

Tricycle for Paraplegic

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Acknowledgement

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I would also like to express my sincere gratitude to the Institute and Design centre for helping me with the environment to learn from and providing with workshops and other facilities to help accomplish my tasks. I also would like to thank all my fellow classmates for their tremendous support throughout the project.

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Date: 7th July, 2013

Place: IDC, IIT Bombay

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Mobility & Vehicle Design

Certification

This dissertation entitled **Design of Tricycle for Paraplegic** by **Unni Mohan M** is approved as Summer Internship Training (Project 1) for the degree M.Des (Mobility & Vehicle Design).

Examiners:

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Chairman:

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Place: IDC, IIT-Bombay

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Introduction

The project idea was suggested by Prof Nishant Sharma. Professor had previously used a standard tricycle. This experience of using trike ,had encouraged him to come up with a design project for providing a better designed product for paraplegic .Quick research through the market reveled that model which are available have similar layout and found to be less involving to use.

Tricycles from India

Examples from India



Observations from existing tricycle

No space for storage of crutches and luggage

No lock/handbrakes (for slopes) in present model.

No clutch in many samples to allow reversing. Observed free wheeling problem

No mechanical advantage, lack of gears.

Design itself has become an identity of helplessness

quoted by Devanuj IDC

User Study

To gain better understanding and sensitivity about the project we visited paraplegic foundation in Sion.



Observations on standard tricycle



Transfer is a major/prime problem.

Huge height difference between tricycle and wheelchair

Bell to be rethought.

No designated footrest

Assistive rings to rear wheels since most of the day use wheelchairs

Detailed observations from videos captured on transfer and mobility

Transfer

- Frame members are used for support while transfer
- Right hand kept on seat for lifting body and support, some means of holding can be thought of like a bar in front of seat
- Distance between two seats a concern
- Left hand kept on mudguard for support while transfer.
- Cloth interference during transfer.

•Mobility

- Unlocking wheelchair after settling in the trike
- Pushing the wheel chair from trike
- Both hands are used for getting tricycle moving , lack of mechanical advantage.
- Pedal height is a problem with short people giving them awkward postures while pedaling and steering
- Bending of body when turning the tricycle while pedaling
- Left hand fingers are used to rotate tyre by pushing spokes just like wheel chair

Studies on standard Tricycle

Transfer from wheelchair to tricycle



Body storming was done to analyze transfer from wheel chair to tricycle

- Pulling up the body while transfer was found to be convenient
- Wheel chair and tricycle proximity helps in a confident transfer
- Both Tricycle and wheel chair movement to be arrested while transfer
- Legs should not get trapped between wheelchair and Tricycle

Study of standard trike for storage



Storage space and accessibility of existing trike was studied. A case of transport of a regular sized wheel chair was also considered.

The width was not sufficient and also loading bay is about 33cm from ground.

Study of roof height

-protection from rain and also visibility



This exercise was to understand the feel of volume and height.

Protection from rain with side wind and also visibility was taken into consideration

Ergonomics

An experiment was conducted on the standard tricycle for finding the force applied in Kg at four different positions of pedal.

Male/Female	Specimen	Top	Low	Far	Near
Male	1	13	13.5	16	8
	2	16	11	12	12.5
	3	17.5	18	14	20
	4	16	11	15	15
Average		15.625	13.375	14.25	13.875
Female	1	12.5	9	10	12
	2	11	13	10	10
	3	11	9	7.5	12
	4	10	9	8	10.5
	5	10	9	9	6
Average		10.9	9.8	8.9	10.1

Calculated values of the force at different positions.

Male/Female	Specimen	Top	Low	Far
Male	1	16	12.5	24
	2	28	15	18
	3	27	25	25
	4	27.5	17.5	29

Maximum strength data.

For designing purpose taking 30 % of 5th percentile strength data is referred.

STRENGTH	GENDER	HAND	MEAN (N)	5 TH PERCENTILE (N)	95 TH PERCENTILE (N)
PUSH STRENGTH	MALE	RIGHT HAND	77	49	106
		LEFT HAND	74	46	101
	FEMALE	RIGHT HAND	62	31	98
		LEFT HAND	58	27	88
PULL STRENGTH	MALE	RIGHT HAND	92	60	123
		LEFT HAND	88	56	119
	FEMALE	RIGHT HAND	71	41	101
		LEFT HAND	68	37	98
LEG STRENGTH	MALE	RIGHT LEG	429	261	598
		LEFT LEG	425	247	604
	FEMALE	RIGHT LEG	319	172	466
		LEFT LEG	304	164	444
FOOT STRENGTH	MALE	RIGHT FOOT	332	163	501
		LEFT FOOT	308	151	464
	FEMALE	RIGHT FOOT	242	101	382
		LEFT FOOT	226	94	358

Source : Anthropometric&StrengthData of Indian Agricultural workers for
Farm Equipment Design
By L. P. Gite

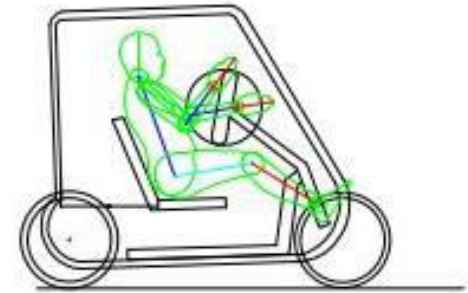
Space available for pedal rotation

5th percentile

50th percentile

95th percentile

Thigh angle 10 degree



Thigh angle 5 degrees



Optimum area available for pedal rotation is the circle with 350mm diameter.

Seat travel has been found out to be 40mm.

Seat height is fixed at 485mm

Workshop-Brainstorming



A workshop was organized to discuss over the observations till date and to brainstorm on various aspects of design like frame, geometry, materials, features, ergonomic, aesthetic, manufacturability, safety, protection, drive, braking, steering and storage.

Data came out the session where grouped. The data was used to come up with design directions.

Compiled data from workshop

Frame And Geometry		Material	Features
Geometry of Trike	Less Adjustability- Rigid Design	Lightweight	Stackability (Parking)
	Narrow Footprint: Elevator friendly, Local train Friendly,	FRP	Vehicle can be pulled
Proper ground clearnace	Indoor Usage	Sheet Metal	Locking System
CoG position	Sleek Design	Rust Proof	Vandal Proof
Single frame body (Monocoque)	Indoor Usage	Aluminium Rims	Repairing/Puncturing Kit
Topple Proof	Variable Wheelbase		
Collapsible Frame	Independent Suspension: Shock+Rigid Members		
Anti Skid	Sliding footrest to accommodate wheelchair		
Wheelchair to trike convertible	Longivity		
Brake Energy Regeneration	All terrain: Good grip tires		
Brake Interlock with Crutches			
Elevator Friendly			

Vehicle Configurability

Mobile Commerce Vehicle
Extended use of tricycle
e.g. Agriculture

Safety and Protection

Emergency Brake
Protection form hot sun rays (seat)
Avoid Splashes
Locking of with wheelchair
Hazard Indication
Indicator for night
Protection from side splash
Clothing protection from moving trike
Covering of moving parts

Aesthetics

Compelling option
Standout in traffic

Manufacturability

Easy to repair

Hood

Inflatable Roof
Foldable hood
Sun guard
rain protection
dust protection
solar panels on top (eco friendly)
vipers action integration

Vehicle Body Protection

Side protection to rear wheel
Protection from front

Ergonomics

Human Body and Comfort

Reduction of body twist during turns

Arm support

Two seating postures

Fatigue resistant in pedalling and sitting

Brake lever position

Pedal and brake at nearest position

Customisable features

Seat cushion angle

Intuitive design

Proper back rest angle

Padding for leg protection

Phycological aspects

Belt to attach to seat

Bell operation

Proper foot rest design

Adjustable foot rest

Head rest

Pedal

Pedal holding problem

Variable pedal length

Pedal orientation

Ergonomic position of crank wheel and brake

Diameter of handle and padding

Bell position

Visibility

Rear visibility

Proper visibility

Flouracent strips

Seat

Seat as shock absorber

Ergonomic structure

Landing gear type seat
Adjustable or rotary seats

Seat rest hinged

Cross legs when seat is high

Inflatable seats

Continous support from back rest

Knees cannot go above pelvic height

Elbow clearance

Consider about Male or Female

Age variation

Protection from side wheels

Transfer

Ingress and egress

Body of trike aiding in holding

Both side access
Ease of transfer

Handle support for standing and climbing

Rear sliding mechanism

Sliding foot rest to accommodate wheel chair

Protection form side wheels

Handle for additional support

Crutches as key to trike

Drive

- Multiple gearing
- Proper mechanical advantage
- Additional drive assist for slopes
- Variable speeds
- Straight line stability
- Differential
- Front or rear wheel drive?
- Possibility of locking in slopes
- Reversible trike
- Use of simple machines
- Rings in wheels
- Handle can be locked

Braking

- Emergency Braking

Steering

- Turning circle radius
- Optimum rake and trails
- Circular steering wheel
- Extreme steering and cranking
- Discrete steer and handling
- Adjustable pedal(Horizontal - Vertical)
- Less steering effort

Storage

- Crutch storage
- Water storage
- Luggage storage
- Possibility of carrying passenger
- Emergency stuff storage
- Wheel chair storage
- First aid kit

Design Directions

1. Providing a new identity for mobility
2. Light weight and a compelling option
3. Ease of transfer form wheelchair ,crutches ,low height mobility devices .
4. Proper mechanical advantage.
5. Comfortable enough for long hours.
6. Access of all controls without shifting hands from pedal
7. Options for changing orientation of pedals.
8. Interlock for brake when not in use or transfer
9. Terrain and indoor friendly design
10. Protection form rain and sun.
11. Options of multiple drives

Ideations with wire frame

Model -1



Features:

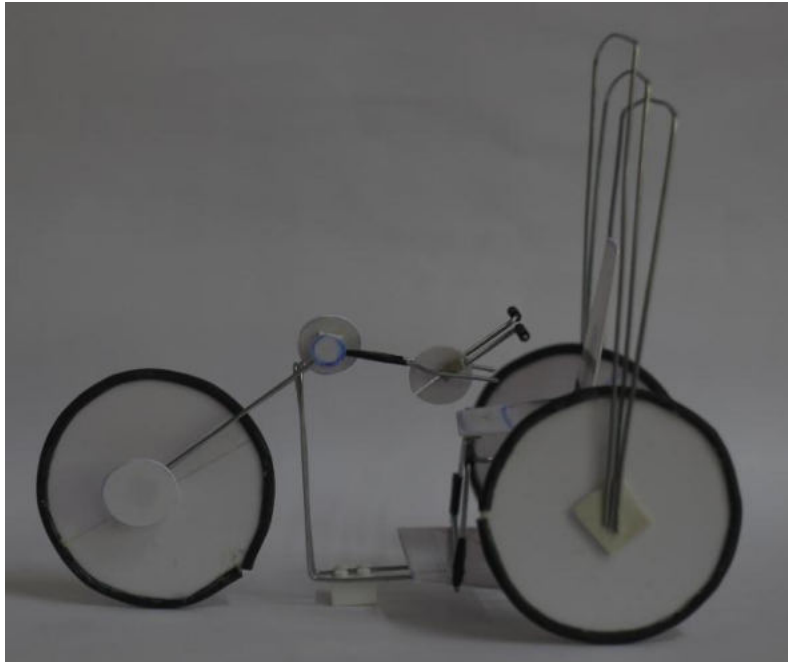
1. Hood/Roof
2. Front Wheel Traction
3. Crutch Space
4. Luggage Space
5. Spring Action below seat



Suggestions:

1. Ease Side Access to seat
2. Use smaller front wheel
3. Increase Luggage Space
4. Look for lighter roof
5. Get better foot rest

Model -2



Features:

1. Foldable Hood
2. Sliding foot rest so that empty space can be utilized for wheelchair ingress.



Suggestions/Improvements:

1. Lower rake angle
2. Try continuous body
3. Side ingress.

Model -3



Features:

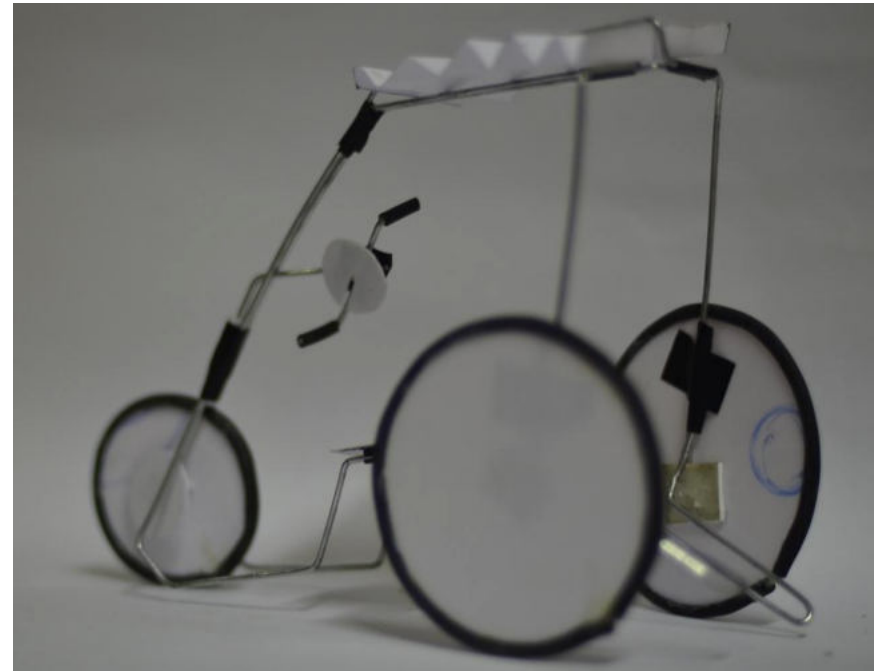
1. Continuous body
2. Low Rake angle
3. Side ingress space
4. 40-60 distribution for better traction



Suggestions/Improvements:

1. Inculcate seat too in single frame body
2. Smaller front tire
3. Light roof solutions-Inspire from raft.
4. Lower seat height
5. Rear sliding action for egress
6. Luggage Space

Model -4



Features:

1. Foldable roof
2. Provision for sliding of seat to rear

Model -5



Drive Concepts

Inputs for drive concepts-

Layouts for drive concepts-

Front wheel drive and steer-

Drive unit becomes compact and confined to front only

Rear can be provided with simple independent suspension

Rear wheel drive front wheel steer

Better traction on slopes

Chain running from front to rear without twisting while steer,
floor board are is affected

Need of a differential box at rear,

Actions for drive-

Pedal

Rowing

Combination of above two

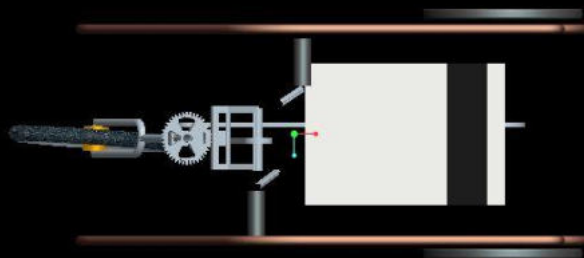
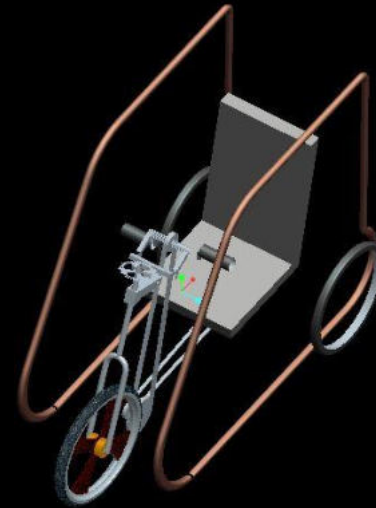
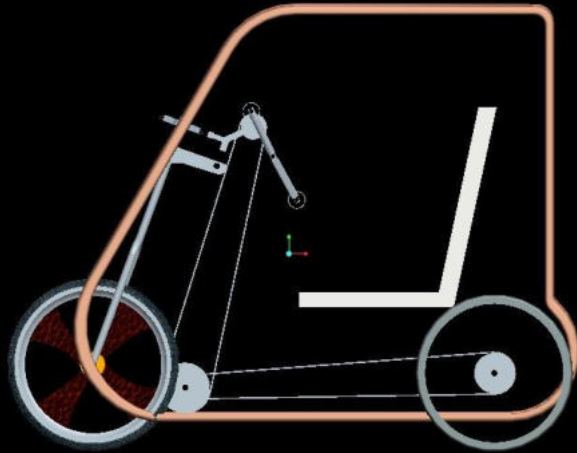
Types of Steer-

Rotating

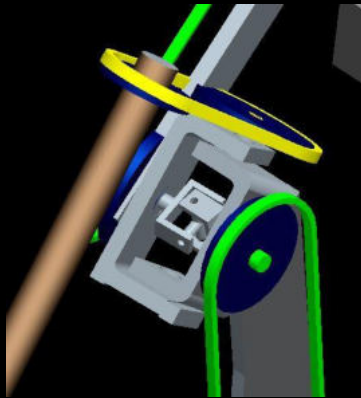
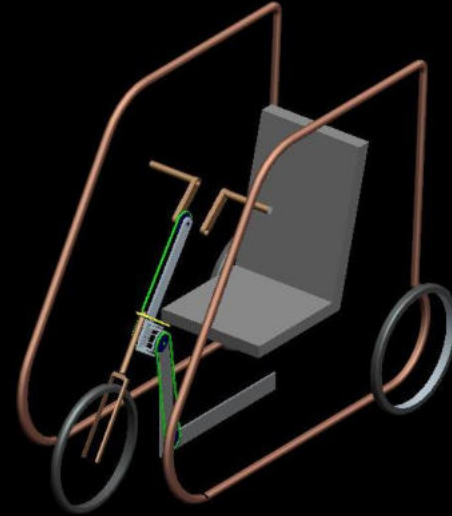
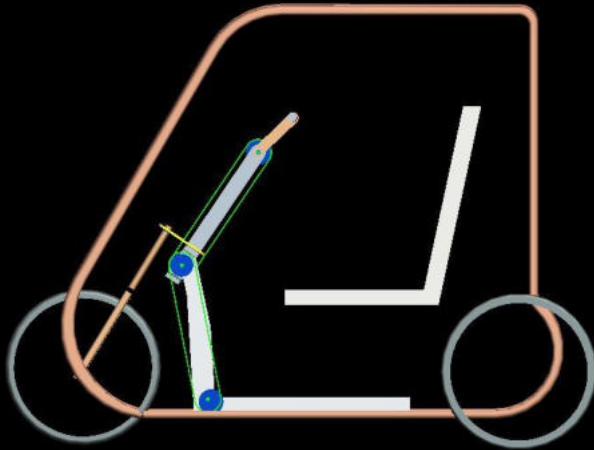
Tilting

Sliding-(rack and pinion)

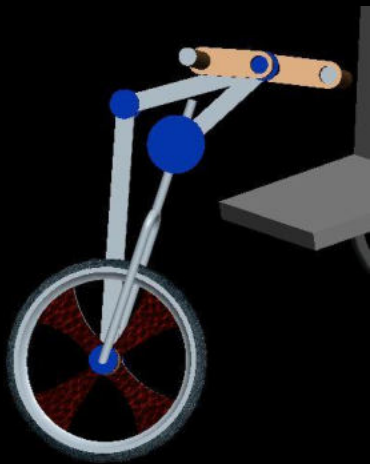
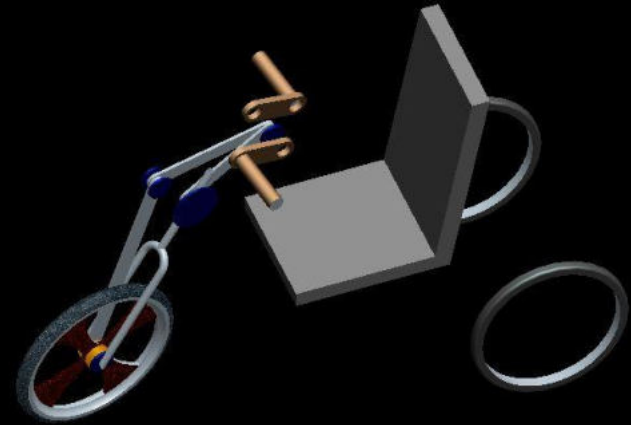
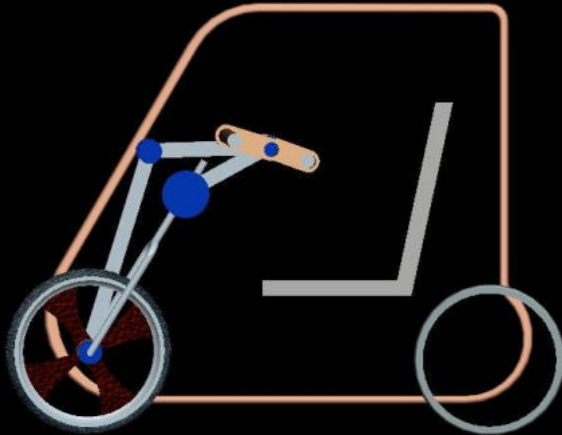
Concept-1



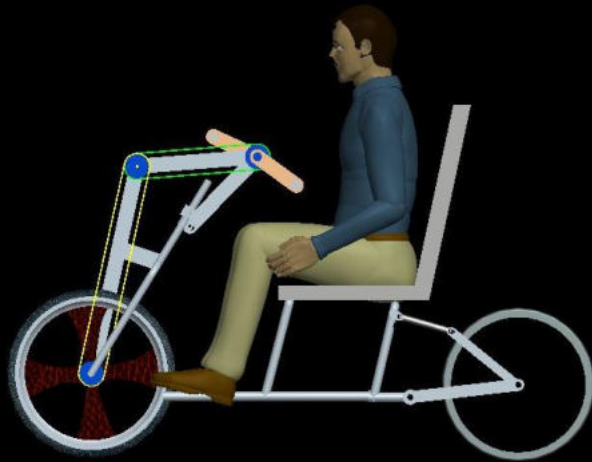
- Front steer , Rear drive
- Steering-sliding (rack and pinion)
- Pedal for cycling



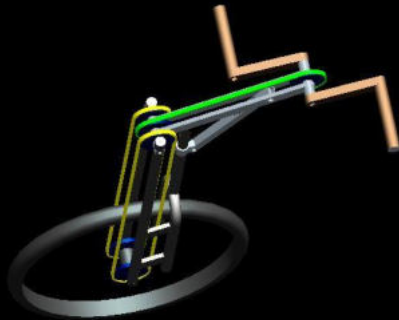
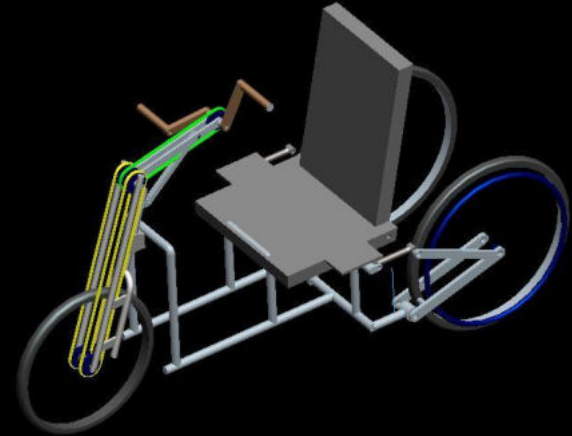
- Front steer , Rear drive
- Steering-Rotary with universal box
- 75 degree angle for steering-direct
- Steering angle increased by additional chain drive



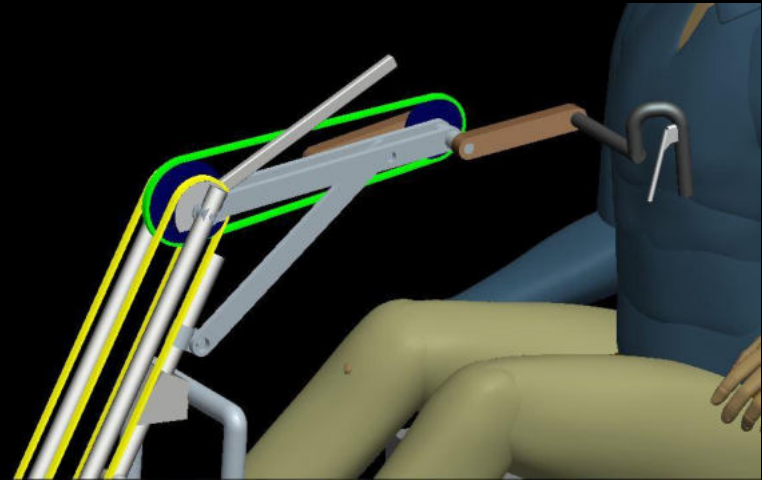
- Front steer , Front drive
- Steering-Rotary and Direct
- Both pedal and rowing action
- Pedal for regular terrain
- Rowing for elevation-better torque.
- Pedal assembly is used for rowing



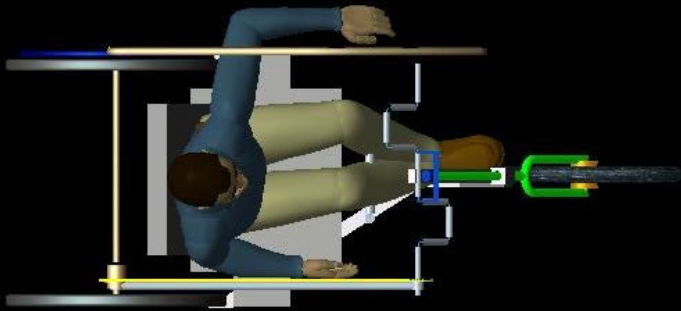
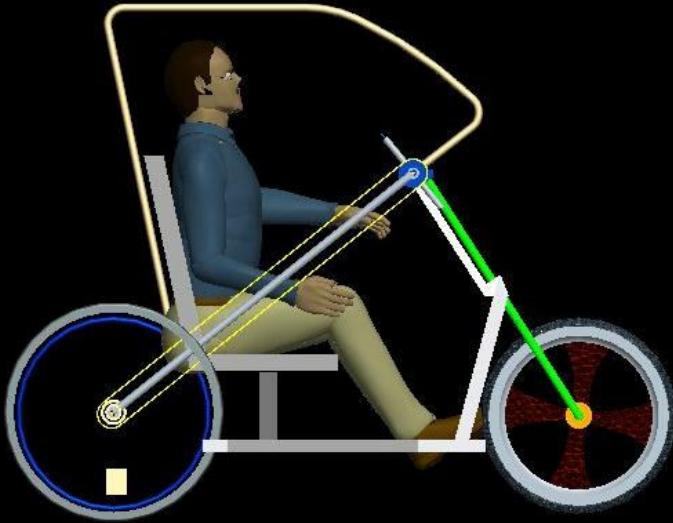
- Front steer , Front drive
- Rowing has better leverage by shifting the assembly to front.



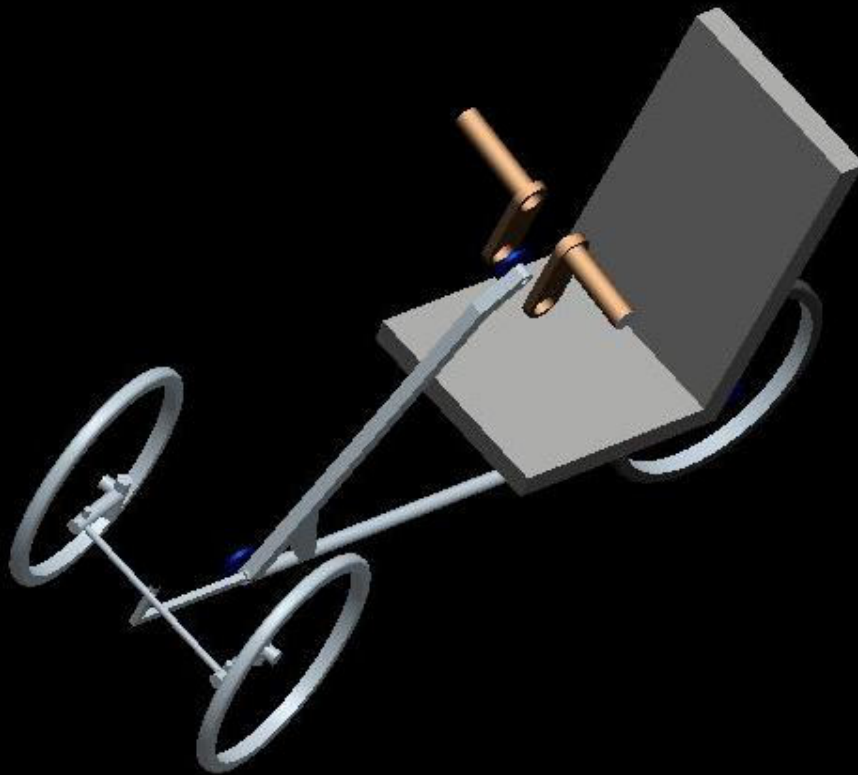
- Front steer , Front drive
- Assembly made compact by working on reducing rake .



- Front steer , Front drive
- Separate lever for rowing.
- Handle designed to be vertically held



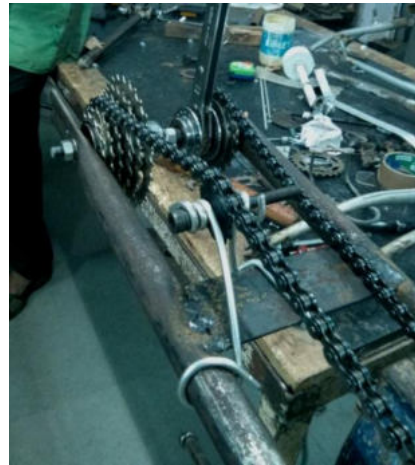
- Front steer , Rear drive
- Sliding steering action
- Pedal action for drive
- Chain taken from one side for simplicity and efficiency.
- Only one side entry



- Front steer , Rear drive
- Tilting action for steering
- Pedal action for drive
- Chain taken through the centre.

Prototype

Exploration of concept -3 by prototyping





Concept 3 proto-1



Features

Two drive modes

1. Pedal for cycling-regular terrain
2. Rowing lever for higher torque-elevations and small steps



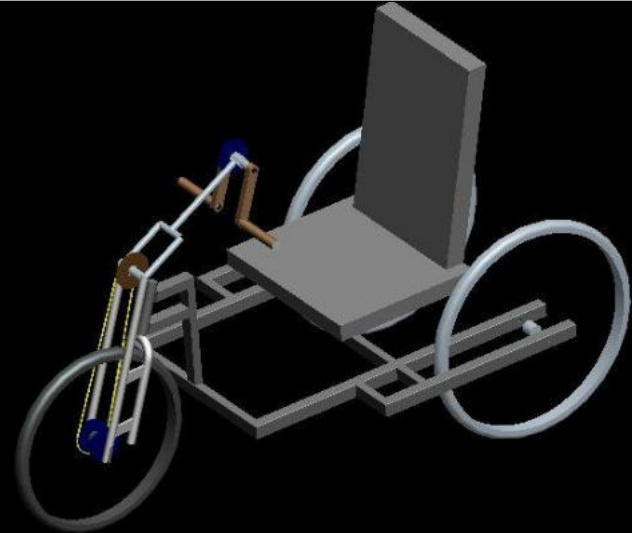
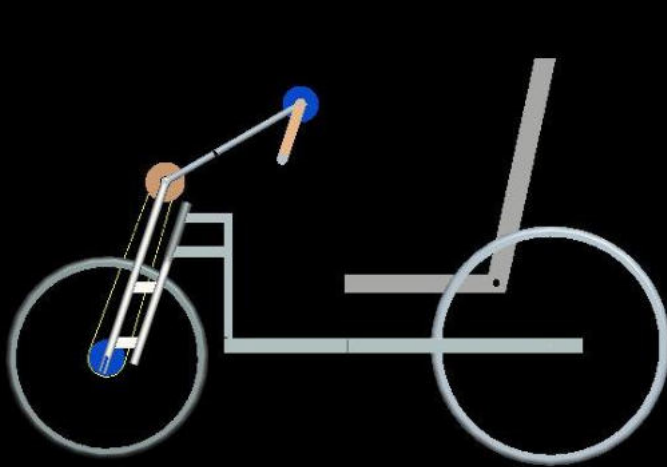
- Ground clearance is high at 30cm for the sake of easy manufacturability of prototype

Observations

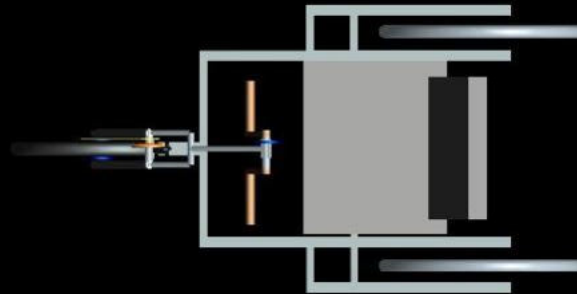
- Position of pedals at nearest and farthest positions from body was found to be comfortable
- Rear wheel rings are accessible for rear movement



- Large rake and trail gave the tricycle side way pull , difficulty in bringing back handle to centre after a turn.
- Mechanical advantage of pedal at 1.2 was not sufficient to pull tricycle on the slope in front of IDC.
- Rowing action had enough torque to climb slopes with self locking to prevent reverse while on gradient.
- Rear track width at 780 found to be stable enough during test ride



Feed backs from prototye-1 for rake and trail is taken care
Trailing part is retained , Pedal positions are retained

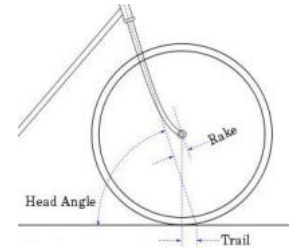


Concept 3 proto-2



Rowing action has been discarded by adding a gear system for providing mechanical advantages of 1.8, 1.5 and 1.2

Trail has been kept to minimum value .

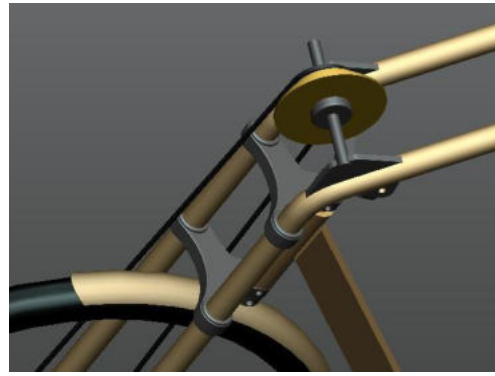
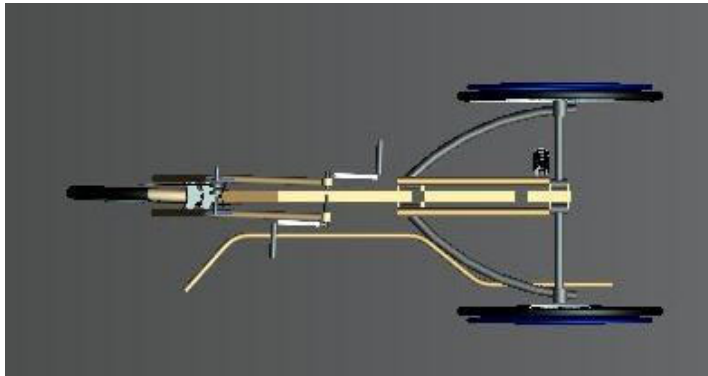
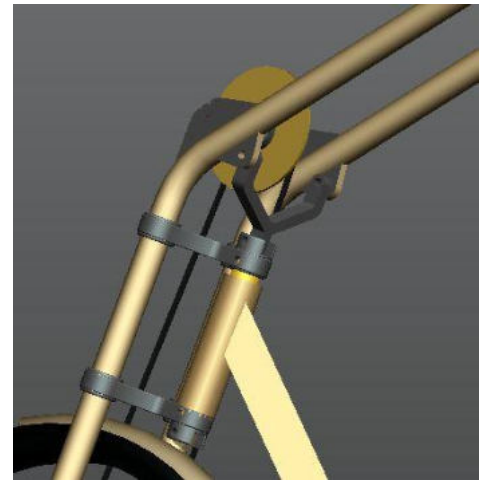
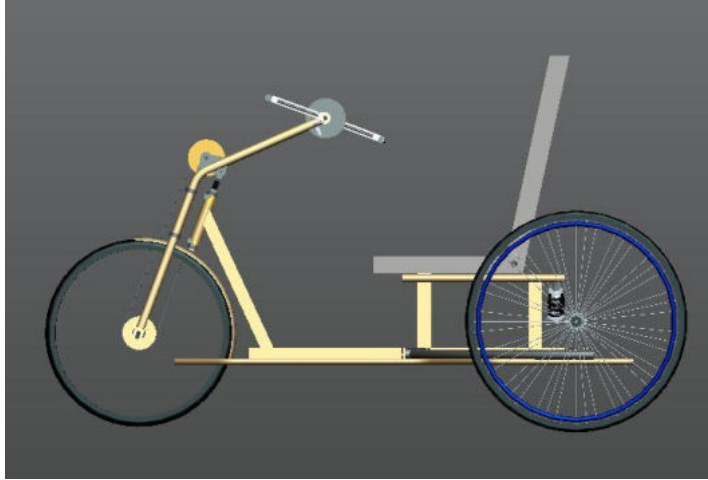


Handling was found to have improved with the elimination of side pull while turning.

With the introduction of gears tricycle performed satisfactorily on level surfaces and on slopes

Maximum speed was found to be near to jogging speed.

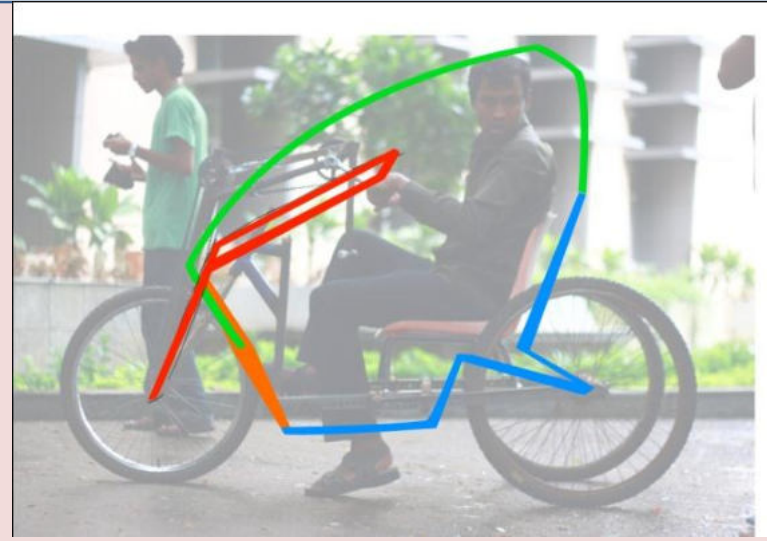
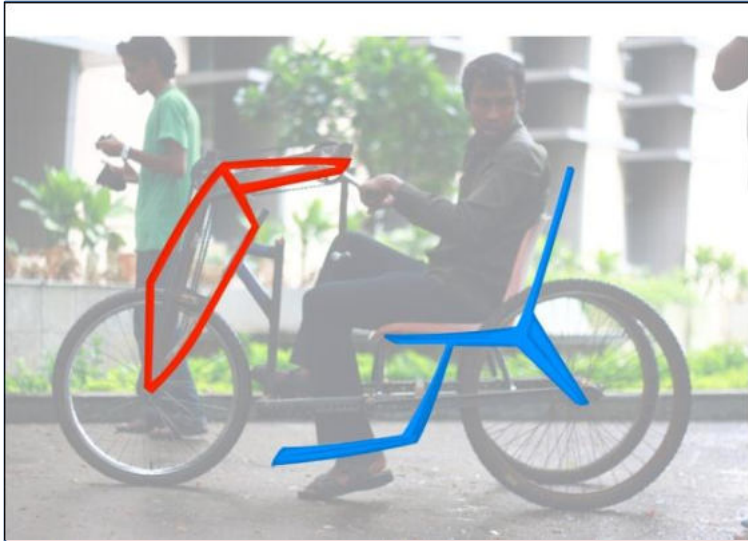


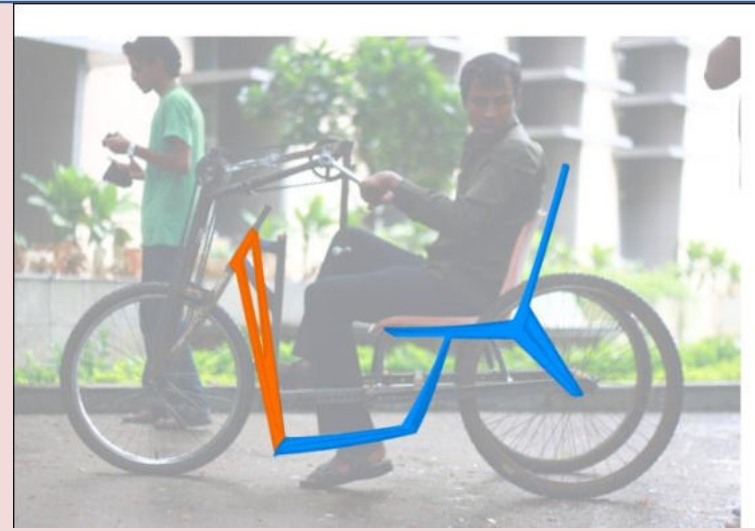
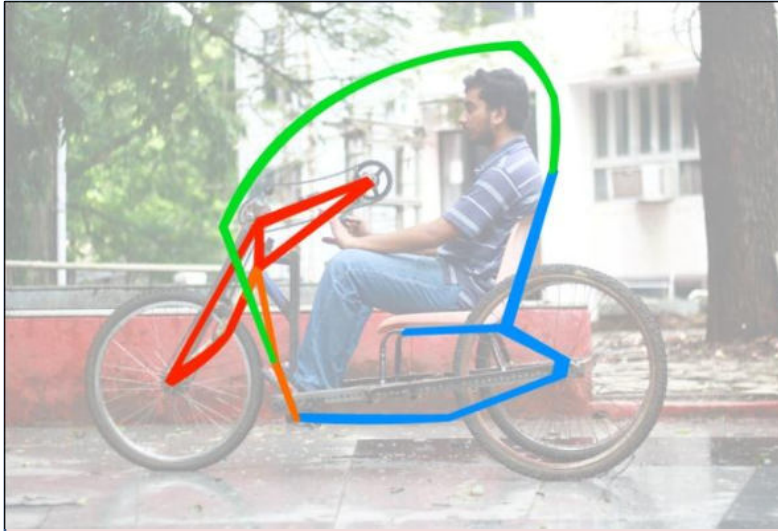


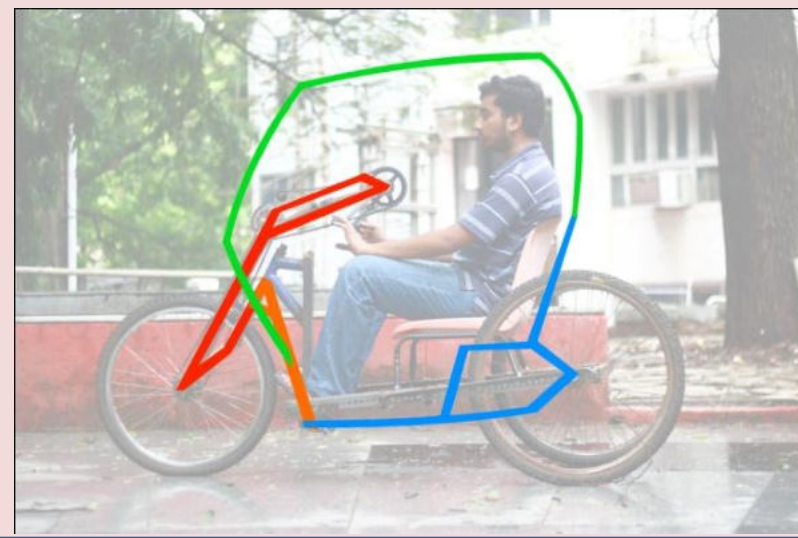
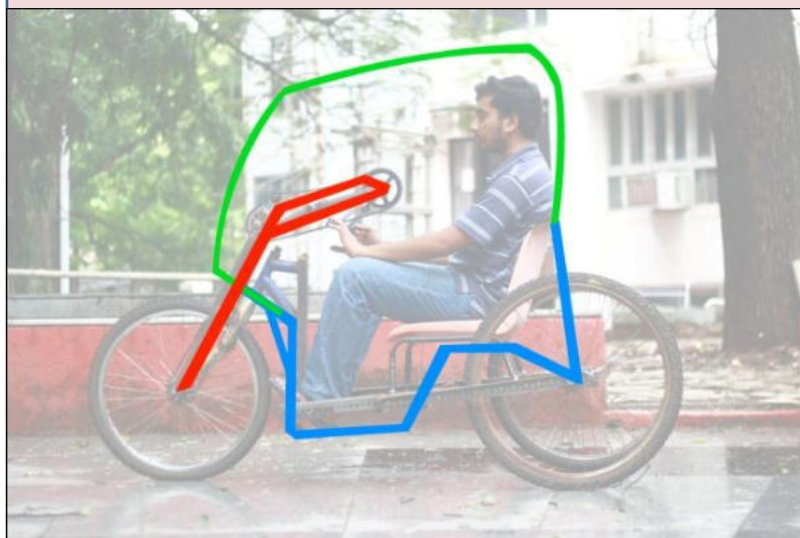
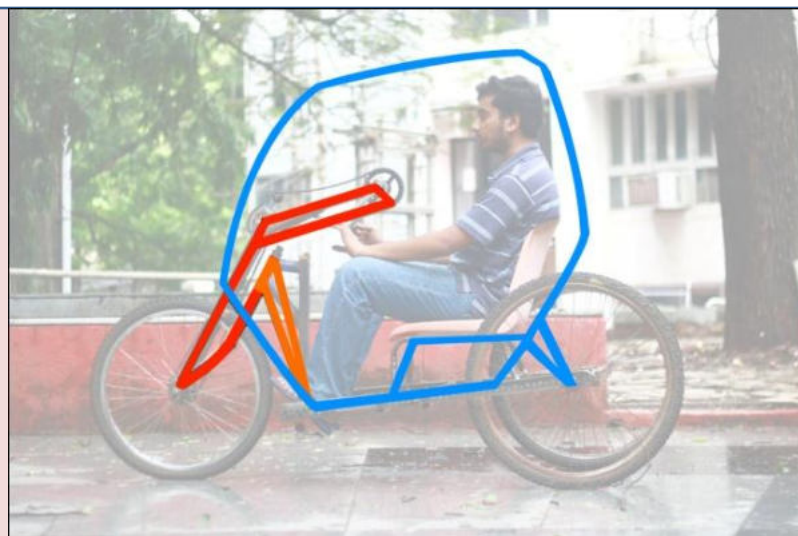
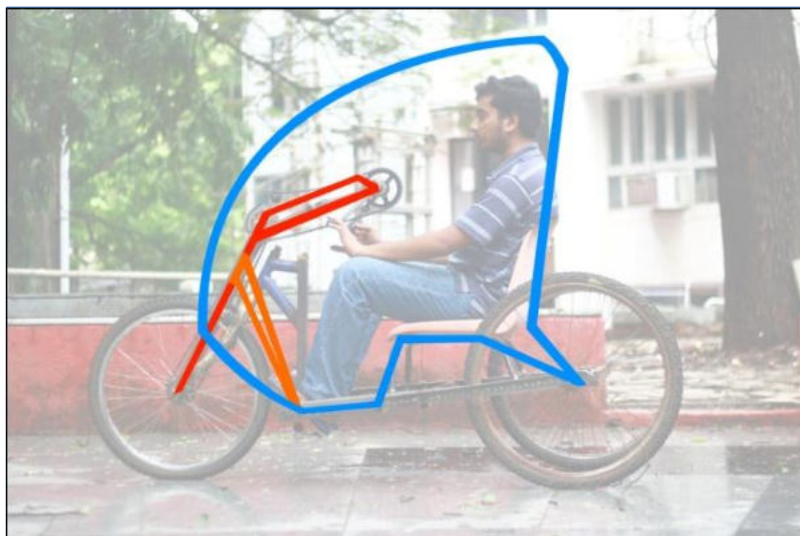
Front fork is simplified with few members.
 Single Skelton frame with swing arms on the side for holding rear wheels.
 Outer frame to encourage easy transfer from wheel chair

Explorations on Prototype

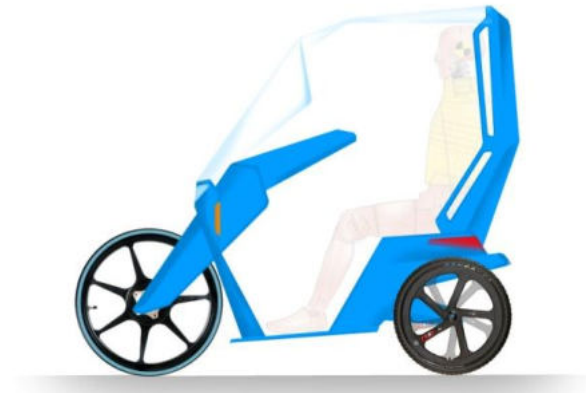




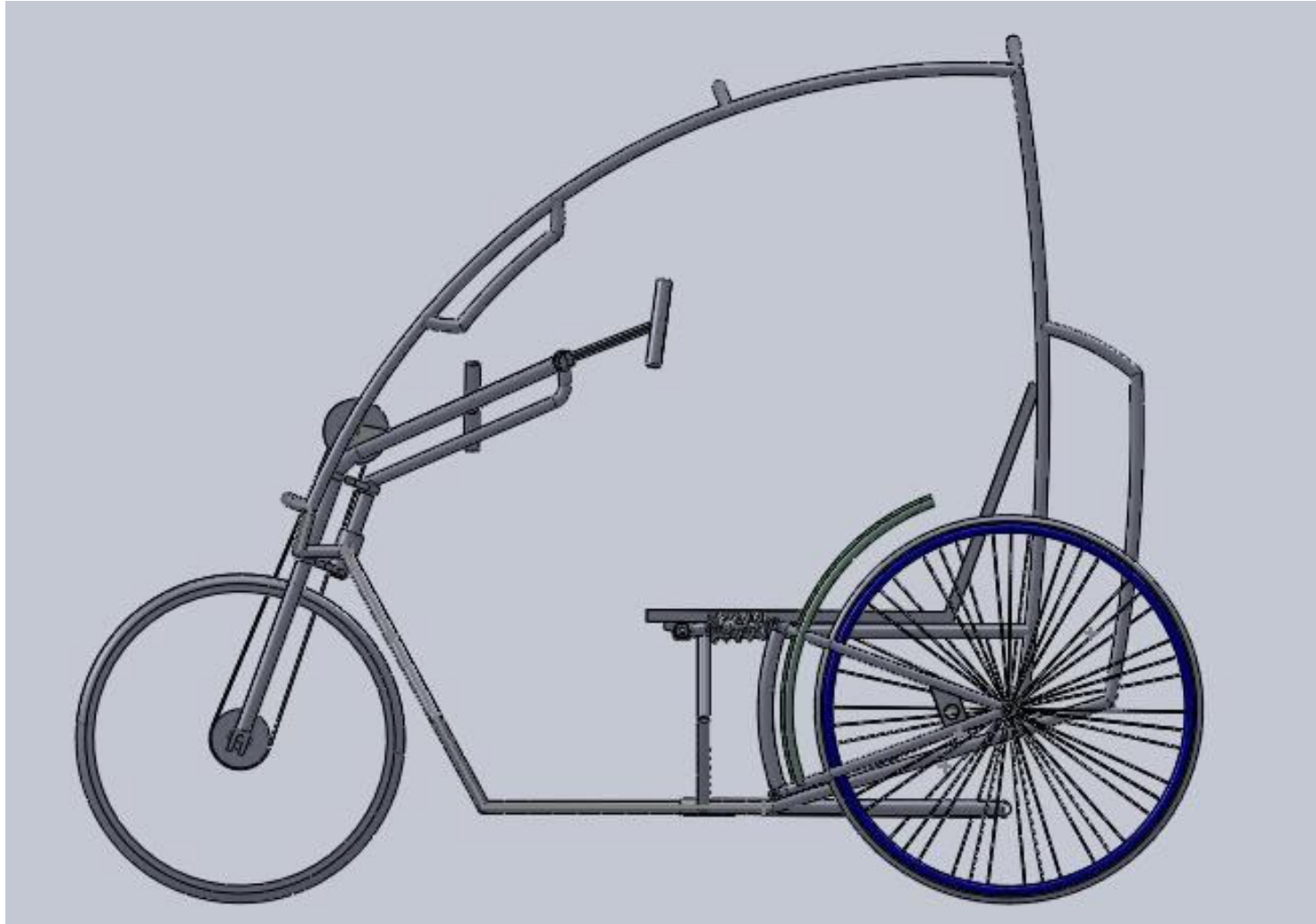


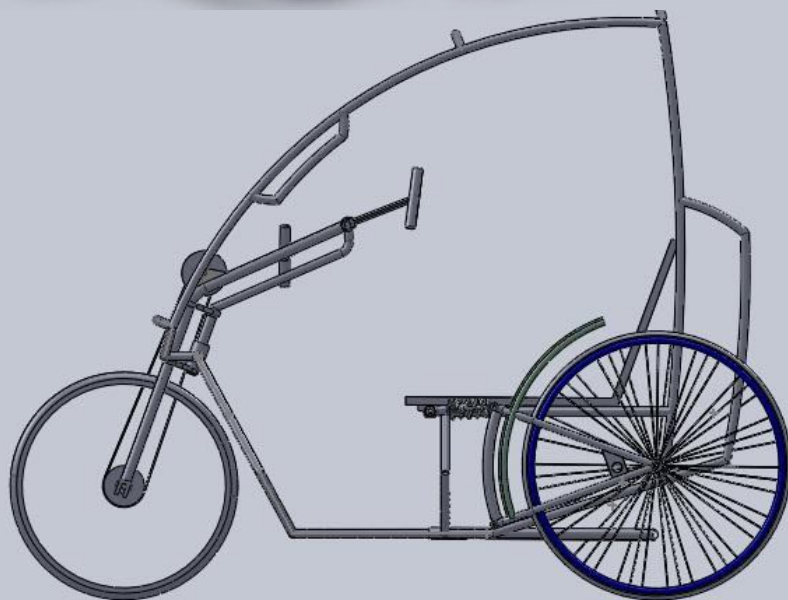
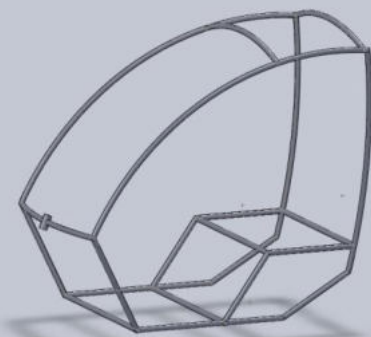
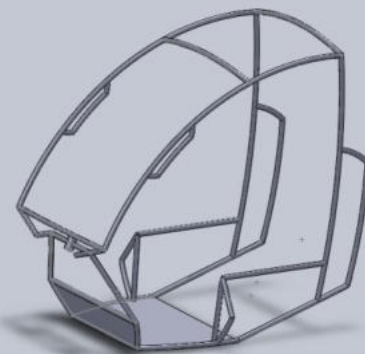
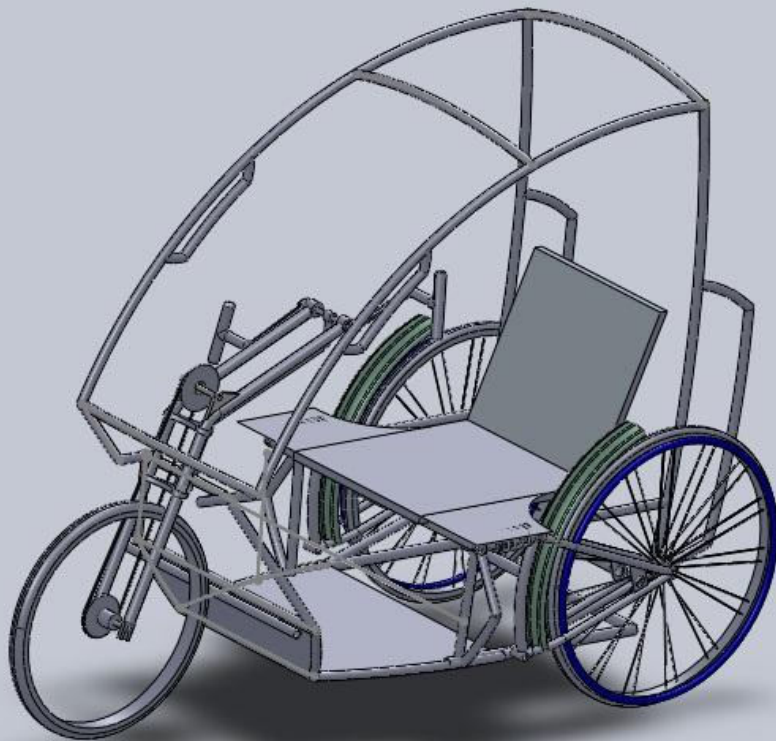


2-D Renders



3-D Model



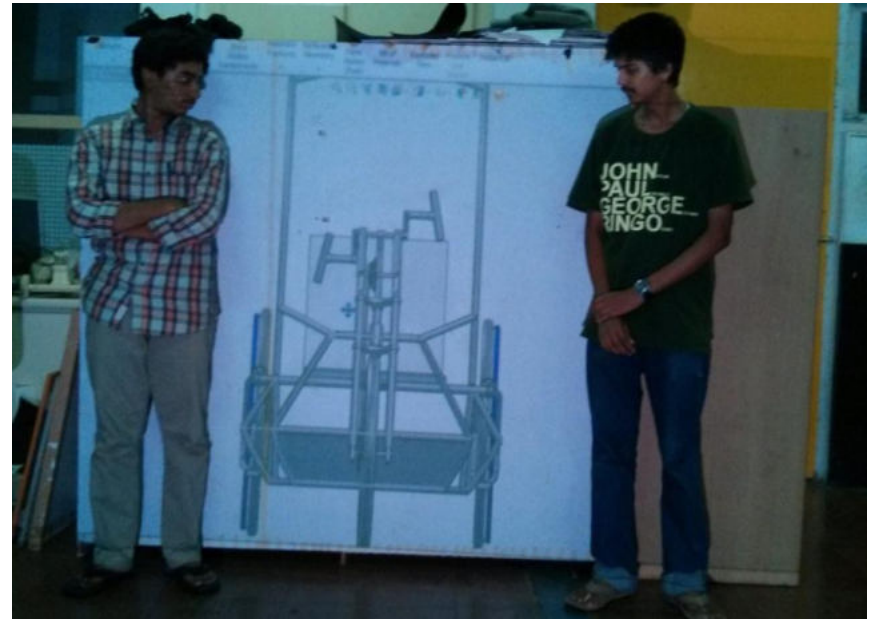


Scale and Proportion

CAD model was projected to full scale to review proportion and scale



Side projection



Front projection

Roof height and feel of space and accessibility was visually analyzed and found to be satisfactory

Pivot point of pedal- 1m

Seat height- 0.485m

Rear Track - 0.780m

3-D Render



Learning

The opportunity to interact and spent time with people having problems with mobility has been an eye opener and a wonderful experience.

Learned various mechanisms used for personal mobility.

The project helped to develop a new mechanism for rowing action.

Reference

1. Anthropometric & Strength Data of Indian Agricultural workers for Farm Equipment Design
By L. P . Gite.
2. Wikipedia

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- Thank you