ERGONOMIC WHEELCHAIR DESIGN

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in

INDUSTRIAL DESIGN

By

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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis titled **"Ergonomic Wheelchair Design"** submitted by **Shikha Oram (Roll No. 110ID0270)** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Industrial Design at National Institute of Technology, Rourkela is an authentic work carried out by her in my supervision and guidance.

To the best of knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of Degree or Diploma.

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Abstract

Wheelchair is a mobility gadget designed to be replacement for walking, moving physically challenged people from one place to other with the help of attendee or by means of self-propelling. The wheelchair is divided into two categories based on the power used mobility: Manually powered wheelchair, electrically powered wheel chair. This project focuses on redesign of electrically driven wheelchair, which runs with electric power however joystick is required for manual operation to operate the movements of chair.

The design of wheelchair happened by means of literature review to know its evaluation from past to present generation. Different methodologies have been proposed based on human anthropometric data and tested for sitting and lying as well as standing mechanism of the wheelchair to maximize the utility of chair by including features like back reclination and lifting of wheelchair.. Wheelchairs are not only for those who have no use of their lower extremities, but also for those who tire out easily because of muscular and nerve degenerating conditions. This work is to provide ergonomic constraints for user's maximum comfort while dealing with various body movements like sitting, lying and lifting.

The final output is a wheelchair with very simple mechanism which gives the facility to lie down by reclining the chair backwards and lift upto the desired level with maximum upto standing height. Apart from this simple mechanism ergonomic constraints have been given so that patient can avoid large pressure on body parts allowing body flexibility.

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1. INTRODUCTION

The emphasis within ergonomics is to ensure that design complement the strength and abilities of people and minimize the effects of their limitations, rather than forcing them to adapt. In achieving this aim, it becomes necessary to understand and design for the variability represented in the population, spanning attributes such as age, size, strength, cognitive ability, prior experience, cultural expectations and goals. While discussing about wheelchairs, ergonomics encompasses four key criteria: Force, Repetition, Duration, and Posture.

Heavy impact jolts on our joints and causes undue tension in muscles. Wheelers have their own way of actuating while snapping their arms at the end of a push that consequently puts undesirable pressure around the shoulder joints. Running along a bump at a significant speed in a power wheelchair or a scooter results in unnecessary jolt. Repetition is a very obvious phenomenon. The number of pushes can be minimized by coasting (that means keeping the tires inflated and the chair well be maintained) while slow speed can also be advantageous as more pushes are needed for going faster.

Continuous muscular effort is also referred to as duration. It not only requires or involve heavy lifting but also time taken for operation of a particular task. Many small continuous exertions are as more stressful to the tissues than a brief but heavy effort. One example is leaning on armrests mainly due to the reason of poor seat and back reclination that can put continuous load around the shoulders. It is a very good example of "static" exertions. Poor posture is a duration overexertion. Continuous work and heavy is imposed on the neck and shoulder if we are seated in a poor posture, i.e. slumping or leaning forward. The real key for ergonomic design is movement. Remaining postures like active and altering position in entire day not only involve in the continuously exerting muscles. Lack of proper posture in the chairs can often lead to a person spending a lot of time on the armrests. Here the problem of seat angle and back angle arises and adjusting them in accordance to the degree of upper body balance and the body shape. In order to stabilize the poor seating makes the person slump. The recommended posture that is considered to be optimal is relatively more upright, allowing the spinal cord to support the back.

1.1 ORIGIN OF PROBLEM AND PROBLEM STATEMENT

Quite a significant number of persons are unable to walk freely due to some or the other problem with their legs. Many physical disabilities like paralysis, blindness, polio and other deficiencies, thousands of people fail to walk. There are many disabilities that a person in a wheelchair can have—from cerebral palsy at birth through a debilitating illness later in life. At times a disability can make the person a temporary user of the wheelchair. It is a common and a stereotypic belief and thought that wheelchairs are only for those with obsolete lower extremities, but this is not so. To the contrary it is quite beneficial to those who have trouble in walking or are a patient to easy tiredness because of reasons like nerve and muscle degenerating conditions.

Diabetes is an example of nerve degenerating condition which often people do not consider. In the advanced condition of diabetes or a temporary disability where nerves are affected, diabetes may not allow regeneration of nerves. While people having nerve problems may be able to walk, they may be unable to walk to a considerable distance. Wheelchairs make it possible such people with to leave the house, go for an outing, and do things that demand extensive walking.

Problem Statement : For someone in seating position, the parts of the body that are most at risk for tissue breakdown include the ischialtuberosites, coccyx, sacrum and great trochanters. Seat of wheelchair in horizontal level leaves the patient constraint in a particular level only they cannot reach higher level such as book shelves or a level higher than their sitting position or standing vertically to stretch their body.

1.2 OBJECTIVE OF WORK

- The main objective is to design the mechanism involving push back or reclining and lifting system of seat, automatic brake control to avoid unnecessary collision and speed controls.
- Give new design and outlook to the wheel chair based on the ergonomic aspects of the chair for maximum comfort of the user and thus maximize the utility of wheel chair.

1.3 TARGET USERS

(i) Person suffering from cerebral palsy at birth through a devitalizing illness later in life.

(ii) Disability that can temporarily put a person in a wheel chair like polio patients, lack of co-ordination between body parts.

(iii) Those who tire out easily because of muscle and nerve degenerating conditions.

(iv) Physical disability due to lack of body parts during accidents.

(v) Paralysis of lower part of body.

(vi) Very weak aged person.

2. LITERATURE REVIEW

2.1 BACK GROUND AND HISTORY OF WHEELCHAIR

Very first records of wheeled seats were used for transporting the disabled date to three centuries later in China. The Chinese people used their invented wheelbarrow for moving people as well as carrying heavy objects. A distinction between these two functions was not made until next hundred years, around 525 CE, when images of wheeled chairs made specifically to carry people which occurred in Chinese art [3].

The chair originally built by ancient Egyptians. It was used for the elite. The wheel was invented near 4000 BC. The original wheeled vehicles looked like carts and were pulled by animals. First known dedicated wheelchair (invented in 1595 and called an invalids chair) was made for Phillip II of Spain by an unknown inventor. In 1655, Stephen Farfel, a paraplegic watchmaker, built a self-propelling chair on a three wheel chassis[3].

Harry Jennings and his disabled friend Herbert Everest, both mechanical engineers, invented the first lightweight, steel, collapsible wheelchair in 1933. Everest had broken his back in a mining accident. The two saw the business potential of the invention and went on to become the first mass-manufacturers of wheelchairs: Everest and Jennings. Their "x-brace" design is still in common use, albeit with updated materials and other improvements[3].

I. The Bath Chair

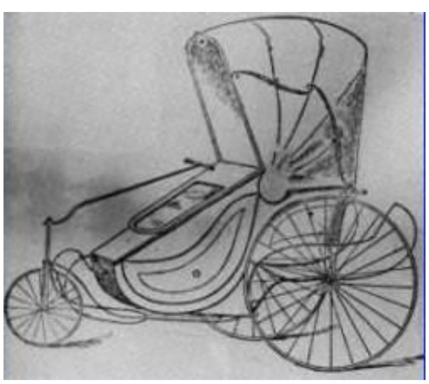


Figure 1. Bath Wheel chair [1]

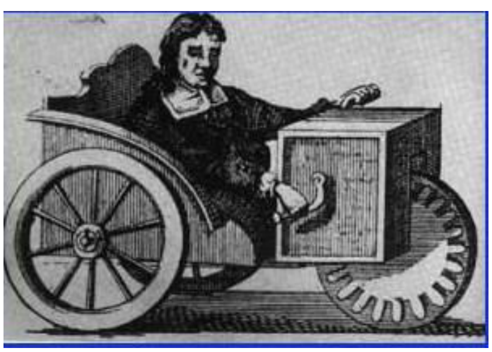
- It was developed in Bath, England
- It was Invented by John Dawsonin 1783
- Dominated the market of 19th century
- Two large wheels, one small wheel

- Comfort for the disabled person because more of an issue.
- Convertibles chair (reclining back and adjustable foot rests) was invented.

Figure 2. 18th Century Wheelchair [1]

II. Late 1800s

The Bath wheelchair was not that comfortable and during the last half of the 19th century many improvements were made to wheelchairs. An 1869 patent for a wheelchair showed the first model with rear push wheels and small front caster wheels. Between, 1867 to 1875, inventors added new hollow rubber wheels similar to those used on bicycles on metal rims. Self-propulsion was invented in 1881[3]



- Stephen Farfler Paraplegic watchmaker, built his own wheelchair at 22 years of age.

Figure 3. Self Propelling Wheelchair [1]

III. The 1900s

In 1900, the first spoked wheels were used on wheelchairs. The first motorized wheelchair was manufactured in London, in 1916.[3]

IV. **The Folding Wheelchair**

Harry Jennings an engineer, built the first folding, tubular steel wheelchair in 1931. That was the initial wheelchair similar to what is in modern use today. That wheelchair was built for a paraplegic friend of Jennings called Herbert Everest. Everest & Jennings, founded a company together that monopolized the wheelchair market for many years. [3]

V. **Power wheel chair**

An electric powered wheelchair is a wheel chair which is moved by the means of various electric and navigational controls, and employs usually a small joystick maintained on the arm rest, rather than manual power.[3]

VI. **Electric wheelchair**

George Johann Klein, a Canadian inventor, invented electric wheelchair for the injured war veterans. Electric wheelchair is one of Canada's greatest inventions that is found to have benefited the mankind. Electric wheelchairs invention is a result of the need to give them independence and mobility.[3]

Electric wheelchairs are somehow a heavier device than manual wheelchairs because the frame has to be stronger in order to accommodate the battery and motors. From just using standard batteries and a joy stick controller, right up to using microprocessor controlled gyroscopic circuitry which enables the chair to rise on two Electric wheelchairs are propelled also varies, and these different methods give different characteristics to the wheelchairs. The following are the three basic methods of propulsion:[3]

2.1 ERGONOMIC ASPECTS OF WHEEL CHAIR

Ergonomicsis the **s**cientific discipline apprehensive to understand the interaction between human beings and element of the system where he is living. It is employed in fulfilling the goals of health and productivity. Wheelchair users in particular face the problem of being forced to spend long periods in the same position. The result can be pain, deformatities and decubitus ulcers [2].

Ergonomics deals with four key criteria. Force, Repetition, Duration, .Posture. Let's consider how they apply to wheeling.

1 Force- Heavy impact jolts our joints can cause tension in our muscles as a response. Many wheelers have their own way of actuating where they end up snapping their arms at the end of a push which consequently puts undesirable pressure on the shoulder joints. Running over a bump at a significant speed in a power wheelchair or scooter can result in unnecessary impact.

2 Repetition- Repetition is a pretty obvious phenomenon. The number of pushes it takes to travel a given distance? In order to minimize the number of pushes coasting (which means keeping your tires inflated and your chair well maintained) and slow speed can be advantageous as more pushes are needed to go faster.

3 Duration- Continuous muscular effort refers to duration. Small continuous exertions are as more stressful to your tissues than a brief yet heavy effort. For example, leaning on armrests – usually due to the reason of poor seat and back relation, puts continuous load on shoulders. It is a classic example of "static" exertions. Poor posture is a duration overexertion. Heavy and continuous work is imposed on the neck and shoulder if we are seated in a poor posture, like slumping or leaning forward. But the real key here is movement. Remaining active and altering posture throughout the day would not involve in the continually exertion of muscles.

4 Posture- Lack of good posture in their chairs often lead to people spending a lot of time on armrests or table. This is a matter of seat angle and back angle, adjusting them in accordance to your degree of upper body balance and your body shape. In order to get stabilized poor seating makes you slump. The suggested posture which is considered to be optimal is relatively more upright, allowing your spine to support a person.

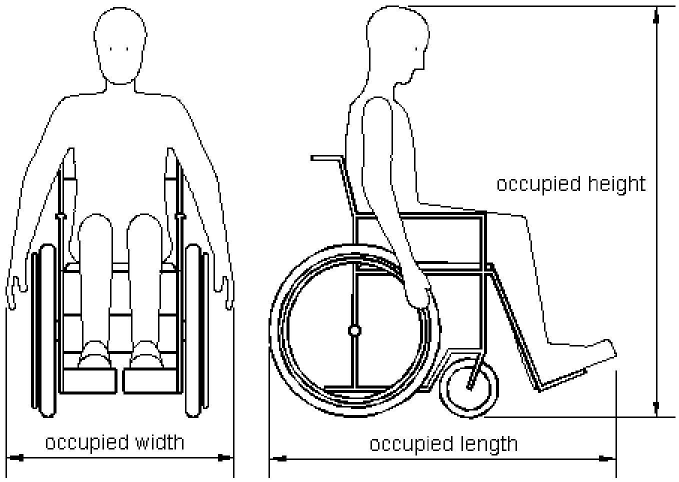


Figure 4. Diagram for occupied width, height and length

Figure 5. Side View

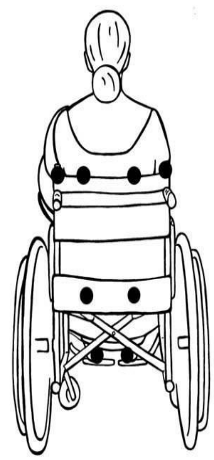


Figure 6.pressure Sensitive areas (Back View)

2.3 Seating and postural support elements

Wheelchairs provide postural support and sitting as well as mobility. Good postural support is very important, especially for people who suffer unstable spine or are likely to develop secondary deformities. Good seating and postural support have high significance can mean the difference between the user being active and an independent member of society and the user being completely dependent and at risk of serious injury or even death. Seating and postural support is provided by all body contacts. All these parts together of the wheelchair help the user to maintain a functional posture and comfort and to provide pressure relief. This is important for people who have problems like sensation in skin. [2]

Table1. Typical values (in mm)

	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
Occupied length	1200	1240	1300	1300
Occupied width	740	620	680	700
Occupied height	1500	1500	1530	1590

Table2. Recommended maximum limits (in mm)

	Manual wheelchair	Electrically powered wheelchair		
		Class A	Class B	Class C
Occupied length	1300	1300	1300	1300
Occupied width	800	700	700	700
Occupied height	1600	1600	1600	1600

2.2 HUMAN DIMENSION AND ERGONOMIC STUDY

Ergonomics is the methodical discipline concerned to comprehend the interaction between human beings and various elements of the system where a person is living. Ergonomics is employed in fulfilling the goals of health and productivity.

Ergonomics with wheelchair users

Ergonomic study of wheelchair is the interaction in relation to various aspects of vehicle mechanics and user’s physical and mental condition. Wheelchair designed ergonomically reduces the strain that is caused due to longer use of product. Ergonomics in the wheelchair considers four main criteria’s like force, repetition, duration, posture [3].

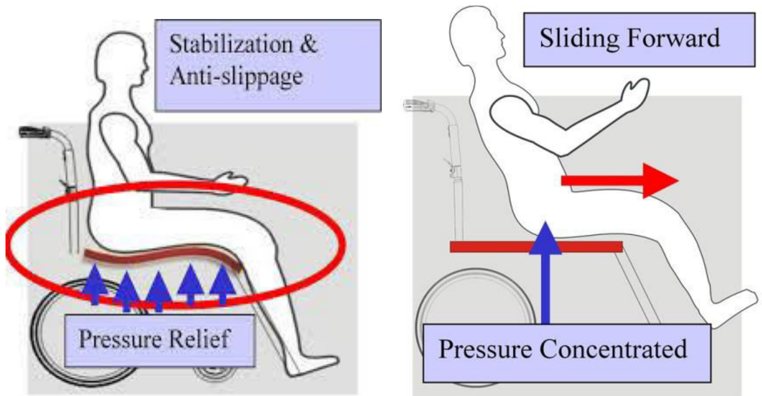
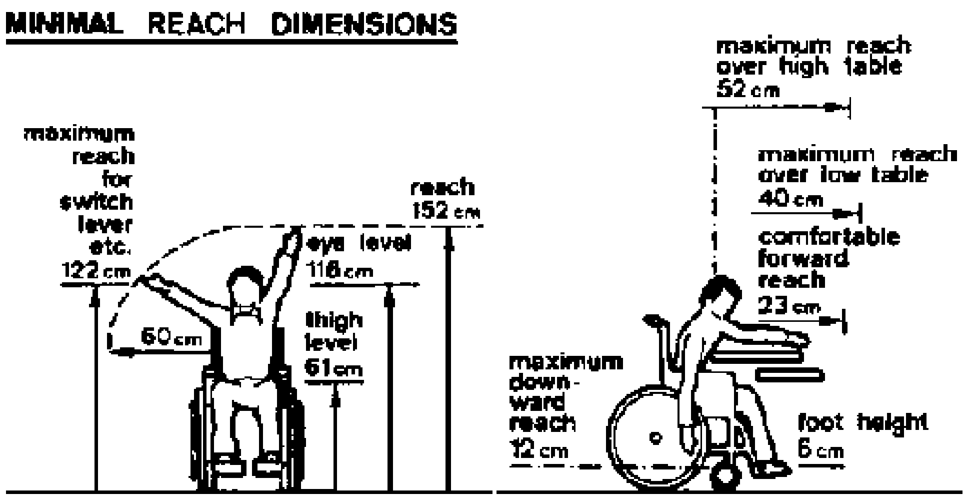


Figure 7. Ergonomic surface Design of wheelchair seat



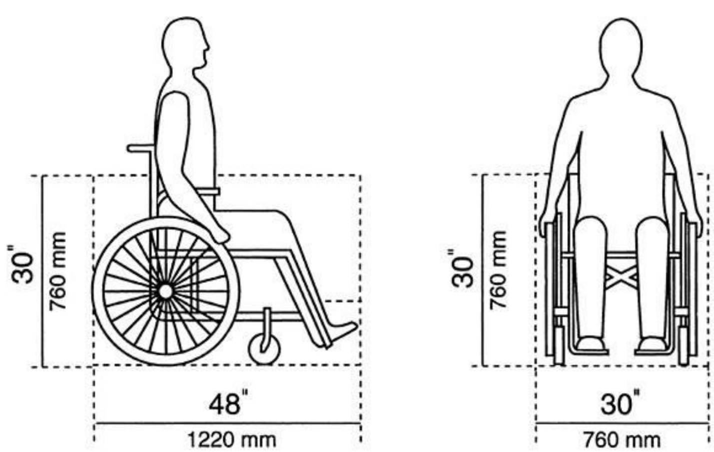


Figure 8. Human dimensions on wheelchair [7]

3. METHODOLOGY

3.1CONCEPT GENERATION

Based on study and data analysis and questionnaires, the below list briefly illustrates essence of customer voice.

Refined Customer Voice

- Adjustable arm rest
- Improved back rest design
- Adjustable and cushioned foot rest
- Improved braking design
- Multiple use
- Less weight
- Less cost

Technical Voice

- Change of material
- Ergonomic design
- Functionality
- Usability
- Weight
- Mechanism
- Safety
- Economic

3.1 CONCEPT SKETCHES

3.1.1 Mechanism for seat lifting

Figure 9. Mechanism for seat lifting [6]

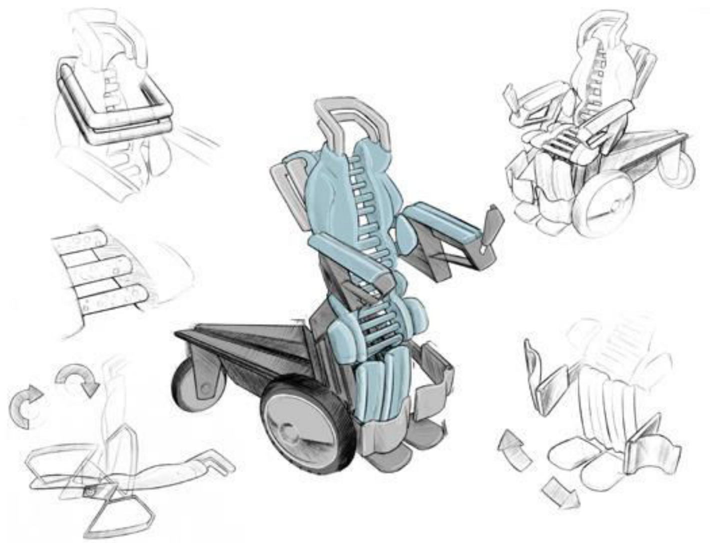


Figure 10. Mechanism for seat lifting[6]

3.1.2 Mechanism for back recline

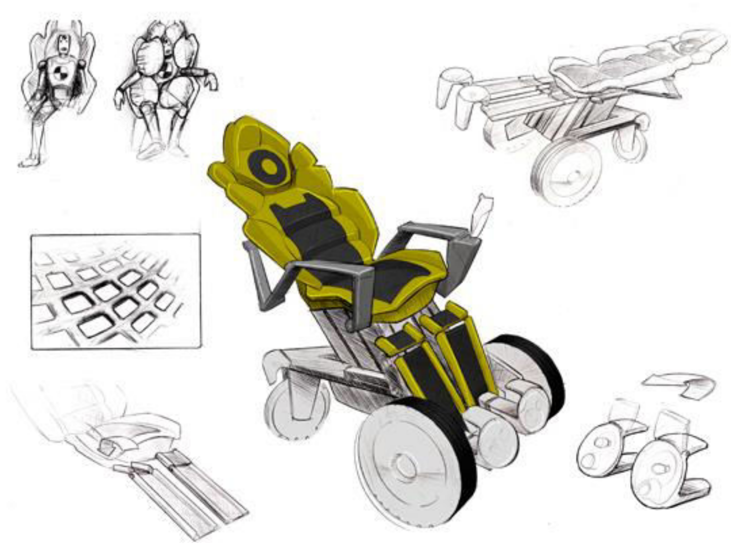


Figure 11. Mechanism for back reclination[6]

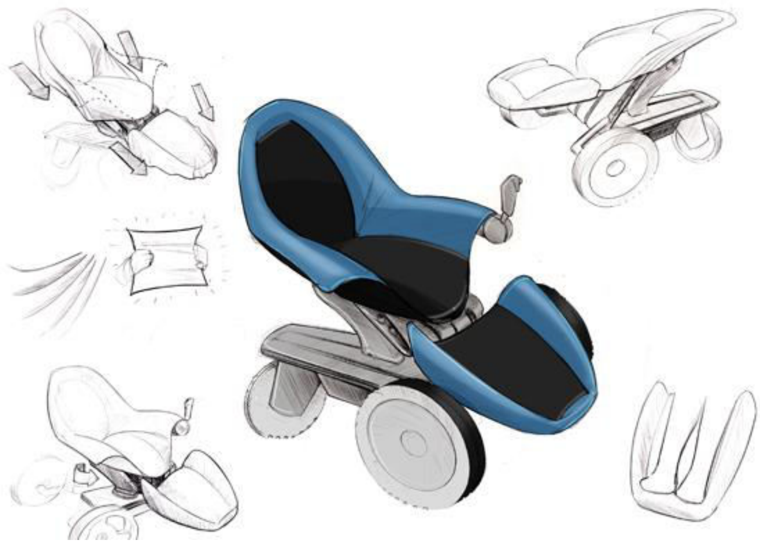


Figure 12. Mechanism for Back Rclination[6]

3.2MECHANISM DEVELOPMENT AND SIMULATION

3.2.1 Mechanism I (by using 3 gears)

SIMULATON OF BACK RECLINATION: To maintain the smooth reclination of back, it is necessary to give rotation of back with small angles of say 30 degrees. Here 30 degrees interval has been taken. A -- Gear A, Back seat is mounted on Gear A.

B -- Gear B, Meshed with Gear A

C – Interior of Knob with radius equal to radius of Gear B.

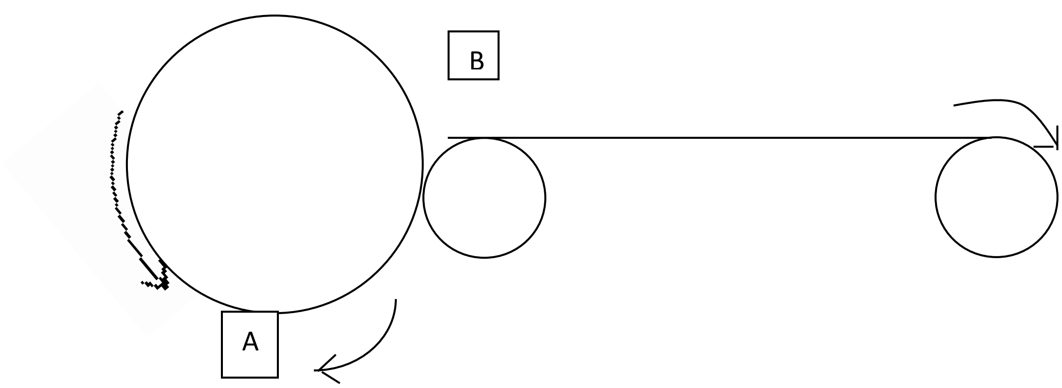


Figure 13. Line diagram for back reclination mechanism using gears

Let N_c = Revolution of C, N_b= Revolution of B, N_a=Revolution of A

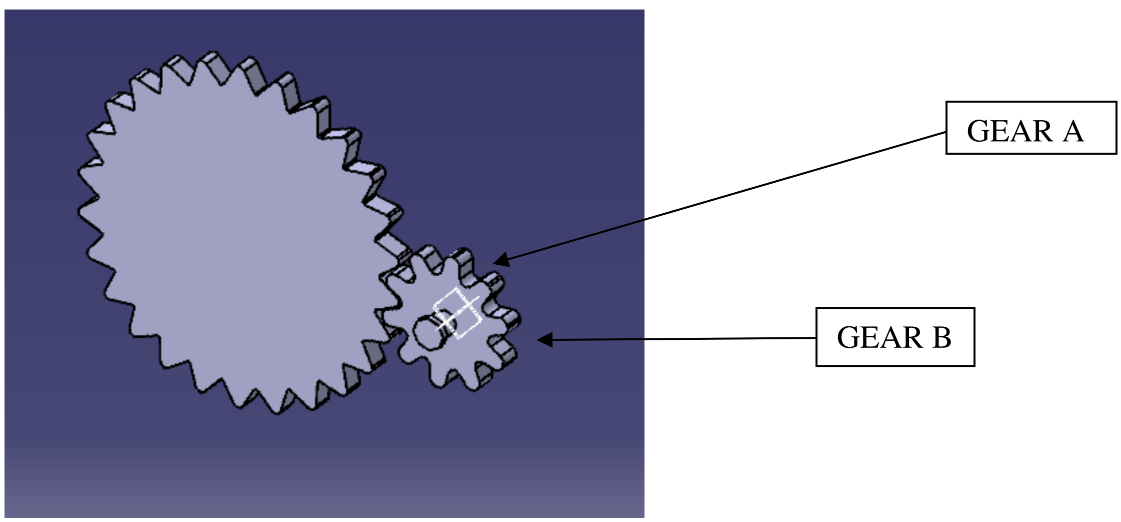
T_a= Number of Teethes of Gear A=30, T_b=Number of Teethes of Gear B=10

3.2.1.1 **Explanation of Diagram and Mechanism:** In the above diagram Gear B having 10 teethes is connected to shaft with radius of shaft equal to radius of Gear B by the help of spring or string, meanwhile Gear B is meshed with Gear A having 30 teethes. Rotation of knob by the person in clockwise direction makes the shaft C to rotate in clockwise direction. Since shaft and Gear B are connected with each other, transmission of motion in Gear B is accomplished by the help of spring in the same clockwise direction. Gear B having 10 teethes is meshed with Gear A having 30 teethes maintaining a Gear Ratio of 3:1. Thus one complete rotation of knob in clockwise direction leads to rotation of Gear A in anti-clockwise direction by 30 degrees [4].

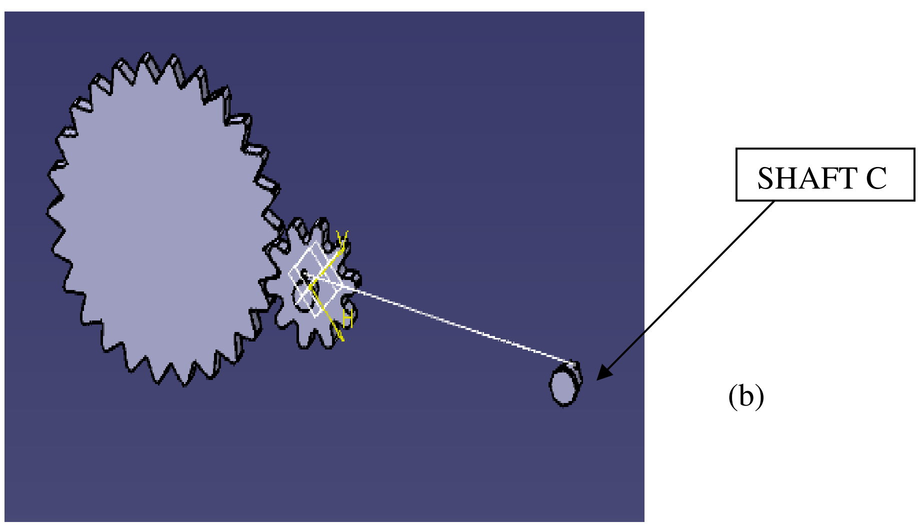
Table.7 Deterination of gear rotation angles

LINE	REVOLUTION (C)	REVOLUTION (A)	REVOLUTION (B)
1.	**x**	**N_a=x**	**N_b= -(T_a/T_b)x**
2.	**360**degree	**360** degree	**-30** degree
3.	**2*360** degree	**2*360** degree	**-60** degree
4.	**3*360** degree	**3*360** degree	**-90** degree
5.	**4*360** degree	**4*360** degree	**-120** degree
6.	**5*360** degree	**5*360** degree	**-150** degree
7.	**6*360** degree	**6*360** degree	**-180** degree

3.2.1.2 CATIA MODELS



(a)



(b)

Figure14. (a) Meshing of Gear A and Gear B

Figure 15. (b) Connecting wire between knob and meshing gears

3.2.2 Mechanism II (by using kinematic joints)

The rear wheels can be designed of the wheelchair as movable ones, so that the whole mass center of the wheelchair can move between the rear and front wheels of the chair. When the design is done, the wheelchair is safe for the users under different operations.

Creative New Design Methodology

According to the modifications based on existing mechanisms, Dr. Yan a scientist presented a creative design methodology to generate all possible topological structures of the given mechanism.

The steps are:

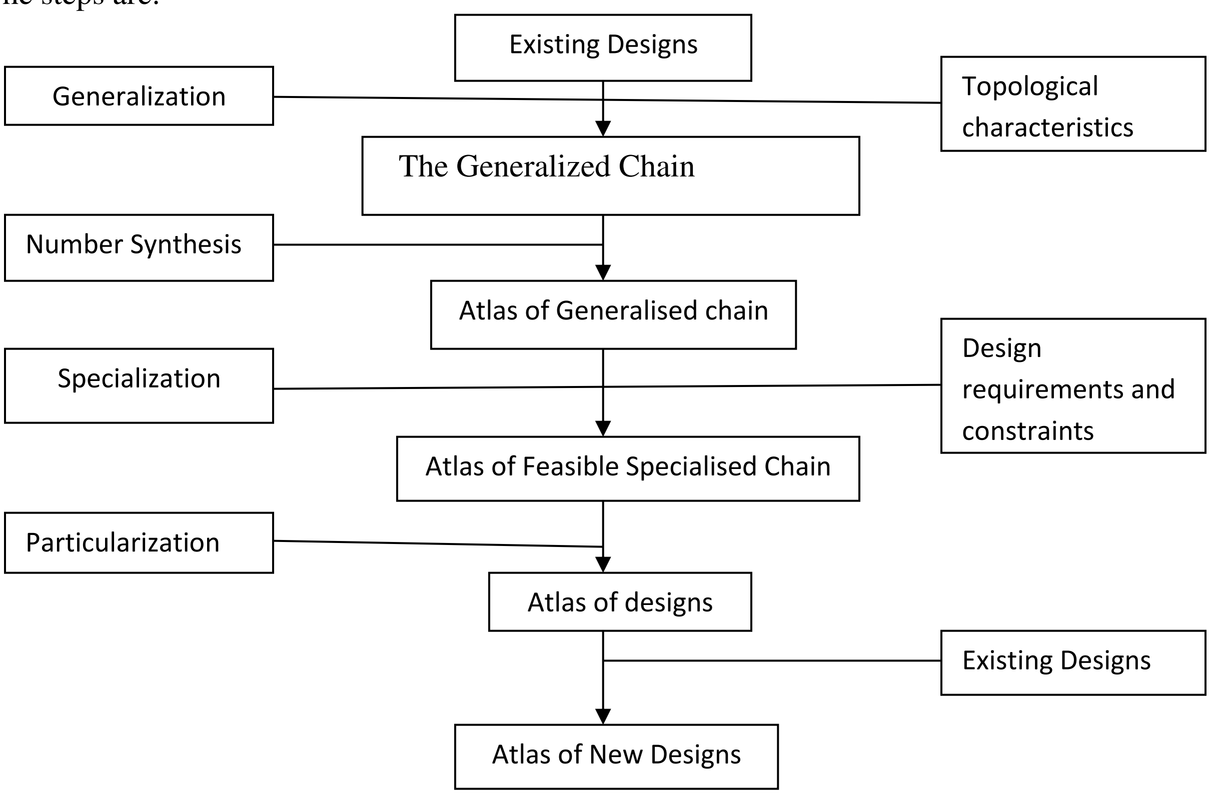


Figure 16. Flow chart of Design Methodology

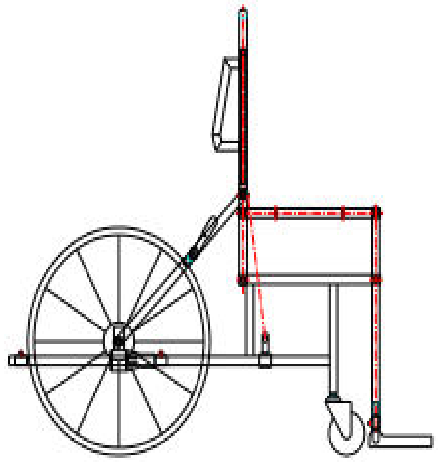


Figure 17 .Wheelchair under sitting state

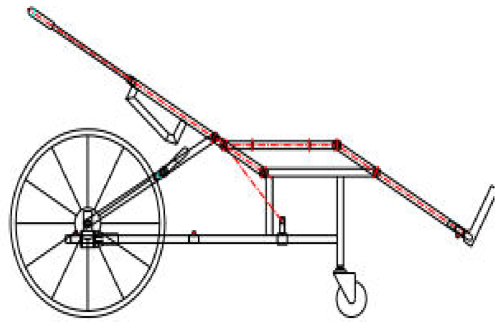


Figure 18 .Wheelchair under lying state

The rear wheels of the wheelchair is movable ones in the concept thus the whole mass centre of the wheelchair is able to move between the rear and front wheels of the chair. The design requirements for the mechanism are[1]:

- The ground link is must required as the wheelchair body.
- The handle link is must required to install the handle.
- The treadle link is must required to install the treadle.
- The back link is must required to support the back of user.
- There are at least four revolute and one cam joint.
  - The must be a cam joint joint incident to the back link and the ground link.

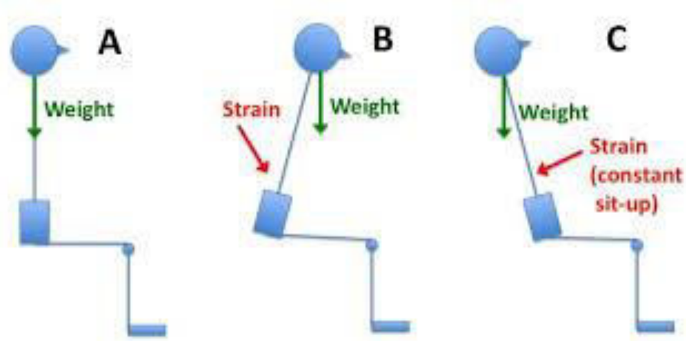


Figure 19. Correct sitting posture to support the weight of the body

Benefits of lying and lifting seat mechanism

When the person stand his thoracic cage is extended and chest wall and diaphragm are able to contract, relax and expand normally and also comfortably. The capacity of lungs improves and oxygen intake is increased, therefore the supply of oxygen to brain and organs is improved. The person is able to think, speak and breathe more easily.

When the person find it difficult swallowing he can change position and also allow food to settle better in my stomach. Standing means that the abdomen is not compressed therefore my digestive system is able to work more effectively so it's easier to eat comfortably and enjoyably.

3.3FINAL CONCEPT SELECTION

Two concepts were suggested, 1st one was using three gears and 2nd one using kinematic link mechanism. Implementing gears in wheelchair would make wheelchair slightly heavy because of extra weight of the three gears. And also Gear mechanism allowed only push back mechanism and was not suitable for standing operation of wheelchair.

While the kinematic link concept is more acceptable as there is no excess weight added to the chair and this is mechanism allows efficient transmission of motion which is discussed in prototype development part. Further Kinematic link mechanism also approves the standing operation of wheelchair.

Thus Final concept is kinematic link mechanism which uses various kinematic links like arm rest ink, seat link, back seat link and treadle link to be assembled in intelligent way so that they can successfully operate for lying and standing positions.

Therefore the criteria for final concept selection involves

- Less weight of the wheelchair.
- Smooth operation.
- Mechanism feasible for both reclining and standing operations.

3.4 PROTOTYPE DEVELOPMENT

A prototype is a release model of a product built to check as a concept to act as a testing thing to be replicated or learned from. Prototyping is very important which provides specifications for a working system and a real environment rather than a theoretical one.

In this project Proof of Principle Prototype is built using woods, nails, hinge and thermo coal.

Explanation of Mechanism

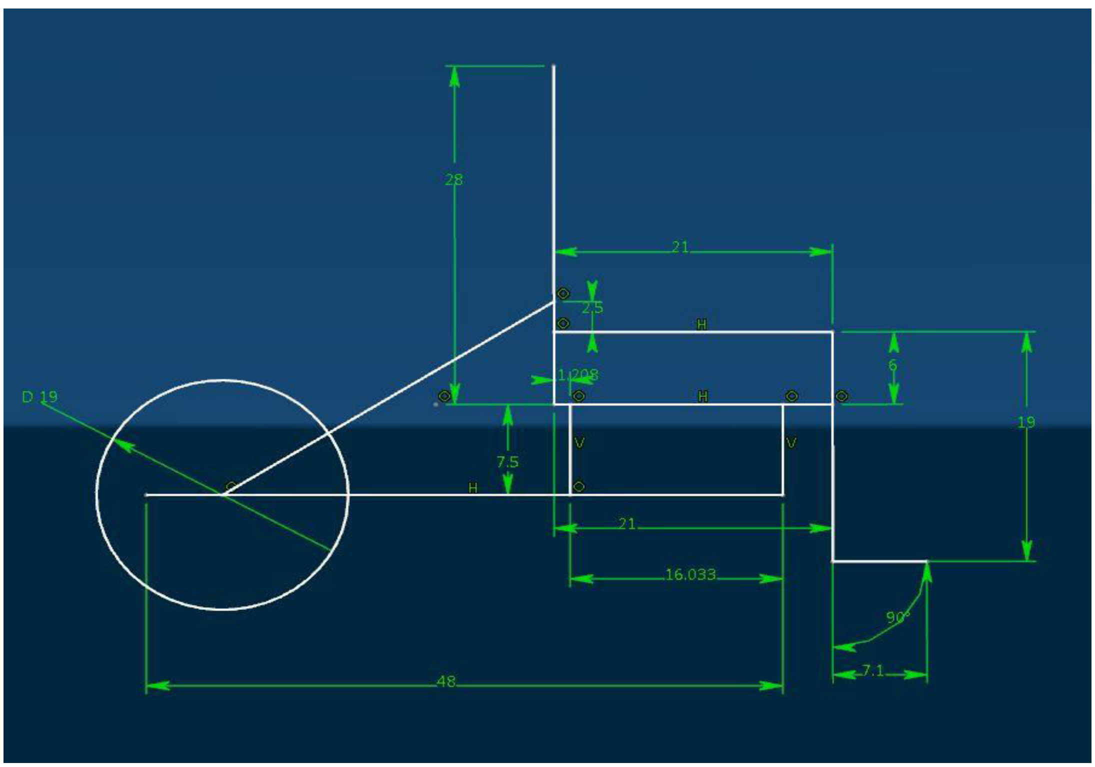


Figure 20 2D CAD mechnism of the model The mechanism comprises of 4 links (i) Seat (ii) Back seat (iii) Arm rests (iv) Treadle

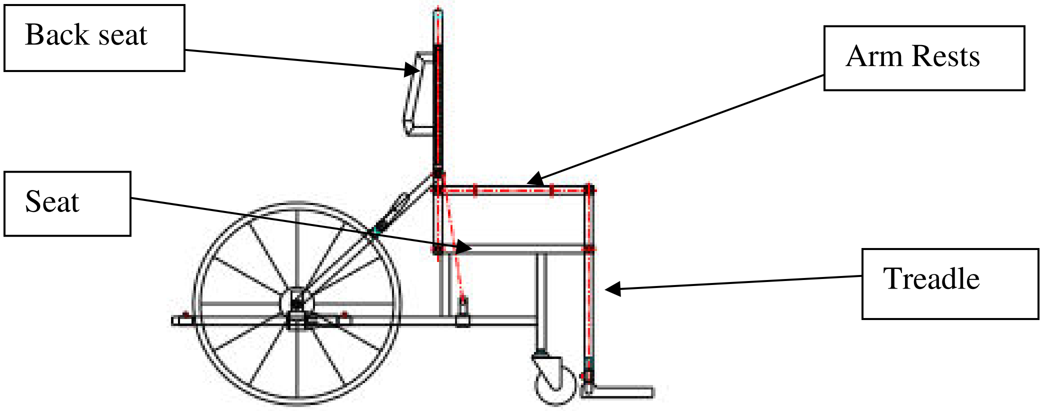


Figure 21 .Side View of Wheelchair showing important links

Movement of Treadle is paralleled with the movement of Back seat. This is accomplished by implementing 4 revolute joints on four corners.

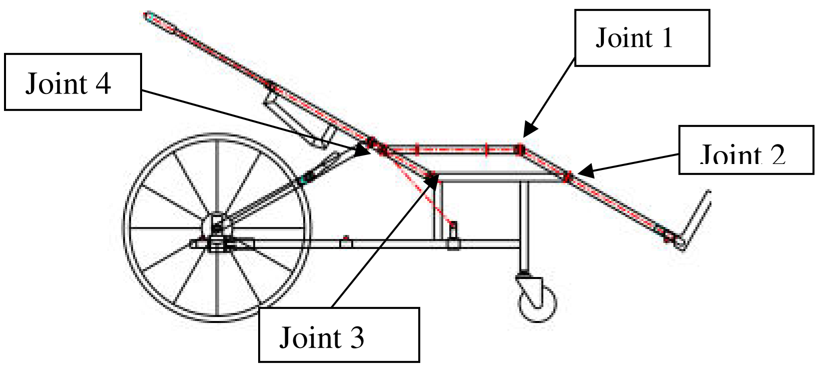


Figure 22. Wheelchair showing various joints

- Joint 1 Joined by one end of arm rest link and one end of treadle link.
- Joint 2 Joined by one end of seat link and Treadle link
- Joint 3 Joined by 2^{nd} end of seat link and one end of back seat link.
- Joint 4 Joined by 2^{nd} end of arm rest link and back seat link.

For prototype development Joint 1 and Joint 2 are set by using hinges. And Joint 3 and Joint 4 is set by using nails. Hinge setting in Joint 1 and Joint 2 establishes two revolute motion around the seat and arm rest. Since Joint 3 and Joint 4 are joined by nails they are free to make kinematic motion although the motion is dependent on the movement of treadle link.

After going through the literature review the dimensions of the wheelchair is decided and proof of principle prototype is built. Citing the ergonomic needs of the wheelchair from literature review the surface of the seat and back seat is designed to provide maximum comfort to the user.

There is wavy pattern used for cushioning of leg rest, this pattern is used because small areas which do not make contact with the leg provides sufficient area for air ventilation.

4. RESULTS AND DISCUSSION

The prototype is scaled to 1:2 ratios. Thus the original dimensions of the Wheelchair are specified below:

I. Sitting seat size = (25cm × 21cm)* 2 = (50cm × 42cm)
II. Back Seat Size = (28cm × 25 cm) * 2 = (56 cm × 50cm)
III. Arm Rest Length = 21cm * 2 = 42 cm
IV. Height between Arm rest and Sitting Seat= 6 * 2 = 12 cm
V. Treadle Length = 19 * 2 = 38 cm
VI. Distance Between Front Wheels and Rear Wheels = 35cm * 2 = 70 cm

For relaxing the following calculations are made:-

- The back seat of the wheelchair can be pushed back up to 160 degrees with respect to sitting seat. A person can flex his back up to 160 degrees; similarly he can raise his legs up to 70 degrees corresponding to movement of back seat.

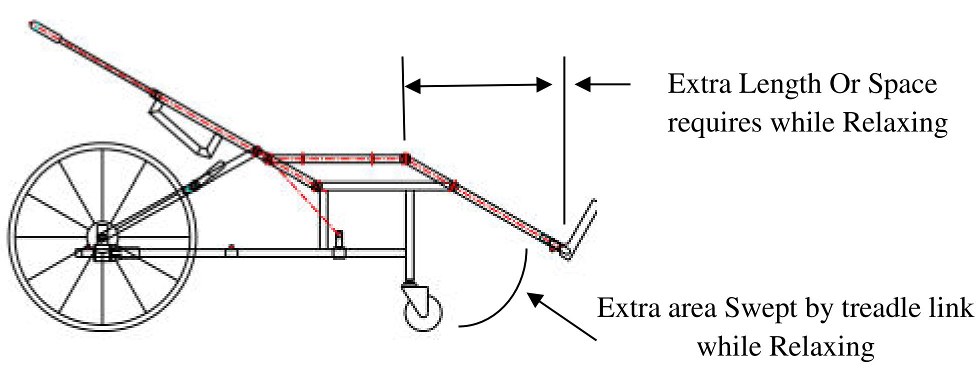


Figure 23 Extra Length Occupied while Relaxing

- Extra Area Swept By Treadle and Front Leg of the Wheelchair is = Length of Leg × Length of treadle × ½ = (9cm × 19cm)/2 = 85.5 cm sqr.

  Thus extra length= (Extra Area Swept × 2)/ Length of Front Leg = (85.5×2)/9 = 19 cm

  Actual extra length required = 19cm × 2 = 38 cm

  Therefore, while relaxing extra space of 38cm is required in front to allow stretching of lower limbs.

For lifting of Wheelchair Following calculations are made:-

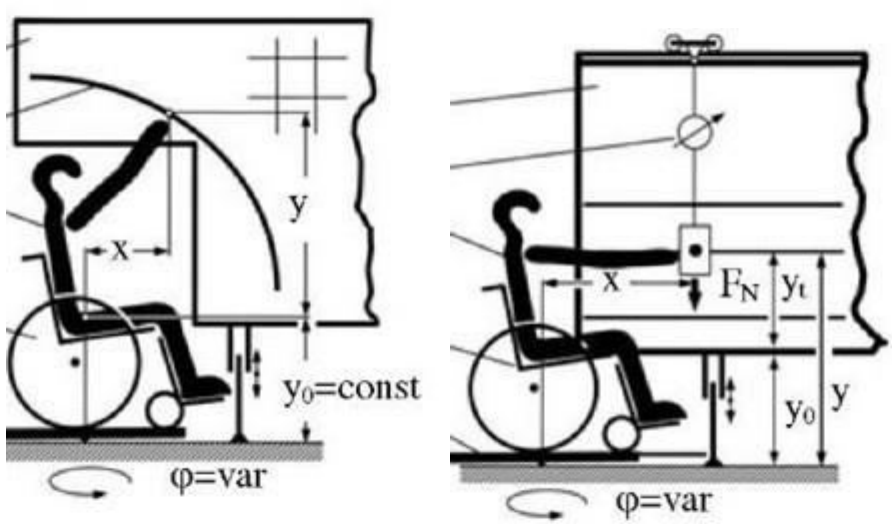
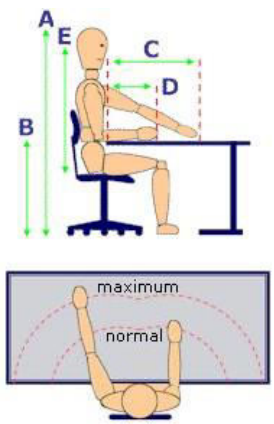


Figure 24 Workspace Calculation while lifting Wheelchair

Individual Diagrams on arm reaches can be represented by a special spline type curve and a Non- Uniform Rational B- Spline (NURBS) surface as it was spread on the set of curves. In the analysis of forces, the numerical data FN= f(x,y,9) is obtained from transformations which can be achieved by various electronic form[5]. Crude values and data sets of FN force in the distance function x and at a constant height values y and constant angle 9 is obtained from four parametrical measurements that requires important reverse calculation to obtain three parametrical record of the x, y, 9 surface of the FN =const. layer.[5]

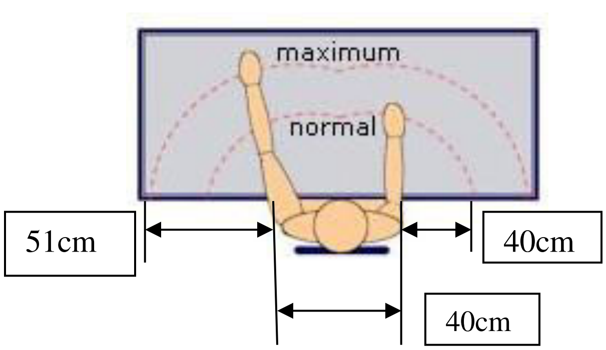


Anthropometric estimates for British adults aged 19-65 years (in mm, from Pheasant)			
Dimension	*5th %ile*	*50th %ile*	*95th %ile*
A Max head height	-	-	1450
B Work surface height	660	710	760
	635	685	735
C Shoulder-grip length (max working limit)	610	665	715
	555	600	650
D Elbow-fingertip length (normal working limit)	440	475	510
	400	430	460
E Sitting eye height (above seat surface)	735	790	845
	685	740	795

MALE FEMALE

Figure 25 Anthropometric estimations for Adults aged 19- 65 years

Shoulder grip length (max working limit) – in 5th percentile female is 555mm.
Shoulder grip length (max working limit)- in 95th percentile male is 715mm.
Elbow fingertip length (normal working limit) in 5th percentile female is 400mm.
Elbow fingertip length (normal working limit) in 95th percentile male is 510mm.
Average shoulder width in 50th percentile male is 400mm
Calculations :-



Thus Limiting Horizontal curve length under person's reach = (Π ×51cm)/4 + 40cm = 80.05 cm

By collecting the anthropometric data it can be acknowledged that keeping body as centre and arm length of 51cm as radius the limiting region for reaching desired object can be generated. Based on the concepts suggested in previous chapters final result of product manufacturing and specifications can be drawn out and it is shown in tables below.

Table 3. Product Design Specifications

Features	Description	Specifications
Dimensional details	Dimensions	Length=1140mm Width=700mm Height=1250mm
Ergonomics	Approximate net weight	25kgs
	Maximum with stainable weight	Upto 190 kgs
Material	Tube pipe, wheel rim	Stainless 304
Wheel	Dimensions	Rear wheel 610mm with solid tyre. Front wheel 210mm with solid tyre
Aesthetics	Body	Smooth curvatures, No straight and

This table shows the approximation of Product Design Specifications that can be employed for actual product development. The above data is collected based on market study of different wheelchairs.

Table 4. Product Manufacturing Specifications

Sl. No.	Description	Specification
1.	Structure	Steel tubing, Plastics Cushioned seat, hand rest with wood..
2.	Color	Light blue, black, white, grey, and colourful powder coated materials an optional as per customer request.
3.	Arm rest , Foot rest	Well cushioned for comfortable resting of hands and adjustable footrest.
4.	Manufacturing process	Cutting, bending, welding, injection moulding, pressing, grinding, filing and assembling parts.
5.	Ergonomics	Head rest, hand rest, foot rest, comfortable seat width.

4.1 REAL PROTOTYPE MODELS

Figure 26. Final Prototype model

Figure 27. Prototype in lying state

Figure 28. Prototype in Standing State

4.2 CATIA MODELS

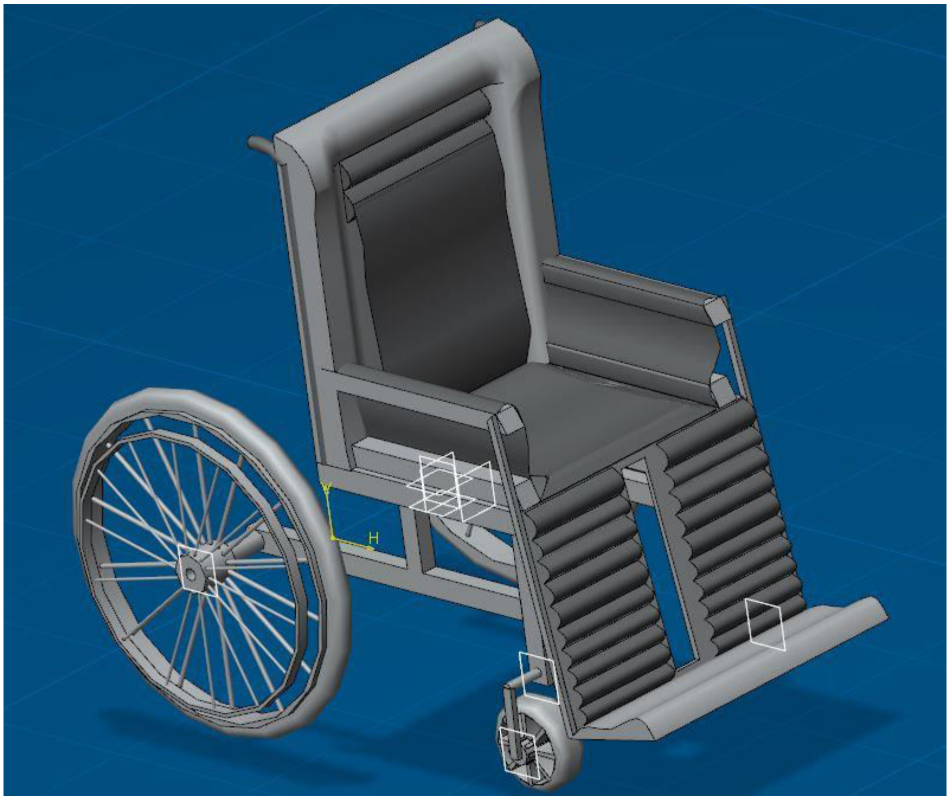


Figure 29. Final CATIA Model of Wheelchair

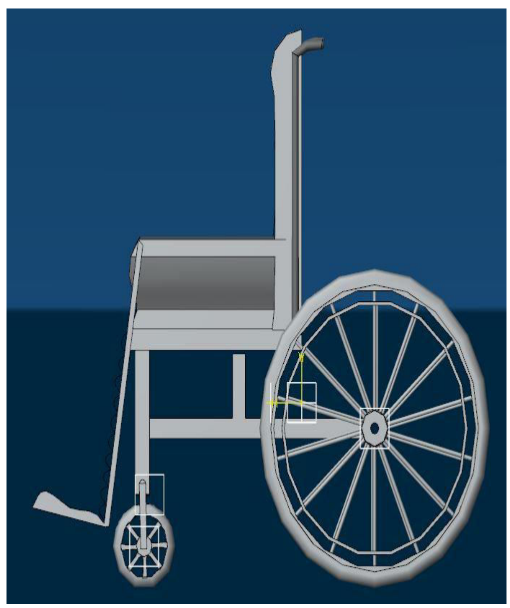


Figure 30. Front View of Wheelchair

Figure 31. Side View of Wheelchair

5. CONCLUSION

The final wheelchair is designed using kinematic link mechanism which came out to be very efficient method for two important operations called lying and standing functions. This is an ergonomic wheelchair because it takes into consideration all the human factors for wheelchair dimensions for seat height, width, arm rest positioning and the surface design of sitting seat, back resting seat and leg rest. Before developing prototype the model is built in CATIA and tested for simulation. The prototype model is developed by wood for link mechanism while thermocoal is used for surface modelling.

Thus the Final Proof of Principle Prototype is constructed which can successfully demonstrate the functioning of wheelchair with improved surface design for pressure relief around back (spinal cord) and relieves leg sores, improves blood circulation and digestion reducing compression of stomach. The standing mechanism can be also used to raise or adjust height to reach the desired level. Similarly the back reclination mechanism can also be adjusted accordingly as required. Final Wheelchair is constructed with basic elements or parts needed for construction of a general wheelchair. Basic elements refer to seat, back support seat arms and treadle are the fundamental parts of a wheelchair. These parts are assembled in very intelligent way to support back reclination and raising the seat height, and do not use any extra inputs to support the mechanism. Hence, the wheelchair is very light and also very cheap to be manufactured because of no extra cost of inputs. However, the model can be automated by using motors and adding some features like obstacle sensitivity, braking control etc.

5.1 FUTURE WORK

In the past, wheelchair was powered with human hands but it was difficult to move several hundreds of meters. Thus the automatic wheelchair is an advanced and modified design of existing ones. Some features like automatic speed control, wireless communications, digital image processing. These all technologies make it multi-functioning and multipurpose wheelchair [2].

Thus following suggestions are given for future work-

I. Future work of project is incorporating electrical components like batteries, motors, joystick, sensors by using embedded system. By using similar coding environment with PC based solution, the size and power consumption is minimized.

II. Features which can be associated in future work are omni-direction wheeled, goal seeking, obstacle avoidance and light sensing.

REFERENCES

1. ” Wheelchair Vehicle Access System,” United States Patent, No.US 2003/0108412, Jun. 12,2003 by P.H. Zimmer.

2. ” Elevator Chair,” United States Patent, No. 2003/0011228, Jan. 16,2003 S. Komura, T. Kaneda, K.Yamashita, K. Adachi, and I. Mizuseki.

3. Yan, H., S., Creative Design of Mechanical Devices, Springer-Verlag,1998

4. Theory of Machines, By SS.Ratan

5. http://what-when-how.com/universal-access-in-human-computer-interaction-uahci-2011/integral-model-of-the-area-of-reaches-and-forces-of-a-disabled-person-with-dysfunction-of-lower-limbs-as-a-tool-in-virtual-assessment-of-manipulation-possibilities-in-selected-work-environments-unive/

6. Google images ergonomic wheelchair sketches.

7. http://suntran.com/pop_access_measurements.htm.