ASME Report Cover Page & Vehicle Description Form

Human Powered Vehicle Challenge

Competition Location: MARWADI UNIVERSITY

Competition Date: 28/2/2020-1/3/2020

This required document for all teams is to be incorporated in to your Design Report.

Please Observe Your Due Dates; see the ASME HPVC website and rules for due dates.

Vehicle Description

University name: Kalinga Institute of Industrial Technology
Vehicle name: TRAVOS
Vehicle number: 48
Vehicle configuration:

Upright	______	Semi-recumbent	Fully Recumbent
Prone	______	Other (specify)	__________________

Frame material: Chromoly AISI 4130
Fairing material(s): Carbon Fibre
Number of wheels: 2
Vehicle Dimensions (cm)
Length: 161cm
Width: 61cm
Height: 125cm
Wheelbase: 110cm
Weight Distribution (kg)
Front: 54.7%
Rear: 45.3%
Total Weight (kg): 21.046Kg
Wheel Size (m)
Front: 20”
Rear: 20”
Frontal area (m^2): 0.713sq m
Steering (Front or Rear): Front
Braking (Front, Rear, or Both): Both
Estimated Coefficient of Drag: 0.026

Vehicle history (e.g., has it competed before? where? when?):
No, the vehicle has not competed in any event at the time of submission of this design report.

KIIT UNIVERSITY
(Declared U/S 3 of UGC Act, 1956)
Bhubaneswar, Odisha, India

TEAM KETAV
PASSION.AMBITION.DETERMINATION

ASME HPVC TEAM

PRESENTS

TRAVOS

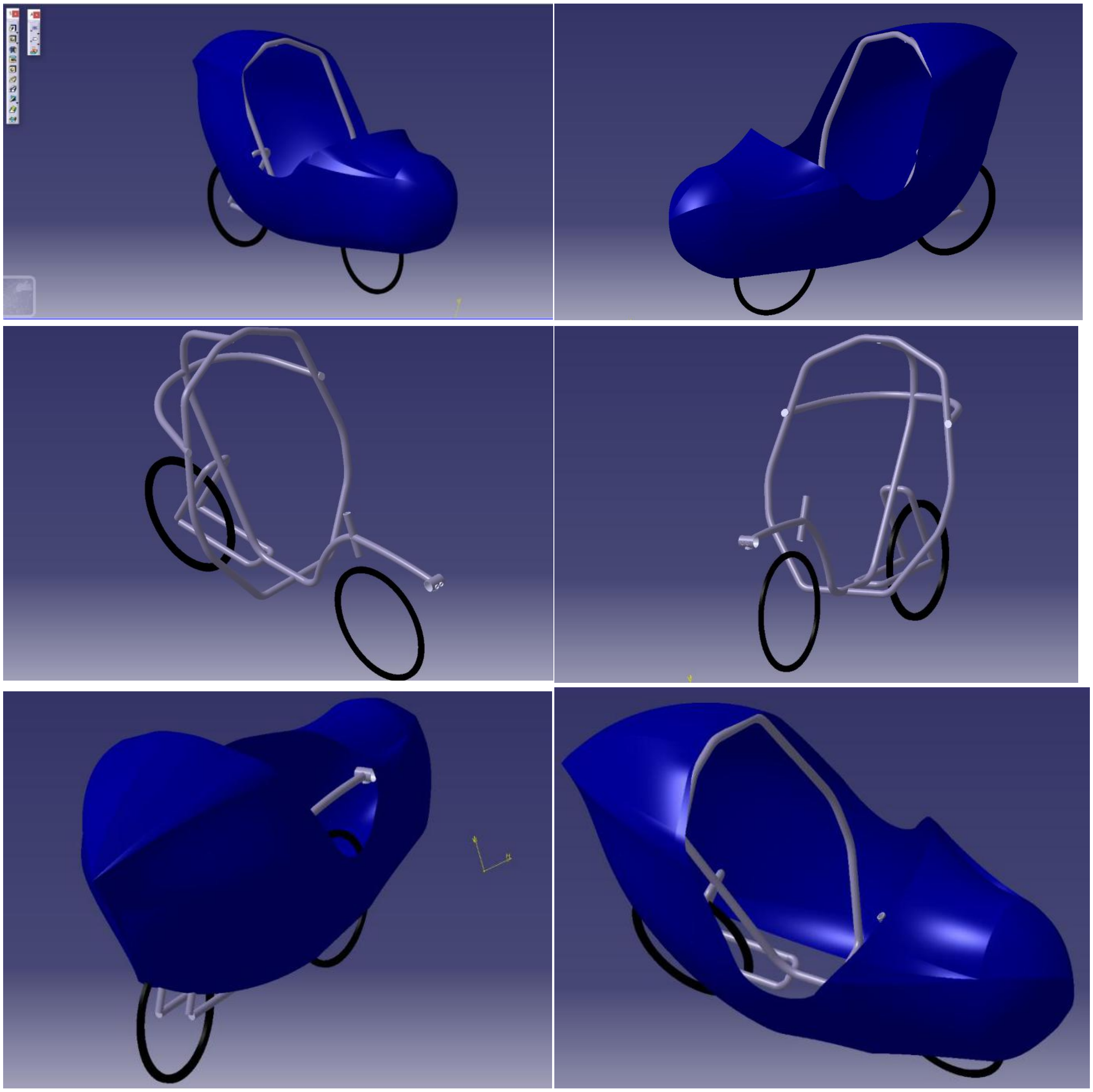
VEHICLE#48

FACULTY ADVISOR: Dr. ISHAM PNIGRAHI

TEAM MEMBERS

Sayan Chatterjee	Zeenat Nazmin Ahmed	Vaibhav Bhardwaj
Akash Thakur	Deepmalya Biswas	Arkaprabha Ghosh
Rishab Sirvastava	Akarsh Ravi	Debarshi Kundu
Jasprit Singh Sandhu	Maitraya Prasad Goswami	Mrinmoy Sharma
Neelesh Ranjan	Om Prakash	Rohit Das Gupta
Sonam Sharma	Aman Sinha	Biki Kumar Shah
Debashree Dutta	Gaurav Kumar	Siddhant
Sohini Rudra	Soumik Chakrabarty	Sudhanshu Kumar
Aditi Singh	Ankit Chaudhary	Ayush Dwivedi
Debankan Chakraborty	Md. Adnaan Khan	M.d Ahsan Raza
Neethi Baruah	Netra Mohan Damle	Priyaranjan
Suyash Vishwakarma	Trinanjana Bagchi	Prabhav Sinha

3-D VIEW OF VEHICLE



ABSTRACT

Team Ketav, in its seventh consecutive appearance in the ASME's HPVC event, introduces the "TRAVOS", a fully recumbent vehicle focusing on three goals, efficiency, safety, and comfort. The vehicle has been meticulously designed to create an optimized frame and tested upon intensively along with proper analysis and testing to ensure that the vehicle is completely safe and to ascertain maximum efficiency.

Standardized equipment along with pulleys are being used for the drive train. Chromoly AISI 4130 has been selected for the chassis due to its high manufacturability and to increase the durability of the vehicle.

Aluminum T6-6061 has been used to create lightweight and durable pulleys.

The team has worked extensively on the various aspects of design and engineering along with rigorous analysis via CATIA V-5 R-21 and ANSYS'19 R-2 student version.

The final vehicle design weighs in at 21.046 kg and is a front-wheel-driven, 2 wheeled bike with a field of vision of 180 degrees. All the safety features necessitated by ASME have been supplemented to the vehicle for maximum protection.

CONTENT

1) DESIGN

1.1) NEW DESIGN

TRAVOS is a brand new vehicle manufactured by team KETAV for the 2019-2020 session. This year's vehicle comes with a unique approach to a brand new transmission system and a lower ground clearance.

1.2) DESIGN METHODOLOGY

1.2.1) DESIGN OBJECTIVE

Team KETAV has designed, manufactured and tested TRAVOS during 2019-2020 session with the end goal of idealizing our mission statement:

" *To manufacture a recumbent bicycle, keeping in mind an appropriate extent of rider's comfort without hampering the safety of riders and also showcasing a good degree of efficiency under vigorous terrain conditions, thereby improving the scope of HPVs in the technological arena*."

The vehicle overall is structured and manufactured keeping harmony between the safety features and aesthetics.

1.2.2) BACKGROUND RESEARCH

Before designing the prototype, members of the various departments have researched on the improvements that can be implemented in our new vehicle. Firstly, we got acquainted with the rules and constraints from the HPVC Rule book within which we had to build our vehicle. Then we went through various research papers and videos on Human Powered Vehicles to get a better idea of the concept. The fairing of our vehicle has been inspired by the fairing of Aerovelo, the fastest HPV on land. The ground clearance of the vehicle is lower than our previous vehicle and a 58 teeth crank has been preferred over 56 teeth crank to achieve an increased speed. This time we are using Aluminum T6- 6061 pulleys in the transmission system instead of nylon pulleys to decrease the wear and tear rate of the pulley. The characteristics of Chromoly AISI 4130 have been properly studied from different websites and blog posts like Bikehub for better knowledge. We learned a great deal on the effect of various types of stresses on the RPS and frame of the vehicle from the book 'Theory of Machines' by S.S. Rattan and ''Analytical Mechanics of Gears' by Earle Buckingham which helped us to polish our knowledge on gears.

1.2.3) PRIOR WORK

Our new vehicle Travos is an evolved version of our previous vehicle,KRATOS MK-III. Some of the features,like the transmission have been changed to improvise the vehicle and meet the riders' comfort while other features like the chassis design, use of Chromoly AISI 4130 as the material of the vehicle have remained the same. The seat angle has been reduced, ground clearance has been lowered and Aluminum T6-6061 pulley has been used instead of nylon pulley in the transmission system. The concept of ergonomics was taken into consideration to figure out the perfect dimensions of the frame by taking into account the average standard height of the riders. The seat has been fabricated with FRP, chalk powder and resin just like the previous years.

1.2.4) TIMELINE AND PLANNING

SL.NO.	WORK TO BE DONE	TIME ALLOTTED	STATUS
1	TEAM FORMATION	21/07/2019-23-07/2019	completed
2	PREVIOUS REPORT ANALYSIS	25/07/2019-28/07/2019	completed
3	FRAME ANALYSIS AND MATERIAL STUDY	03/08/2019-06/08/2019	completed
4	CATIA MODELLING AND ANALYSIS	10/08/2019-12/08/2019	completed
5	PROTOTYPE FORMATION	02/08/2019-05/08/2019	completed
6	PROCUREMENT OF MATERIAL	07/08/2019-08/08/2019	completed
7	PRINTING OF FLEX	09/08/2019-09/08/2019	completed
8	MATERIAL STRENGTH TEST	11/08/2019-12/08/2019	completed
9	CHASSIS MANUFACTURING	18/08/2019-27/08/2019	completed
10	ROLLOVER FABRICATION	30/08/2019-02/09/2019	completed
11	WHEEL MONITORING AND ASSEMBLY OF DRIVETRAIN	28/08/2019-29/08/2019	completed
12	BRAKE TEST	06/09/2019-06/09/2019	completed
13	WHEEL ALIGNMENT	04/09/2019-05/09/2019	completed
14	CASTING OF FAIRING	10/10/2019-20/10/2019	completed
15	RPS AND PERFORMANCE TESTING	08/09/2019-10/09/2019	completed
16	OBSTACLE TESTING	10/09/2019-11/09/2019	completed
17	MATERIAL TESTING	14/08/2019-16/08/2019	completed
18	WELDING TEST	02/09/2019-02/09/2019	completed
19	SEAT CUSTOMIZATION	29/08/2019-01/09/2019	completed
20	RPS LOADING TEST	11/09/2019-12/09/2019	completed

1.2.5) DESIGN CRITERIA

	ASME Constraints	Team Goals
Safety	• RPS: Roll bar that can support 2670N per driver/stroker top load with elastic deflection less than 5.1 cm and 1330N per driver/stroker side load with elastic deflection less than 3.8 cm. • Safety harness to secure the rider to the vehicle at all times when in motion. • In case of a collision safety harness to firmly hold back the rider in the vehicle. • Participants must be in fully enclosed shoes, proper dressing and properly fitted helmets with fastened straps that meet CPSC safety standard for bicycle helmets. • Addition of headlights, tail lights,horn and proper reflectors	✔RPS that can support up to 2670 N top load with a deflection of 0.17179 cm and side load of 1330 N will have deflection of 0.33399 cm. ✔Rear view mirrors are installed. ✔Reflectors on both sides are installed. ✔Helmets and safety gears are used. ✔Headlights and tail lights are also used. ✔Horns to alert the approaching vehicles. ✔Four-point seat belts are used.
Performance	• Each vehicle must demonstrate that it can come to a speed of 25 km/hr in a distance of 6.0 m. • Can turn within a 8.0 m radius. • Demonstrate stability by travelling for 30m in a straight line at a speed of 5 to 8 km/hr.	√ To achieve a top speed of 50 kmph. √ To achieve a turning radius of 3.0 m. √ To optimize the frontal profile of the vehicle for drag reduction. √ To lower the C.G of the vehicle to increase stability. √ To achieve a compact chassis structure by keeping the rider at a centralized point.

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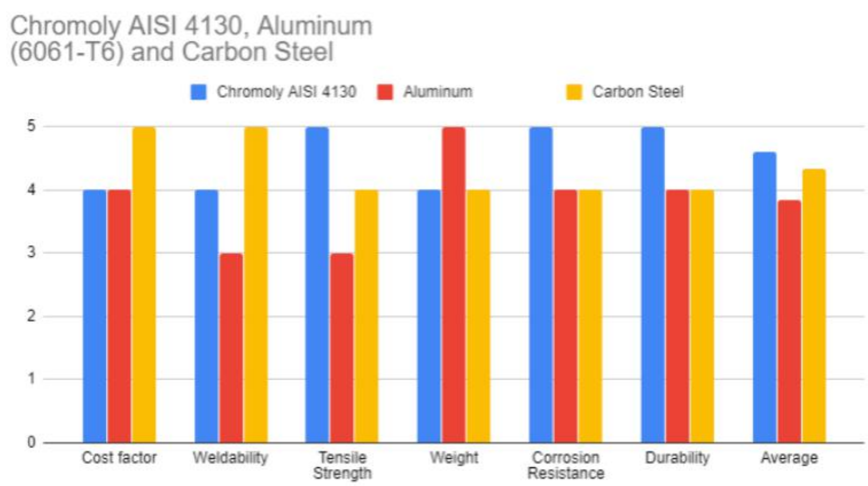
1.2.6) ALTERNATIVES AND EVALUATION

The team has gone through a phase of exhaustive research and selection to finalize the various components of the vehicle. These comparisons are done based on research, testing and prior experience, and has been represented graphically, in the form of bar graphs.

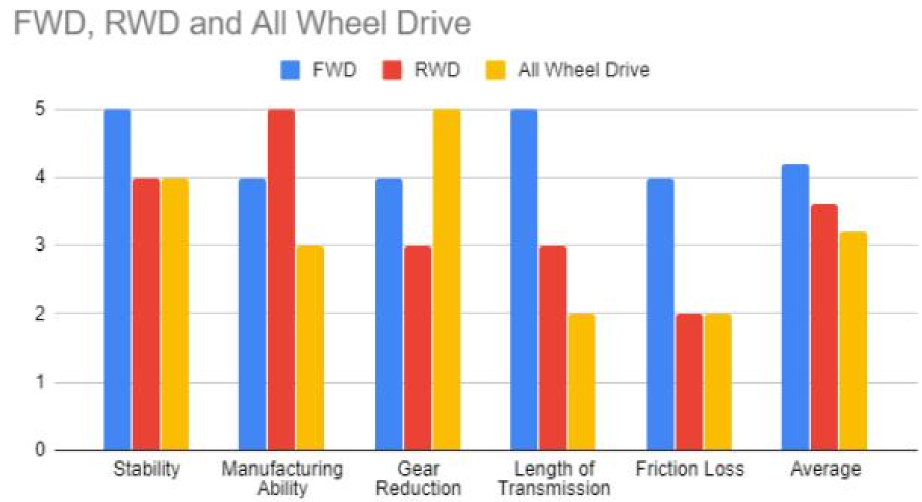
SCORE	QUALITY
5	Excellent
4	Very good
3	Good
2	Bad
1	Very bad

1.2.6.1) Selection of Chassis Material:



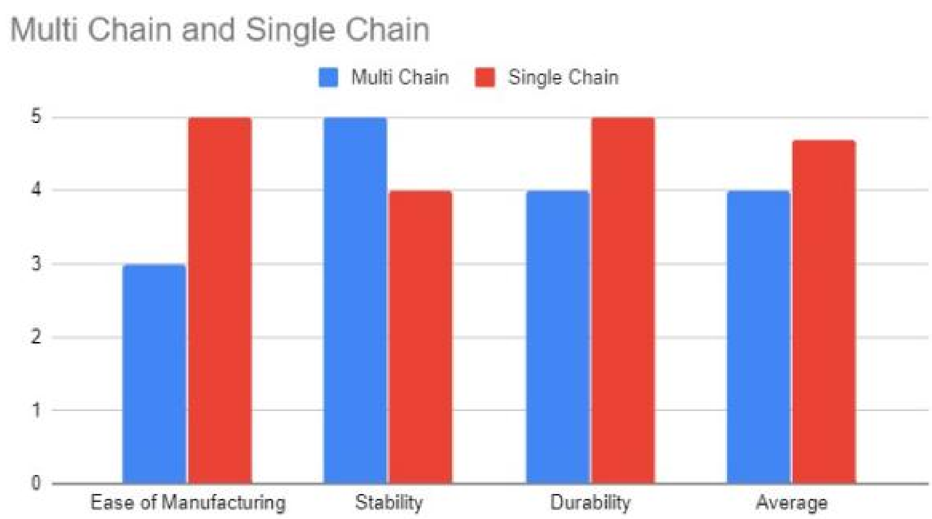
We have preferred Chromoly AISI 4130 as our frame material over Aluminium 6061-T6 and Carbon Steel due to it being more durable,and having better tensile strength and apart from being lightweight, it provides high corrosion resistance.

1.2.6.2) Selection of Transmission System:



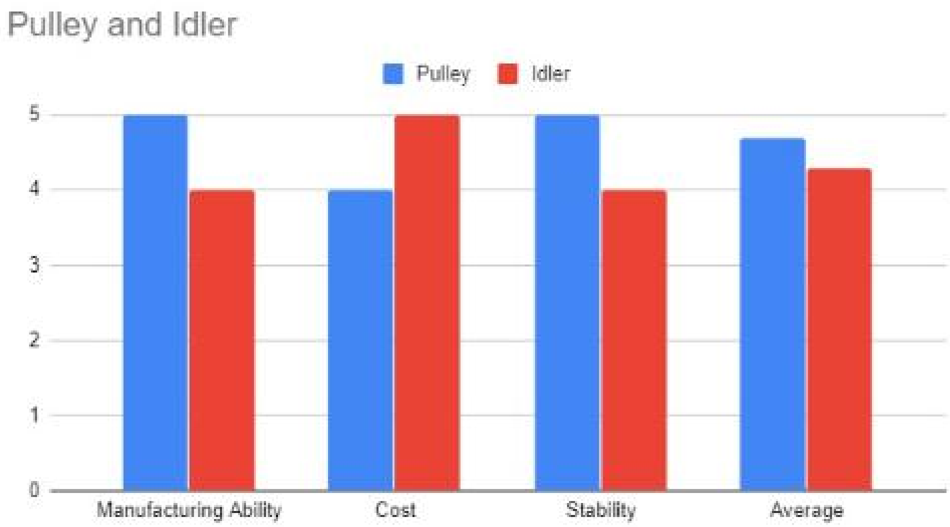
We have preferred Forward Wheel Drive ahead of Rear Wheel Drive and All Wheel Drive because of the higher stability we get from front wheel drive, it has a shorter transmission and number of rotating parts reduce, hence reducing frictional losses.

1.2.6.3) Multi Chain System vs Single Chain System:



We have preferred a Single Chain Transmission System over a Multi Chain Transmission System because a single chain is easier for manufacturing, and is more durable as compared to a multi chain.

1.2.6.4) Pulley vs Idler



We have preferred to use pulleys over idlers this year due to them being available at a lower cost than idlers, and with better manufacturing ability and stability.

1.2.7) STRUCTURED DESIGN METHODS

Team KETAV has used a PUGH chart analysis this year for analyzing the vehicle characteristics with respect to the needs of the consumer.

+ signifies a better performance as compared to the baseline performance indicator.

0 signifies that performance observed is approximately at par with the baseline performance indicator

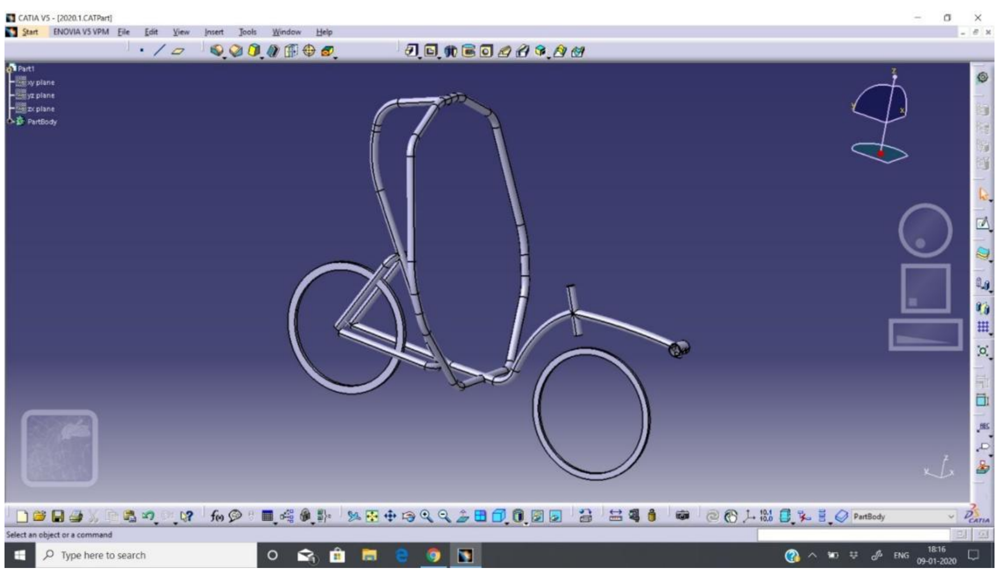
- indicates a below par performance observed with respect to the baseline performance indicator.

From the above chart, the team concluded that rider safety, rider awareness and the ease of engineering have completely been taken care of under the construction of TRAVOS. The cost of the vehicle has been somewhat expensive, owing to the team's uncompromising priority on other parameters, especially the safety and comfort of the rider along with high speed and durability.

1.2.8) <u>VEHICLE DESIGN SPECIFICATION</u>

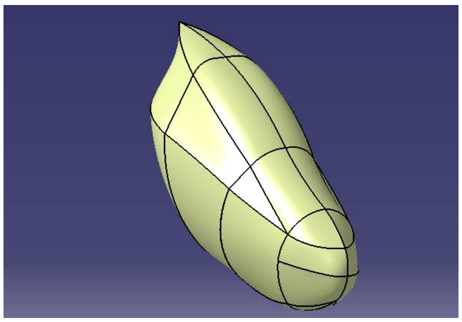
1.2.8.1) <u>CHASSIS</u>

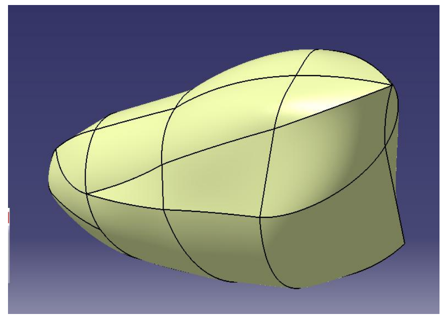
A front-wheel-drive vehicle has been finalized owing to its optimum speed and performance. Chromoly AISI 4130 has been used due to it being lightweight and having high tensile strength. The wheelbase has been increased to 110 cm from 101 cm to maintain stability at higher speeds. Ground clearance has been reduced to 25 cm to achieve more stability. Lower weight Aluminium alloy wheel sets have been used. According to the HPVC constraints, a proper rollover protection system has been attached to the chassis to shield the upper half of the rider for absorbing high-speed impacts. The entire prototype was designed keeping the backrest angle as 123°.To integrate the seat belts, mounts have been welded to the mainframe.



1.2.8.2) <u>FAIRING</u>

This year, the fairing of TRAVOS has been constructed using carbon fiber. Initially the fairing sketch was partitioned at an interval of 15cm, and the fairing design was printed on a 1:1 scale. Then, the mould for fairing was made by fusing two plywood pieces together and the printed flex was pasted on it, and was shaped according to the requirement. Then the structure was made by thermocol and Plaster Of Paris(POP) . Once the POP dried out, a mixture of FRP and resin was coated on the fairing. Once the team got the required fairing design, it was finally built with carbon fiber 200 GSM.





1.2.8.3) <u>TRANSMISSION</u>

TRAVOS has been manufactured as a front-wheel driven vehicle. The detailed description of transmission is explained below:

a) A 58 teeth crank has been used this year in TRAVOS to attain an improved speed quotient and hence superior ease in riding was observed on usage.

b) The wheel size has been kept unchanged i.e. 20 inches. This helps in better stability and maintaining a shorter wheelbase.

c) The chain has a definite path because of the use of pulleys. Pulleys are used instead of movable idlers for the ease of riding. The use of pulleys allowed us to achieve a greater steering angle, which is beneficial on track.

d) This year, the team has used 7-speed cassette derailleur instead of a 9-speed cassette derailleur, as used previously. The reason for that is while using 9-speed derailleur cassette previously, the last two gears were unused on the track. So the team decided to use a lower gear set.

e) The power is transmitted from the crank to pulley via the chain, the pulley is attached to the head tube. From there it moves to the 7-speed cassette derailleur. Then the chain moves to the second pulley, attached in between the first pulley and the crank from where it moves back to the crank.

1.2.8.3) INNOVATION (Deployable wheels)

a) It will be attached to the rear wheels which will balance the vehicle at rest position or when the vehicle loses balance while in operation.

b) The wheels can be lowered or raised with the help of a lever, which can be locked at different angles.

c) These wheels will protect the vehicle from damage against sudden impacts, and will also keep the vehicle steady at normal riding speeds.

d) This will also ensure rider's safety while riding, because it will prevent any sort of impact on the rider, in case the vehicle disbalances.

2) ANALYSIS

2.1) ROLLOVER PROTECTION SYSTEM ANALYSIS

2.1.1) OBJECTIVE

To check the feasibility of the rollover protection system's design under applied load conditions using the Static structural module of ANSYS, the study of side load and top load analysis has been conducted. The method followed has been tabulated below.

2.1.2) METHODOLOGY

Top load Analysis	**Side load analysis**
The prototype was designed according to the prescribed load conditions. The lower end of the frame was fixed. A load of 2670N was applied. The total deformation was noted.	A similar method was applied for the side load analysis. The lower frame and the other end of the side of RPS were fixed. The load of 1330N was applied at the side at shoulder height. The analysis was done to obtain the maximum deflection.
Results and Discussion	
A maximum deformation of 0.17 cm was observed at the top most part of the RPS.	A maximum deformation of 0.33 cm was observed.

2.2) STRUCTURAL AND ANALYTICAL CALCULATIONS

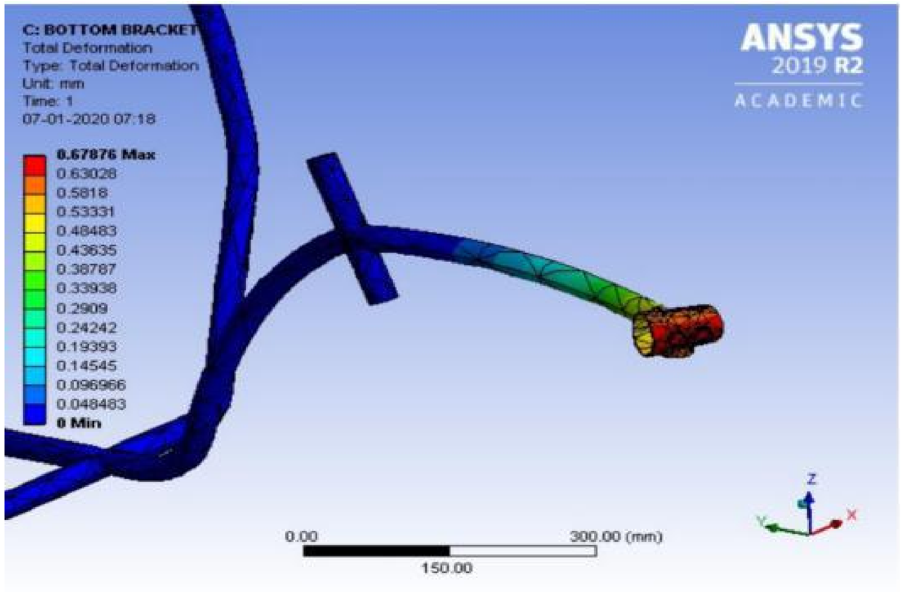
2.2.1) FRAME ANALYSIS

OBJECTIVE	**ANALYSIS CASE DEFINITION**	**MODELING**	**RESULTS**	**DESIGN MODIFICATIONS**
To ensure the reliability of the design of the vehicle, loads were applied on the seats to check if the frame is strong enough to bear the weight of the heaviest rider in our team along with an acceptable performance graph.	It must be ensured whether the seat can take enough load proportionate to the heaviest rider in our team for the vehicle to show a smooth and effective performance.	A load of 1000 N was put on the bar on which seat has been mounted.	The topmost part of the second member approached 0.991 cm.	The distortion found finally was insignificant and subsequently no alterations were considered from the design point of view.

2.2.2) BOTTOM BRACKET ANALYSIS

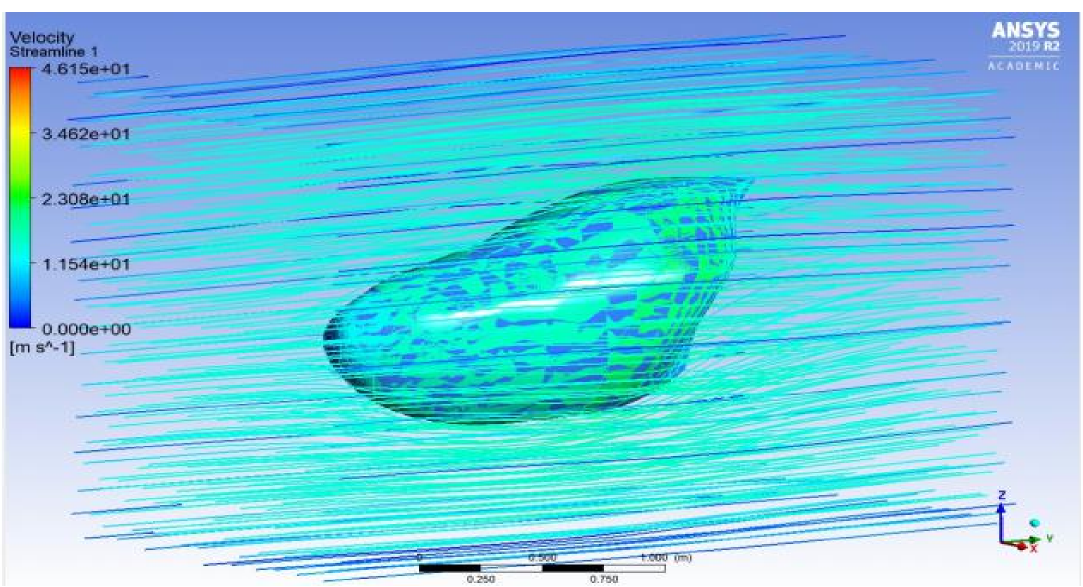
The bottom bracket analysis was crucial for determining the overall feasibility of the design. The head tube was fixed during analysis via ANSYS. A load of 1300

N was applied in the positive Y-axis and a load of 300 N was applied in negative Y-axis. Maximum deformation of 0.0678 cm was observed.



2.3) AERODYNAMIC ANALYSIS

For achieving maximum speed, the aerodynamic drag and aerodynamic stability of Travos needed to be optimum. The fairing was designed using CATIA and CFD (Computational Fluid Dynamic) and analysis was done using ANSYS Fluent. The analysis was done considering the velocity of wind to be 50 kmph. The coefficient of drag was found out to be 0.026. The material used was carbon fibre GSM 200. The material was chosen after a comparative analysis between glass fibre, FRP and Teflon. Carbon fibre was chosen because of it being lightweight and the possession superior strength.

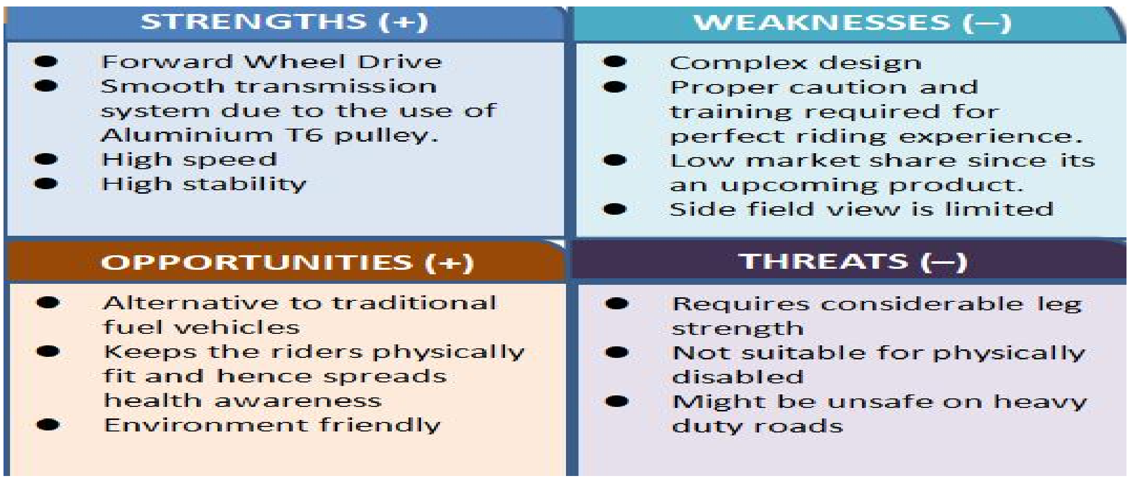


2.4) COST ANALYSIS

Components/Parts	Quantity	Unit price(INR)	Total(INR)
Brake System			
Clutch Lever	2 pcs	50	100
Brake Wire Cable	2 pcs	35	70
Disc	2 pcs	400	779
Calliper	2 pcs	150	300
Calliper Mounting	2 pcs	50	100
Frame			
Chromoly (along with hot bending)	_	6000	6000
Fabrication			
Carbon Fibre	_	_	32000
Carbon Fibre Mold	_	_	15000
Hand Cutter Blade	5pcs	15	75
Hand Flapping Blade	5 pcs	15	75
Hand Grinder Blade	2 pcs	20	40
Grease	1 pc	20	20
Hand Gloves	2 pcs	20	40
Safety Glasses	2 pcs	20	40
Welding Glasses	2 pcs	25	50
Safety			
Seat (FRP,Resin)	1 pc	500	500
Seat Belt	1 pc	150	150
Helmet	1 pcs	100	100
Guard	1pcs	200	200
Light	2 pcs	50	100
Bell	1 pc	30	30
Rollover Protection	1 pc	300	300
Other Accessories			

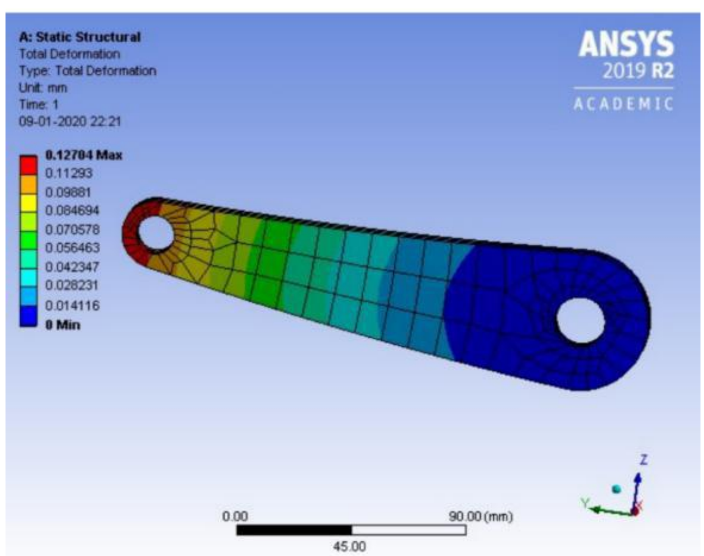
Nut/ bolt/ Flat Plate Locknut/ Washer Drill bit/ Mceal Marker/ Whitener/ Measuring Tape	_	_	600
Total			**56669**

2.5)<u>SWOT ANALYSIS</u>



2.6) <u>PEDAL MOMENT ANALYSIS</u>

Pedal crank analysis was performed to know how much force the pedal crank can withstand without failure. A force of 1300 N was applied on the pedal in the positive Y-axis. The deformation was found out to be 0.0127cm. This helps the riders' to perform better as they know the maximum force the pedal crank can tolerate.



2.7) CENTER OF GRAVITY

For a bicycle the very first priorities tended to be proper balancing and appropriate center of gravity. To have the center of gravity to our advantage, it needed to be as close to the ground as possible.

Total weight (T) = 21.046 kg

Frontal weight (F_w) =11.52 kg

Rear weight (R_w) = 9.53 kg

Actual wheelbase (W_b)= 110 cm

Height of the stand (H) = 38 cm

Rear weight (when kept on stand) (R_N) = 7.89 kg

R_f and R_r = Radius of wheels=27.94cm

Weight distribution (Front:Rear) = 54.7:45.3

1.2.9.1)C. G (Horizontal)

x = (R_w x W_b)/T = 9.53 x 110/21.046= 47.545 cm (From rear wheel center)

1.2.9.2)C.G (Vertical)

$Y = \cot[\sin^{-1}(H/W_{b)} \times \{[(R_N \times W_b) / (R_N + F_w)]-x\} + [(R_f + R_r)/2]$ (from ground)

$= \cot[\sin^{-1} (38/110) \times \{[(7.89 \times 110)/(19.41)] - 47.545\}] + 27.94$

= 28.174 cm (from ground)

1.2.9.2)C.G of vehicle

When we consider origin at rear wheel center

(x,y) = (47.545 , 28.174) in cm

3)TESTING

3.1) ROLLOVER PROTECTION SYSTEM:

3.1.1) TOP LOAD TESTING

Team KETAV conducted a compression test by loading a weight of 2670N on the top of the vehicle with the help of a weight bar, which was placed directly over the vehicle's RPS structure.

RESULTS

The maximum total elastic deflection as prescribed by the ASME is 5.1cm (2 inches), and the elastic deflection observed on testing the TRAVOS was found to be 0.17cm. No deformation was observed.

3.1.2) SIDE LOAD TESTING

The side load testing was completed by testing the vehicle on the gym, where the side of the seat which was supposed to be mounted was held sideways keeping the other side suspended. Then , a force was applied where the roll bar is attached. This year, a virtual simulation of the test was also carried out using ANSYS 19. software.

RESULTS

The maximum constraint value for elastic deflection prescribed by the ASME is 3.8cm, whereas the value for elastic deflection for TRAVOS was observed to be 0.33cm.

3.2) DEVELOPMENT TESTING

3.2.1) PROTOTYPE DEVELOPMENT TESTING

Objective	To test whether the design of the vehicle this year is sufficiently skilled to meet the necessities of the rider based on comfort,speed and so forth.
Methodology	The rigorous analysis of reports were done and information from the previous years were contemplated cautiously. Our older vehicles KRATOS MKIII, KRATOS 2.0 and VALAK were taken as models which improved our vehicle this year helping us overcome the anomalies experienced in the past events.

Taking into account the riders' comfort, we decided to test various ergonomic positions to extract the best results out of it. We took three basic recumbent angles 120°, 123° and 150°, of which 123° turned out to be the considerable one. The process finally gave us a comfortable and convenient riding posture and we came up with these final results in our design.

3.3) <u>CHASSIS DEVELOPMENT TESTING</u>

OBJECTIVE	METHOD	RESULTS
To make the vehicle accustomed to road like conditions, such situations have been simulated(e.g. bumpers and similar obstacles) which will help in increasing the overall performance.	The vehicle was tested through obstacles of varying heights, and an ergonomic analysis considering the average heights of the riders, was completed.	● Seat height was taken to be 100 cm. ● Bottom Bracket distance from the seat was taken to 75cm.

3.4) <u>PERFORMANCE TESTING</u>

3.4.1) <u>TURNING RADIUS TEST</u>: The vehicle was driven around circles of varying radii and the optimum turning radius was observed to be 3m.

3.4.2) <u>BRAKE TEST :</u> The riders tested the efficiency of the brakes on the vehicle by driving the vehicle upto a speed 50 kmph and then brakes were applied just before a designated point. It was ascertained that the vehicle stopped within 0.8 m of applying the brakes. The brakes were eventually found to be in good working condition.

3.4.3) <u>SPEED TEST:</u> The fastest speed attained by TRAVOS was found to be 50 kmph. Vehicle was relatively stable at both higher and lower speeds without any anomalies .

3.4.4) <u>MANEUVERABILITY TEST :</u> The vehicle was made to tackle the obstacles which were placed 4.0 m apart from one another and hence the ease in maneuverability was tested. Ultimately, no problems were encountered and the vehicle passed the test.

3.4.5) <u>MATERIAL TEST:</u> Chromoly AISI 4130 was used in the manufacturing of the chassis of TRAVOS. Hence, it was put through a tensile test with the help of a universal testing machine, and the team was satisfied by the results.

KITT UNIVRSITY

BHUBANESWAR

TENSILE TEST REPORT

Machine Model	: TUF-C-1000	Test File Name	: Aman tensile1.Utm
Machine Serial No	: 2018/48	Date & Time	: 09/01/2020
Customer Name	: Fine Spavy Assco. & Engg. Pvt Ltd	Customer Address	: C-45/2, M.I.D.C. Miraj 416410 Sangli Maharashtra
Order No.	:	Test Type	: Tensile
Lot No.	:	Heat No.	:

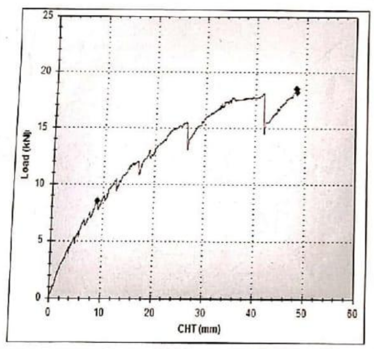
Input Data

Specimen Shape	: Hollow Round	
SpecimenType	: AISI4130	
Specimen Description	: Dia:30mm	
Specimen Inner Diameter	: 28	mm
Specimen Outer Diameter	: 30	mm
Initial G.L. For % elong	: 136	mm
Pre Load Value	: 0	kN
Max. Load	: 1000	kN
Max. Elongation	: 250	mm
Specimen Cross Section Area	: 91.106	mm2
Final Specimen ID	: 26	mm
Final Specimen OD	: 29	mm
Final Gauge Length	: 140	mm
Final Area	: 129.59	mm2

Output Data

Load At Yield	: 8.5	kN
Elongation At Yield	: 10.470	mm
Yield Stress	: 93.298	N/mm2
Load at Peak	: 18.500	kN
Elongation at Peak	: 48.130	mm
Tensile Strength	: 419.021	N/mm2
Load At Break	: 18.200	kN
Elongation At Break	: 48.340	mm
Breaking Strength	: 398.799	N/mm2
% Reduction Area	: - - -	%
% Elongation	: 18.86	%

Load Vs. Cross Head Travel



Tested By admin

4) SAFETY

4.1) <u>RPS SAFETY</u>: A rollover protection system has been used in the vehicle to protect the riders from injuries caused by vehicle when it overturns. The regulations include both strength and energy absorption requirement of the structure. In case of an accident, this system helps to decrease the intensity of crash and protects the rider from striking the surface.

4.2) <u>SAFETY HARNESS</u>: TRAVOS has a 4 point seat belt which prevents the rider from falling out of the moving vehicle. The seat belt fits all the riders excellently. It is secured with all four attachment points welded between rollbar and steel cap plate.

4.3) <u>STEERING SYSTEM</u>:Considering the riders' comfort, a customized steering has been attached to the front fork after measuring every riders' height.The steering system has been installed ensuring utmost stability.

4.4) BRAKING SYSTEM: TRAVOS has been installed with hydraulic braking system as it produces more stopping power for the same input and also helps to eliminate the friction between cables. Each wheel has its own braking system.

4.5) SHARP EDGES, PROTRUSIONS, PINCH POINTS: Some abrasions were generated during manufacturing which were later rounded off. Keeping the riders safety in mind, all the welded joints were blunted. The wheel chain and pulley has been covered properly.

4.6) RIDERS FIELD OF VIEW:The vehicle provides a visibility range of 180 degrees to the rider,which allow the riders to be more aware of their surroundings.

4.7) SAFETY ACCESSORIES:

- **Horn**: A loud horn has been provided to TRAVOS to prevent any mishap.
- **Tail Light**: A red tail light at the rear side of TRAVOS has been provided to obtain a clear visibility of the vehicle from a distance in low light situations.
- **Head Light**: A bright white headlight has been fixed in the front of TRAVOS having a minimum visibility range of 150m in low light situations.
- **Side Reflectors**: Red reflectors have been used at the side of the fairing making it noticeable on the track.
- **Rear View Mirrors**: Two rear view mirrors have been attached to the vehicle which enables the visibility of the objects behind the vehicle.

5) AESTHETICS

TEAM KETAV has tried its best to match the standards of efficiency with the aesthetic aspect of the vehicle and it is highly credible that the team has been successful to maintain that. The aesthetic appeal of the vehicle has been enhanced by the use of a sleek fairing built with carbon fibre GSM 200 and rear view mirrors installed to maintain ease of maneuverability. The reflectors have also added to the aesthetic quotient.

6) CONCLUSION

TRAVOS has been installed with unique features that enables the cyclist to travel conveniently and securely to places. The functionality of the vehicle is multifaceted. In this era where the environment seeks urgent attention, recumbent vehicles are supposedly to set a good example towards the agenda. With rigorous testing and analysis being done, the vehicle is hence concluded to be safe and comfortable from the rider’s perspective.