chosen for the human powered vehicle over mid drive motors because it was not suitable for a front wheel drive recumbent. These motors have few moving parts, leading to less wear, both for the motor and the chain and any other components of the transmission. They are mounted in sealed cases, not required any kind of maintenance.

Battery

Li-ion battery was chosen over led acid battery because for the same battery capacity, li-ion batteries take less space also its efficiency and lifespan are better.
Motor is designed to operate at 36V,
To reach the intended voltage we have to connect
10 3.7V cells in series (10s)
*10*3.7V=37V*
*3 batteries like this connected in parallel (10s3p): 3*2.9Ah = 8.7Ah.*
*37*8.7Ah=321.9Wh*
321.9Wh battery pack generated.
250W motor will burn 250Wh in 1 hour, a 321Wh battery pack will last for 1.288 hours.
Let's consider a medium velocity of 20km/h, the range is approximate 25.76km.
We admit that this range is not ideal in actual scenario the range will be lesser.
We preferred removable battery pack because in most of the places do not have charging infra outside. So, it will be more suitable and convenient for our HPV that it contains removable battery.

Pedal assist system:

It is a mode that provides power only when the rider is pedaling, the motor will stop pedaling or if he actuates the brake. PAS is much healthier for batteries; power demand is much more constant and gives more range. The PAS system we used in our HPV is based on bottom bracket torque sensor. We chose this over cadence sensor because cadence sensor is based on the spinning of the pedal but torque sensor is based on the torque being applied by the rider on the pedal to provide the rider more effortless riding.

Figure 6(a): Bottom Bracket Torque Sensor

Figure 6(b): Battery

Figure 6(c): Hub Motor

VII.C. Learnings:

While doing numerous researches for development our electric hybrid HPV we came to know about issues related to electric vehicles and also some of their solutions. There are some limitations in our vehicle like low charging capacity, high charging time and high cost also.

VII.D. Execution:

We are using the hub motor in the rear wheels to avoid interfere with the pedals, transmissions or derailleur and also to avoid the risk of having the wheel spinning and loosing traction.
There is a good space behind the RPS so we decided to develop a box and weld it behind the RPS for microcontroller and removable battery.
Handle is equipped with display to indicate about the speed and battery status.

Figure 6(d): Battery and microcontroller casing

VIII. Analysis

VIII.A. Rollover/ Side Protection System Analysis

Main aim of this analysis was to design a RPS which can protect the rider from any head or body injuries if he/she is met with an undesirable accident. The material selected for the frame and roll over was Al6063-T6 in the form of circular pipes. The model made in the CATIA v5r20 software was first de-featured and all the parts which were not part of the analysis were suppressed to simplify it. Four-point harness was safely fixed on the roll hoop keeping rider's safety as first priority and then the model was analyzed on the ANSYS R20.1 software using the static structural workbench by generating mesh on the body.

	Objective	Methodology	Result
RPS Top Load Analysis	To analyze the behavior of the vehicle under the top load specified by the ASME.	The FEA analysis was done on the HPV model in ANSYS software.	The deformation observed was 10.48 mm.
RPS Side Load Analysis	To analyze the behavior of the vehicle under the side load specified by the ASME.	The FEA analysis was done on the HPV model in ANSYS software.	The deformation observed was 8.26 mm.

Table 9: RPS Analysis Summary

VIII.A.1. Top Load Analysis

The RPS was given a fixed support at the bottom and a load of 2670 N was applied on the top point of it at an angle of 12° from the vertical as per the ASME rule. The direction of the load applied was in the downwards direction towards the rear axle of the vehicle.

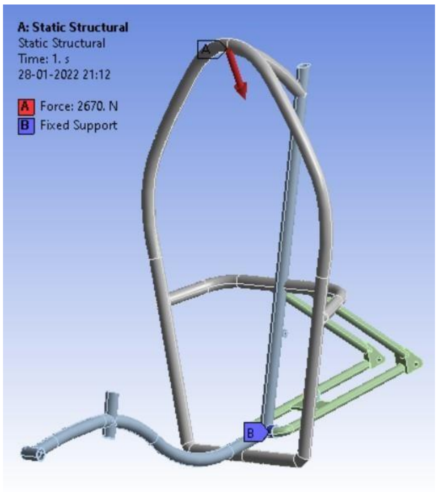


Figure 7(a): Total Load Condition Modeled

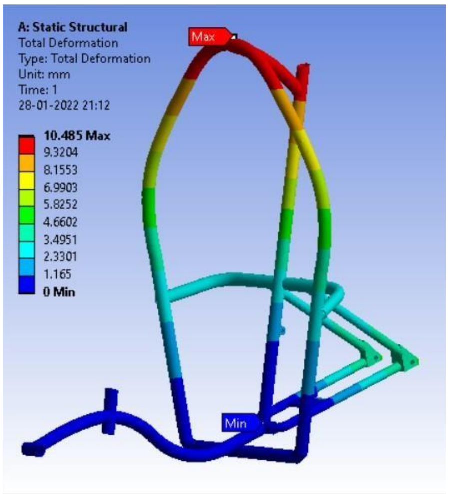


Figure 7(b): Total Deformation due to top load

Conclusion	• The maximum deformation is permissible as it is less than 5.1cm as per the ASME rulebook. • The rider would be in no contact with the ground in case of any accident.

Table 10: Conclusion of Top Load Analysis of RPS

VIII.A.2. Side Load Analysis

The RPS was given a fixed support at the bottom and a load of 1330N was applied on the right side of it, at shoulder height, (considering the average shoulder height as 70cm) as per the ASME rule.

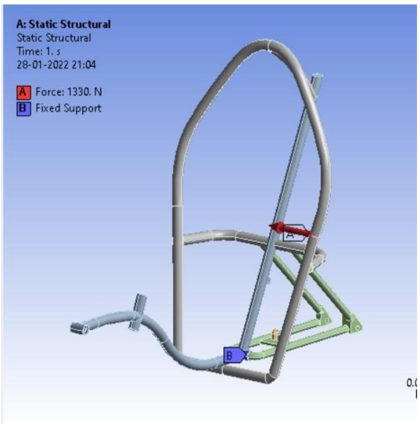


Figure 8(a): Side Load Condition Modeled

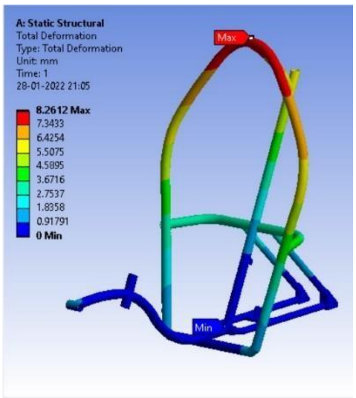


Figure 8(b): Elastic Deformation due to side load

Conclusion	• The maximum deformation is permissible as it is less than 3.1cm as per the ASME rulebook. • The rider would be protected from the sides in case of any accident.

Table 11: Conclusion of Side Load Analysis of RPS

VIII.B. Structural Analysis

Objective	To understand the behavior of frame and optimize the HPV according to associated force by estimating the maximum equivalent (von-mises) stress on the vehicle and its position while pedaling.
Methodology	HPV model is designed in CATIA V5 R20 and finite elemental analysis is performed in ANSYS 20.1.

Table 12: Structural Analysis- Objective and Methodology

VIII.B.1. Static Frame Analysis

The most important factor for the frame is its strength. So, it should be strong enough to sustain the rider's weight. The load will be increased because of some impact and bump force.

Calculation of pedaling moment

Considering weight of rider 85 kg (with safety equipment) and crank length off 17 cm, the maximum power generated by our rider is 745 watts at 100 rpm. Hence torque calculated at this power and rpm comes out to be 71142N-mm. (moment on bb shell)

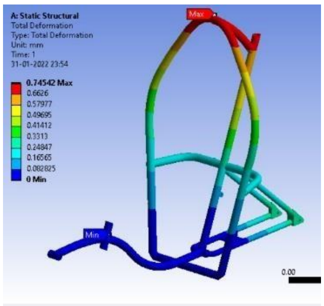


Figure 9(b): Total deformation

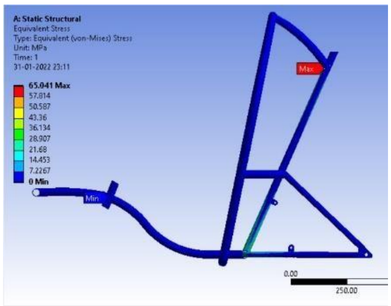


Figure 9(c): Maximum Equivalent Stress

Result	• The maximum equivalent (von-mises) stress comes out to be 65.041 MPa. • The total deformation came out to be 0.7mm.
Conclusion	• As the maximum equivalent stress is less than the tensile yield strength of Aluminum (280MPa), it is capable of withstanding sufficient load acting on the HPV.

Table 13: Static Frame Analysis- Result and Conclusion **VIII.C.**

Aerodynamic Analyses

Items	Description
Objectives	To analyze the aerodynamic behavior of vehicle in motion and minimize the aerodynamic drag force.
Methodology	Model of fairing was designed in SOLIDWORKS and aerodynamic behavior of vehicle was determined by using Computational Fluid Dynamics of vehicle in ANSYS 20.1.
Result	Maximum drag force was found to be 5.06N and drag coefficient was 0.109(in Ansys and 0.201 theoretically) at speed 20m/s for front wind inlet and drag force of 27.08 N.
Assumption	Air with constant density, no slip condition, Isothermal Condition (T=298k).

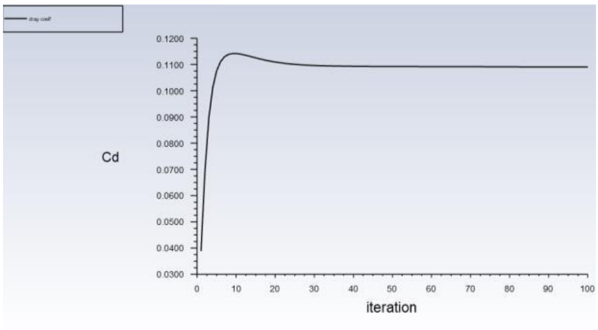
Table 14: Aerodynamic Analysis Summary

Methods

After various researches, rough model was made. By taking appropriate dimensions, the fairing was designed in CATIA and then for the purpose of analysis it is carried out in ANSYS18.1. The vehicle was enclosed by suitable enclosure and further it was appropriately meshed. The analysis was carried out using CFD by taking pressure 1atm and velocity of fluid at inlet as 10m/s for front wind whereas 7m/s for cross wind.

VIII.C.1. Front Wind Analysis

The model was imported to ANSYS18.1 and analysis was done by taking Density of Air = **1.225 kg/m^3** and Viscosity = **1.7894* 10^{-5}kg/m-s**. For CFD, high emphasis was given on the mesh, and its smoothness quality was given high and also, element order was given linear to refine the small details of the fairing. K epsilon(2eqn) standard model was used as it is best suited for flow away from the region. Standard initialization from the inlet was chosen with the air velocity of **20m/s**. The model also proved to be stable under high under relaxation factors which also helped us in observing faster convergence without losses in accuracy. At the last iteration, **the drag coefficient came out to be 0.109**. It could be observed from the analysis that the fairing was letting the flow stayed attached to the fairing for a longer period.



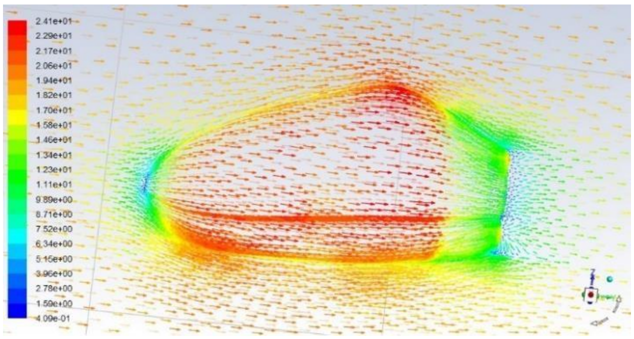
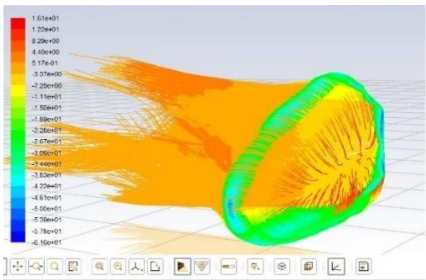


Figure 10(a): Graph- Drag Coefficient vs Iteration

Figure 10(b): Velocity Vector colored by Velocity magnitude

VIII.C.2. Cross Wind Analysis

Cross wind Analysis was performed to optimize the design. The impact area come out to be 1.14m^2 and drag coefficient was **0.53** by taking the cross-wind velocity as 7m/s. This was done to ensure that side winds Drag force doesn't become a major problem in vehicle stability. Prior knowledge of the subject helped to modify the design and the drag force came out to be **17.79 N**.



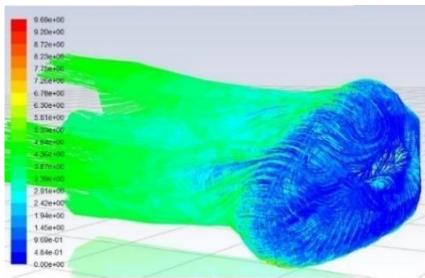


Figure 11(a): Path lines colored by static pressure

Figure 11(b): Path lines colored by Velocity

Theoretical Drag coefficient Calculation (for front wind)

As we know, $C_d = 2F_d / (D * u^2 * A)$ where, C_d = Drag Coefficient; F_d= Drag Force; u = Velocity of Air; A = Frontal Projected Area; and D = Density of Air.

From all the observations and calculations, we concluded as follows:

$$Cd = \frac{2 * 27.08}{1.2 * 20 * 20 * 0.56} = \mathbf{0.201}$$

Conclusion	Changes were made to ensure that the coefficient of drag is about 0.2 and it was achieved in the final iterations.

Table 15: Aerodynamic Analysis Conclusion

VIII.D. Cost Analysis:

The total estimated cost of the fabrication of our HPV Quarentino 2.0 was found to be Rs. 2,870. The given costs of the respective items are taken from the standard market price. Our objective to do the cost analysis was to reduce the overall cost of the HPV by selecting good source for components' purchase and cutting cost on unnecessary items.

Part	Cost Per Part	Quantity	Total Cost (including taxes)
Frame and RPS			
Round tube of Aluminum 6063 -T6 (OD 30mm & thickness 3mm)	Rs. 165/kg	5kg	Rs. 825
Round tube of Aluminum 6063- T6(OD 20mm & thickness 2mm)	Rs. 165/kg	1.9kg	Rs. 313.5
Fairing			
Resin	Rs. 115/kg	20kg	Rs. 2300
Glass fiber	Rs. 180/kg	15kg	Rs. 2700
Styrofoam (For Mould)	Rs. 70/piece	50 pieces	Rs. 3500
Adhesive	Rs. 117/Pack	10 packs	Rs. 1170

Fork and Suspension

Shock absorbable Front fork	Rs. 2500	1	Rs. 2500
Rear Wheel Shocker	Rs. 1000	1	Rs. 1000

Drive Train			
48 Teeth Crank Set	Rs. 800	1	Rs. 800
Pedal Set	Rs. 250	1	Rs. 250
Chain	Rs. 300	1	Rs. 300
Idler	Rs. 250	2	Rs. 500
Bottom Bracket	Rs. 700	1	Rs. 700
Front Derailleur	Rs. 600	1	Rs. 600
Rear Derailleur	Rs. 1600	1	Rs. 1600
Gear Shifter Set	Rs. 800	1	Rs. 800
Steering Mechanism			
Steering Handle	Rs. 1250	1	Rs. 1250
Cup Set and Bearing	Rs. 329	1	Rs. 329
Brakes			
Disc Brake	Rs. 350	2	Rs. 700
Brake Cables	Rs. 130	2	Rs. 260
Wheels			
Front wheel	Rs. 919	1	Rs. 919
Rear Wheel	Rs. 1200	1	Rs. 1200

Axle	Rs. 300	2	Rs. 600
Seat			
Seat Frame	Rs. 500	1	Rs. 500
Seat Cushion	Rs. 300	1	Rs. 300
Safety			
Bell	Rs. 100	1	Rs. 100
Helmet, Knee & Elbow Pads	Rs. 700	1	Rs. 700
Electrical Peripherals			
Speedometer	Rs. 345	1	Rs. 345
Headlights	Rs. 250	1	Rs. 250
Tail lights	Rs. 200	1	Rs. 200
Indicator set	Rs. 200	1	Rs. 200
Batteries	Rs. 150	1	Rs. 150
Ultrasonic sensor	Rs. 80	1	Rs. 80
Miscellaneous			
Nuts, Bolts and Washers	Rs. 40	10	Rs. 400
Grease Lubricant	Rs.160	1	Rs. 160
Total			**Rs.28,710.5**

VIII.E. Other Analysis

VIII.E.1. Rapid Upper Limb Assessment (RULA):

Objective	To evaluate the exposure of rider to ergonomic risk factors associated with upper extremity.
Methodology	RULA scores were recorded with the help of human builder workbench of CATIA considering intermittent riding.

How long does a rider ride his bike mainly depends upon the level of comfort and safety the cycle is providing. And for this, he should have a good posture in his whole track while riding. This analysis assesses the biochemical and postural loading on the whole body with particular attention to the neck, trunk and upper limbs.

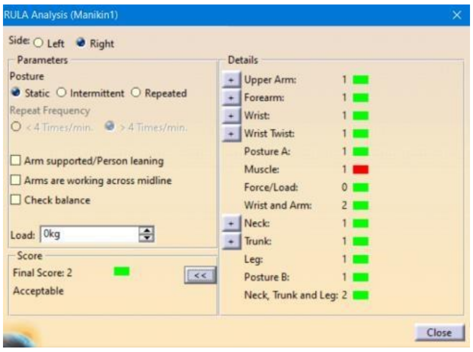


Figure 12(a): Right side RULA analysis

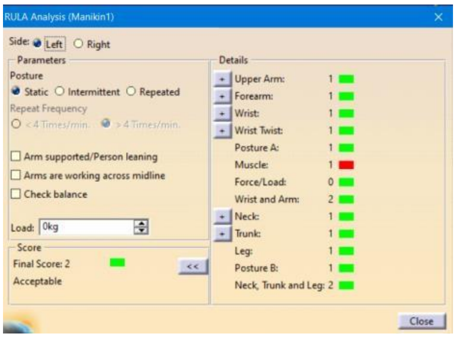


Figure 12(b): Left side RULA analysis

Result	The Overall Score obtained is 2.
Conclusion	The design is acceptable with a low risk factor.

Table 16: Result of RULA

VIII.E.2. Vision Analysis

Objective	**Methodology**	**Result**	**Conclusion**
To determine the vision range of the rider while riding.	Vision Analysis was performed in the CATIA workbench.	Rider could see more than 3m ahead of the pedal.	The rider has sufficient visibility of the path.

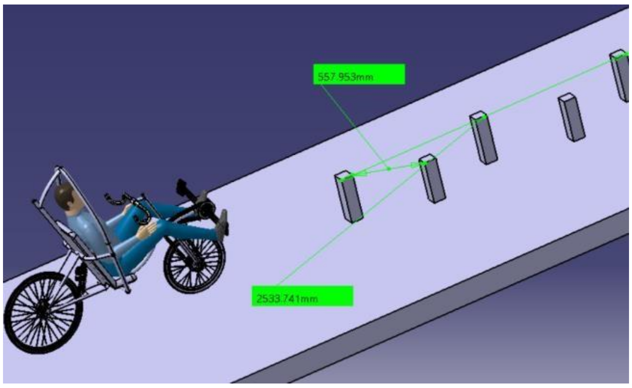


Figure 13(a): CAD Model showing Mannequin

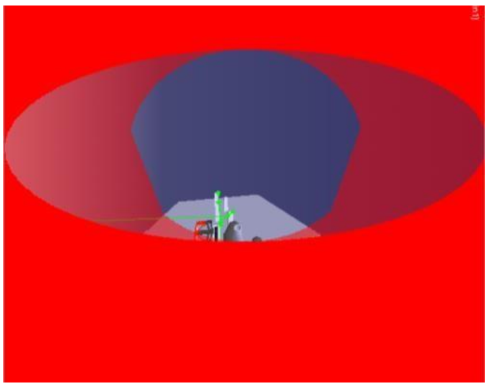


Figure 13(b): Frontal View of the Rider

VIII.E.3. Crash Analysis:

As accidents can happen anywhere anytime, the vehicle needs to be ready for crashes. The HPV vehicle can crash to another vehicle, any tree etc. while traversing. The frame was analyzed at a speed of 36kmph colliding with a steel wall like structure. The wall was constrained in all direction and the load was applied equal to rider's weight on the frame in motion.

Objective	To analyze the response of the frame under the case of crash.
Methodology	HPV model is designed in CATIA V5 R20 and finite elemental analysis is performed in ANSYS 18.1.
Result	• Maximum deformation at a velocity of 45 kmph is 0.34cm. • The maximum equivalent (von-misses) stress comes out to be 240.1 MPa.

Mass of Vehicle: 18.5Kg; Total mass with the Rider: 85Kg (Our heaviest rider)
We assumed that the vehicle to strike the wall at a velocity of 10 m/s (36 Km/h) and Factor of Safety of vehicle be 1.3.

Calculation of Impact Forces at the Front

Momentum(P)=m*V = 85*10 = 850 Kg m/s.

Impact Force (IF)= I*P = 1*850
=850N.

Net force = FOS*IF = 1.3*850 = **1105 N**. This force was applied on the vehicle and a 1000 cycle analysis was done for 0.01 sec which gave a result of 0.34 cm total deformation. Though the analysis could not give a correct result, we made sure that the vehicle would be safe during crash.

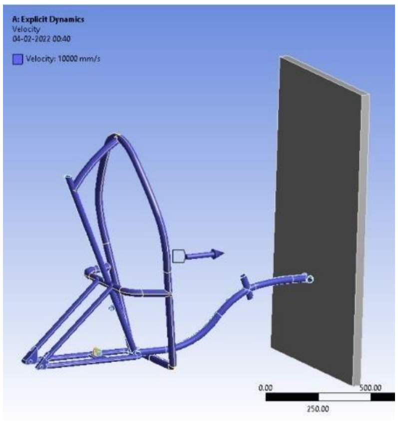


Figure 14(a): Crash Analysis- Velocity Condition

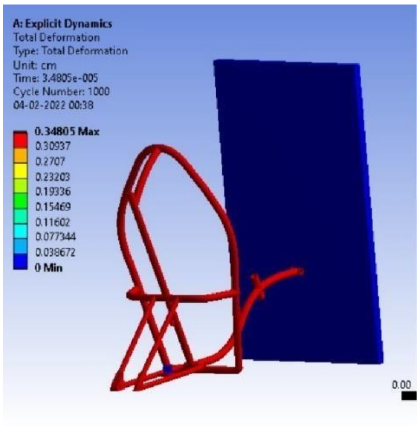
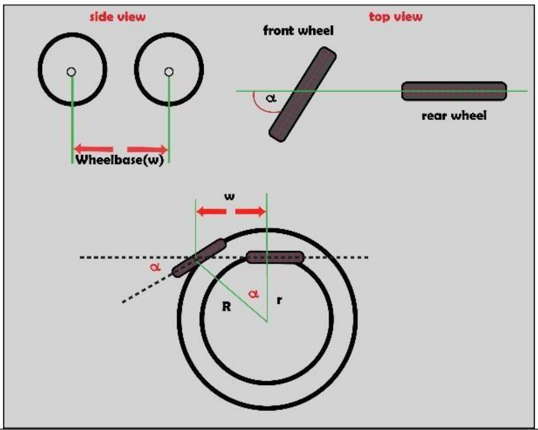


Figure 14(b): Crash Analysis- Equivalent Stress

VIII.E.4. Turning Radius Calculation:

Objective	Methodology	Result	Conclusion



To determine the minimum turning radius of the vehicle.	Using trigonometric equations on the cycle design specifications, turning radius was calculated.	Turning Radius came out to be 3.523m.	Turning radius was within the guidelines of ASME.

For the analysis, we measured the wheelbase of the vehicle and the steering angle, which were as follows

Wheelbase:1.32m, Steering angle: 22degress(max)

From the above mathematical analysis, we applied this trigonometric equation:

Sinα= Wheelbase(w)/Turning Radius(r)

$$r = w/\sin\alpha$$

$$r = 1.32/\sin 22\text{degree}$$

Hence, Turning radius= **3.523m**

Figure 15: Turning Radius visualization

VIII.E.5. Head Tube Analysis:

The head tube is one of the most crucial parts of the vehicle. We must ensure that the head tube does not fail in any terrain. We performed Finite Element Analysis on the Head Tube by applying a perpendicular load of 1000N along the axis of the Head Tube. As the head t

Objective	Methodology	Result

To determine the maximum equivalent(von-mises) stress and deformation of our custom manufactured Head Tube.	Head Tube model is designed in CATIA V5 R20 and finite elemental analysis is performed in ANSYS 20.1.	The maximum deformation is 15mm and maximum stress is 230.07MPa.

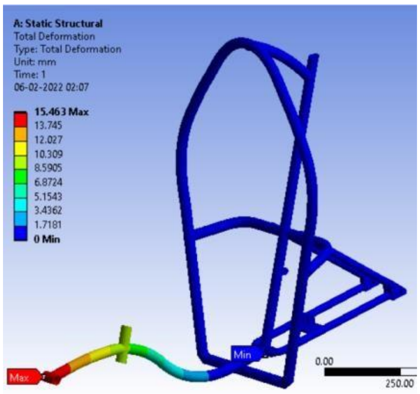


Figure16(a): Head Tube- Total Deformation

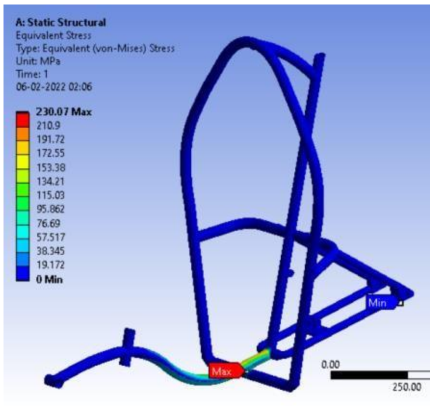


Figure16(b): Head Tube Analysis- Equivalent Stress

Conclusion
As the deformation was larger than expected, we fixed the head tube and **gave it a support at the bottom.**

XI. **Testing**

Due to the COVID restrictions by government, we could not perform the physical testing as our College is closed.

X. Conclusion

The target that we set earlier before designing the vehicle was nearly accomplished. As we wanted to design our vehicle lighter, faster, more convenient, comfortable and cost effectivethan our previous model Quarentino.

X.A. Comparison

Metric	Target value	Estimated value
Coefficient Of Drag	< 0.2	0.109
Field Of View	>200◦	220◦
Turning Radius	< 4meters	3.523meters
Weight	<20kg	19.1kg
Effective Cost	<Rs.30000	Rs.28,710

RPS Top load And Deformation	Max. top load=2670N Max. deformation=3cm	Max. top load=2670N Max. deformation=10.4mm
RPS Side Load And Deformation	Max. side load=1330N Max. deformation=2cm	Max. side load=1330N Max. deformation=8.26mm
Rider Safety and Satisfaction	9/10	9.5/10
Rider Height range	20cm	24cm

Table 17: Comparison between target value and estimated value

X.B. Evaluations

The analysis of CAD model of our HPV on ANSYS-20 has satisfied our requirement for safety and speed in every aspect. By these analysis results our team is confident to present our HPV to the society for the betterment and the sustainable development of the depleting natural resources we have.

X.C. Recommendations

Since we have developed only CAD model of our Quarentino2.0 but not fabricated it. There may be some sort of problem can arise during fabrication or machining of frame materials, assembly of different parts. Additional research and practical application would help in improvement of our HPV.

XI. References

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