

DESIGN OF THREE WHEELER VEHICLE FOR PHYSICALLY CHALLENGED PEOPLE

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Abstract

In today's world, transportation has become one of the prime requirements of people for moving self or goods from one place to another. We have even come across people travelling for more than 200 km every day for reaching their work place. Mobility has thus become an essential part of our lives with many development and improvements happening in this field. Because of the changing lifestyle of today's world, there is a huge reduction in the level of interactions within the people group. In these conditions it becomes more difficult for physically challenged people to commute and to perform their day to day activities like working, education, shopping etc. as they have to constantly depend on others for getting assistance to alight and board the vehicle. In this project, a feasible design solution in form of a user friendly three wheeler vehicle, which allows physically challenged people to commute on their own and perform their activities without anyone's assistance, has been proposed.

The activity was started with customer survey and market study. The questionnaire was framed keeping the needs of physically challenged people in mind. The major inputs received from this study were related to ingress\egress issues, ergonomics, carrying wheel chair and utility space. Considering these inputs from the survey, two concepts, namely - Chariot and Sholay, were generated. Using Pugh matrix Sholay concept was finalised for carrying out the detail design. Layout and detail design was carried using CATIA. The finalised model was analysed to validate for stiffness and Ergonomics. Ergonomics study using Jack software was carried out considering the 5th and 95th percentile manikins to take care of the ergonomic issues. On finalising the design, prototype building activity was initiated. A full scale working prototype model was manufactured for physical validation of the design function.

Outcome of this project is the solution of transport for physically challenged community using which they can commute and lead an independent and normal life.

1. INTRODUCTION

The term Disability covers impairments, activity limitations, and participation restrictions. Impairment is a problem in body function or structure. An activity limitation is a difficulty encountered by an individual in executing a task or action. However participation restriction is a problem experienced by individual involvement in life situations. Disability is caused by impairments to various subsystems of the body – these can be broadly classified under the following categories.

Any impairment which limits physical function of limbs or damage of limbs or organs is a physical disability. Mobility impairment is a category of disability that includes people with varying types of physical disabilities. This type of disability includes upper limb disability, lower limb disability, manual dexterity and disability in co-ordination with different organs of the body. Disability in mobility can either be a congenital or acquired with age problem. This problem could also be the consequence of some disease.

Physical disability is also termed as handicap, when physically challenged people come across social cultural or physical barriers which prevent their access to different system in the day to day life which are available for other common people. Thus handicap is the loss of opportunities to take part at equal level with others. One of the areas where physically challenged people lose out is transportation. Transport disability keep out current physically challenged people from all form of transport like public, private and personal transportation. These in turn limit their ability to interact with others in the society and take up jobs or business away from their home. Access to transport will give them freedom to live independent life.



Fig. 1 Difficulty faced by the physically challenged person [1]

Census 2001 has revealed that over 21million people, about 2.1% of the population, in India are suffering from one or the other kind of disability [1]. Among the total disabled in the country, 12.6 million are males and 9.3 million are females. Although the number of disabled is more in rural than urban areas, such proportions of the disabled males and females are 57-58% and 42-43% respectively. The disability rate (number of disabled per 100,000 populations) for the country as whole works out to 2130. This is 2,369 in the case of males and 1,874 in the case of females.

Table 1. Number of disabled population and the type of disability [1]

	Population	Percentage (%)
Total population	1,028,610,328	100.0
Total disabled population	21,906,769	2.1
Disability rate (per lakh population)	2,130	--
Type of Disability		
(a) Vision	10,634,881	1.0
(b) Speech	1,640,868	0.2
(c) Hearing	1,261,722	0.1
(d) Movement	6,105,477	0.6
(e) Mental	2,263,821	0.2

The disability distribution in urban and rural India is shown in Figure 2

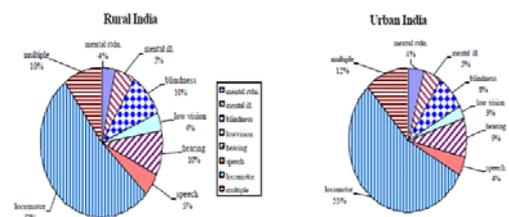


Fig. 2 Percentage distribution based on type of disability [2]

From the statistics it is evident that majority, 52% in Rural and 55% in urban area, of the physically challenged lack facility for transport. Among these are, 1217 males and 785 females per million people [2] these numbers are taken from NSS 58th rounds of survey.

For people with lower limb disability accessibility and movement from one place to another place is primary issues. Access to public areas such as city streets and public buildings and restrooms are some of the more places where physically challenged people face problem.

In recent years a noticeable changes have taken place in the society which can be seen in the form of installation of elevators, automatic doors, wide doors and corridors, transit lifts, wheelchair ramps, curb cuts, and the elimination of unnecessary steps where ramps and elevators are not available, allowing people in wheelchairs and with other mobility impairments to use public sidewalks and public transit more easily and more safely. From the above statistic lower limb disability is second higher and for them ease of transit is the demand and giving workable solution is the mail requirement.

2. CONCEPT DESIGN

In this phase information available was analysed, concepts were generated based on the requirements, and based on their merits and demerits a concept was finalised. The process can be broadly put down as given below.

- Transfer Function Generation
- Concept Generation
- Concept Finalisation

Transfer Function Generation: A transfer function describes the relationship between lower level requirements and higher level requirements for example for example Wheel chair is the function and it is higher level requirement, space for wheel chare in the vehicle, position of the wheel chair and entry of wheel chair is lower level requirements. This describes the relationship between the nominal values, and then it is called a y-hat model. If it describes the relationship between the variations, then it is called an s-hat model.

In the project the Y component which is the output measure are listed.

- Ingress / Egress
- Wheel Chair used as Vehicle seat
- Ergonomics

In the Figure 3, the equation showing the relation between output measure and the Input parameters affecting the output are listed.

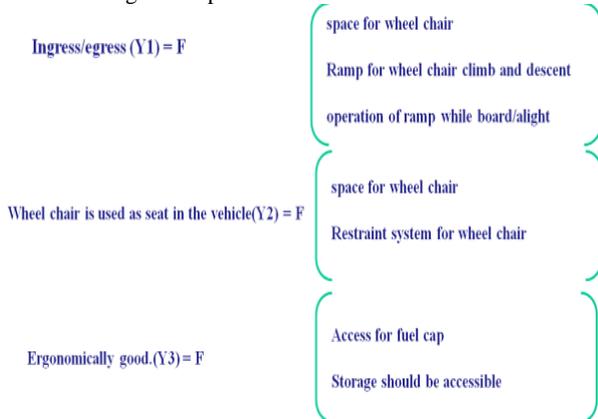


Fig. 3 Relation between our output measure and the input parameters

The above X parameters was drilled down to measurable parameters. This activity is mentioned as critical to quality flow down. The CTQ flow down chart for Y1 and Y 2 is shown below in Figure 4. In this case most of the parameters are related to the ergonomic part. Hence the digital mock up analysis will provide critical outputs.

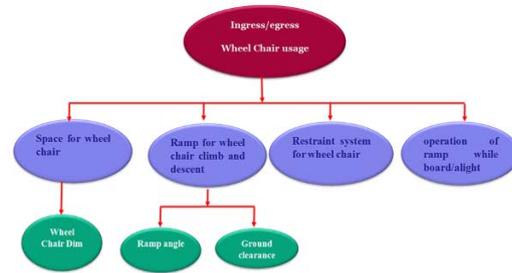


Fig. 4 CTQ Flow down

The above drilled down parameters were measured for developing the layout and detailed design. With these information concept generation phase was started

Concept Generation:In the project the ideas were generated through brainstorming and descriptive combination methods. These methods were grouped under two baskets namely

- Function Board
- Life Style Board

Function Board:The Function board mainly focuses on the functional requirements of the product. Some of the basic functions which are expected of this product are shown in Figure 5.

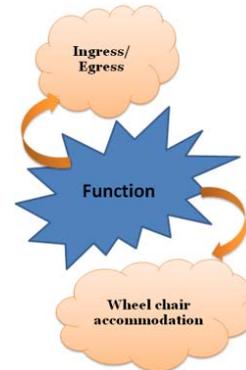


Fig. 5 Function board

Hence the concepts generated should have its main focus on the above requirements.

Life Style Board

Life style is social classification between the groups which is distinguished by the behaviour, likes and dislikes. It is important to identify life style to address the targeted group. The life style board (Figure 6) shows the group of people who are associated with this social life style. Under this life style people will fell free from physical barriers. In the images in this life style board physically challenged people are braking all the barriers and doing what they like the most, like extreme sports, long distance travelling and dancing making it clear that they want to lead a normal life like anybody else.



Fig. 6 Lifestyle Board [9]

Mood of a person mainly depends upon the life style and their activities. The mood of these adventure seekers mainly reflects thrill, victory, popularity and happiness which they get from all this.



Fig. 7 Mood Board

Since the Theme of our vehicle is "Independence " it should have some of these above mentioned characteristics like Sporty , Thrilling and Adventurous.

With the Inputs from the above Baskets as guidance the following concepts were developed.

Concept 1 - Chariot

Concept 2 - Sholay

For both the concepts, theme is considered as Adventurous and Sporty. Based on this the Two wheeler motor cycle was selected as the prime mover for the vehicle. Yamaha Gladiator motor cycle was taken for building the vehicle because of sporty looks and technical specification like button start, mileage and power.

The above concepts are explained in detail below Chariot



Fig. 8 Chariot Concept

The Chariot concept was derived for the features that are similar to that of chariots used in the olden days. The similarities are listed below.

Seating position is at the Rear Centre similar to that of Chariot,Entry to the vehicle seating is through the Rear,It has got 3 wheels - 1 in Front and 2 in Rear similar to Chariots (Horse in front and 2 wheels at Rear).The steering control is at the centre of the vehicle.

Concept One Description

In this concept the current two wheeler needs to be split into halves. The front half will be used as it is and the rear half will be modified (Figure 9) to suit the physically challenged user and his requirements.. In the rear half the chassis is converted in such a way that it can accommodate the wheel chair in the centre. The front portion of the chassis is connected to the two wheeler chassis through bolts or welding thereby forming a single structure as shown in the Figure 9.

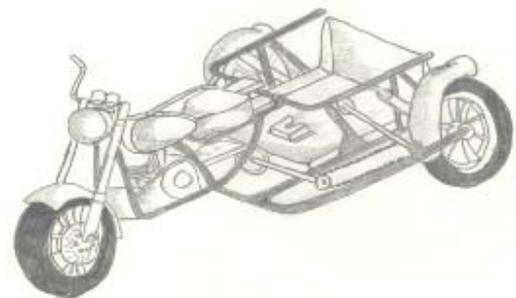


Fig. 9 Chariot concept sketch

The chassis is raised to the top to form a frame structure which acts as a protection for the user and also a support for the rear suspension system. The drive is given to both the rear wheels through gear and chain mechanism.

Over the rear chassis the floor panel is mounted. The main function of the floor panel is to provide a resting surface for the wheel chair. To the floor panel is also mounted a restrain system to lock the wheel chair. This is required to avoid relative movement of the wheel chair when the vehicle is accelerating or decelerating.

The rear of the floor has a ramp integrated in it. This ramp can be rotated about the hinge axis in line with the floor. The ramp can be opened so that the top edge of the ramp will be rested on the ground. The wheel chair will climb through this ramp on to the floor. After the wheel chair gets inside the vehicle the ramp will be rotated and closed. It will be locked in the top.

The handle of the vehicle is extended so that it can be accessed from sitting on the wheel chair. The utility box is provided in the Rear Top chassis frame.

Merit

Ride and Handling of this concept is good since the layout is balanced

De Merit

Material wastage, and hence the cost, is more as the rear structure of the bike is not used. It is also less flexible for adaptability

Sholay



Fig. 10 Sholay Concept

This concept was named after the famous Bollywood movie Sholay. In this Seating position is at the side car Entry to the vehicle seating is through the rear. It has got 3 wheels - 1 in Front and 2 in rear. The steering control is on the side car of the vehicle

Concept Two Description

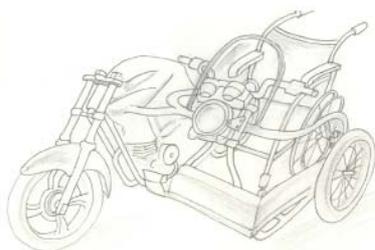


Fig. 11 Sholay concept sketch

Here two-wheeler requires minimum modification. The side car is built separately and is attached to the vehicle in the sides by bolting/welding. The side car is made in such a way that it accommodates wheel chair from rear.

The chassis construction is in such a way that on one side it will be connected to the bike and on the other side a wheel will support it. The wheel of the side car is not driven wheel and it follows the other two wheels. The chassis is raised on the top in the side car to support the suspension for the outer side. This member also serves as a protection for the customer inside the vehicle.

The floor and the ramp construction are similar to that of the chariot concept which is explained below.

Over the rear chassis the floor panel is mounted. The main function of the floor panel is to provide a resting surface for the wheel chair. The floor panel also mounts a restrain system to lock the wheel chair. This is required to avoid the relative movement of the wheel chair when the vehicle is accelerating or decelerating.

The rear of the floor has a ramp integrated in it. This ramp can be rotated about the hinge axis in line with the floor. The ramp can be opened so that the top edge of the ramp will be rested on the ground. The wheel chair will climb through this ramp on to the floor. After the wheel chair gets inside the vehicle the ramp will be rotated and closed. It will be locked in the top.

In this concept the steering handle is provided on the side car. It gives good ergonomic accessibility for the customer. The utility box is provided in the rear top chassis frame. In both the cases accessibility to the fuel cap is better.

Merit

Cost impact will be less as the unit can be separately attached to the bike, Better adaptability to other vehicles compared to the previous concept, Less work content involved.

De Merit

The ride and handling will be at a reduced level compared to the previous concept due to its offset configuration. Since we have got two proposals it is necessary to drill down to one best proposal before proceeding for the final design.

Concept Finalisation

Both the above concepts have their own merits and demerits. Hence, it is important to effectively analyze which option is the better one. To make decisions effective, one must carry out two steps Minimize the possibility of misrepresenting a solution that may be effective. Fully consider the different ramifications of a decision. To perform this activity PUGH matrix was used.

PUGH Matrix

Pugh Concept Selection is a quantitative technique used to rank the multi-dimensional options of an option set. It is frequently used in engineering for making design decisions. The advantage of the decision making matrix is that subjective opinions about one alternative versus another can be made more objective.

The decision matrix criteria's for project has been identified and listed in the PUGH table as shown below Table 2

Table 2. Pugh Matrix for Concept selection

Criteria	Concept		
	Chariot	Sholay	Remark
Ergonomics	-	+	Access for fuel cap
Adaptability	-	+	Separate Side Car
Cost	-	+	
work content	-	+	
Ride and handling	+	-	
Total (+)	1	4	
Total(-)	4	1	

From the above Table 2, following inferences were drawn

Ergonomics

Is better in Sholay concept compared to the Chariot concept because in the case of Sholay the handle is provided in the side car just where the customers seating position is.

Adaptability

Is better in Sholay concept because it doesn't require any major modification in the existing vehicle. It can be used as an add-on bolted piece in other vehicles.

Cost

The Sholay concept is better because of the modification content and the drive mechanisms. In this case there is no change in the drive mechanism for the rear wheels whereas in the Chariot concept we have to provide separate drive chain for both the rear wheels.

Work Content

Since there is no modification in the existing vehicle the Sholay concept has less work content compared to the Chariot.

Ride and Handling

In the Chariot proposal since the rear wheels are symmetrical on both sides of the vehicle and the steering control is in the centre it has much better ride and handling compared to that of the Sholay.

Based on the above ratings it can be concluded that the Sholay concept has more positives compared to that of the Chariot. Hence it was decided to proceed ahead with the Sholay concept.

3. DETAIL DESIGN

Having concluded the final selection of concepts based on the evaluation criteria, detailed product development phase was initiated.

Layout Design

The design process was started with the layout. Before detailing the features of the vehicle it was required to understand the overall packaging of the vehicle. Vehicle construction is always inside out concept. This means the vehicle is built around the systems that are packaged inside.

Here the main packaging system is the passenger along with the wheel chair. The chassis structure designed should be able to package the wheel chair and the passenger.

The next packaging system is the additional wheel and the suspension system. The wheel and the suspension system should follow the interior space requirement and should be as close to the vehicle body as possible for better stability.

The other critical factor which needs to be analysed is the ground clearance. This needs to be analysed as per the national road standards as very low clearance will lead to fouling of the vehicle with the ground leading to damage of the vehicle and discomfort to the customer. If the clearance is very high the ride and handling of the vehicle will be affected.

Along with the packaging factor ergonomic requirements of the customer will also need to be

considered. There are 2 critical regions where the ergonomics needs to be considered.

1. Ramp Angle

2. Fuel cap access

Ramp angle needs to be decided for ease of use and better comfort. High ramp angle will lead to higher effort exerted by the user while climbing the ramp.

Fuel lid position should be in such a position where user can easily access without getting down of the vehicle. A block representation of the layout is shown in Figure 12.

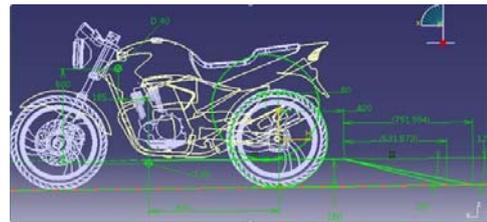


Fig. 12 Gladiator vehicle layout

The above diagrams cover the required dimensions for the vehicle layout. After completion of the Layout design DFMEA was conducted

Detailed Design

The detailed design phase started with master section generation. Before creating the concept surfaces it was required to confirm on the layout dimensions. The master section is the tool which is used to perform this activity.

Master section is a 2D section showing all the interface systems and the required interactions with the systems. Interactions here refer to the mounting and the clearance requirements.

Master sections define the section dimensions of any particular region. The master sections are generated at all the critical zones of the vehicle. This is done so that the schemes and the joineries are well defined before the start of the surface generation. Since it will be time consuming if we need to work on the 3D surfaces during this feasibility phase. The location where all sections needs to be generated is decided by the designer depending upon the vehicle configuration.

In project the sections were worked out on all critical joineries. Images of some of the master sections created for this project are shown in Figure 13. Once the Master sections were generated the next step was to build up on the CAD surface based on the schemes and joineries decided upon. During this phase the interaction with all the other agencies like manufacturing, CAE were initiated. This was done so that the modifications after completion of the design can be reduced.

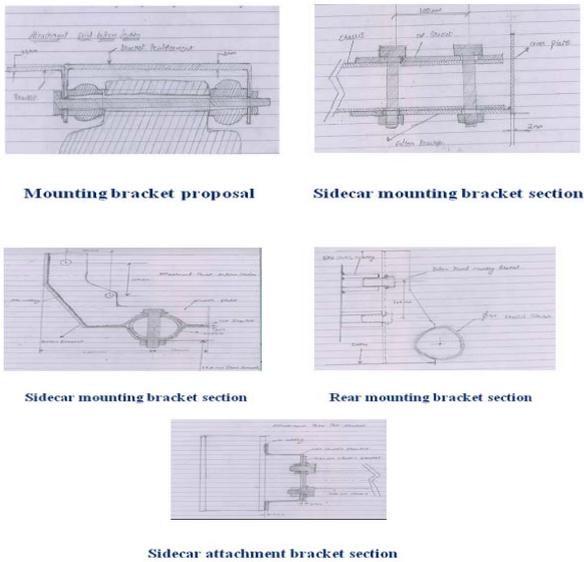


Fig. 13 Master Sections

Based on the concepts that has been finalised upon the design process was started. The requirement here is to provide a mounting frame for the following systems

- Wheel Chair
- Passenger
- Wheel
- Handle
- Suspension

Also this frame needs to be mounted on to the vehicle base (Bike chassis) the space frame concept seemed to be the best fit for this kind of vehicle requirement because

- It has minimum material requirement
- It has better structural behaviour
- There is no mass production requirement

Based on the above points it was decided to proceed ahead with the space frame concept. In the case of space frame choice of cross-section of the tubes used in frame is an important decision as it affects manufacturing, cost, weight and structural behaviour.

The sections which are readily available for space frame in market were considered. The sections considered for the design were

- Hexagonal
- Rectangular
- Circular

All the 3 sections were analysed for the above mentioned criteria's. The results are displayed in the Table 3 below.

Table 3. Section matrix

Geometry	Area	section modulus	Manufacturing feasibility	Material availability
	93.005885	898.4974636	NOT GOOD	NOT GOOD
	1152	8941.75319	NOT GOOD	AVAILABLE
	146.2729	1378.14252	GOOD	AVAILABLE

After the study of the above table the decision was taken to go ahead with the circular section. This is because even though the tubes structural behaviour is less compared to other sections its manufacturability is much better. The structural part can be stiffen by addition of further materials. But the manufacturability is also critical in this case. Hence, more weightage is given for the manufacturability and the decision has been taken accordingly.

Once the section was decided the CAD modelling was initiated. The stages of development of the model are shown in Figure 14.

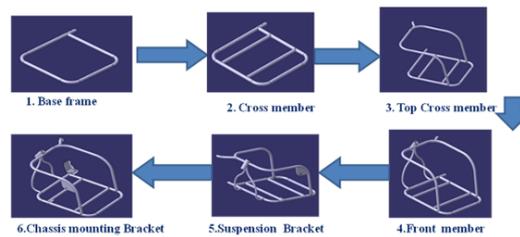


Fig. 11 Step by step procedure of model development

1. The design was started from the base of the frame. This envelops the complete resting region required for the wheel chair along with the mounting arrangement to the vehicle.

2. The second step was to generate the in between connecting members for stiffening of the base frame and also the provide a mounting for the floor panel and thereby for the resting of the wheel chair

3. The next step was to create the top member which has a mounting with the vehicle on one side and having the steering arrangement in the front.

4. After raising up the Top frame the Front member is provided. This member is added as a support for the Top frame and also plays a role in the mounting of the Handle and other units

5. On completion of the Front member the focus is shifted to the suspension bracket. It is on this member the top end of the suspension is connected to. This member is a Load carrier.

6. The final structure to complete is the Frame is the connecting bracket. This is bracket through which the frame is connected to the Vehicle.

Once the chassis design is completed the Design of Floor panel was initiated. The floor panel performs the role of the cover part of the chassis on which the Wheel chair will be resting. Since the wheel chair load is directly on to the floor in addition to providing the support, Floor here acts as a load carrying member also. It should be stiff enough to withstand the accelerated durability loads of the wheel chair along with the passenger.

On completion of the Floor panel design it was essential to work out the ramp structure. This ramp structure is required for taking the wheel chair inside and outside of the vehicle, though it doesn't undergo dynamic loads like floor. It his panel should be strong enough to withstand the static load of the wheel chair along with the passenger.

Now the basic chassis and the panel structure was completed. It was time to work on the mechanism for the ramp so that it can be opened and closed for the wheel chair entry and exit.

The ramp mechanism should be in such a way that the customer should be able to operate it from the outside while boarding. After boarding the customer should be able to close the ramp without much effort - all this while sitting in a wheel chair. The same should happen for getting out of the vehicle also.

One more critical mechanism is the restrain for the wheel chair in the vehicle. Since there is no positive mounting of the wheel chair on the floor there should be a proper restrain mechanism to lock the wheel chair in its position. The main function of this mechanism is to prevent the relative movement of the wheel chair and the vehicle during travelling.

Once the mechanism design is completed the efforts need to shift towards the steering support member. The function of the steering support member is to connect the handle from the side car to the Front wheel of the main vehicle.

Along with this packaging of the handle, head lamp and other electronic units like odometer, speedometer, fuel indicator etc.will need to be considered the

CAE

On completion of the design it was necessary to analyse the structural behavior of the system. For this virtual validation was used. The design verification plan for the same was derived during the DFMEA process. This was derived considering the Real World Usage Profile of the vehicle (RWUP).

The load case was defined as 843 N X 3 times the gravitational load of the complete system. This Load is applied on the resting points of the wheel chair

The boundary conditions were the vehicle fixing points, wheel and suspension fixing points. The material considered for the pipe was ERWI G000157 with a thickness of 1 mm. The yield strength for this material is 170 MPa.

Acceptance criteria used was stress < Yield strength (170 MPA), Deflection <=1.5 mm

Figure 15 shows the CAE model of the system.

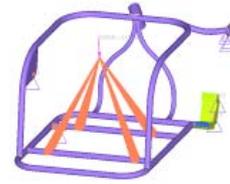


Fig. 12 CAE for base model

The analysis for the above model was performed. Results are displayed in Figure 16

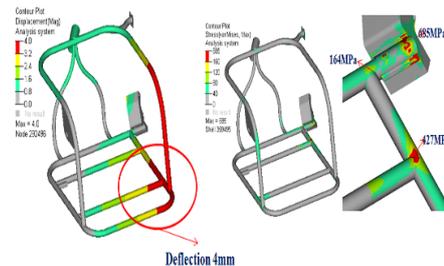


Fig. 13 CAE Results

It can be noted the analysis results are not on the favourable side. The deflection values are on higher side at 4 mm and there is lot of region where the stress is more than the yield strength of the material.

For improving the situation an additional mounting with the vehicle was given (Figure 17).

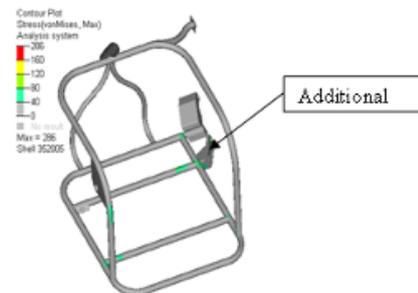


Fig. 14 Additional Mounting Bracket

With this additional bracket the analysis was performed again. This time the results were much better (Figure 18).

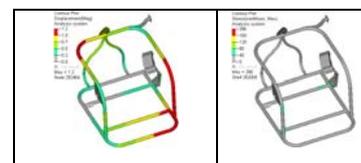


Fig. 15 CAE results for the modified frame design

The deflection drastically reduced from 4 mm to 1.2 mm. Also the high stress zones are significantly reduced. For further improvement in the results once more iteration is performed with the increase thickness of the bracket.

The bracket thickness has been increased from 1 mm to 2 mm. Below Figure 19 are the results for the same.

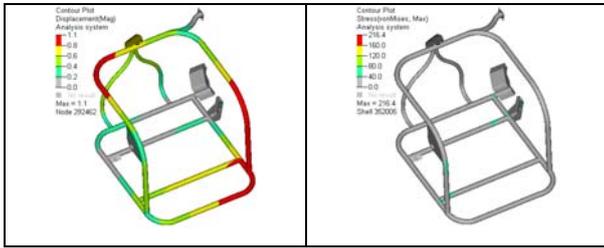


Fig. 16 CAE Result for 2 mm thick bracket

It can be seen from the results that there is no significant change in the deflection which has been dropped down to 1.1 mm from 1.2 mm. But the stress is completely under the Yield strength zone. Hence the structural part is concluded with this option.

Ergonomic Study

One of the critical requirements of this vehicle is ergonomics as derived from VOC. Hence the Ergonomic study is equally essential to that of the Structural study.

Ergonomics is the science or occupation that applies theories, principles, data and methods to product design, with the goal to optimise user comfort, health and safety, as well as overall system performance.

For performing this study Digital Mock up software and its template manikins is used. The Figure 20 showing the ergonomic accessibility study of the utilities in the vehicle by the customer sitting on the wheel chair.

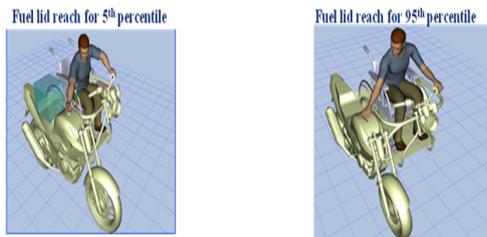


Fig. 20 Ergonomic Accessibility study

The above study shows the fuel lid accessibility for users from 5th and 95th percentile groups.



Fig. 21 Study of handle reach

Figure 21 shows the study for the handle reach of the customer from the wheel chair.

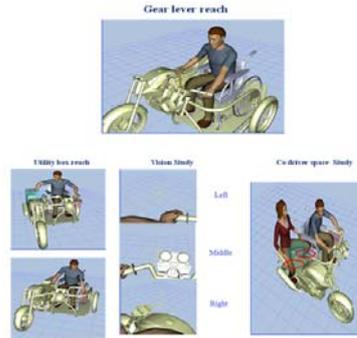


Fig. 22 Ergonomic condition of customer

Figure 22 shows various studies done on the designed vehicle to check the ergonomic condition of the customer.

As seen above, all the ergonomic requirements were comfortably met with this design.

Improvements

All the above improvements which were suggested by different agencies like CAE, manufacturability and the ergonomic study were implemented in the CAD design.

With all these inputs the final design looks like the vehicle shown in the Figure 23.



Fig. 23 CAD design

Table 4. Bill of Material

BOM weight			
SL.No	Part Name	thickness	weight in Kg
1	Chassis Frame	1.2mm	11.8
2	Front bracket	2mm	0.99
3	Rear bracket	2mm	0.56
4	Floor	1mm	7.6
5	Swing arm	1.5mm	0.67
6	Ramp	1mm	4
TOTAL			25.62
Storage space			18Ltr

A bill of material was generated for the data so that it can be sent to manufacturing agency for prototype build. Entire sidecar was dismantled in six different parts (Table 4).The final design was taken up for prototype build in the control stage.

4. REFERENCES

- [1] Office of the Registrar General and Census Commissioner, India
- [2] Dr. Jose Murickan S.J., M.A.Ph.D. Georgekutty Kareparampil M.A., Persons With Disabilities In Society, Kerala Federation , 1995
- [3] Taken from Agile Buddha
<http://www.agilebuddha.com/agile/faster-time-to-market-or-lower-cost-of-development-is-a-delighter-anymore/>
- [4] Bike India volume 7 issue 11 June2012 Magazine
- [5] http://suntran.com/pop_access_measurements.htm
- [6] Alivin R. Tiller, Henry Dreyfuss Associates, The Measure of Man and Woman Details?? Publisher? Year?
- [7] Transport for all's photo stream
<http://www.flickr.com/photos/62704958@N05/sets/72157630208155358/with/7408075292/>
- [8] <http://theclevermonkey.blogspot.in/2011/07/black-widow-gets-side-car.html>
- [9] <http://mech.utah.edu/blog/unique-mobility-products-enhance-lives-of-physically-disabled/>