Design of a Wheelchair

Project -2
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Need for wheelchair design

- 50-60 million physically disabled people in our country.

- When the influx of Chinese companies entering the market with their consumer products in different sectors they would not be focusing on the disability sector as it comprises of a relatively less user population therefore less marketability. Therefore it is the time for the entrepreneurs and designers to foresee this as a prospective challenge to provide for this user segment.
Why wheelchair Design project?

The wheelchair project is taken because a need was felt for a wheelchair in India which suites the Indian patients and gives them the much needed comfort and motivation to use a wheelchair. It was also to seek meaningfulness in my work by contributing my little bit into the disability sector where I personally feel lies immense possibilities and the results generate very significant and obviously comforting change in the lives of the user.

• The design of a suitable wheelchair for developing countries presents several problems:
• Wheelchair design poses as a challenging project due to following reasons:
  • 1) Large variation in Socio-economic status of user class.
  • 2) Various user categories therefore:
  • Involves good understanding of user needs and psychology.
  • Involves understanding of market and targeting this user segment.
  • 3) Possibility of exploration and innovation.
  • 4) Involves good material; and process understanding.
  • 5) Involves understanding and utilising ergonomics at different junctures.
  • 6) Involves product detailing as a very important element.
Aspects of the wheelchair

User
- age
- disability
- psychology
- occupation
- family
- economy

Product
- manual
- electric
- components: Joystick, pneumatic, motor
- Lever, handrim, pedal

Environment
- indoor
- outdoor
  - house
  - office
  - desktop
  - Factory floor

Material and technology
- No. of components
- Sequence of assembly
- Processes
- cost
- time

Usage
- smooth
- rough
- sports
- roads
- playgrounds
- shopping
- socialising

Reading
- cooking
- relaxing
- socialising
- Toilet usage

freedom to be
Process of data collection

Stage-1

Wheelchairs available (Indian and international scenario)

- Study of types and components
Typical wheelchair materials and processes

Frame or basic structure
- Tubular sections - aluminum alloys, titanium and carbon fibers
- Plastics used more in frame design. Reinforced plastics - carbon epoxy tubes, composites foams or honeycomb cores, are light and strong.
- Tubular m.s. sections - bending and welding is used.

Seats
canvas, Rexene, and nylon

Footrests
aluminum or m.s or P.V.C depending upon the user and needs.

Wheels
wire spoke wheels with metal frame, molded poly propylene

Tyres
pneumatic tyres - rubber with a tubing inside. Non pneumatic tyres - urethane or other synthetics

Casters
Different kinds of casters p.v.c. injection molded in different sizes

Drive systems
tp.p or chrome plated m/s
National job development center, kiwanis
Types
Other vehicles designed for similar user group
Outcome of stage-1 study

The study resulted in a better understanding of -

1. Types of wheelchairs available in India and abroad.
2. Component design.
3. Materials and technologies at the disposal.
4. Fabrication methods and tools and space requirement.
5. Time taken and sequence of assembly.
6. Existing details.
### Stage-2 Understanding and defining Disability

#### User group and Indian scenario

A mobility impairing disorders causes a person to use the wheel chair. A survey was conducted at the All India Institute of Physical and Medical Rehabilitation to classify the percentage of wheel chair users according to their disabilities.

<table>
<thead>
<tr>
<th>CONDITION OF DISABILITY</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>*- Paraplegic</td>
<td>Both lower limbs are paralysed. Injury/infection to the Spinal Cord. Caused by Infection/accidents</td>
</tr>
<tr>
<td>*- Poliomyelitis</td>
<td>Polio virus damage nerve cells paralysing muscles</td>
</tr>
<tr>
<td>*- Quadriplegic</td>
<td>All four limbs are paralysed. Injury at a higher position of the spinal cord</td>
</tr>
<tr>
<td>*- Muscular Dystrophy</td>
<td>Hereditary disability, gene distrophin absent. A progressive disability</td>
</tr>
<tr>
<td>*- Congenital Diseases</td>
<td>By birth, fragile bone or deformity</td>
</tr>
<tr>
<td>*- Amputees</td>
<td>Caused by accidents absence of lower limbs</td>
</tr>
<tr>
<td>*- Hemiplegic</td>
<td>Half side paralysed</td>
</tr>
<tr>
<td>*- Rheumatoid arthritis</td>
<td>Auto immune disorder, inflammatory disorder, younger ladies and girls</td>
</tr>
<tr>
<td>*- Muscle diseases</td>
<td>Weakening of the muscles leading to a subsequent disability of the limb</td>
</tr>
<tr>
<td>*- Oesto-artherithis</td>
<td>Progressive disability prevalent in old people, caused due to wear and tear</td>
</tr>
<tr>
<td>*- Ankylosing spondilitis</td>
<td>Progressive disability, joints gets stiffer, restriction of the movement</td>
</tr>
<tr>
<td>*- Spinal Muscular Atropy</td>
<td>Hereditary disability, muscles weaken</td>
</tr>
<tr>
<td>*- Cerebral Palsy</td>
<td>Damage to a developing brain, no control over motor movements</td>
</tr>
<tr>
<td>*- Multiple Soierosis</td>
<td>Eating away of cells of the spinal cord resulting in paralysis</td>
</tr>
</tbody>
</table>
Target Segment

User category
Poliomyelitis
Amputee
Paraplegic
Spinal injury

Users whose lower limbs are immobile due to any disease or accident like the above. Therefore the user should be able to propel the wheelchair independently by himself have considerable upper body strength.

Environment

The wheelchair is predominantly an indoor vehicle which is used to move around inside homes. But this does not negate its possibility to be transported and taken to another location and moved around in public spaces like shopping malls, local bazaar or cinema halls.

The wheelchair user is a middle or upper economic class urban resident.
Focus of the project and defining the deliverables

1. To design a wheelchair which would aid in:
   - Climbing up and coming down staircase.
   - Human power driven
2. Ease of transferability.
3. Integration of parts, components.

Aspects to Climbing staircase

- Climbing up one kerb or step.
- Climbing down one kerb or step.
- Climbing up staircase
- Climbing down staircase

Transferability

- Self transfer of user from wheelchair to pot (western)
- Self transfer of user from wheelchair to chair or car.

Integration of parts

- Weight reduction.
- Ease of assembly
  - time
  - convenience
- Lesser joints - increase in stability, strength

Aesthetics

- To derive a new aesthetic language from new and existing materials and processes
Stage-3 Activity analysis

Strong upper body - well built fore arms and chest. Strong neck, less lower body weight.

Good gripping power.
Transfer and getting in and out of the wheelchair

**Sitting to standing**

1. **2 hand support**
   - Skew lower body

2. **With hand grips**
   - Shifts upper body

3. **Hands behind one foot on the floor**

4. **Turning the body grip**
   - Footrest as fulcrum

5. **Bending forward to put weight and take support from vehicle**

**Sitting to shifting**

1. **External support with one hand other behind the body**
   - Shifting the upper body

2. **Lifting the body with two supports one external one internal**

3. **Taking support of the vehicle and placing the upper body on the other seat.**
Inferences drawn -

Clearance required for front facing standing up

Breaking grounding stability
The vehicle needs to provide a steady and rigid support, it should not move while in user is transferring.

Enough clearance space for side transfer.
Removable side wheel and arm rest
Concerns

Climbing up and own staircase

Balance
- Angle - distribution
- of weight and C.G

Maneuverability
- mechanism, 
- ergonomics

Force
- weight of the wheelchair
- transfer of power

Safety
- breaking mechanism

Transferability

Objectives

Force
Stage-4

Concept generation

- Concept for mechanism
  - Climbing steps
  - Transferability
  - Maneuverability
  - Retractability
    (physics numericals and consulting mechanical department faculty)

- Form generation
  - Exploration in materials
    (through renderings and models)

- Construction
  - Components and details (joints and junctions, finishes)
    (consulting fabricators, looking for parallels in furniture and automobile industry)
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Concept generation
Stage-5
Final Concept selection and evaluation
Final Concept selection and evaluation
Staircase
Single step or kerb
Single step or kerb
Small level change
Two point contact the traction can be used to overcome the level change
Final Concept selection and evaluation

Why a need for a “Test model”?

- To check **traction**
- **Force** required for climbing as well as the amount of resistance force or breaking required.
- To check **placement** and center of gravity in order to achieve balance, while climbing.
- To estimate how much needs to be added and reduced in terms of dimensions and weight of different components.
- To place different parts and their co-ordination between each other.
- Adjustment of **center of gravity** and managing a balance between the theoretical and the psychological.
Final Concept selection and evaluation
conclusions drawn test model at this stage

1. Gears and treads to be made deeper.
2. Decrease pitch between two treads.
3. Detail aligning the chain wheels.
4. Weight reduction.
5. More possibility of increasing transmission ratio.
Concept generation (form and construction)
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Concept generation (form and construction)
Selection criteria-

1. Maneuverability
Force transmission, turning radius, ease of breaking and turning

2. Ease of assembly
Number of parts and joints, nature of combining different materials and their behavior

3. Ease of construction

4. Visual Appeal

5. Weight to strength ratio
Minimise on weight and maximise on strength
Detail 1

- 20mm dia. M.S. tubular section
- Aluminium die-casted member
- Bolt with allenkey nut
- Pivot for actuator support
- Pin to allow rotation of member
- Rubber grip for footrest (capped on top of tube)

Pivot for actuator support

- 20mm dia. M.S. tubular section
- Aluminium die-casted member
- Bolt with allenkey nut
- Rubber grip for footrest (capped on top of tube)

Welded joint
Detail 2

- Self-skinning semi-flexible PUF
- Insert moulded 20mm M.S. tubular section
- Press fit joint with circular rings to allow 90-degree rotation of handgrip
- Insert moulded 20mm M.S. tubular section
- Welded joint
- Press fit joint with circular rings to allow 90-degree rotation of handgrip
- Insert moulded 20mm M.S. tubular section
- Self-skinning semi-flexible PUF
- Metal screws inside threaded studs
- Insert moulded 20mm M.S. tubular section
Detail 3

- 22mm dia. M.S. tubular section
- 6mm wall thickness metal die-casted aluminium member
- Hexagonal head on insert-casted bolt (10mm dia.)
- Casing for placing bearing with sirclip
- 20mm dia. axle rod

- 6mm wall thickness metal die-casted aluminium member
- Axle
- Casing for placing bearing with sirclip
Detail 4

- Fibre-reinforced rubber belt (pitch > 1/2\textquoteright), 4mm thk.
- 6mm wall thickness metal die-cast aluminium member
- Hexagonal head on insert-casted bolt (10mm dia.)
- 65mm dia. nylon wheel
- 6mm wall thickness metal die-cast aluminium member
- Cross-bracing
Detail 5

- Tubular section edge-welded to both members
- 20mm dia. M.S. tubular section
- 22mm dia. M.S. tubular section

Welded point
interface
<table>
<thead>
<tr>
<th>Part</th>
<th>Component</th>
<th>Length/Volume/Area</th>
<th>No. of Pieces</th>
<th>Rate</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKREST</td>
<td>FRAME (22mm dia)</td>
<td>2.7meters</td>
<td></td>
<td>Rs 66/mt</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>FABRIC</td>
<td>1meters</td>
<td></td>
<td>Rs 711 per mt</td>
<td>710</td>
</tr>
<tr>
<td></td>
<td>GRIP (RUBBER)</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
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<tr>
<td>SEAT</td>
<td>FRAME (22mm dia)</td>
<td>1.4meters</td>
<td></td>
<td>Rs 66/mt</td>
<td>90</td>
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<tr>
<td></td>
<td>FABRIC</td>
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<td></td>
<td>Rs 711 per mt</td>
<td>Used from previous</td>
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<tr>
<td>WHEELS</td>
<td>WHEEL FRAME</td>
<td></td>
<td>2</td>
<td>Rs 711 per mt</td>
<td>600</td>
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<td></td>
<td>E (POLYPROPYLENE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYRES (PNEUMATIC RUBBER)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>ARMREST</td>
<td>P.U.</td>
<td></td>
<td>2</td>
<td>Rs 66/mt</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>TUBULAR SEC. (20mm dia)</td>
<td>.6meters</td>
<td></td>
<td>Rs 60/mt</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>RUBBER GRIP</td>
<td></td>
<td>2</td>
<td>Rs 60/mt</td>
<td>40</td>
</tr>
<tr>
<td>FOOTREST</td>
<td>TUBULAR SEC. (20mm dia)</td>
<td>1.7meters</td>
<td>2</td>
<td>Rs 60/mt</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>ALLUMIN. DIE CAST</td>
<td>1.8 kg</td>
<td>2</td>
<td>Rs 180/kg</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>RUBBER GRIP</td>
<td></td>
<td>2</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>ALUMIN. JOINT</td>
<td>BELT</td>
<td></td>
<td>2</td>
<td></td>
<td>1400</td>
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<tr>
<td></td>
<td>NYLON WHEELS</td>
<td>10</td>
<td></td>
<td>Rs 180/kg</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>ALL. FRAME</td>
<td>10 kg</td>
<td>2</td>
<td>Rs 180/kg</td>
<td>3600</td>
</tr>
<tr>
<td></td>
<td>GEAR</td>
<td></td>
<td>2</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>ACTUATOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>MISC.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500 = 9100</td>
</tr>
</tbody>
</table>
Stair Climber Design

- ratchet
- chain
- nub
- frame
- cylinder

Internal Force Diagram of Stair Climber
- $F_s$ = Applied Force
- $F_r$ = required force to move one track
- $W_k$ = weight force
- $r_i$ = radius of wheel i

External Forces Applied on Stair Climber
- $W_{total} = 500 \text{ lb}$
- $\theta = 45.0^\circ$
- $W_k = 353.55 \text{ lb}$
- $N = 353.55 \text{ lb}$
- $u_k = 0.75$
- $f_k = 265.17 \text{ lb}$
- $F_T = W_k + f_k$
- $= 618.72 \text{ lb}$