Chapter-1

Introduction

1.1 Product Design:

Product Design is a process of generating new object or service through a set of strategic and tactical activities, from idea generation to commercialization, manufacturing and implementation of that product or services. Product Designers conceptualize and evaluate ideas, making them tangible products in a more systematic approach.

Developing a design concept is the initial part of design engineering. Design concepts that can be engineered are special. We are not trying just to design something that looks new. We are trying to find a balance between all the different factors that influence a product.

1.2 Our Proposals:

1.2.1 Proposal 1:

***Load Carrier for Labor*:**

"Load Carrier for Labor “is a product to improve the working condition of laborers and workers at many places globally — construction sites, factories, ports, railway stations etc. The objective is to prevent various occupational hazards and demonstrating ergonomic consideration for the welfare of human life.

Features:

- The principal object of the product is to facilitate three methods of lifting and shifting of the loads by worker, such as - (i) above the head, (ii) at the back and (iii) push or pull action.
- The main structures of the device can be made from cane materials, plastic and metal components. It is possible to make the entire structure in plastic or metal.

Description:

The new design has two major parts, one that holds the load and the other that rests on the shoulder. Device has two knobs, which facilitates the change of required function manually from one to another in one minute duration. This allows three modular functions for carrying lighter loads on the head, medium loads at the back and heavier loads to push or pull as trolley. Ergonomically the load is distributed on the shoulder and at the lumber support by softer material.

Uses:

Load lifting and load carrying in construction sites, factories, ports, railway stations etc.

1.2.2 Proposal 2:

***Stair Climbing Wheelchair*:**

"Stair Climbing Wheelchair" is a specially modified wheelchair that can climb most of the obstacles very easily. This innovative device can ascend or descend almost any type of stair from spiral staircases to wood or stone step surfaces.

Features:

- The main object of the product is to provide the low mobility people a greater mobility.
- The traditional existing wheelchairs can be converted to this, with a low cost, ensuring a greater extent of mobility than before.
- It is safe and comfortable.

Description:

The stair climbing wheelchair has four steps connected to the wheelchair by means of adjustable gears and switches. It can be used generally just like a traditional wheelchair. But by adjusting the gears it can engage the steps. These steps can climb the stairs very efficiently when push rim attached to the rear wheel is rotated. It can also move down the stairs with similar fashion. Then after ascending or descending the stairs it can again be converted to a traditional wheelchair. Thus it can give the low mobility people the access of climbing stairs without other's assistance.

Uses:

- The main use of the product is to climb the stairs easily.
- It can serve as general wheelchair also.

1.2.3 Proposal 3:

<u>Four-row pinpoint seeder:</u>

Four-row pinpoint seeder is used in green house planting. It allows faster seeding in production beds than single row seeder.

Features:

- It is extremely quick.
- Simple to adjust and operate.
- It plants lettuces, carrots and other greens very close or can plant a wider spacing by filling either alternate hoppers or terminal hoppers.
- The seed depth can be controlled by angling the handle more or less.
- Suitable for small seeds.
- Even seed pouring rate can be adjusted by selecting the seed hole size (dimples).

Description:

Four-row pinpoint seeder enables to plant four rows of varying space with pinpoint accuracy. This seeder is ideal for planting small to medium size seeds. There are four hoppers to put the seeds and the distance between two consecutive hoppers is 2.25". So depending on the choice, the distance can be adjusted. In the bottom of each hopper there are dimples. The dimples can be selected according to seed size. Once that has been done. One can slide the shaft back and forth to select the dimples. All the brushes are adjustable and that will limit the amount of seed is actually dropping out, ideally one or two. There are knobs in the hoppers that regulate the flow of the seeds. The plows which are on the back side at the bottom of the seeder makes the furrows and dispenses the seeds.

Uses:

- It is extremely used for planting small sized seeds.
- For quick operation.

1.3 Selected Proposal:

After consulting with our course teachers, the second proposal “**Stair Climbing Wheelchair**” was granted as our project.

Causes for Selection:

In most of the multi-stored buildings, there is elevator or escalator to lift the low mobility people from one floor to another. But at the entry of these buildings, there is few steps of stair. Traditional wheel-chair cannot lift overcome these steps without the assistance of others. On the other hand by using our product, a low mobility person frequently steps up or step down solely with a very safe and comfortable way. Moreover, It can be used generally just like a traditional wheelchair.

As there is no local manufacturer of **Stair Climbing Wheelchair**, we have to buy this from modern countries with a huge cost. Our target is to reduce the cost and make it feasible in our financial condition.

Chapter – 2

Understanding Customer Needs Through Survey

2.1 Introduction:

Disability is to an increasing extent being addressed as an issue to be included into mainstream development. This follows the recognition that people with disabilities are citizens with equal rights, who – given the opportunity are able to contribute economically and socially to their households and communities. It is estimated by WHO (World Health Organization) that around 7-10% of population of Bangladesh are disabled. According to World Bank, this may make up to 15-20% of total population in any developing country. But unfortunately people with disabilities are often discriminated against, socially marginalized and do not have access to basic social services.

For these reasons, a wheelchair with capacity to climb any stairs will increase the mobility of these disabled people to a great extent. Moreover, these people can be utilized in many social or productive sectors than before. This will help them personally as well as bring more prosper to nation.
As a primary research, we identified our main customers are:

- Disabled individuals
- Government's Health Projects
- NGO and Other organizations

We carried out a survey for developing customer requirements for our stair climbing wheelchair among some of the above customers in a very short period of time.

2.2 Areas and Locations of Survey:

1. National Institute of Traumatology and Orthopedic Rehabilitation (Dhaka Pongu Hospital), Syed MahbubMorshedAveneu, Dhaka 1207, Bangladesh.
2. Centre for Disability in Development,
   House#C/88, Road 13/A,Banani,Dhaka,Bangladesh.
3. Trauma Center,
   22/8/A, Block-B, Mirpur Road Shyamoli, Dhaka-1207, Bangladesh.

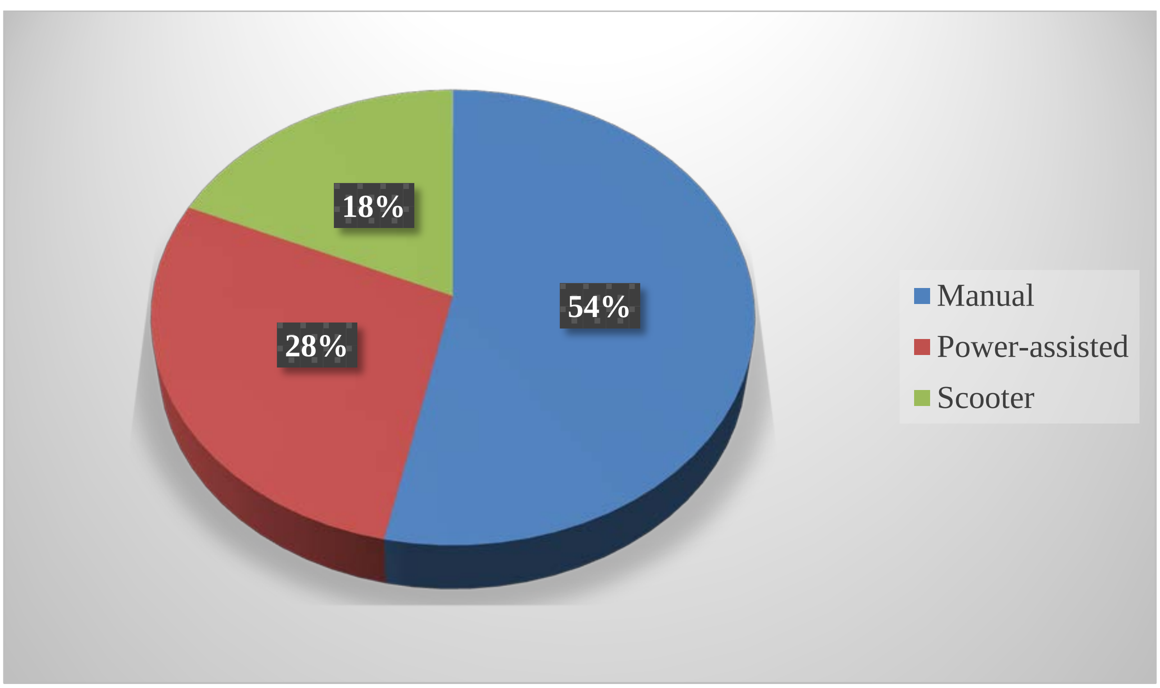
4. Dhaka Medical College and Hospital,
   Secretariat Road, Dhaka 1000, Bangladesh.

2.3 Survey Result:

The survey was done among 60 people. The results of the survey are shown below with the help of pie charts along with percentages:

1. What type of wheelchair(s) do you currently use regularly?
   - Manual
   - Power-assisted
   - Scooter

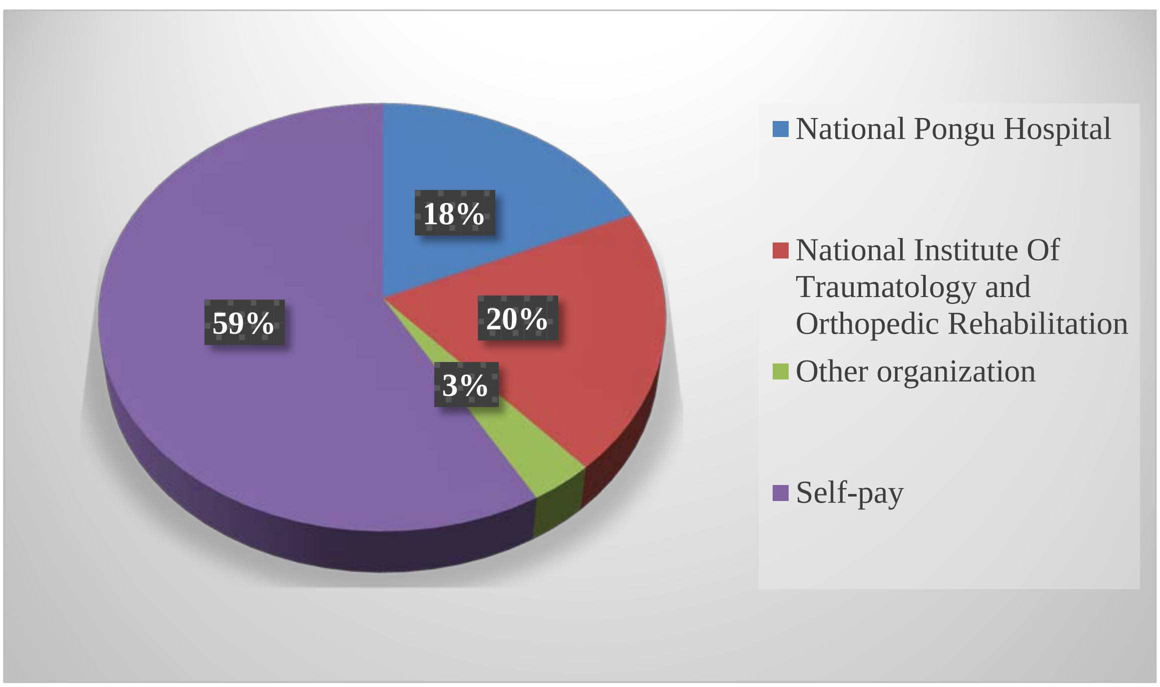
Option	Response Count	Response Percent (%)
Manual	32	54
Power-assisted	17	28
Scooter	11	18



2. Who paid for your current wheelchair?

- National Pongu Hospital
- National Institute Of Traumatology and Orthopedic Rehabilitation
- Other organization
- Self-pay

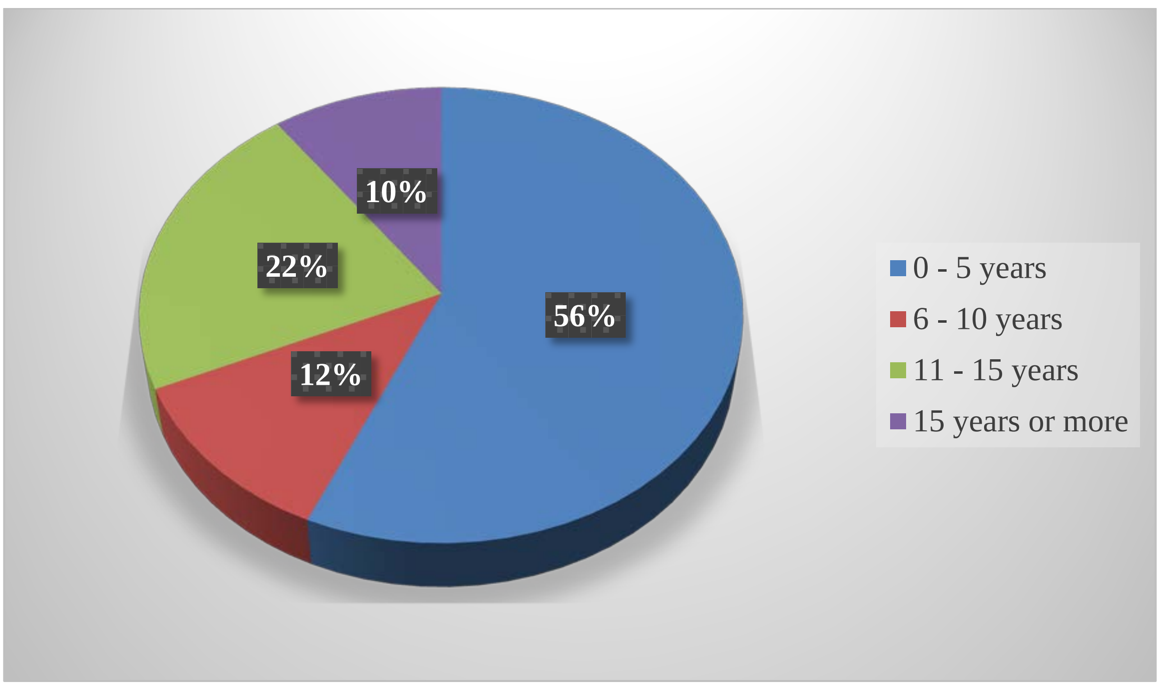
Option	Response Count	Response Percent (%)
National Pongu Hospital	11	18
National Institute Of Traumatology and Orthopedic Rehabilitation	12	20
Other organization	2	3
Self-pay	35	59



3. How many years have you used a wheelchair?

- 0 - 5 years
- 6 - 10 years
- 11 - 15 years
- 15 years or more

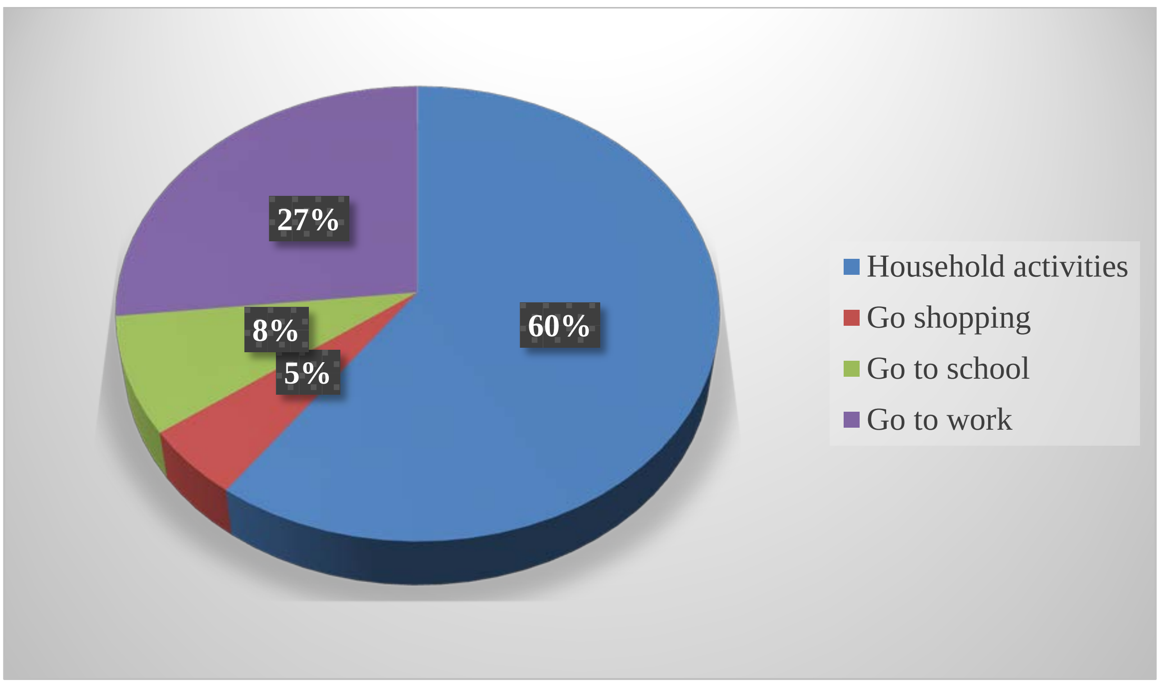
Option	Response Count	Response Percent (%)
0 - 5 years	34	56
6 - 10 years	7	12
11 - 15 years	13	22
15 years or more	6	10



4. What activity are you involved in on a daily or regular basis?

- Household activity
- Go shopping
- Go to school
- Go to work

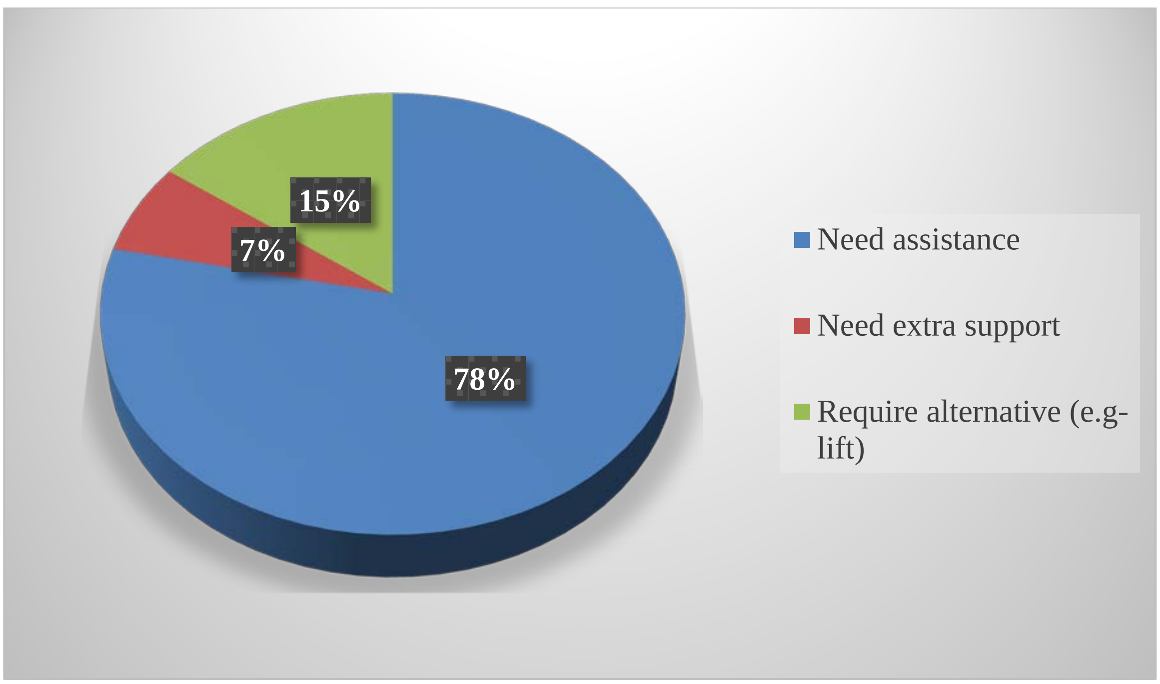
Option	Response Count	Response Percent (%)
Household activities	36	60
Go shopping	3	5
Go to school	5	8
Go to work	16	27



5. What kind of problem do you face during climbing up or downward to a stair?

- Need assistance
- Need extra support
- Require alternative (e.g- lift)

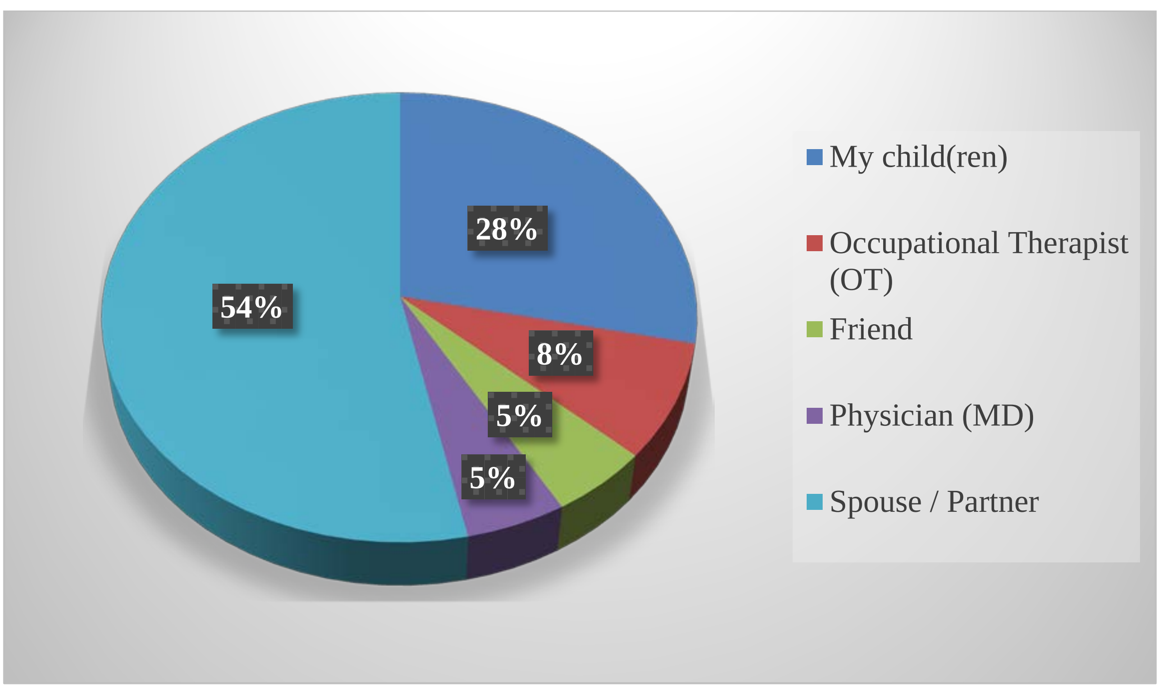
Option	Response Count	Response Percent (%)
Need assistance	47	78
Need extra support	4	7
Require alternative (e. g- lift)	9	15



6. Who was present during your most current wheelchair assessment? (Select any one option)

- My child(ren)
- Occupational Therapist (OT)
- Friend
- Physician (MD)
- Spouse / Partner

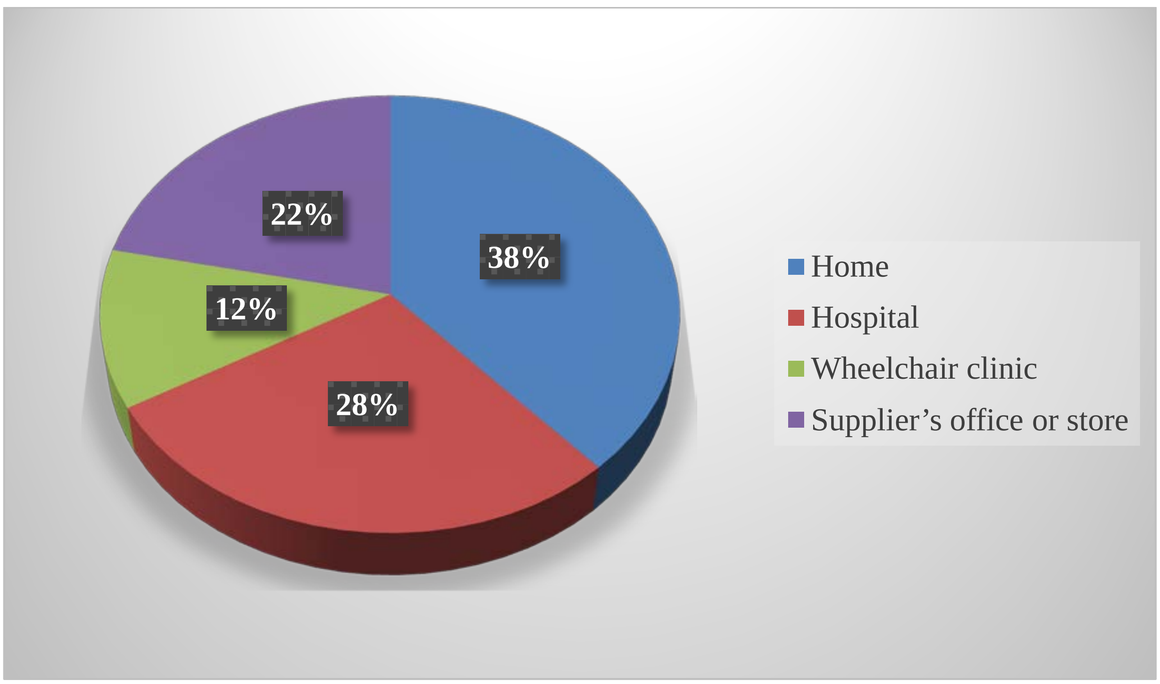
Option	Response Count	Response Percent (%)
My child(ren)	17	28
Occupational Therapist (OT)	5	8
Friend	3	5
Physician (MD)	3	5
Spouse / Partner	32	54



7. Where was your most current wheelchair assessment?

- Home
- Hospital
- Wheelchair clinic
- Supplier’s office or store

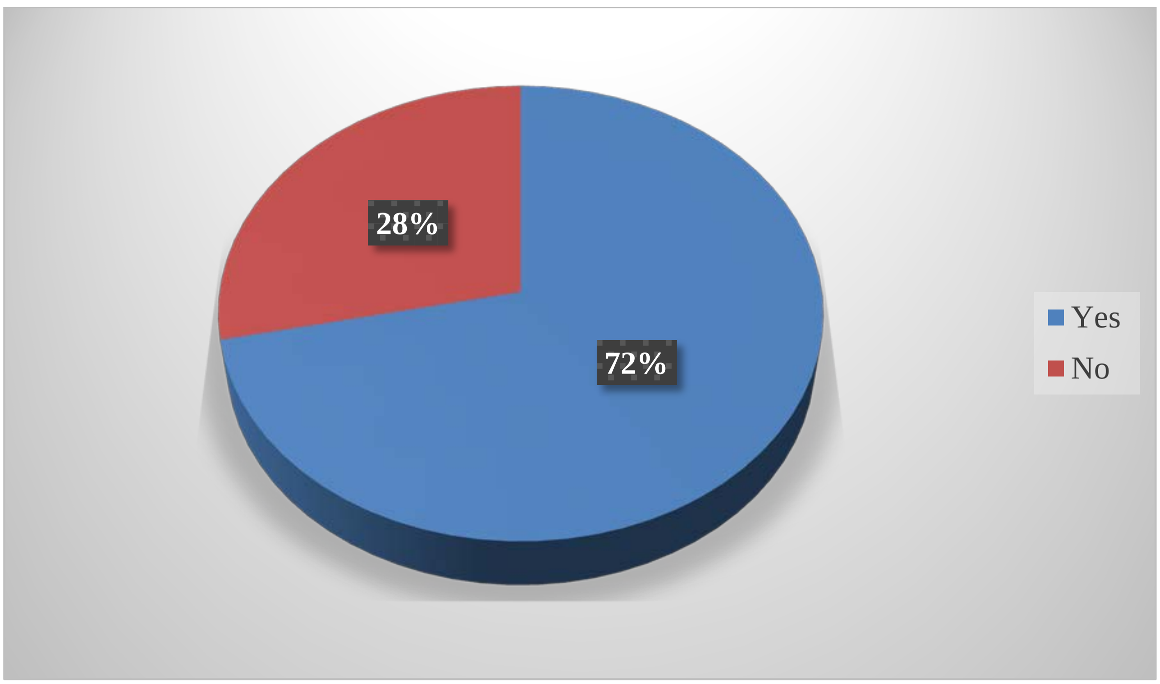
Option	Response Count	Response Percent (%)
Home	23	38
Hospital	17	28
Wheelchair clinic	7	12
Supplier’s office or store	13	22



8. Did you have an opportunity to try one or more wheelchairs and/or configurations before your current wheelchair was ordered?

- Yes
- No

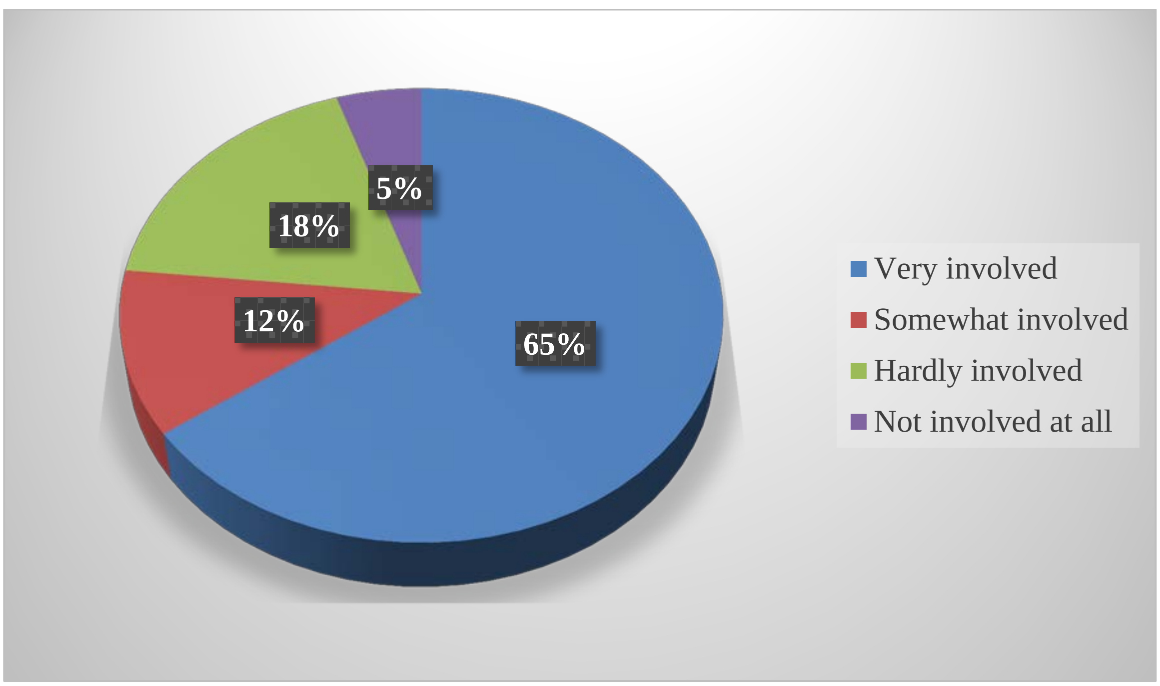
Option	Response Count	Response Percent (%)
Yes	43	72
No	17	28



9. What was your level of decision making in the selection of your most recent wheelchair?

- Very involved
- Somewhat involved
- Hardly involved
- Not involved at all

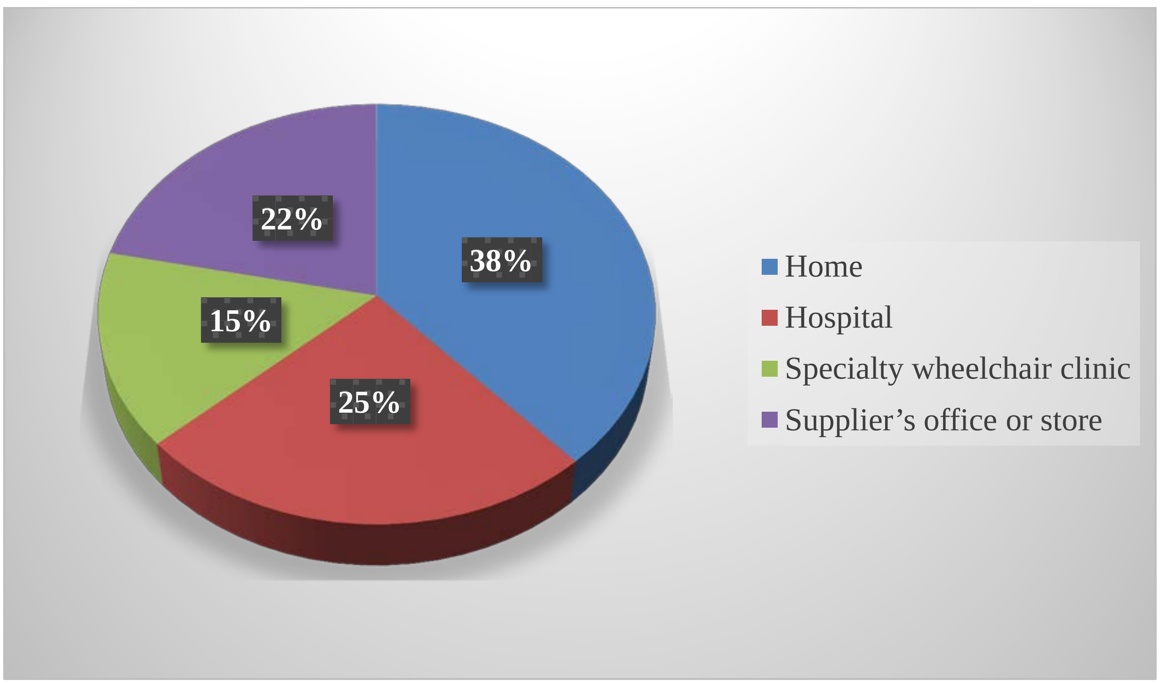
Option	Response Count	Response Percent (%)
Very involved	39	65
Somewhat involved	7	12
Hardly involved	11	18
Not involved at all	3	5



10. Where did you accept delivery of your most recent wheelchair?

- Home
- Hospital
- Specialty wheelchair clinic
- Supplier's office or store

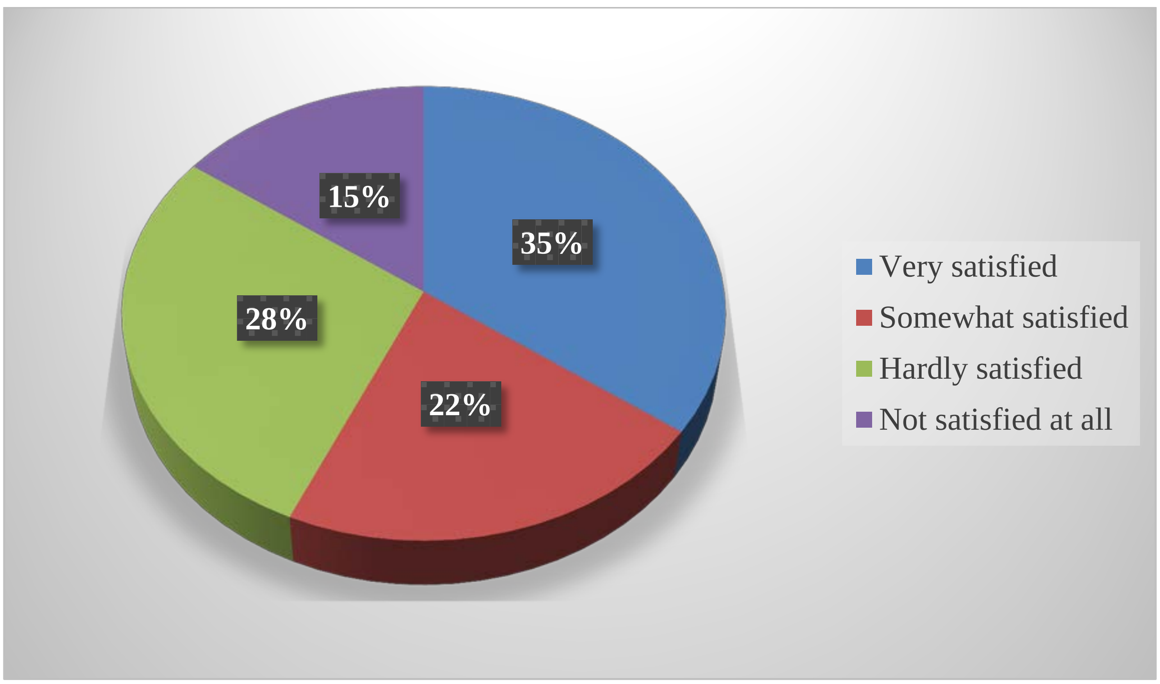
Option	Response Count	Response Percent (%)
Home	23	38
Hospital	15	25
Specialty wheelchair clinic	9	15
Supplier's office or store	13	22



11. Are you satisfied with the manner that your current wheelchair was delivered?

- Very satisfied
- Somewhat satisfied
- Hardly satisfied
- Not satisfied at all

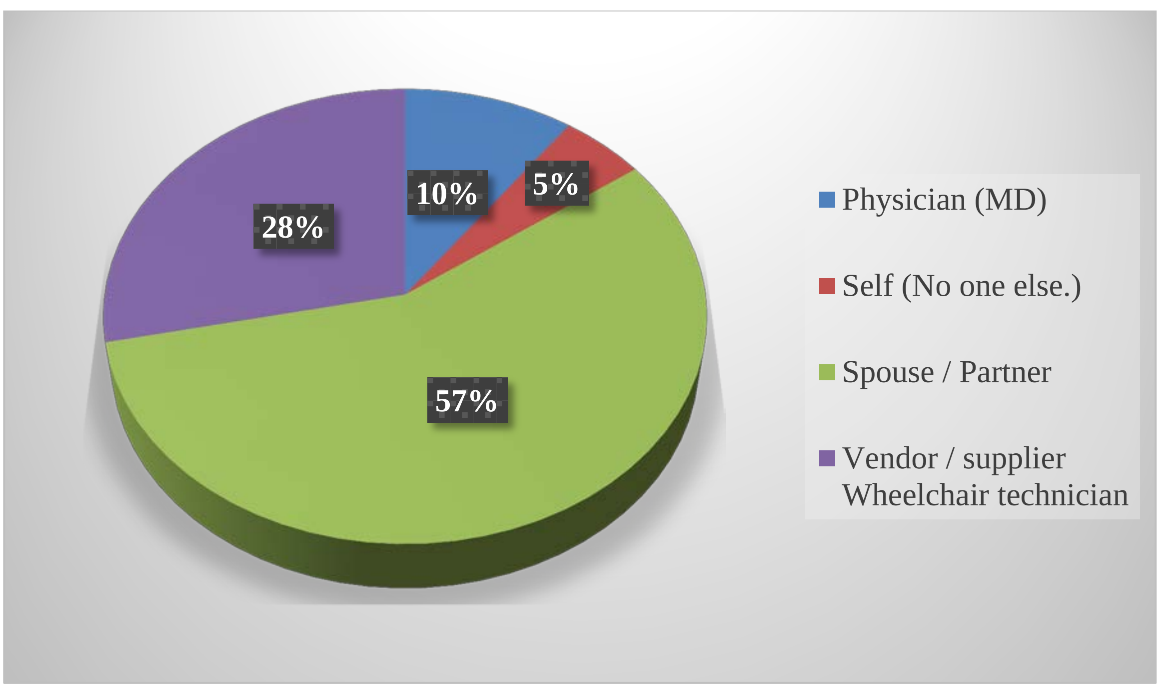
Option	Response Count	Response Percent (%)
Very satisfied	21	35
Somewhat satisfied	13	22
Hardly satisfied	17	28
Not satisfied at all	9	15



12. Who helped adjust your wheelchair when it was delivered?

- Physician (MD)
- Self (No one else.)
- Spouse / Partner
- Vendor / supplier Wheelchair technician
- Assistive Tech Provider (ATP)

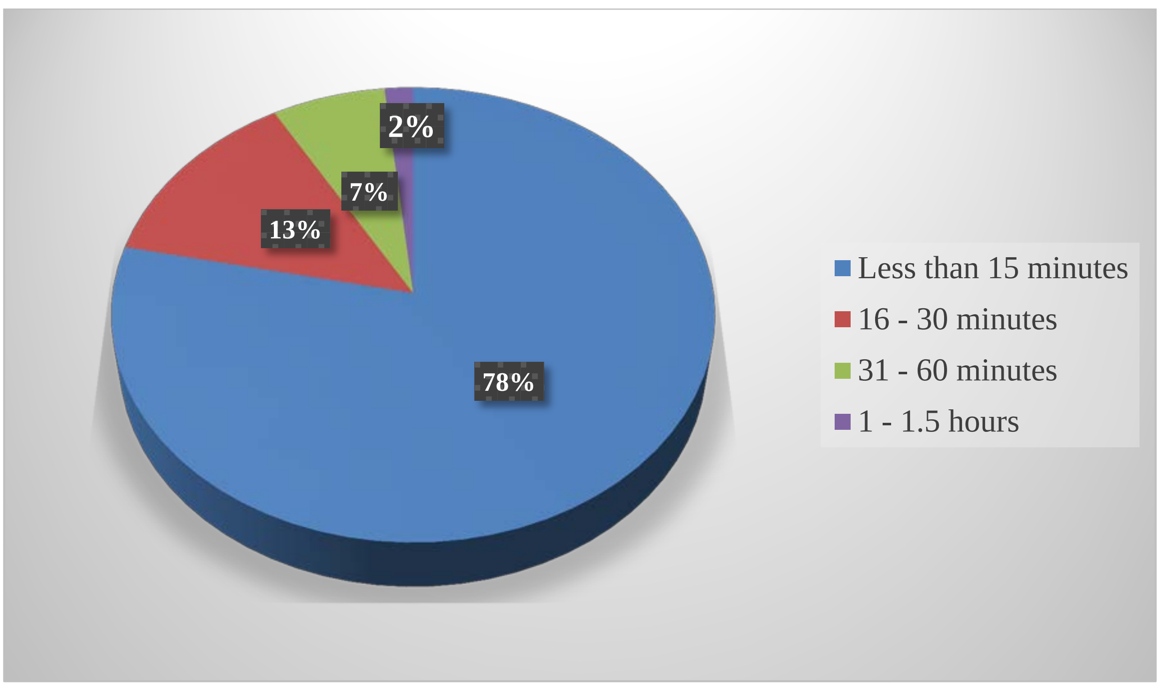
Option	Response Count	Response Percent (%)
Physician (MD)	6	10
Self (No one else.)	3	5
Spouse / Partner	34	57
Vendor / supplier Wheelchair technician	17	28
Assistive Tech Provider (ATP)	6	10



13. How much time was spent on your most recent wheelchair fitting process?

- Less than 15 minutes
- 16 - 30 minutes
- 31 - 60 minutes
- 1 - 1.5 hours
- More than 1.5 hours

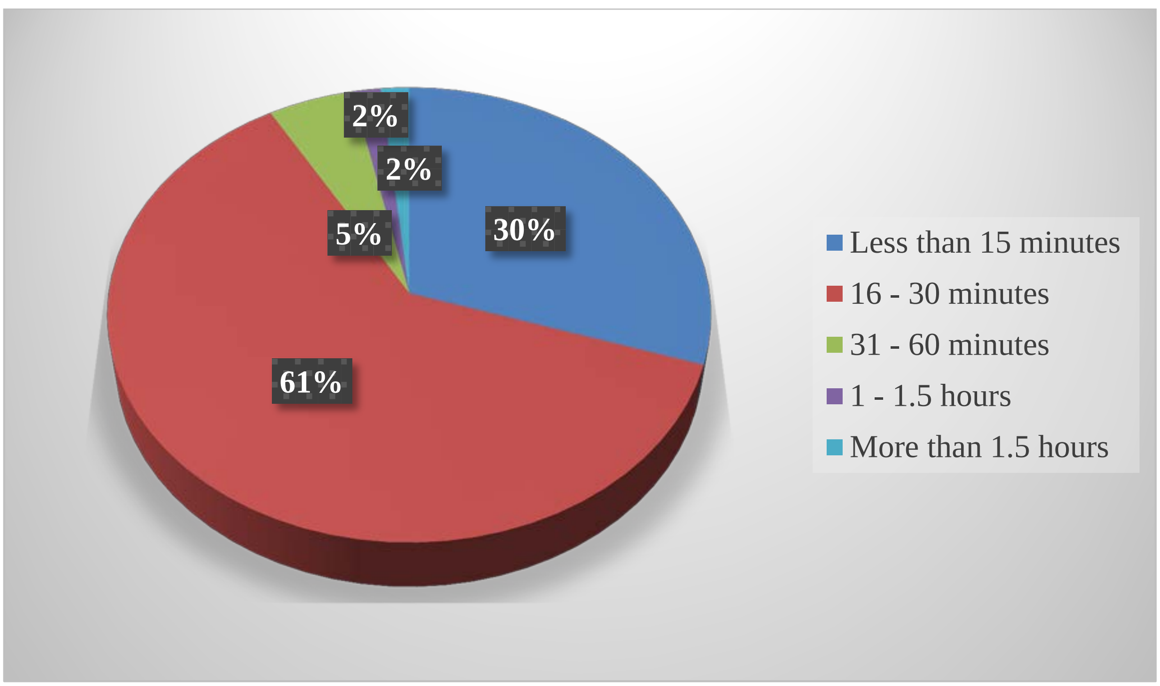
Option	Response Count	Response Percent (%)
Less than 15 minutes	47	78
16 - 30 minutes	8	13
31 - 60 minutes	4	7
1 - 1.5 hours	1	2
More than 1.5 hours	47	78



14. How much time was spent on your most recent wheelchair education and training process?

- Less than 15 minutes
- 16 - 30 minutes
- 31 - 60 minutes
- 1 - 1.5 hours
- More than 1.5 hours

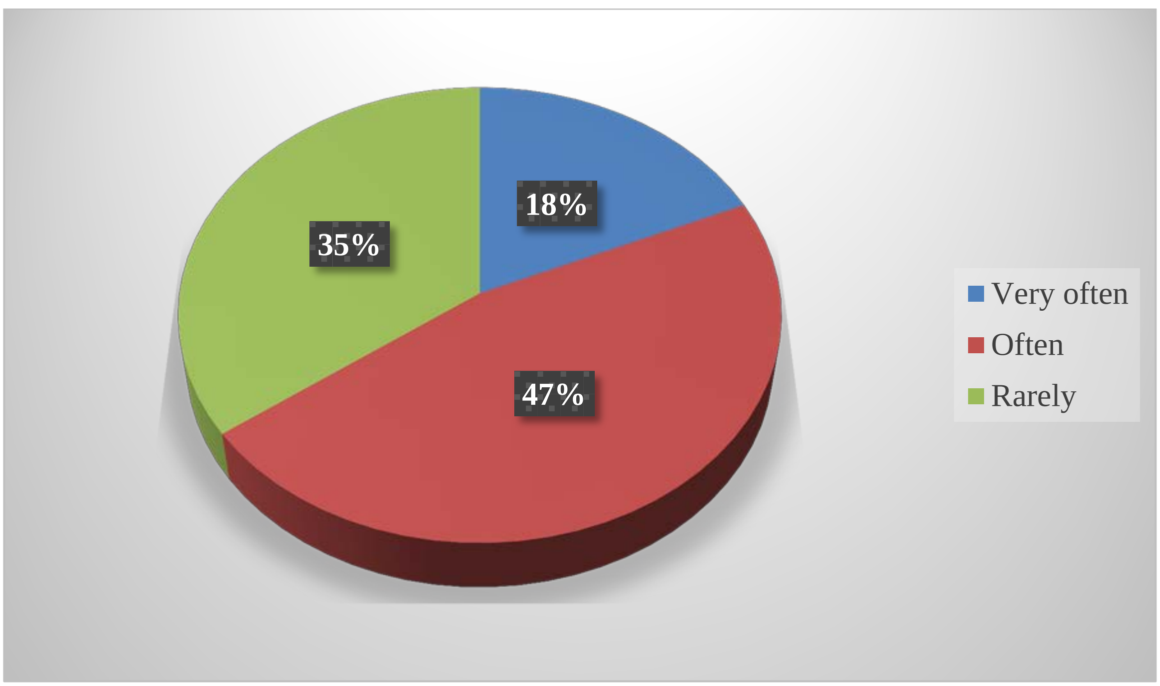
Option	Response Count	Response Percent (%)
Less than 15 minutes	18	30
16 - 30 minutes	37	61
31 - 60 minutes	3	5
1 - 1.5 hours	1	2
More than 1.5 hours	1	2



15. How often assistance is available during climbing the stairs?

- Very often
- Often
- Rarely

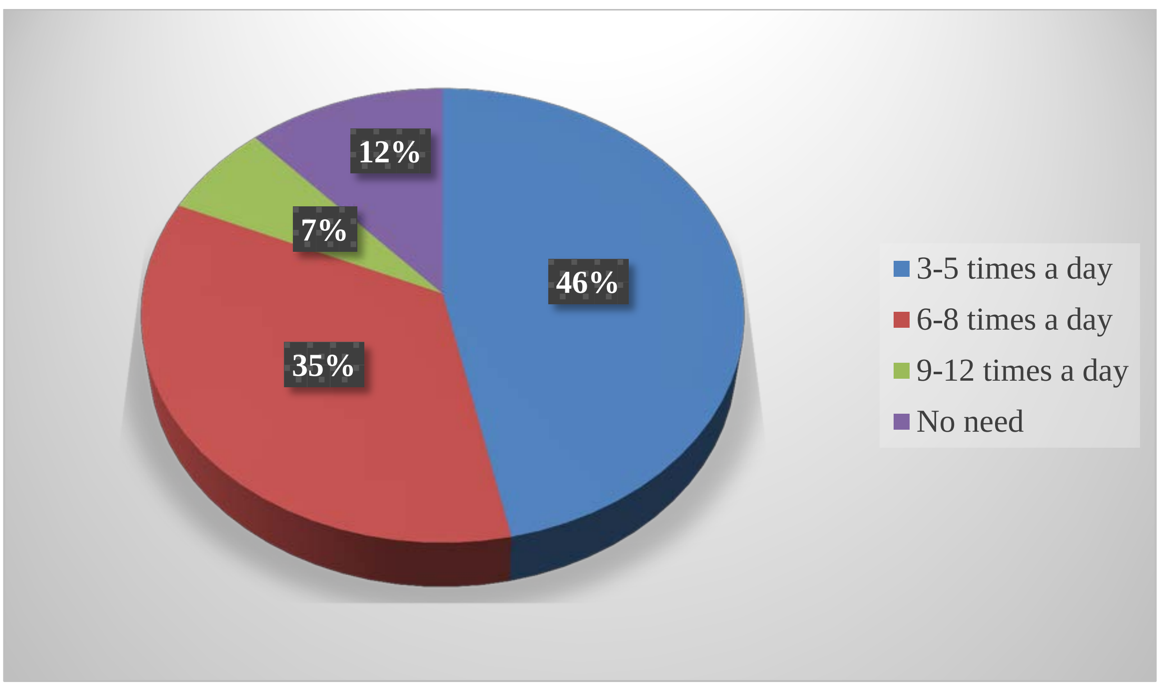
Option	Response Count	Response Percent (%)
Very often	11	18
Often	28	47
Rarely	21	35



16. How often you need to ascend or descend stairs?

- 3-5 times a day
- 6-8 times a day
- 9-12 times a day
- No need

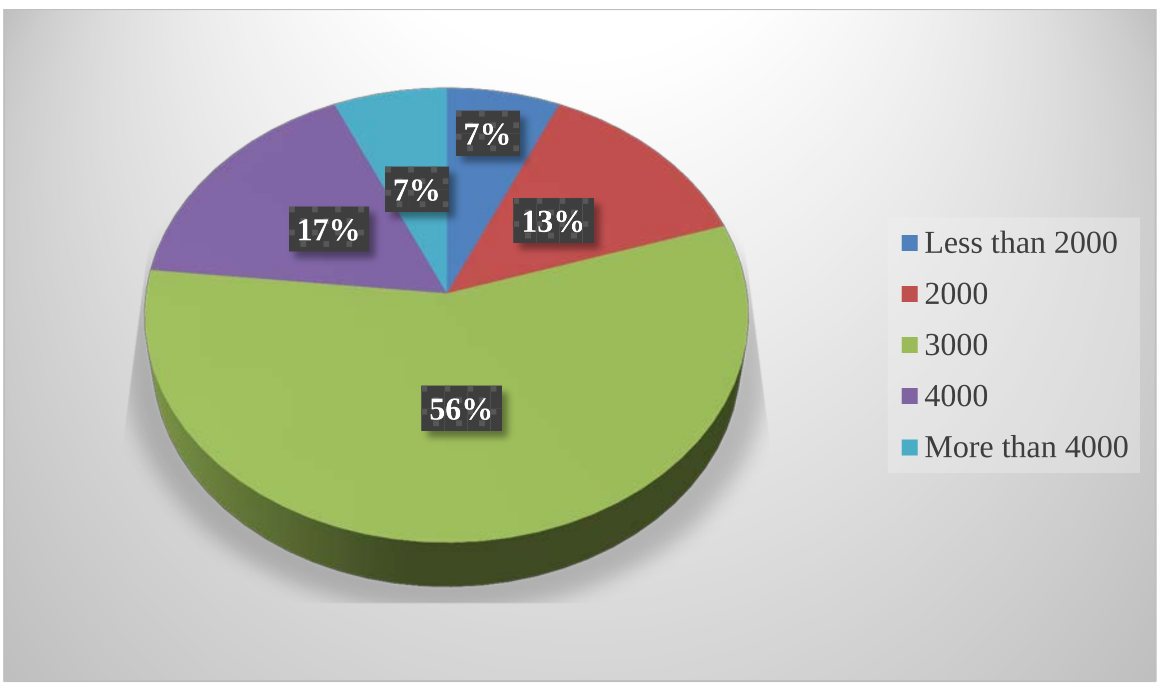
Option	Response Count	Response Percent (%)
3-5 times a day	28	46
6-8 times a day	21	35
9-12 times a day	4	7
No need	7	12



17. How much additional payment you can afford for the special assembles or fittings (taka)?

- Less than 2000
- 2000
- 3000
- 4000
- More than 4000

Option	Response Count	Response Percent (%)
Less than 2000	4	7
2000	8	13
3000	34	56
4000	10	17
More than 4000	4	7



2.4 Customer's Requirement Evaluation:

Customer Requirement	Relative Weight/ Importance (Scaleof 10)
Easy To Move	10
Good Stability	9
Minimum Effort For Movement	8
Easy Conversion	9
Comfortable	8
Low Cost	7
Easy To Maintain/Repair	7
Reliability	10
Operating Speed	6

2.5 Conclusion:

Survey plays an important role in product design. Through survey the customer requirements are collected and convert it into product specification. Surveys use questionnaires that are carefully crafted and applied either through the mail, over the telephone, or in face-to-face interviews. Surveys are well suited for collecting requirements on products to be redesigned or on new. After being finished with surveying, we now can move to the next step for developing House of Quality.

Chapter - 3

Incorporating the Voice of Customer in Product Design with Quality Function Deployment (QFD)

3.1 Introduction

According to the Japanese Quality function deployment (QFD) is, "Listen to the voice of the market (customers)" which refers to "Understanding the design problem". Understanding the design problem is a must for developing a quality product. Quality function deployment (QFD) is the translation of user requirements and requests into a technical description of what needs to be designed. The goal of QFD is to build a product that does exactly what the customer wants instead of delivering a product that emphasizes expertise the builder already has.

Besides finding the right problem to solve, developing "engineering specifications" is an even more difficult problem. Many techniques are adopted for creating engineering specifications. In a QFD process, multi-skilled teams collaborate to arrive at a common understanding of the customer needs, and determine the appropriate technical requirements of each stage. QFD method's main advantage is that it is organized to develop the major pieces of information necessary to understanding the problem:

1. Listening to the voice of the customers
2. Improving team work
3. Improving production efficiency
4. Customer-driven process, not technology-driven process
5. Reducing development time and costs
6. Developing the specifications
7. Inspecting how the specifications meet customers' requirements
8. Determining how well the competition meets the goals
9. Determining goals targets to work toward

Since we have already collected customer needs by conducting survey, the next step in the QFD technique is to evaluate the importance of each of the customers' requirements (out of 10 scale). This is accomplished by generating a weighting factor.

3.2 Quality Function Deployment's House of Quality

Quality Function Deployment's House of Quality is shown below:

High Relationship □ (Rating= 5)

Medium Relationship o (Rating= 3)

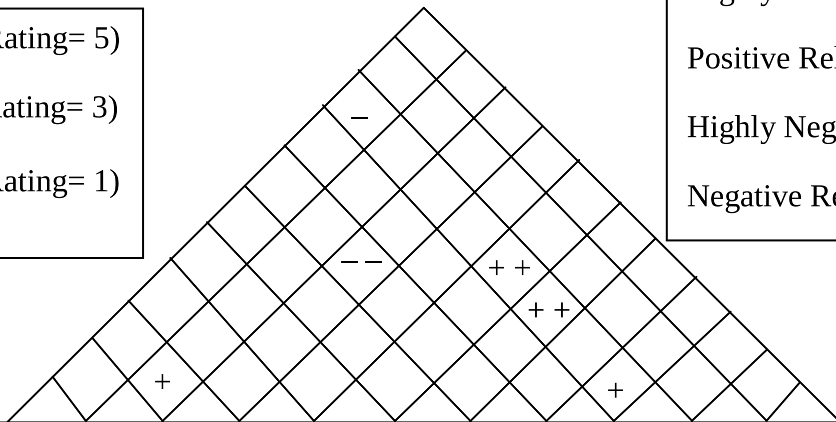
Low Relationship ♦ (Rating= 1)

Highly Positive Relationship ++

Positive Relationship +

Highly Negative Relationship - -

Negative Relationship -



G- Good

F- Fair

P- Poor

Customer Requirements \ Technical Requirements	Customer Importance	Frame Weight	Conversion Steps	Conversion Force	Warranty Maintenance	Seat Material	Wheel Design	Ergonomic Design	Seat Dimension	Weight Capacity	Stairs Climbing Assembly	Break Kit	Sunrise Medical	Our Product
Easy To Move	10	□	♦	o			□	o		o		♦	G	F
Good Stability	8	♦			□	□	o	o		□	□	o	G	G
Minimum Effort For Movement	5	□	□	□				♦					G	F
Easy Conversion	10		□	o			o	□			□	o	G	F
Comfortable	7			♦		□	o	□	□	□			G	F
Low Cost	8	□	♦		□	□	o	o	□	□		♦	P	G
Easy To Maintain/Repair	7		□	o	o		o	♦			□	□	F	G
Reliability	10				□	♦	□	□		□	o	o	G	F
Operating Speed	8	□	□	□			□			♦	o		G	F
Importance Rating		188	168	153	151	125	260	249	75	203	179	137		

3.3 Conclusion

The QFD technique ensures that the problem is well understood. It helps organizations to reach agreement on measurement systems and performance specifications that will meet customer requirements. It is designed to improve a company’s strategic competitiveness. It also prioritizes the steps that a business must take in order to satisfy the spoken and unspoken requirements of the customer. We have developed QFD in a short time due to lack of time. But in reality, QFD is a lengthy process. It may appear to slow the design process, but in actuality it does not, as time spent developing information now is returned in time saved later in the process.

Chapter- 4

Functional Decomposition

4.1 Introduction

Functional decomposition is the method of decomposing of a system into its component functions and processes as a way of managing complexity. A good functional decomposition becomes increasingly important as complexity increases. It creates a top-down view which shows levels of increasingly detailed processes within a system. A functional decomposition model (or diagram) is used to represent the total decomposition and structure of the processes of a system.

There are four basic steps in applying the techniques and several guidelines for successful decomposition. These are given below.

Step 1: Find the Overall Function That Needs to Be Accomplished

All design problems have one or two “most important” functions. These must be reduced to a simple clause and put in a **black box.** The inputs to this box are all the energy, material, and information that flow into the boundary of the system. The outputs are what flow out of the system.

Step 2: Create Sub-function Descriptions

This step focuses on identifying the sub-functions needed.

Step 3: Order the Sub-functions

The goal is to add order to the functions generated in the previous step. For many redesign problems, this occurs simultaneously with their identification in step 2, but for some material processing systems this is a major step. The goal here is to order the functions found in step 2 to accomplish the overall function in step 1.

Step 4: Refine Sub-functions

The goal is to decompose the sub-function structure as finely as possible. This means examining each sub-function to see if it can be further divided into more sub-functions.

4.2 Black Box Model of Functional Decomposition:

A *black box* model is more useful way to perform the functional decomposition. In this model, the product is modeled abstractly as a black box with inputs and outputs. The flow of inputs (material, energy, and information) to outputs is sufficient to describe a technical system or product. The inside of the black box is developed by functionally decomposing the prime product function.

Black box diagram of our stair climbing wheelchair is shown below.

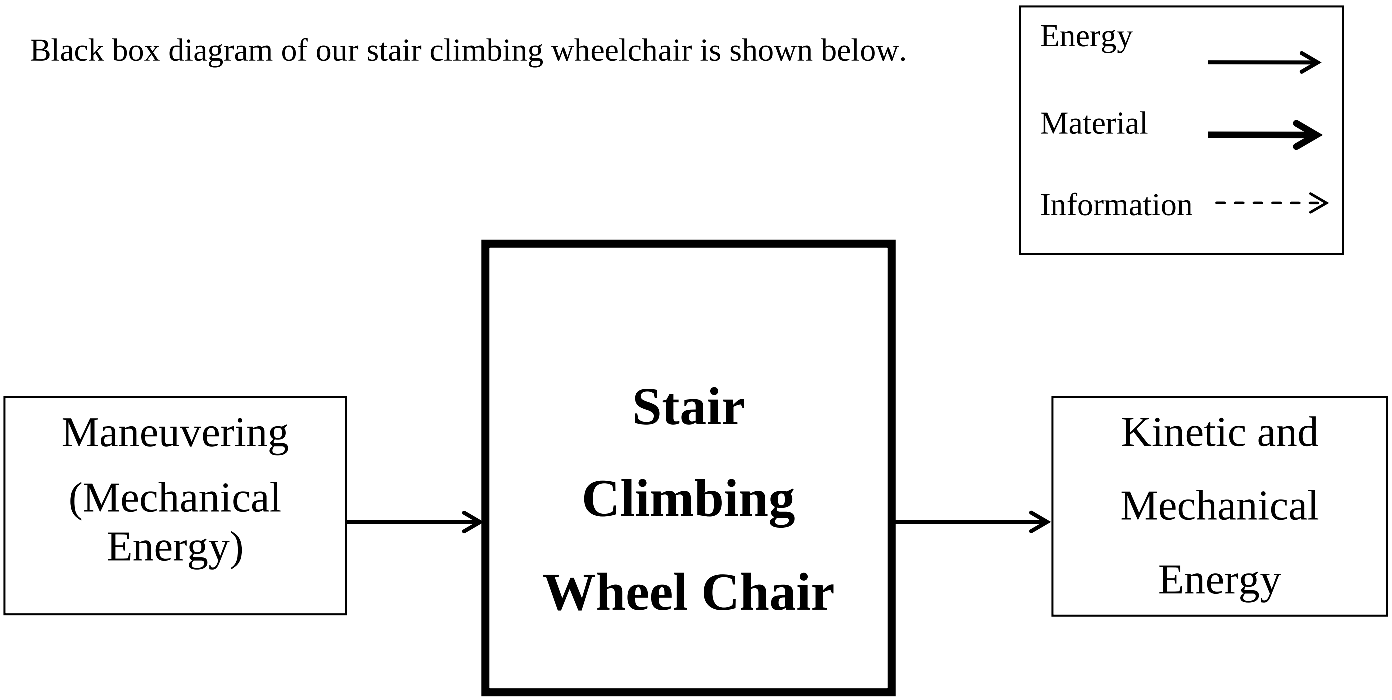


Figure 4.1: Black Box Model of the Stair Climbing Wheel Chair

There are generally three types of input and corresponding output in a black-box. They are

- Energy input and output
- Material input and output
- Information input and output

Some product's black-box may have all three types of input and output, and some may have less than three. In case of our product, there is no traceable material or information flow.

Energy flow: Our product will receive maneuvering from the operator and converts this energy into kinetic and mechanical energy.

Component Hierarchy:

An elementary approach to functional decomposition is to decompose the prime function hierarchically into sub functions; when all sub functions are satisfied, the prime function is satisfied. This can be repeated iteratively down several levels developing a *function tree*. Function trees are fast and easy to construct, but this ease of construction comes at the expense of understanding interactions between sub functions.

Component hierarchy of our stair climbing wheelchair is shown below:

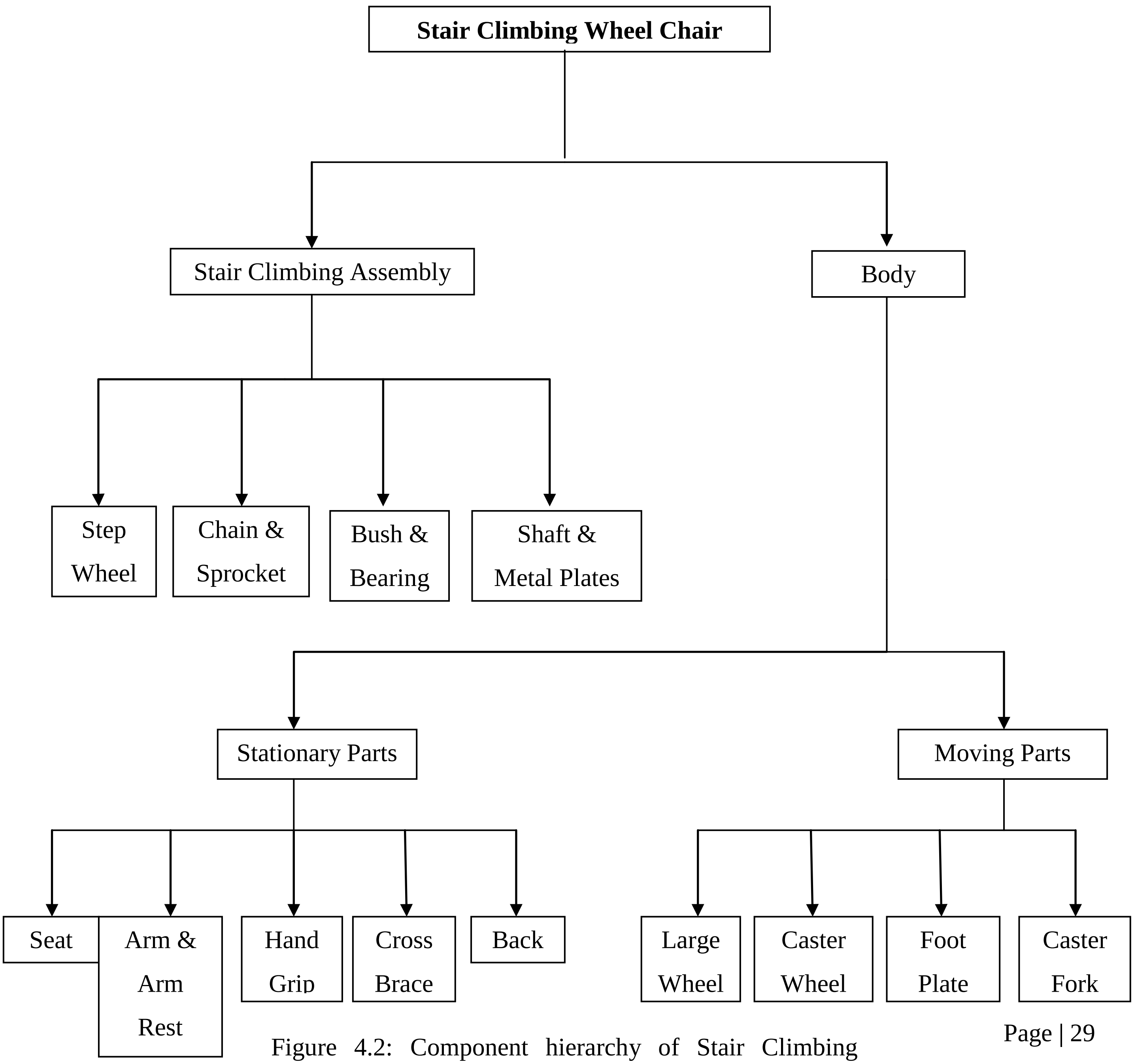


Figure 4.2: Component hierarchy of Stair Climbing

4.4 Cluster Function Structure for Stair Climbing Wheel Chair

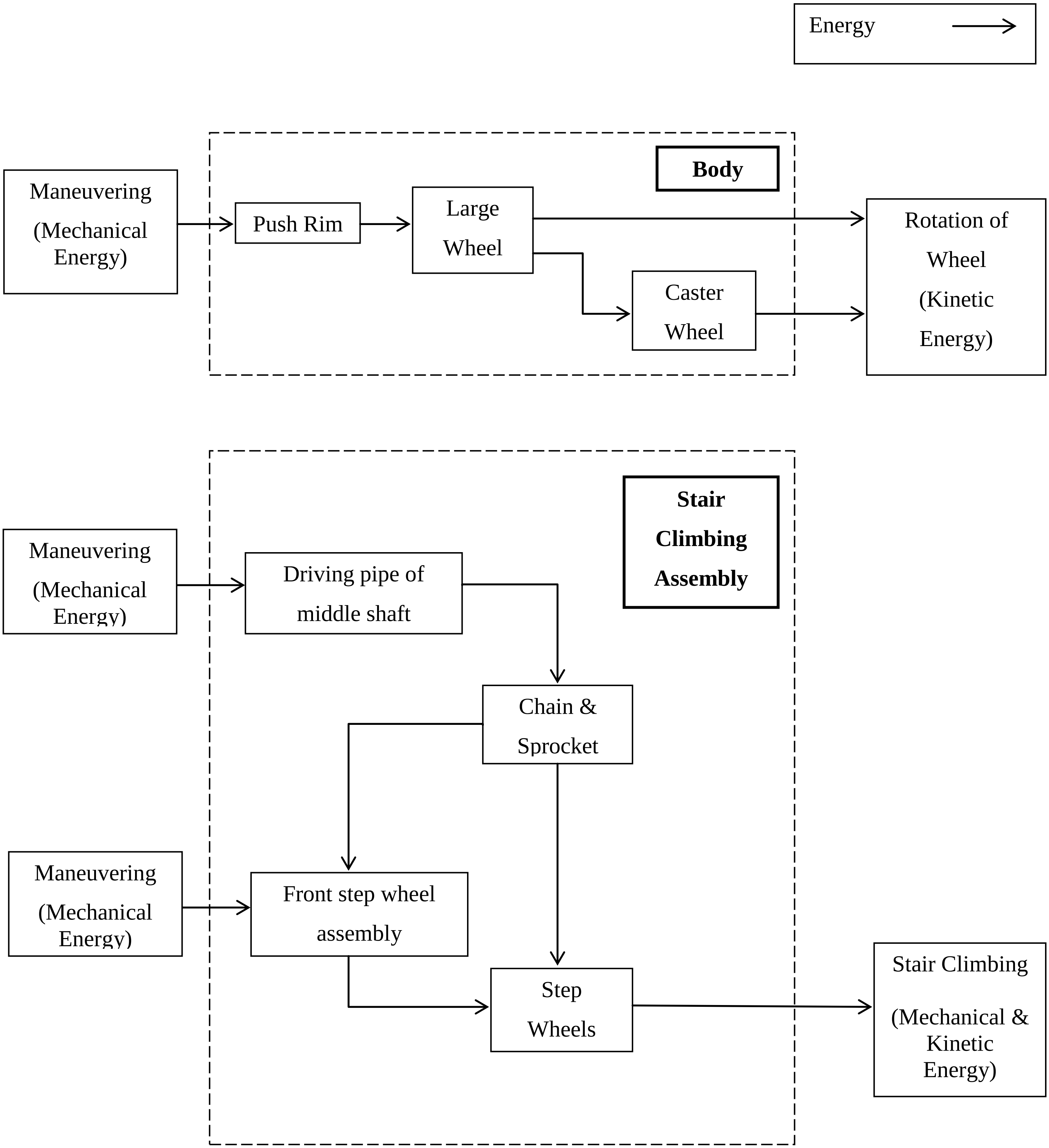


Figure 4.3: Cluster Function of Stair Climbing Wheel Chair

4.5 Conclusion:

We can conclude that these three different methods are very useful way for generating a successful functional decomposition. They have also their unique characteristics. The Black box model gives the idea about the whole material, energy and information input and output of the product. But as the name says “BLACK-BOX”, what happens inside the black-box is not visible. The component hierarchy for different mechanism shows hierarchy of the levels of increasingly detailed processes within the system and the cluster function structure shows the flow of material, energy and information of the whole product with the help of a detail drawing.

Chapter- 5

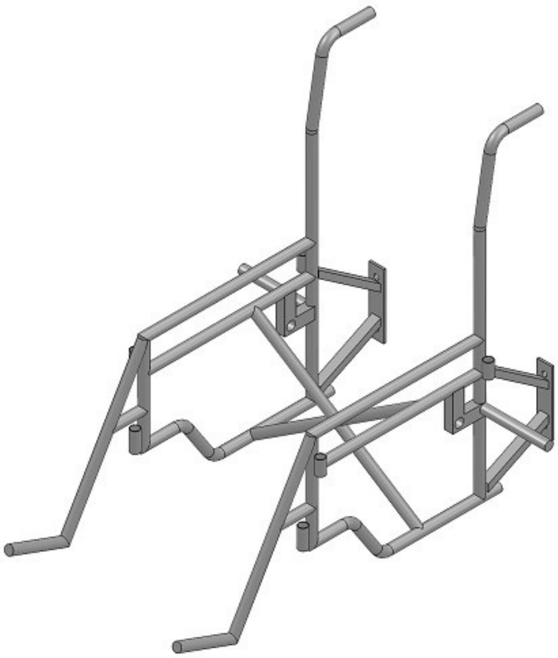
Design Analysis of Stair Climbing Wheel Chair

5.1 Introduction:

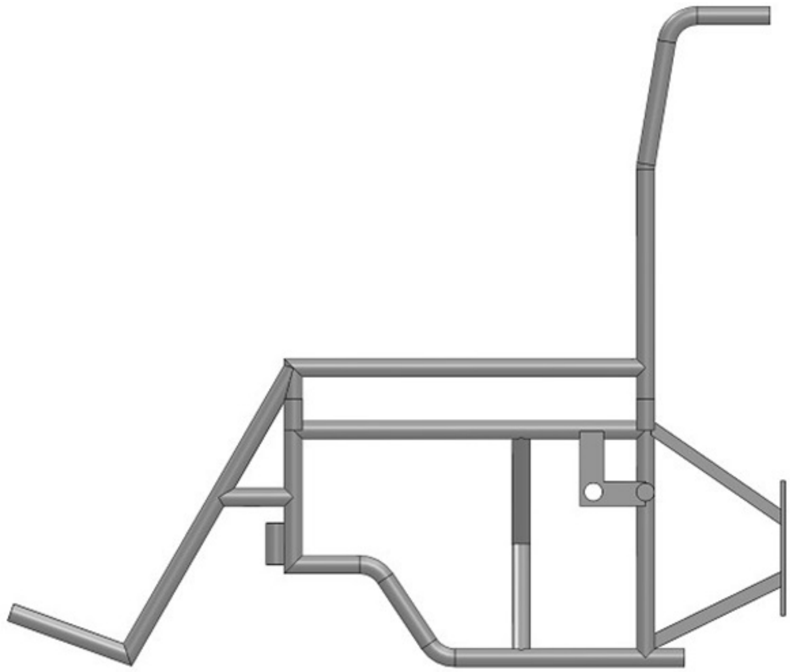
Design analysis is a powerful software technology for simulating physical behavior on the computer. Instead of building a prototype and developing elaborate testing to analyze the physical behavior of a product, engineers can utilize this information quickly and accurately on the computer. Because, design analysis can minimize or even eliminate the need for physical prototyping and testing.

Design analysis is one of the major stages in the product development. Among various stages of product development, the system-level design stage includes a rough-cut design of the product. It may be a sketch or a SolidWorks drawing and so on. After system-level design, detail design is done. For our product, we first developed a system-level design which results in a more detailed design; done on SolidWorks software is shown in this chapter.

Parts of Stair Climbing Wheel Chair



(Isometric view)



(Side view)

Figure: Main Body Frame

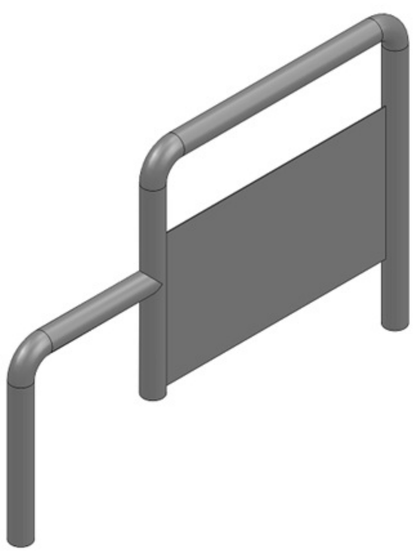


Figure: Arm

Figure: Arm Rest

Figure: Seat

Figure: Back

Figure: Wheel (Large)

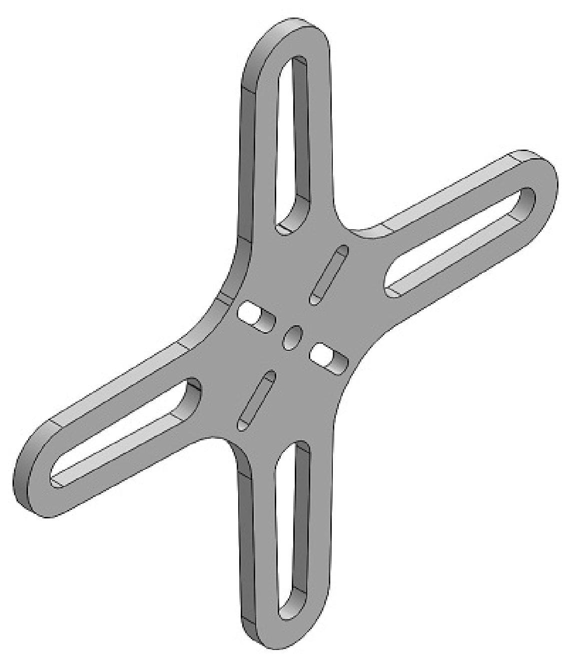


Figure: Step Wheel

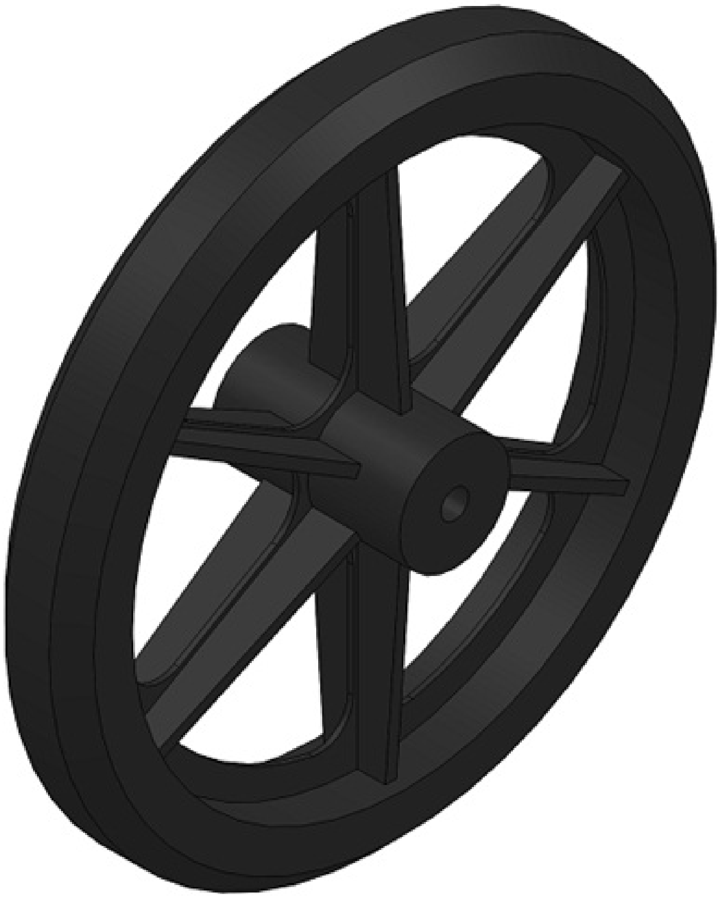


Figure: Caster Wheel

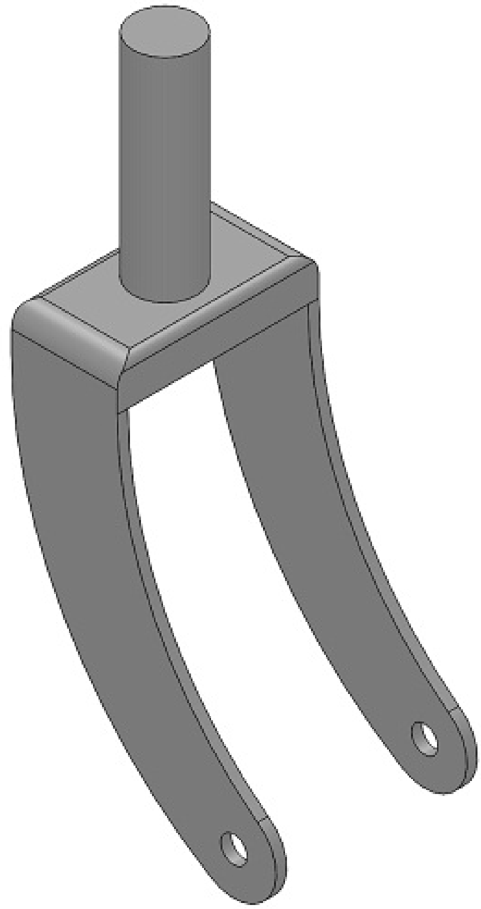


Figure: Caster Fork

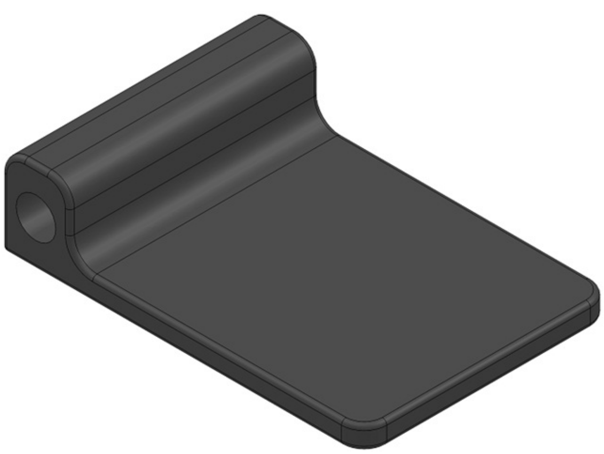


Figure: Foot Rest

Figure: Hand Grip

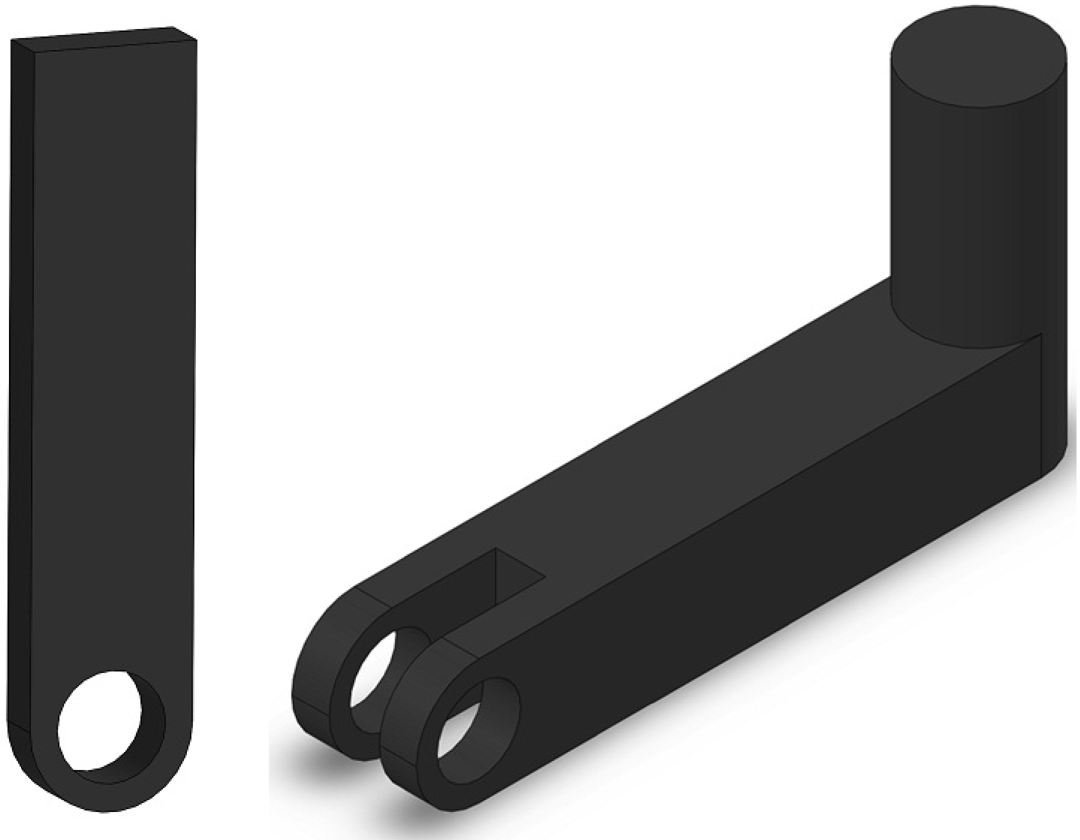


Figure: Wheel (Large) Locking Mechanism

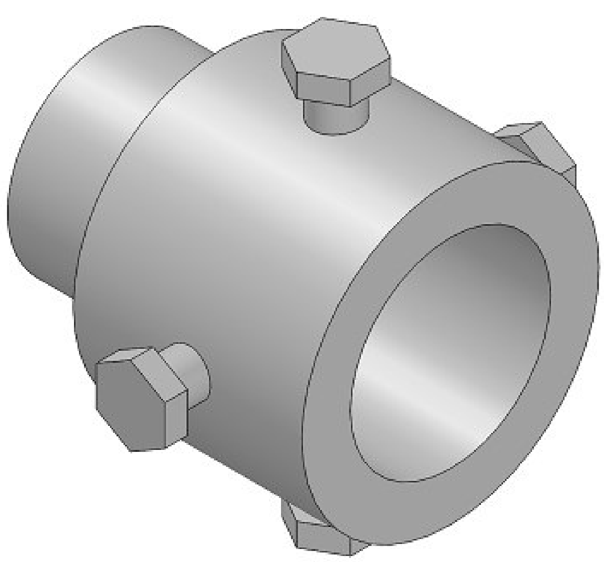


Figure: Bush

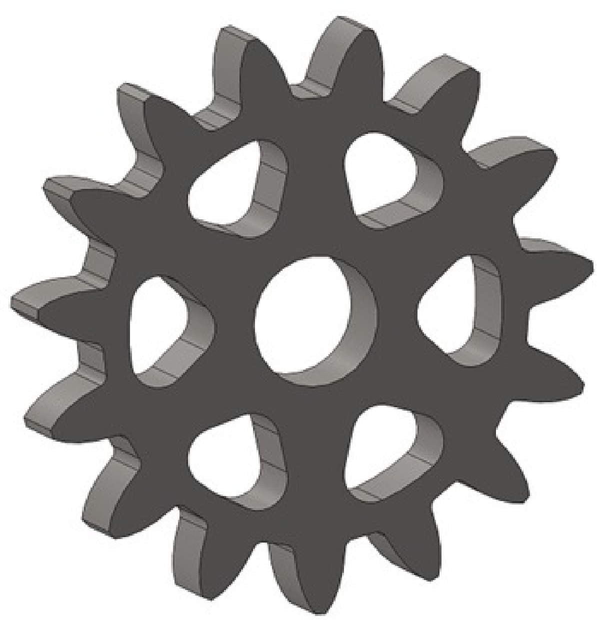


Figure: Sprocket

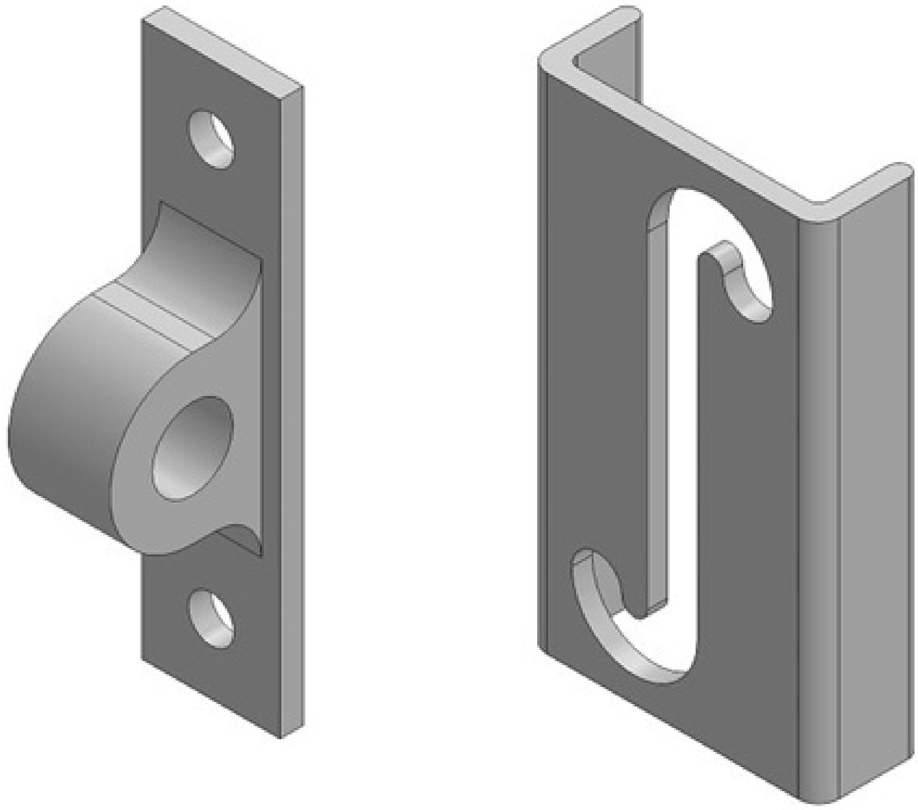


Figure: Bearing and Guiding Slot

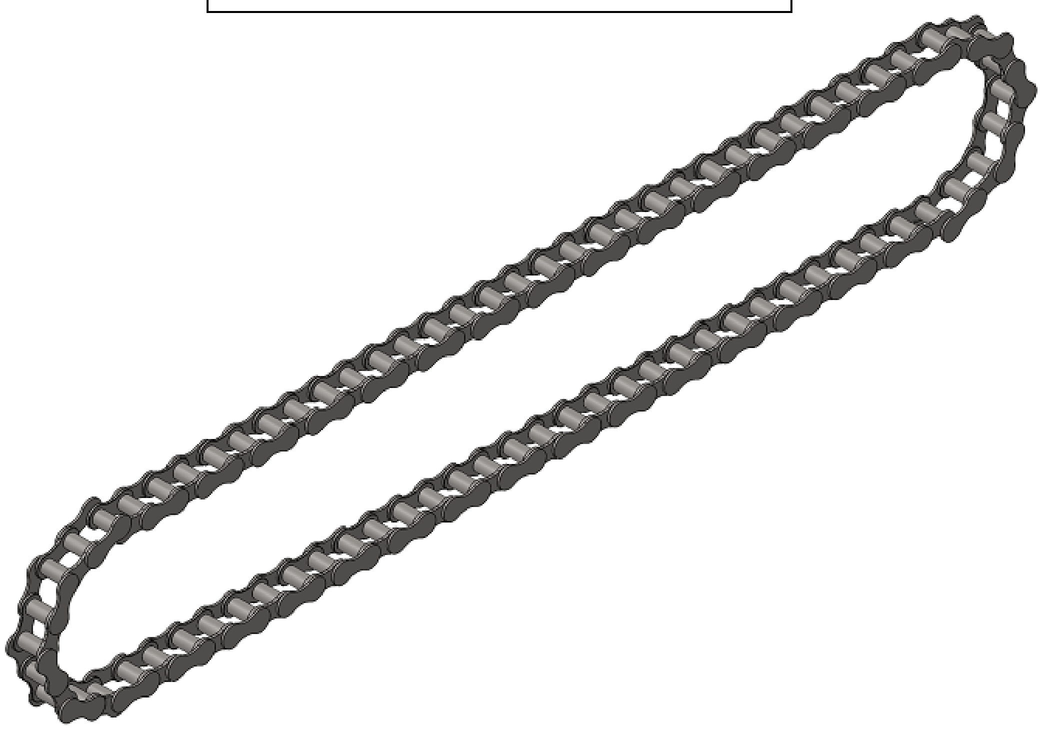


Figure: Chain

Parts of Stair Climbing Wheelchair (With necessary Dimension)

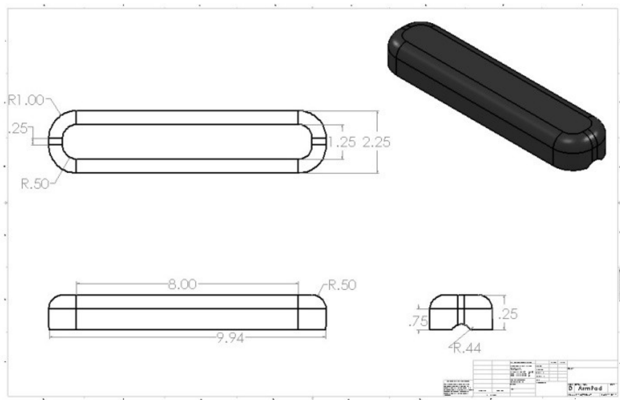


Fig: Arm pad and its dimension (in inch)

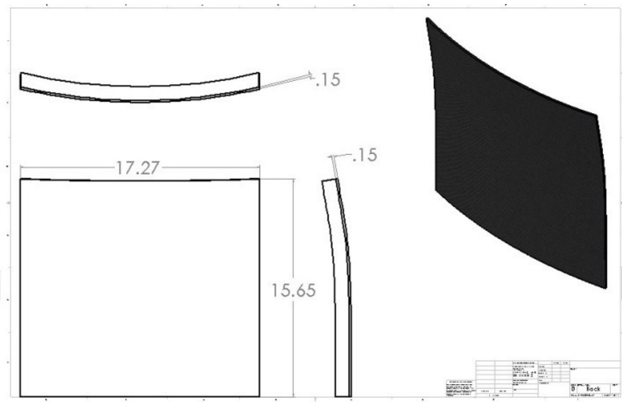


Fig: Back and its dimension (in inch)

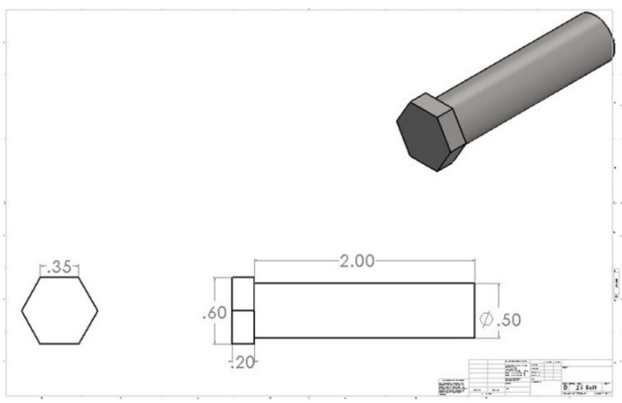


Fig: Bolt and its dimension (in inch)

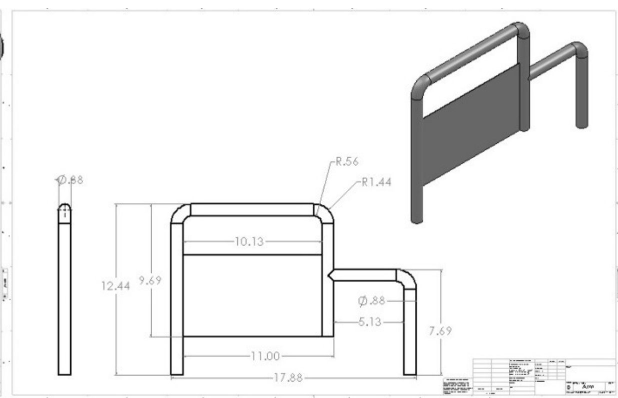


Fig: Arm and its dimension (in inch)

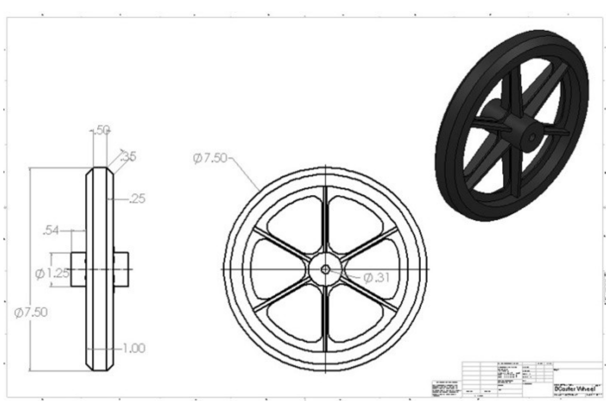


Fig: Caster wheel and its dimension (in inch)

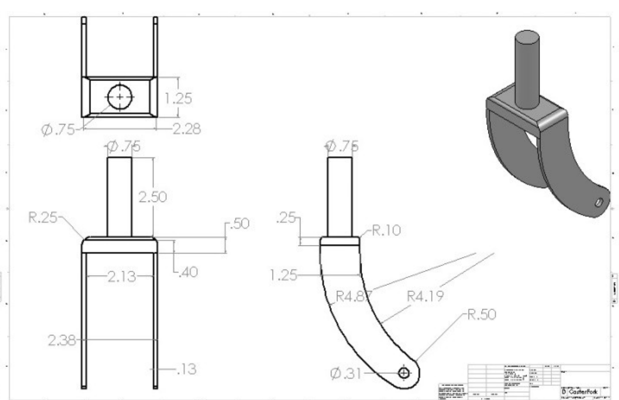
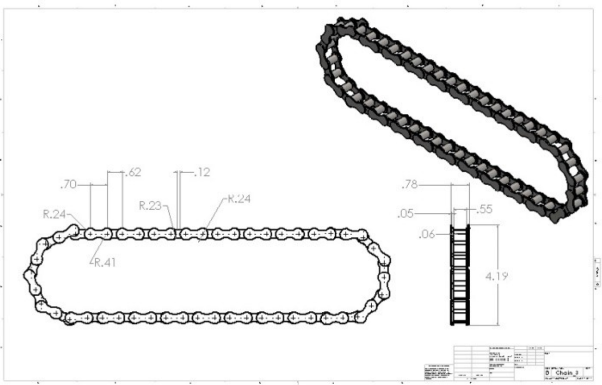


Fig: Caster fork and its dimension (in inch)



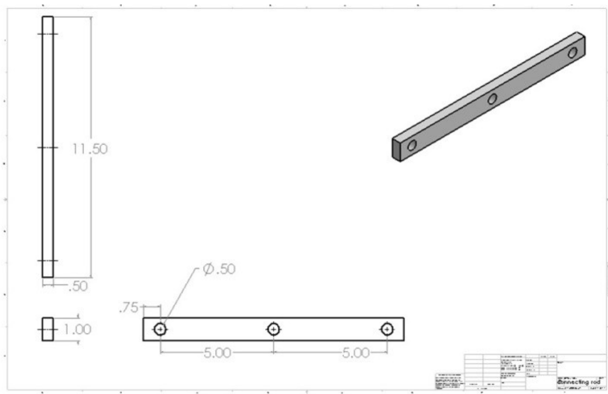
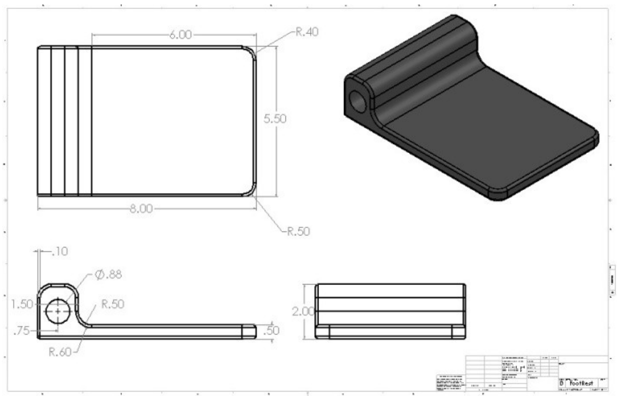


Fig: Chain and its dimension (in inch)

Fig: Connecting rod and its dimension (in inch)



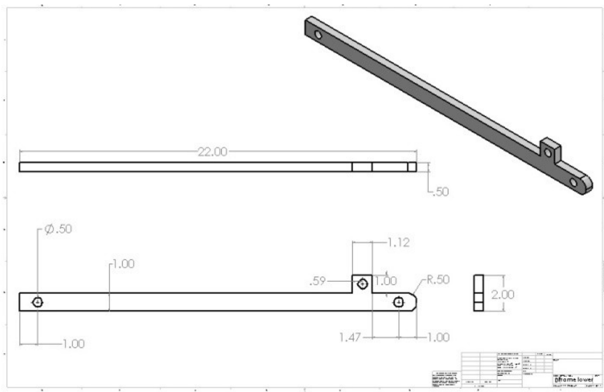
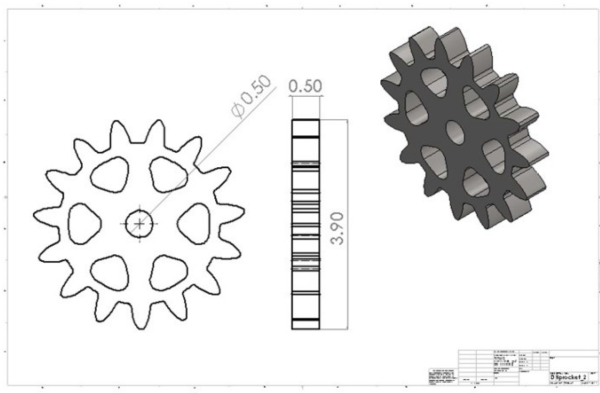


Fig: Foot rest and its dimension (in inch)

Fig: Frame(lower)and its dimension (in inch)



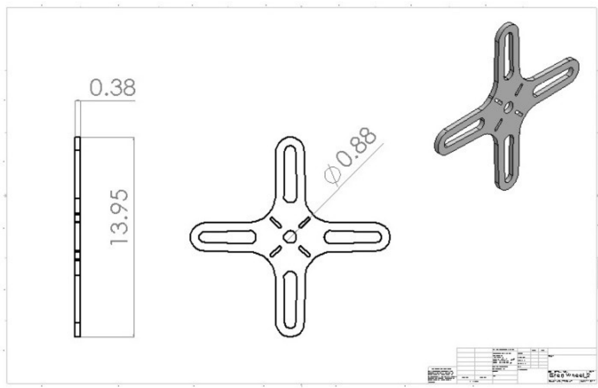


Fig: Sprocket and its dimension (in inch)

Fig: Step wheel and its dimension (in inch)

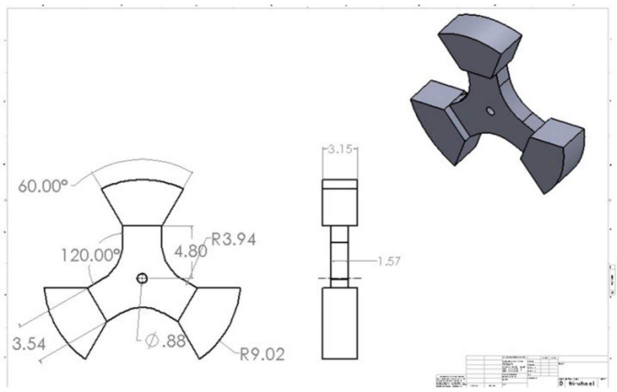


Fig: Tri wheel and its dimension (in inch)

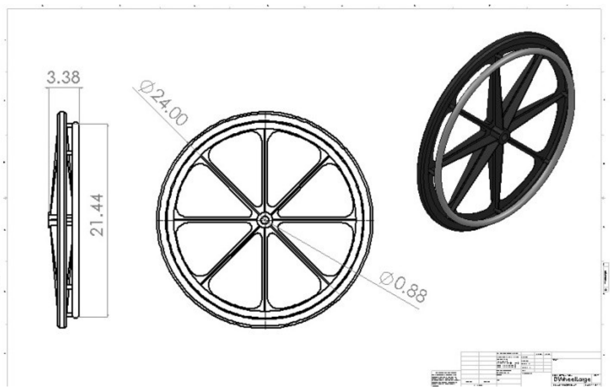


Fig: Wheel large and its dimension (in inch)

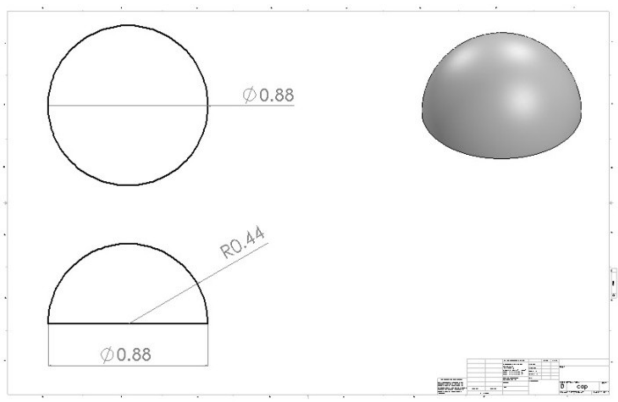


Fig: Cap and its dimension (in inch)

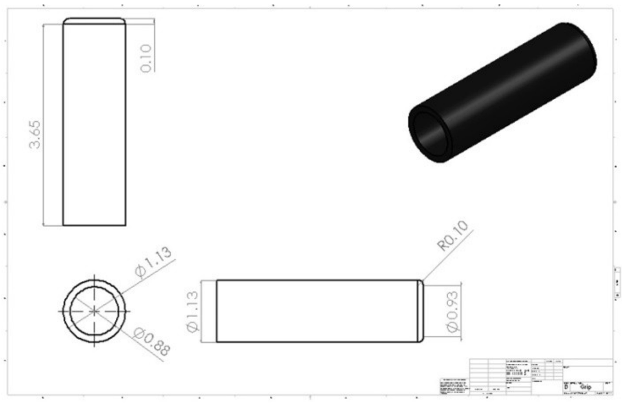


Fig: Grip and its dimension (in inch)

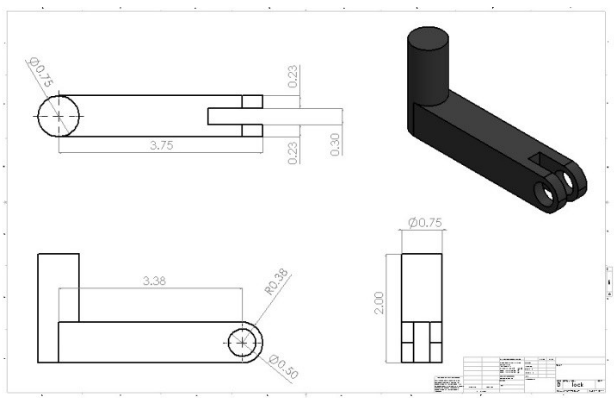


Fig:Lock-1and its dimension (in inch)

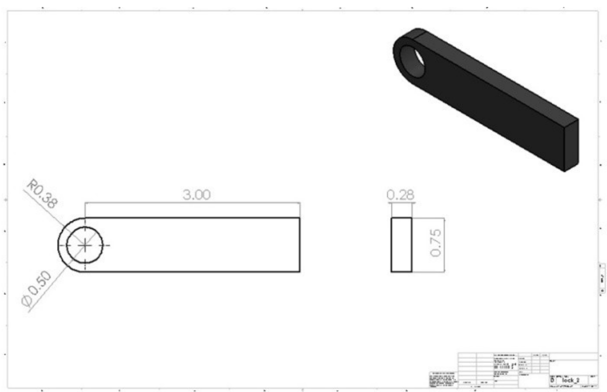
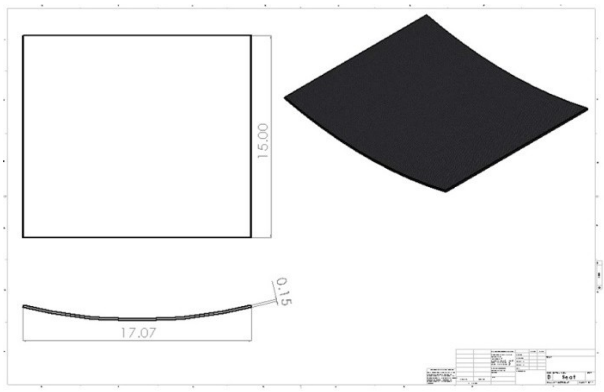


Fig:Lock-2and its dimension (in inch)



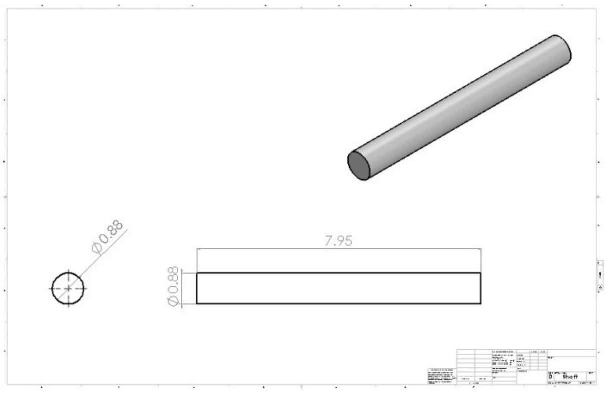


Fig: Seat and its dimension (in inch)

Fig: Shaft and its dimension (in inch)

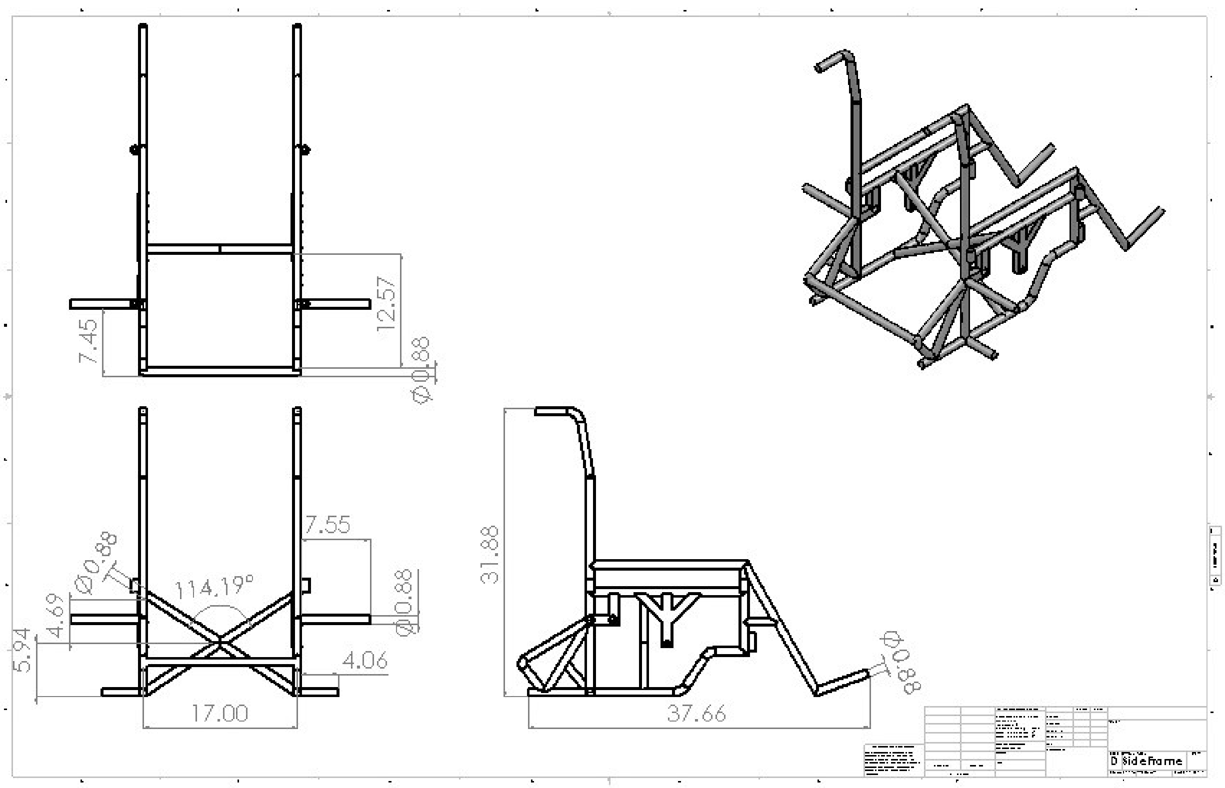


Fig: Main-Frame and its dimension (in inch)

Figure: Main Body
(Isometric View)

Figure: Main Body
(Exploded View)

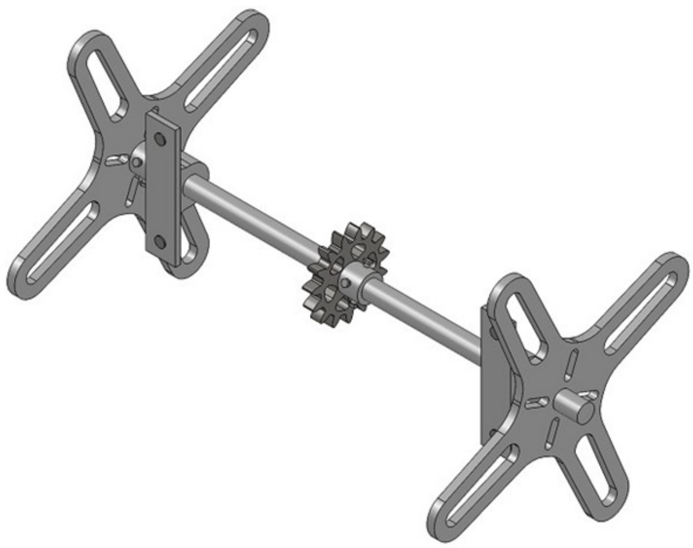


Figure: Rear side Stair Climbing Assembly (Isometric View)

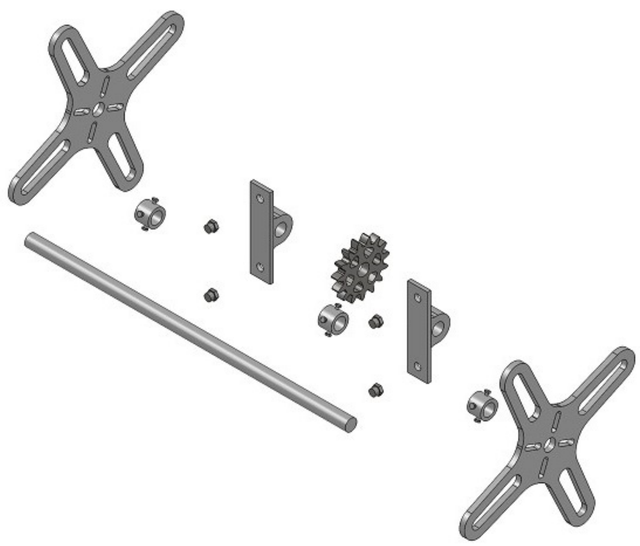


Figure: Rear side Stair Climbing Assembly (Exploded View)

Figure: Middle Stair Climbing Assembly (Isometric View)

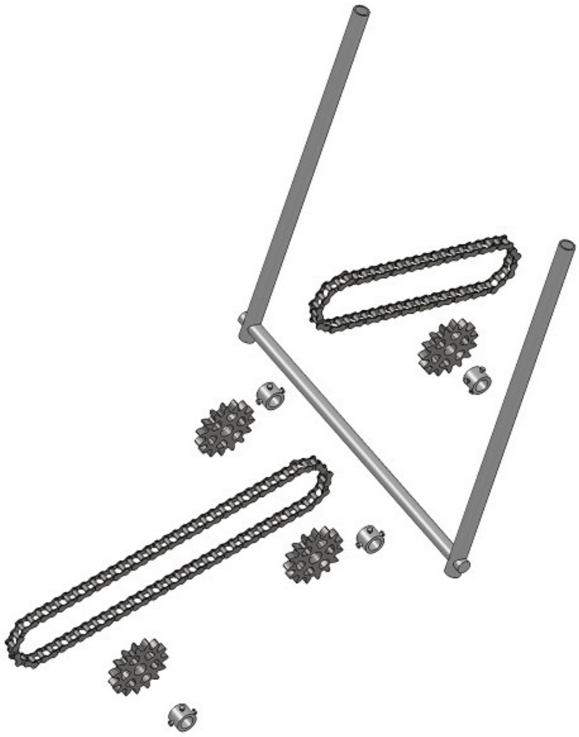


Figure: Middle Stair Climbing Assembly (Exploded View)

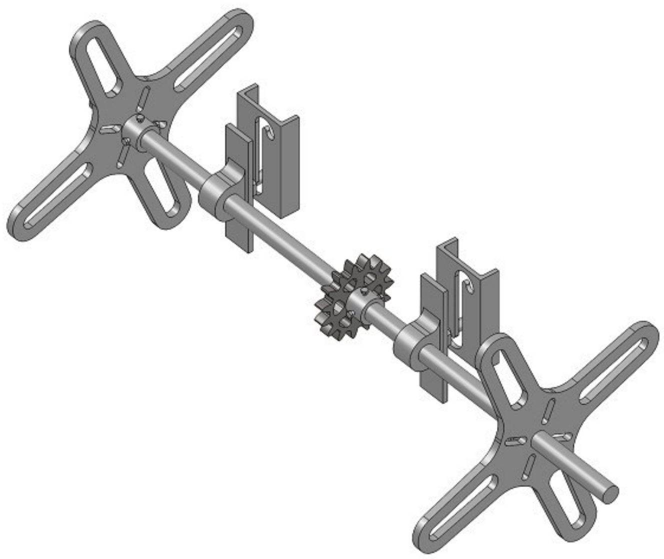


Figure: Front side Stair Climbing Assembly (Isometric View)

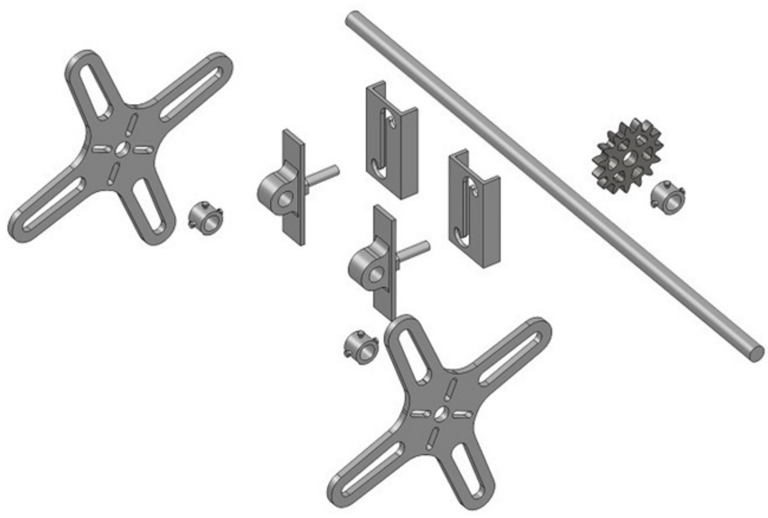


Figure: Front side Stair Climbing Assembly (Exploded View)

Figure: Stair Climbing Wheel Chair (Isometric View)

STRESS ANALYSIS OF CRITICAL PARTS

(SOLIDWORKS 2013)

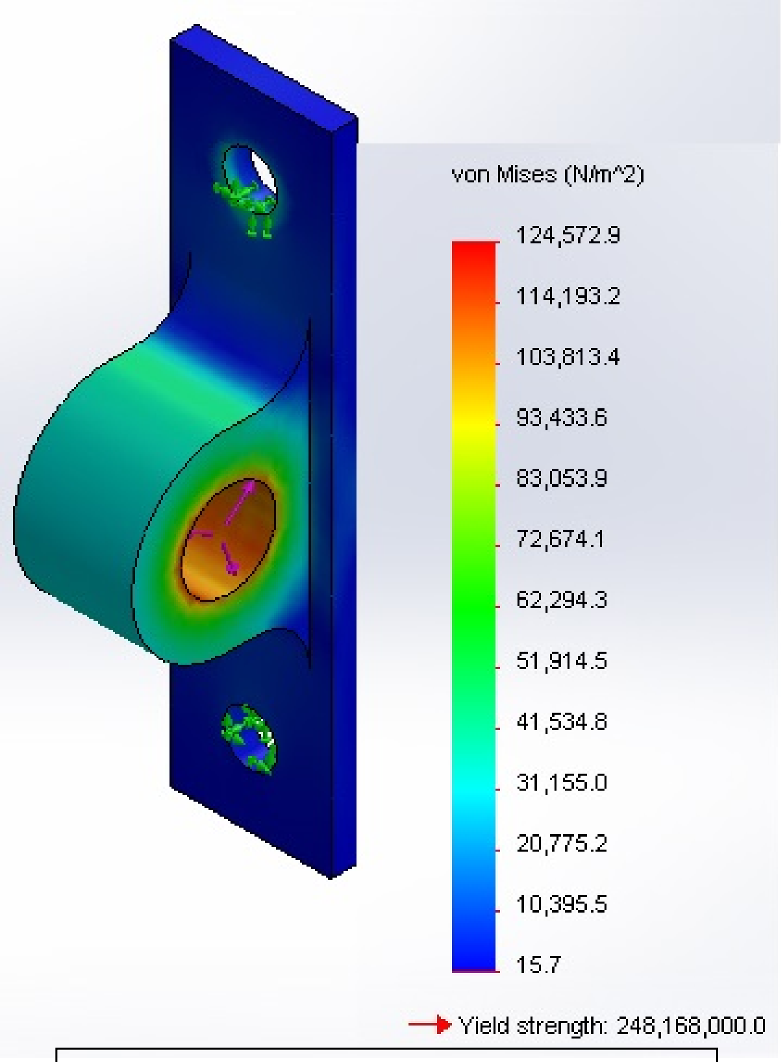


Figure: Stress analysis of Bearing

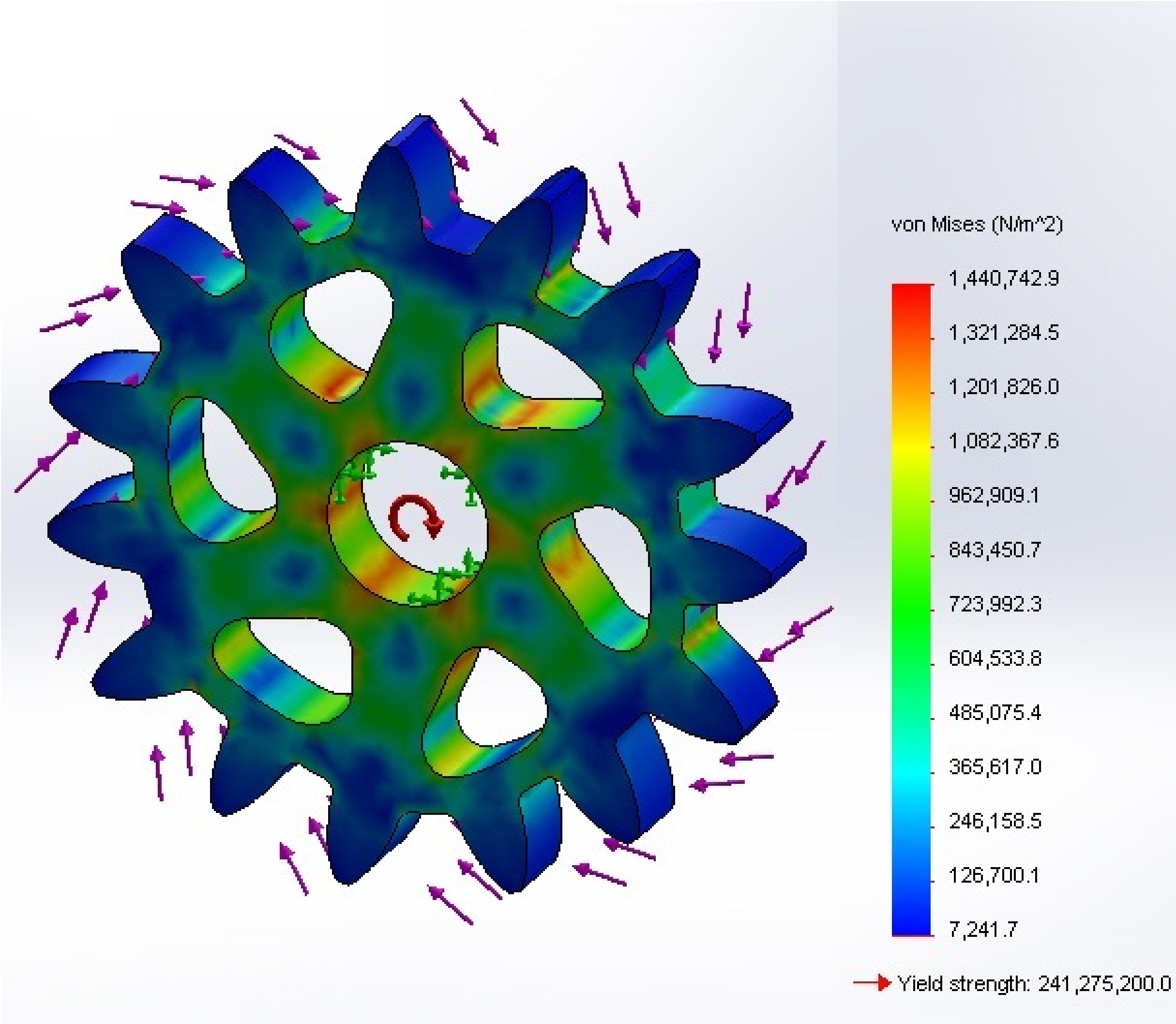


Figure: Stress analysis of Sprocket

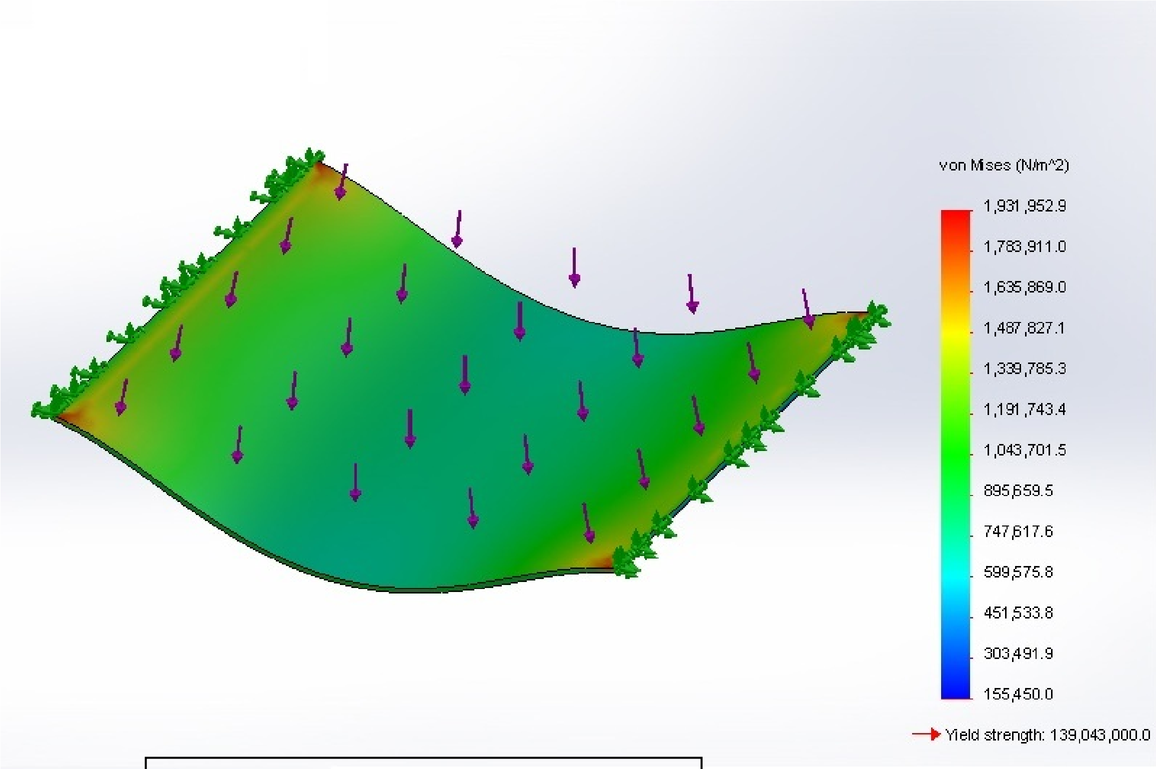


Figure: Stress analysis of Seat

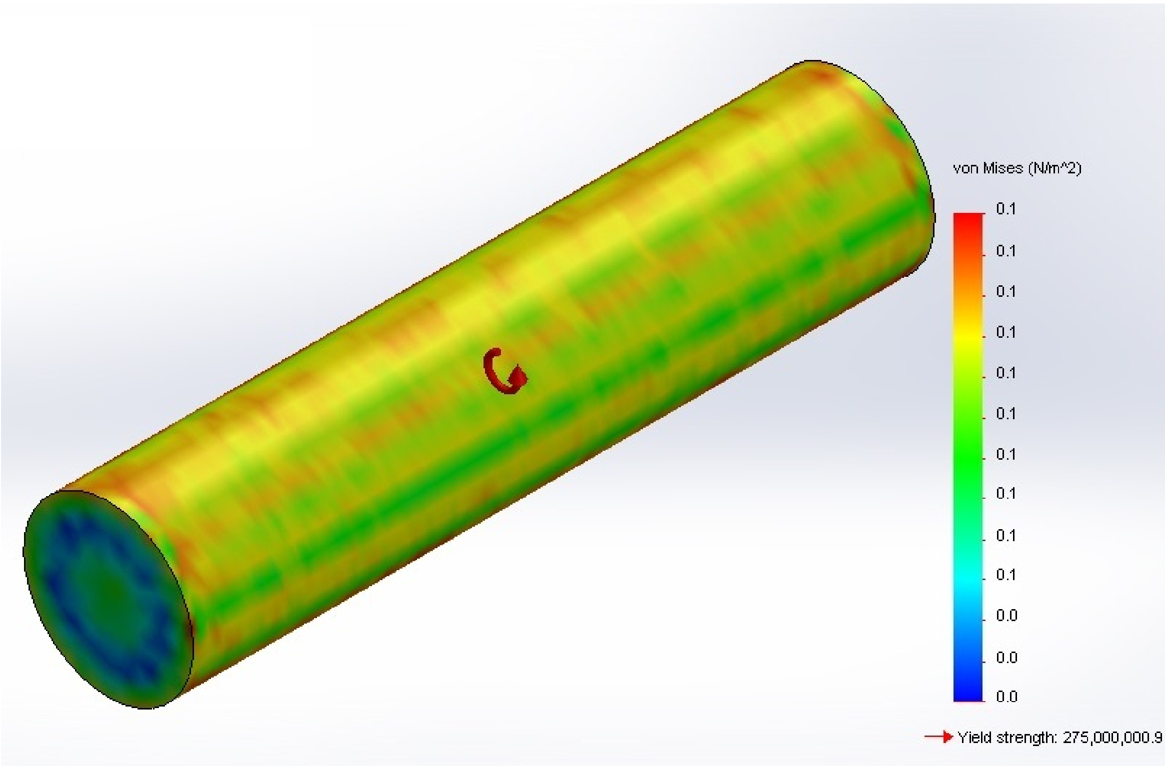


Figure: Stress analysis of Shaft

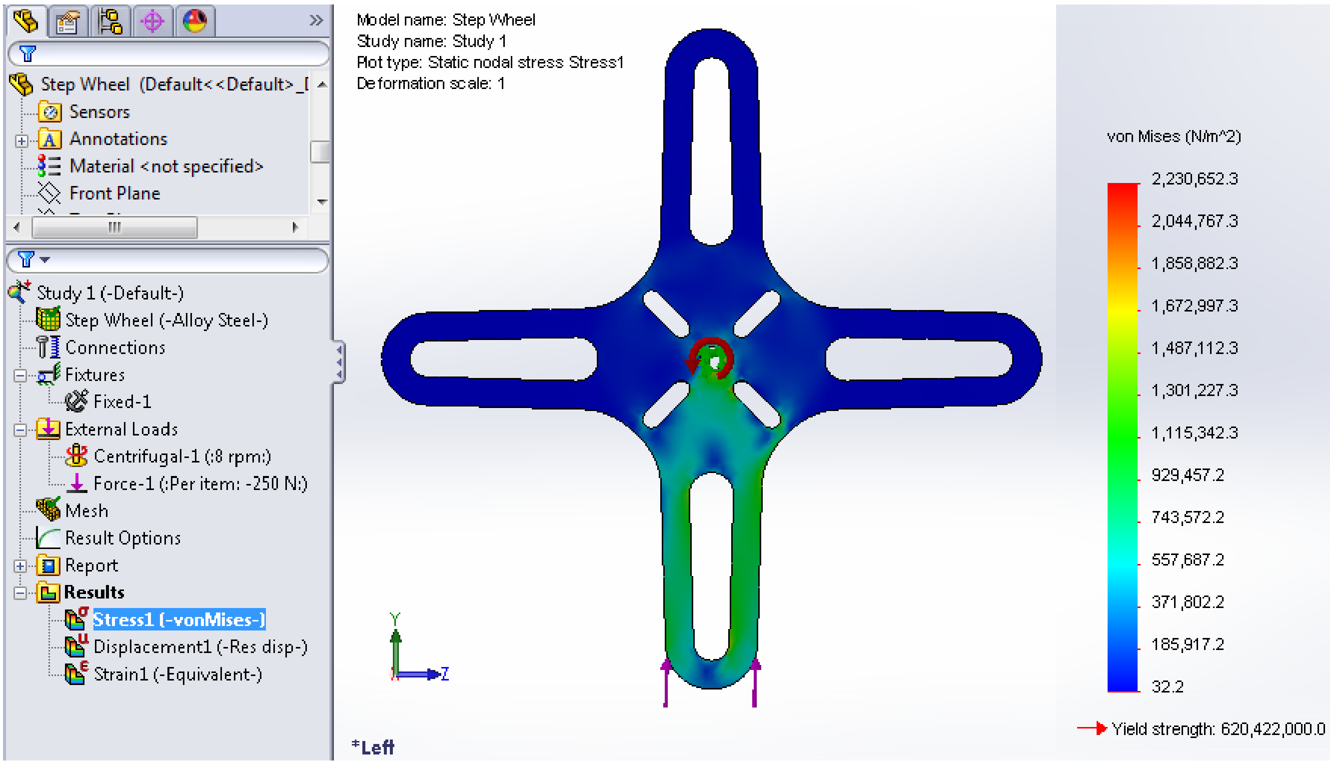


Figure: Stress analysis of Step Wheel (1)

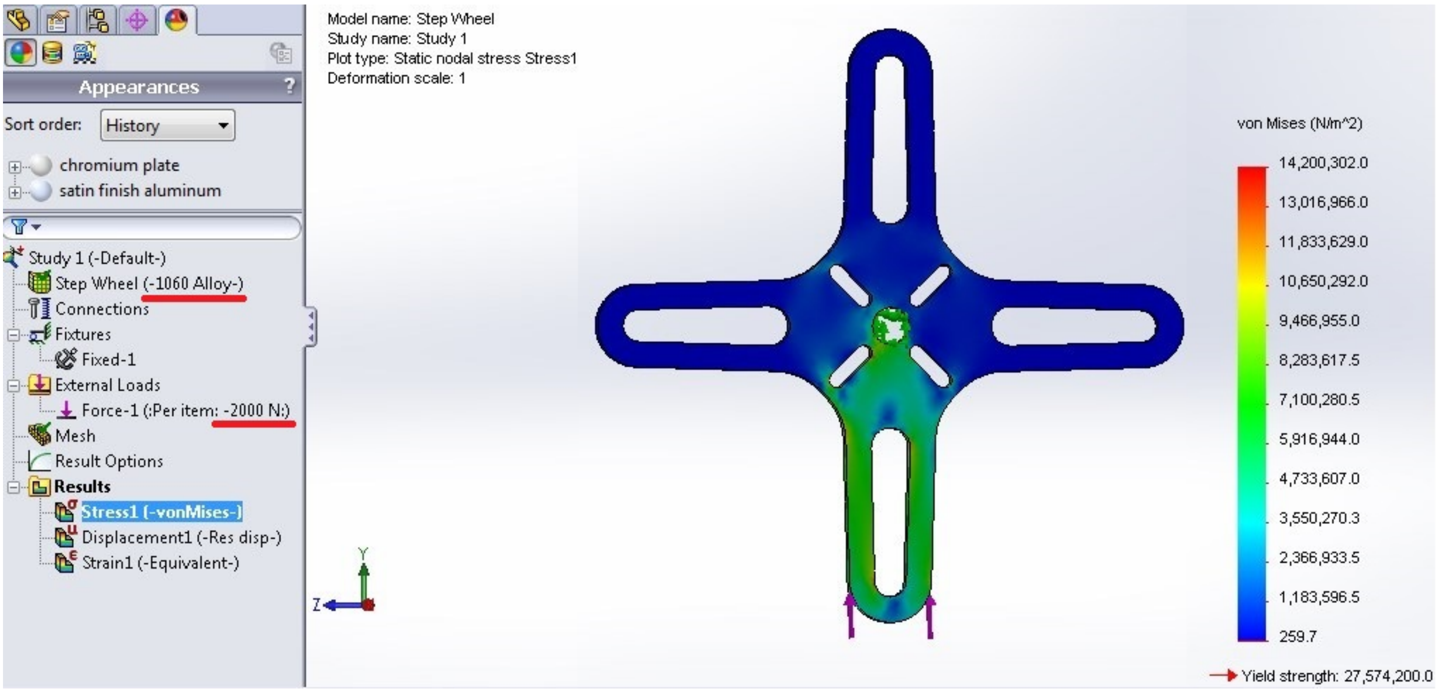


Figure: Stress analysis of Step Wheel (2)

Chapter-6

Alternative Material Selection & Select Best with Weighted Average Method

6.1 Introduction

Materials selection is an important part of a Product Design process of creating new solutions to problems. Design of engineering components is limited by the available materials and new designs are made possible by new materials. Engineering is the profession in which knowledge of the mathematical and natural sciences is applied with judgment to develop ways to utilize, economically. It is desirable for product development teams to adopt the concurrent engineering approach, where materials and manufacturing processes are considered in the early stages of design and are more precisely defined as the design progresses from the concept to the embodiment and finally the detail stage.

There is a need for simple, systematic, and logical methods or mathematical tools to guide decision makers in considering a number of selection attributes and their interrelations and in making right decisions. The Weighted Average Method considers the objective weights of importance of the attributes as well as the subjective preferences of the decision maker to decide the integrated weights of importance of the attributes.

6.2 Structural Parts of Stair Climbing Wheel Chair

1. Body: Stationary parts and Moving parts
2. Stair Climbing Assembly : It enables the wheelchair to climb the stairs by engaging different gears.
3. Step wheel : A specially modified wheel that helps climbing stairs and ensures firmness.
4. Chain and Sprocket
6. Seat
7. Arm and Arm Rest
8. Hand Grip
9. Cross Brace
10. Back
11. Large Wheel
12. Caster Wheel
13. Caster Fork
14. Foot Plate
15. Gear

6.3 Material Selection for Step Wheel

6.3.1 Determination of Relative Importance of Goals Using Digital Logic Method

Selection criteria	Number of positive decisions, N=n(n-1)/2=7(7-1)/2=21																					Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
Cost	1	0	0	1	0	1																3	0.14
Mass Density	0						0	0	0	1	1											2	0.095
Compressive Strength		1					1					1	1	1	1							6	0.285
Availability			1					1				0				1	1	1				5	0.24
Elastic Modulus				0					1				0			0			0	0		1	0.05
Shear Modulus					1					0				0			0		1		0	2	0.095
Co-efficient of thermal expansion						0					0				0			0		1	1	2	0.095
Total Number of Positive Decisions																						21	Σα = 1.00

6.3.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	AISI 347Annealed Stainless Steel		Alloy Steel	
		Scaled Property, ß	Weighted Score, αß	Scaled Property, ß	Weighted Score, αß
Cost	0.140	100	14	80	11.2
Mass Density	0.095	96.25	9.13	100	9.5
Compressive Strength	0.285	90.49	25.79	100	28.5
Availability	0.240	100	24	100	24
Elastic Modulus	0.050	92.85	4.64	100	5
Shear Modulus	0.095	97.47	9.26	100	9.5
Co-efficient of thermal expansion	0.095	76.47	7.26	100	9.5
Material Performance Index, γ			94.08		**97.2**

Result: Material Performance Index is Greatest (97.2) for Alloy Steel. So we should select Alloy Steel for Step Wheel.

Material Properties:

Property	AISI 347Annealed Stainless Steel	Alloy Steel
Elastic Modulus (N/m^2)	1.95E+11	2.1E+11
Shear Modulus (N/m^2)	7.7E+10	7.9E+10
Mass Density (Kg/m^3)	8000	7700
Coefficient of Thermal Expansion(/k)	1.7E-05	1.3E-05
Compressive Strength(N/m^2)	6.5499E+8	7.238E+8

Numerical Value (Rating) for Cost & Availability:

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Compressive Strength, Availability, Elastic Modulus and Shear Modulus-

$$\text{Scaled Property, ß} = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost, Co-efficient of thermal expansion & Mass Density-

$$\text{Scaled Property, ß} = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

6.4 Material Selection for Frame

6.4.1 Determination of Relative Importance of Goals Using Digital Logic Method

Selection criteria	Number of positive decisions, N=n(n-1)/2=7(7-1)/2=21																					Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
Low cost	0	0	0	1	0	0																1	0.048
Light-weight	1						1	1	1	1	0											5	0.238
Strength		1					0					0	0	1	1							3	0.143
Availability			1					0				1				0	1	0				3	0.143
Resistance to wear and tear				0					0				1			1			1	0		3	0.143
Shear Modulus					1					0				0			0		0		0	1	0.048
Machinability						1					1				0			1		1	1	5	0.238
Total Number of Positive Decisions																						21	Σα = 1.00

6.4.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	AISI 347Annealed Stainless Steel		6061 Alloy Aluminum		Alloy Steel	
		Scaled Property, ß	Weighted Score, αß	Scaled Property, ß	Weighted Score, αß	Scaled Property, ß	Weighted Score, αß
Cost	0.048	33.33	1.6	50.00	2.4	100	4.8
Light-weight	0.238	33.75	8.03	100	23.8	35	8.33
Strength	0.143	44.35	6.34	8.9	1.27	100	14.3
Availability	0.143	100	14.3	100	14.3	80	11.44
Resistance to wear and tear	0.143	100	14.3	40	5.72	75	10.73
Shear Modulus	0.048	97.5	4.68	32.9	1.58	100	4.8
Machinability	0.238	50	11.9	100	23.8	75	17.85
Material Performance Index, γ			46.45		**72.87**		72.25

Result: Material Performance Index is Greatest (72.87) for 6061 Alloy Aluminum . So we should select 6061 Alloy Aluminum for Frame.

Material Properties:

Property	AISI 347 Annealed Stainless Steel	6061 Alloy Aluminum	Alloy Steel
Mass Density (kg/m^3)	8000	2700	7700
Yield Strength (MPa)	275	551	620
Shear Modulus (N/m^2)	7.7E+10	2.6E+10	7.90E+10

Numerical Value (Rating) Cost, Availability, Resistance to Wear & Tear, Machinability:

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Strength, Availability, Resistance to Wear & Tear, Machinability and Shear Modulus-

$$\text{Scaled Property, ß} = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost & Mass Density-

$$\text{Scaled Property, ß} = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

6.5 Material Selection for Shaft

6.5.1 Determination of Relative Importance of Goals Using Digital Logic Method

Selection criteria	Number of positive decisions, N=n(n-1)/2=7(7-1)/2=21																					Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
Cost	1	0	0	0	0	1																2	0.095
Light weight	0						1	1	1	1	1											5	0.238
Strength		1					0					1	1	1	0							4	0.191
Availability			1					0				0				0	1	0				2	0.095
Elastic Modulus				1					0				0			1			1	0		3	0.143
Shear Modulus					1					0				0			0		0		1	2	0.095
Machinability						0					0				1			1		1	0	3	0.143
Total Number of Positive Decisions																						21	Σα = 1.00

6.5.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	AISI 347 Annealed Stainless Steel		6061 Aluminium Alloy	
		Scaled Property, ß	Weighted Score, αß	Scaled Property, ß	Weighted Score, αß
Cost	0.095	100	9.5	60	5.7
Light weight	0.238	33.75	8.03	100	23.8
Strength	0.191	100	19.1	18.94	3.62
Availability	0.095	60	5.7	100	9.5
Elastic Modulus	0.143	100	14.3	35.38	5.06
Shear Modulus	0.095	100	9.5	33.76	3.21
Machinability	0.143	20	2.86	100	14.3
Material Performance Index, γ			**68.99**		65.19

Result: Material Performance Index is Greatest (68.99) for AISI 347 Annealed Stainless Steel. So we should select AISI 347 Annealed Stainless Steel for Shaft.

Material Properties:

Property	AISI 347 Annealed Stainless Steel	6061 Aluminium Alloy
Elastic Modulus (GPa)	1.95E+011	6.9E+010
Shear Modulus (N/m^2)	7.70E+010	2.6E+010
Mass Density (Kg/m^3)	8000	2700
Tensile Strength(MPa)	655	124

Numerical Value (Rating) for Cost, Availability & Machinability:

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Strength, Availability, Elastic Modulus, Machinability and Shear Modulus-

$$\text{Scaled Property, ß} = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost & Mass Density-

$$\text{Scaled Property, ß} = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

6.6 Conclusion

We can come to conclusion that we have selected suitable materials for different parts of our Stair Climbing Wheelchair from a set of alternatives with the help of systematic procedures of weighted average method. Now we can move to the next stage of product design which is to select suitable manufacturing criterion for different parts and processes.We are also going to use wighted average method there.

Chapter - 7

Manufacturing Process Selection by Weighted Average Method

7.1 Introduction

Selection of the best manufacturing process among relevant processes for any individual manufacturing operation of a product according to some weighted score is known as manufacturing process selection. In order to reduce production cost, metallurgical change, and material waste as well as improve performance, this procedure helps to fulfill most of the selection criteria.

7.2 Manufacturing Process Selection

We are going to purchase some raw materials such as annealed stainless steel, aluminum bars, alloy steel, alloy aluminum etc. Further manufacture of these raw materials in our production facility will result in desired shape and size for different parts of the product.

We need to AISI annealed stainless steel for shaft, alloy steel for step wheels and for making the frame, 6061 alloy aluminum is needed to be used.

For permanent joining we are going to use welding. Temporary joining is utilized for adjustable parts.
We are not going to manufacture all the parts. Some of the parts are to be purchased.

7.3 Manufacturing Shaft from AISI 347 Annealed Stainless Steel :

7.3.1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of positive decisions, *N=n(n-1)/2=6(6-1)/2=15*															Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	0	0	1	1	1											3	0.200
Dimensional accuracy	1					1	1	1	1							5	0.333
Force Requirement		1				0				1	0	0				2	0.133
Power requirement			0				0			0			1	0		1	0.067
Surface Finish				0				0			1		0		0	1	0.067
Metallurgical change					0				0			1		1	1	3	0.200
Total Number of Positive Decisions																15	∑α= 1.00

7.3.2 Calculation of the Performance Index

Goals	Weighting Factor, α	Turning in Lathe Machine		Extrusion	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.200	60	12.00	100	20.00
Dimensional accuracy	0.333	80	26.64	100	33.30
Force Requirement	0.133	100	13.30	80	10.64
Power requirement	0.067	80	5.36	100	6.70
Surface Finish	0.067	80	5.36	100	6.70
Metallurgical change	0.200	80	16.00	100	20.00
Material Performance Index, γ			78.66		**97.34**

Result: Material Performance Index is Greatest (97.34) for Extrusion. So we should select Extrusion for shaft forming from AISI Annealed Stainless Steel.

Numerical Value (Rating): For cost, dimensional accuracy, force requirement, power requirement, surface finish, and metallurgical change.

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Dimensional accuracy and surface finish.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost, power requirement, force requirement and metallurgical change.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.4 Manufacturing Step Wheels from Alloy Steel:

7.4.1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of positive decisions, *N=n(n-1)/2=6(6-1)/2=15*															Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	0	0	0	0	1											1	0.067
Dimensional accuracy	1					1	0	1	1							4	0.269
Strength		1				0				0	1	1				3	0.200
Defect			1				1			1			1	1		5	0.330
Surface Finish				1				0			0		0		0	1	0.067
Metallurgical change					0	0			0			0		0	1	1	0.067
Total Number of Positive Decisions																15	∑α= 1.00

7.4.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	Forging		Gravity Casting		Low Pressure Casting	
		Scaled Property,β	Weighted Score,αβ	Scaled Property,β	Weighted Score,αβ	Scaled Property,β	Weighted Score,αβ
Cost	0.067	40	3.68	100	6.70	80	5.36
Dimensional Accuracy	0.269	100	26.9	60	16.14	80	21.52
Strength	0.200	100	20.0	60	12	80	16
Defects	0.330	100	33.0	40	13.2	60	19.8
Surface Finish	0.067	100	6.70	80	5.36	80	5.36
Metallurgical Change	0.067	100	6.70	60	4.02	80	5.36
Material Performance Index ,γ			**95.98**		57.52		73.4

Result: Material Performance Index is Greatest (95.98) for Forging. So we should select Forging for manufacturing step wheels from alloy steel.

Numerical Value (Rating): For cost, dimensional accuracy, strength, defect and metallurgical change:

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Dimensional accuracy, strength & surface finish.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost, defect & metallurgical change.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.5 Manufacturing Frame Parts from 6061 Alloy Aluminum:

7.5.1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of positive decisions, *N=n(n-1)/2=5(5-1)/2=10*										Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	0	0	0	1							1	0.10
Dimensional Accuracy	1				1	1	1				4	0.40
Metallurgical Stability		1			0			0	0		1	0.10
Defects			1			0		1		1	3	0.30
Surface Finish				0			0		1	0	1	0.10
Total Number of Positive Decisions											10	$\sum\alpha$ = 1.00

7.5.2 Calculation of the Performance Index

Goals	Weighting Factor, α	Sand Mold Casting		Permanent Mold Casting	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.10	100	10.00	50	5.000
Dimensional Accuracy	0.40	60	24.00	100	40.00
Metallurgical Change	0.10	100	10.00	80	8.00
Defects	0.30	75	22.50	100	30.00
Surface Finish	0.10	70	7.00	100	10.00
Material Performance Index, γ			73.50		**93.00**

Result: Material Performance Index is Greatest (93.00) for Permanent Mold Casting. So we should select Permanent Mold Casting for manufacturing frame parts from 6061 alloy aluminum.

Numerical Value (Rating): For cost, dimensional accuracy, metallurgical change, defects and surface finish.

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Dimensional precision, metallurgical stability and surface finish.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost and defects.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.6 Joining Process for Different parts

7.6.1 Permanent Joining

7.6.1.1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of positive decisions, *N=n(n-1)/2=5(5-1)/2=10*										Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	0	0	1	0							1	0.10
Dimensional accuracy	1				0	0	1				2	0.20
Strength		1			1			0	1		3	0.30
Availability			0			1		1		0	2	0.20
Metallurgical change				1			0		0	1	2	0.20
Total Number of Positive Decisions											10	∑α = 1.00

7.6.1.2 Calculation of the Performance Index

Goals	Weighting Factor, α	Arc welding		TIG welding		MIG welding	
		Scaled Property,β	Weighted Score,αβ	Scaled Property,β	Weighted Score,αβ	Scaled Property,β	Weighted Score,αβ
Cost	0.10	100	10.00	60	6.00	60	6.00
Dimensional accuracy	0.20	80	16.00	100	20.00	80	16.00
Strength	0.30	80	24.00	60	18.00	100	18.00
Availability	0.20	100	20.00	75	15.00	75	15.00
Metallurgical change	0.20	100	20.00	75	15.00	100	15.00
Material Performance Index, γ			**90.00**		74.00		70.00

Result: Material Performance Index is Greatest (90.00) for Arc welding. So we should select Arc Welding for permanent joining.

7.6.2 Temporary Joining

7.6.2.1 Determination of Relative Importance of Goals Using Digital Logic Method

Goals	Number of positive decisions, $N = n(n-1)/2 = 5(5-1)/2 = 10$										Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	0	0	1	1							2	0.20
Strength	1				0	1	1				3	0.30
Availability		1			1			1	0		3	0.30
Surface finish			0			0		0		1	1	0.10
Design flexibility				0			0		1	0	1	0.10
Total Number of Positive Decisions											10	Σα = 1.00

7.6.2.2 Calculation of the Performance Index

Goals	Weighting Factor, α	Nut-bolt		Riveting	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.2	100	20.00	100	20.00
Strength	0.3	100	30.00	80	24.00
Availability	0.3	100	30.00	80	24.00
Surface finish	0.1	80	8.00	100	10.00
Design flexibility	0.1	100	10.00	80	8.00
Material Performance Index, γ			**98.00**		86.00

Result: Material Performance Index is Greatest (98.00) for Nut-bolt. So we should select Nut-bolt for temporary joining.

Numerical Value (Rating): For cost, dimensional accuracy, strength, availability, metallurgical change, surface finishes and design flexibility.

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Dimensional accuracy, strength, availability, surface finish and design flexibility.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost and metallurgical change.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.7 Finishing Process

7.7.1 Determination of Relative Importance of Goals Using Digital Logic Method

Selection criteria	Number of positive decisions, $N = n(n-1)/2 = 5(5-1)/2 = 10$										Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	0	0	1	1							2	0.20
Smoothness	1				1	1	0				3	0.30
Availability		1			0			1	0		2	0.20
Material wastage			0			0		0		1	1	0.10
Time duration				0			1		1	0	2	0.20
Total Number of Positive Decisions											10	Σα = 1.00

7.7.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	Precision grinding		Non-precision grinding & polishing	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.2	60	12.00	100	20.00
Smoothness	0.3	100	30.00	100	30.00
Availability	0.2	80	16.00	100	20.00
Material wastage	0.1	100	10.00	60	6.00
Time duration	0.2	100	20.00	80	16.00
Material Performance Index, γ			88.00		**92.00**

Result: Material Performance Index is Greatest (92.00) for Non-precision grinding & polishing. So we should select Non-precision grinding & polishing for finishing process.

Numerical Value (Rating): For cost, smoothness, availability, material wastage, and time duration.

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Smoothness and availability.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost, material wastage, and time duration.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.8 Coloring Process

7.8.1 Determination of Relative Importance of Goals Using Digital Logic Method

Selection criteria	Number of positive decisions, *N=n(n-1)/2=6(6-1)/2=15*															Positive decisions	Relative emphasis Co-efficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	0	1	0	1	1											3	0.20
Durability	1					1	0	1	1							4	0.27
Power requirement		0				0				0	0	1				1	0.07
Availability			1				1			1			1	1		5	0.33
Wastage of color				0				0			1		0		0	1	0.07
Smoothness					0				0			0		0	1	1	0.07
Total Number of Positive Decisions																15	Σα = 1.00

7.8.2 Calculation of the Performance Index

Selection Criteria	Weighting Factor, α	Heat print by color powder		Color spray	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αB
Cost	0.2	100	20.00	60	12.00
Durability	0.27	70	18.90	100	27.00
Power requirement	0.07	60	4.20	100	7.00
Availability	0.33	100	33.00	80	26.40
Wastage of color	0.07	100	7.00	60	4.20
Smoothness	0.07	80	5.60	100	7.00
Material Performance Index, γ			**88.70**		83.60

Result: Material Performance Index is Greatest (88.70) for Heat print by color powder. So we should select Heat print by color powder for coloring process.

Numerical Value (Rating): For cost, Durability, Power requirement, Availability, Wastage of color, and Smoothness.

Very High	5
High	4
Medium	3
Low	2
Very Low	1

Formulae Used:

1. For goals: Durability, smoothness and availability.

$$\text{Scaled Property, } \beta = \frac{\text{Numerical value of property}}{\text{Maximum value in list}} \times 100$$

2. For goals: Cost, wastage of color, and power requirement.

$$\text{Scaled Property, } \beta = \frac{\text{Minimum value in list}}{\text{Numerical value of property}} \times 100$$

7.9 Purchasing Decision:

A list of materials to be purchased is given below with their required quantity:

Serial	Name of Components	Quantity
1	Block Bearing	6 Pieces
2	Frame(Body)	1 Piece
3	Chain	4 Pieces
4	Sprocket	8 Pieces
5	Handle Wheel	2 Pieces
6	Nut and Bolts	30 Pieces
7	MS Shaft	11 Feet
8	Aluminum Shaft	7 Feet
9	MS Plate	2 Pieces
10	Step Wheel	4 Pieces
11	SS Pipe	6 Feet
12	Bush	8 Pieces

7.10 Conclusion

At the end, to accommodate various requirements for manufacturing stair climbing wheelchair we have selected the best manufacturing processes from a variety of alternatives by means of systematic procedures of weighted average method.

Chapter-8

Prototype Costing

8.1 Introduction

In the product development cycle several engineering tasks like design, process planning and production planning have to be executed. The execution of these tasks mainly involves information processing and decision-making. Progress in a design project is measured by deliverables such as drawings, prototypes, bills of materials (e.g., parts lists), results of analysis, test results, and other representations of the information generated in the project. These deliverables are all models of the final product. During product development, many models (i.e., design information representations) are made of the evolving product. Some of these models are analytical models—quick calculations on a bit of paper or complex computer simulations; some will be graphical representations—simple sketches or orthographic mechanical drawings; some will be SolidWorks models and some will be physical models—prototypes. Because costs is an important factor in manufacturing, adequate information about costs is extremely valuable for all engineering tasks, which can be provided by prototype costing.

8.2 Types and Purposes for Prototypes

The four types of prototypes and their purposes are:

i. **A proof-of-concept or proof-of-function prototype** focuses on developing the function of the product for comparison with the customers' requirements or engineering specifications. This kind of prototype is intended as a learning tool, and exact geometry, materials, and manufacturing process are usually not important. Thus, proof-of-concept prototypes can be built of paper, wood, parts from children's toys, parts from a junkyard, or whatever is handy.

ii. **A proof-of-product prototype** is developed to help refine the components and assemblies. Geometry, materials, and manufacturing process are as important as function for these prototypes.

iii. **A proof-of-process prototype** is used to verify both the geometry and the manufacturing process. For these prototypes, the exact materials and manufacturing processes are used to manufacture samples of the product for functional testing.

iv. **A proof-of-production prototype** is used to verify the entire production process. This prototype is the result of a preproduction run, the products manufactured just prior to production for sale.

Due to low budget, we have not been able to verify all the manufacturing processes for our product prototype. So, the prototype that we have submitted may be considered as a proof-of-concept or proof-of-function prototype.

8.3 Prototype costing for stair climbing wheelchair

Serial	Name of Components	Quantity	Price(TK)
1	Block Bearing	6 Pieces	600
2	Frame(Body)	1 Piece	2500
3	Chain	4 Pieces	400
4	Sprocket	8 Pieces	800
5	Handle Wheel	2 Pieces	700
6	Nut and Bolts	30 Pieces	300
7	MS Shaft	11 Feet	660
8	Aluminum Shaft	7 Feet	700
9	MS Plate	2 Pieces	500
10	Step Wheel	4 Pieces	2000
11	SS Pipe	6 Feet	600
12	Bush	8 Pieces	800
		TOTAL	**10560**

8.4 Conclusion

Estimated prototype cost is a bit higher than we expected. Since we are creating a product first of its kind in Bangladesh and using different parts from different vehicles (e.g. rickshaw and cycle etc.) and make the functions of the product as effective as possible, this cost is reasonable. Besides, we are designing and manufacturing this product for mass production and it is expected that product cost per unit will be much lower than prototype cost.

Chapter-9

Cost Analysis

9.1 Introduction

Cost is directly related to a product's design because cost largely varies with the decisions related to its design. Cost being an important factor has the vital role in the acquisition of a product for the following cases:

1. Apart from the technology and aesthetics, Cost becomes the main driving agent in this era of competition.
2. A customer has also some financial limitations that may shift the acquisition decision toward affordability as an important factor.

In both cases, a successful product supplier must give more attentions on the product cost. Design to cost is a vital strategy of management. An approach to make the product affordable for the customers is to set target cost as an independent design parameter which must be ensured during the product development phases.

The cost analysis method consists of the following elements:

- Identification of the product's cost drivers and consideration of cost drivers in detailing product specifications and emphasizing on cost reduction;
- Balancing customer requirements with affordability;
- Establishment and allocation of target costs down to a level of the components where costs can be effectively managed;
- Exploration of concept and design alternatives for the purpose of developing lower cost design approaches;
- Active consideration of costs during development as an important design parameter appropriately weighted with other decision parameters;
- Access to cost data to support this process and empower development team members;
- Consistency of accounting methods between cost systems and product cost models as well as periodic validation of product cost models; and

- Continuous improvement through process value engineering to improve product value in the long run

In designing our “stair climbing wheelchair, we have performed the required cost analysis from the viewpoint of a mass production system. A break even analysis & sensitivity analysis is also done.

9.2 Cost Analysis

9.2.1 Machine & Associated Costs

1. ***Metal extrusion machine*** (Brand name: Kingrod, China, Model number: P12-7677E)**:**
Buying Cost: 35, 00,000 TK
Life: 25 years
Salvage: 90,000 TK
Quantity: 1

2. ***Gas welding machine*** (Jiangsu, China (Mainland), Model No: RDH1200)**:**
Buying Cost: 12, 00,000 TK
Life: 10 years
Salvage: 35,000 TK
Quantity: 1

3. ***Permanent mold casting machine*** (Brand name: Zhejiang, China, Model number: 718-SKD61)**:**
Buying Cost: 30, 00,000 TK
Life: 25 years
Salvage: 1, 00,000 TK
Quantity: 1

4. ***Arc welding machine*** (Chicago Electric Welding Systems 98233 240 Volt Inverter ARC/TIG Welder with Digital Readout)**:**
Buying Cost: 3, 00,000 TK

Life: 5 years

Salvage: 50,000 TK

Quantity: 1

*5. **Non- precision grinding machine:***

Buying Cost: 5, 00,000 TK

Life: 10 years

Salvage: 5,000 TK

Quantity: 1

*6. **Polishing, measuring, joining & coloring equipment:***

Buying cost (per year): 5, 00,000TK

*7. **Permanent mold Casting Die:***

Buying Cost: 2, 00,000 TK

Life: 7yrs

Salvage: 3000TK

Quantity: 1

8. Forging Machine:

Buying Cost: 3, 00,000 TK

Life: 10 years

Salvage: 27000 TK

Quantity: 1

9.2.2 Cost of furniture, computer and other accessories

Total Furniture & accessories cost for office: 3, 00,000 TK

Life: 10 years

Salvage: 15,000 TK

Computer cost: 1, 00,000 TK

Life: 10 years

Salvage: 10,000 TK

9.2.3 Costs of raw materials (per unit of product)

1. AISI 347 Annealed Stainless Steel

Raw material required =3 Kg

Market price of raw material = 180 TK/Kg

Total Raw Material cost = 540 TK

2. 6061 Alloy Aluminum

Raw material required = 3 Kg

Market price of raw material = 220 TK/Kg

Total Raw Material cost = 660 TK

3. Alloy Steel:

Raw material required = 2.5Kg

Market price of raw material= 190 TK

Total Raw Material cost = 475 TK

9.2.4 Manufacturing costs of different operations (per month)

1. Measuring

Labor cost:

No of workers = 2

Wage/labor = 22,000 Tk.

Total labor cost = 44,000 Tk.

2. Cutting

Labor cost:

No of workers = 2

Wage/labor = 18,000 Tk.

Total labor cost = 36,000 Tk.

3. Casting Operation

Labor cost:

No of workers = 5

Wage/labor = 13,000 Tk.

Total labor cost = 65,000 Tk.

4. Extrusion Operation

Labor cost:

No of workers = 4

Wage/labor = 13,000 Tk.

Total labor cost = 52,000 Tk.

5. Assembly & Joining operation

Labor cost:

No of workers = 4

Wage/labor = 17,000 Tk.

Total labor cost = 68,000 Tk.

6. Finishing operation

Labor cost:

No of workers = 4

Wage/labor = 12,000 Tk.

Total labor cost = 48,000 Tk.

7. Coloring

Labor cost:

No of workers = 2

Wage/labor = 14,000 Tk.

Total labor cost = 28,000 Tk.

Total raw material: 1675 Tk. Per unit

Total labor cost: 3, 41,000 Tk. Per month

Total unit of Production per year: 6,000

Total raw material cost per year: (6,000×1675) =1,00,50,000 Tk.

Total labor cost per year: (3, 97,000×12) =47, 64,000 Tk.

9.2.5 Purchasing Cost

Below is a list of parts which we are going to purchase.

Serial	Name of Components	Quantity	Price(TK)
1	Block Bearing	6 Pieces	600
2	Frame(Body)	1 Piece	2500
3	Chain	4 Pieces	400
4	Sprocket	8 Pieces	800
5	Handle Wheel	2 Pieces	700
6	Nut and Bolts	30 Pieces	300
7	MS Shaft	11 Feet	660
8	Aluminum Shaft	7 Feet	700
9	MS Plate	2 Pieces	500
10	Step Wheel	4 Pieces	2000
11	SS Pipe	6 Feet	600
12	Bush	8 Pieces	800
		TOTAL	**10560**

Some of the above listed parts can be interpreted as manufacturing overhead. Besides we are going to purchase in bundle offer. So a great deal of discount is expected. After analyzing current market we estimated that about thirty five discount will be available if we buy these parts in large amount.

Total purchasing cost for parts per unit product = 10560×0.65 = 6840 TK

Total purchasing cost per year = 6840×6,000 = 2, 49, 60,000TK

9.3 Manufacturing Cost:

1. Direct Material Cost:

Raw Material Cost: 100, 50,000TK

Purchasing Cost: 249, 60,000TK

Direct material cost per year: (10050000+24960000) = **35010000** TK

2. Direct Labor Cost:

Labor cost per year = 47, 64,000TK.

9.4 Manufacturing Overhead Cost per Month:

Cost Item	No. of post	Salary/person	Total (TK)
Production Manager	1	45,000	45,000
Manufacturing Engineer	1	35,000	35,000
Design Engineer	1	35,000	35,000
Assembly Manager	1	25,000	25,000
Quality control Manager	1	25,000	25,000
Power Consumption			15,000
Factory Rent			30,000
		Total	**2, 10,000**

Total manufacturing overhead per year: 2, 10,000×12 = **25, 20,000** TK.

Total manufacturing cost per year: **422, 94,000** TK.

9.5 Selling & Administrative Expenses

9.5.1 Administrative cost

Post	No. of post	Salary/person	Total (TK)
Chief Executive Officer	1	60,000	60,000
HR Manager	1	35,000	35,000
Accountant	1	25,000	25,000
Secretary	1	10,000	10,000
Clerk	2	6,000	12,000
Guard	1	5,000	5,000
Office rent			15,000
Power Bill			2,000
Water Bill			1,000
		Total	**1, 65,000**

9.5.2 Selling Expenses

Cost Items	No. of post	Salary/person	Total (TK)
Marketing Executive	1	25,000	25,000
Advertising			15,000
		Total	**40,000**

Total Selling and administrative cost per year: 40,000×12 = 4, 80,000 TK

Total unit of production per year: 6,000

9.6 Break Even Analysis

Fixed cost

Machine cost = 95, 00,000 TK

Furniture and accessories cost = 3, 00,000 TK

Computer cost: 1, 00,000 Tk.

Labor cost = 4764000Tk

Fixed manufacturing overhead cost = 25, 20,000TK

Fixed selling & administrative cost = 4, 80,000 TK

Total amount of fixed cost: **1, 76, 64,000** Tk. per year.

Variable cost (for the 6,000 products in the first year)

Raw material cost = 100, 50,000 TK

Purchasing cost per year = 2, 49, 60,000TK

Total variable cost per year: **3, 50, 10,000**TK.

Total variable cost per unit production: **3, 50, 10,000**÷ 6000 = **5835**TK.

Selling price per unit: **5835+40% of 5835 = 8169 TK≈ 8170 TK**

The equation for Break Even Analysis:

At Beak Even Point,

Selling price × break-even unit, (x) = Fixed cost+ Variable cost

Total amount of fixed cost: Tk. 1, 76, 64,000

The total variable cost per unit: 5835 TK

Selling price per unit: **8170**TK

So the equation stands as:

8170x =1, 76, 64,000+ 5835x

This yields x =7565 units

So, the Break Even quantity is 7565 units.

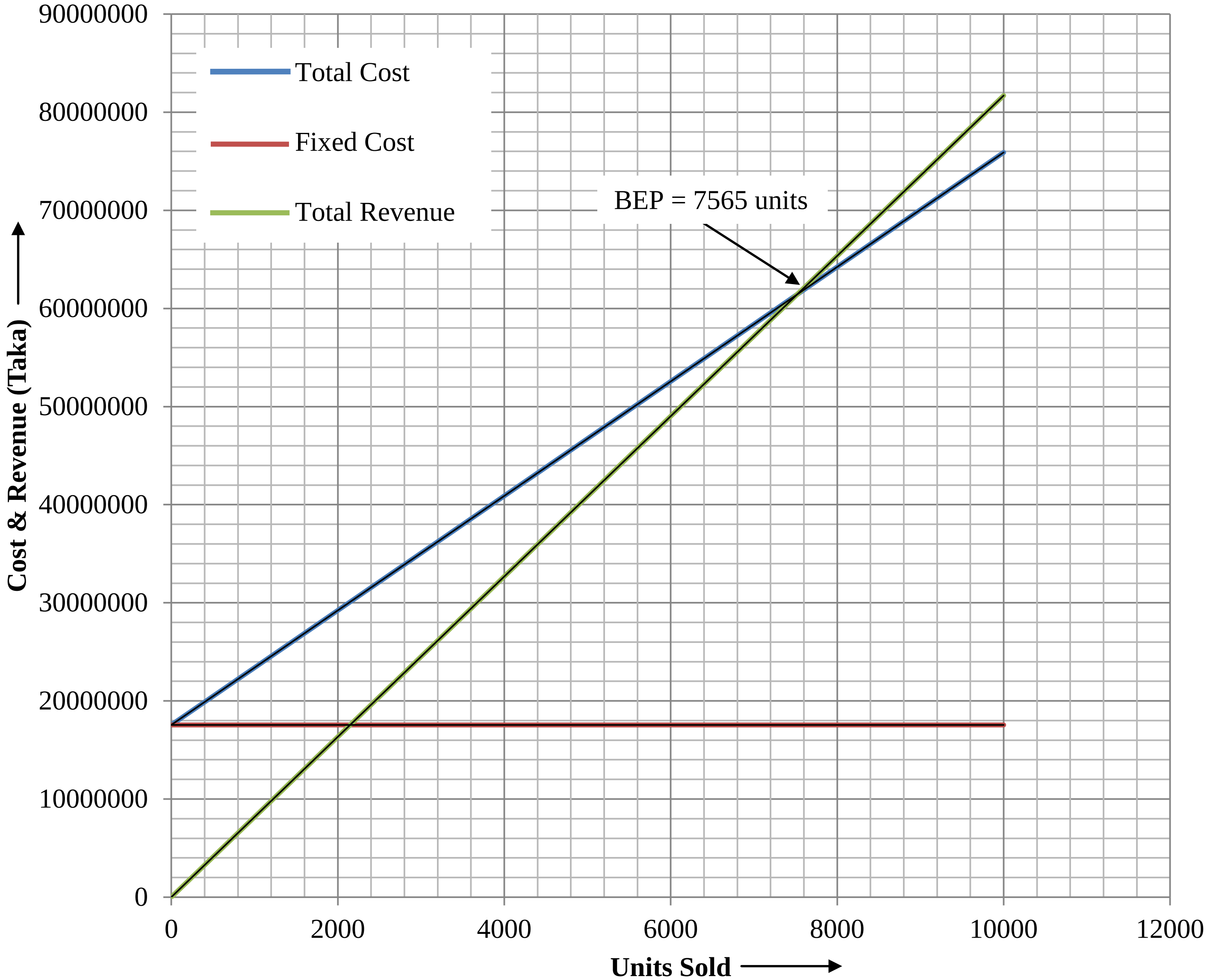


Figure: Graphical Representation of the Break-Even Analysis

Chapter-10

Sensitivity Analysis

10.1 Introduction

The objective of cost analysis and sensitivity analysis is to understand the process of predicting the cost of products. Elements of traditional engineering economics are melded with manufacturing process modeling, life cycle cost management concepts, and selected concepts from environmental life cycle cost assessment to form a practical foundation for predicting the real cost of products.

10.2 Sensitivity Analysis

By changing various parameters by 10% we have calculated the effect of the corresponding parameter on the Break-even quantity of product.

1. **Sensitivity of Direct Material:**

Total direct material cost per year = 3, 50, 10,000 Tk

After 10 % increase total direct material cost = 3, 50, 10,000 Tk + 10 % of 3, 50, 10,000 Tk
= 3,85,11,000 Tk

So, per unit direct material cost = (3,85,11,000 ÷ 6000) Tk = 6,418.5 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost + Variable cost

8170 x = 1, 76, 64,000 + 6,418.5 x

So x = 10085

$$\Delta x = \frac{10085-7565}{7565} \times 100\ \%$$

= 33.31 %

So, direct material cost is quite sensitive.

3. **Sensitivity of Variable Manufacturing Overhead:** Total variable manufacturing overhead cost = 1, 30,000 Tk After 10 % increase it becomes = 1, 43,000 Tk

Total variable cost becomes = 20, 20,000 Tk + 1, 30,000 × 0.1 Tk

= 20, 33,000 Tk

So variable cost per unit = 20, 33,000 ÷ 600 = 3,388 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

7000 x = 3986840 + 3388 x

So x = 1103.78 ≈ 1,104

$$\Delta x = \frac{1104-1098}{1098} \times 100\ \%$$

= 0.55%

So, Variable manufacturing overhead cost is not sensitive.

4. **Sensitivity of Selling & Administrative Cost:**

Total selling & administrative cost per year = 3, 60,000 Tk After 10 % increase it becomes = 3, 96,000 Tk

So total fixed cost per year = 39, 86,840 Tk + 3, 60,000 × 0.1 Tk

= 40, 22,840 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

7000 x = 40, 22,840 + 3367 x

So $x = 1107.31 \approx 1108$

$$\Delta x = \frac{1108 - 1098}{1098} \times 100\ \%$$

= 0.91 %

So, selling & administrative cost is not sensitive.

10.3 Result of Sensitivity Analysis

The results we got from sensitivity analysis:

- Direct material cost is quite sensitive.
- Direct labor cost is not much sensitive.
- Fixed manufacturing overhead cost is relatively sensitive.
- Variable manufacturing overhead cost is not sensitive.
- Selling & administrative cost is not sensitive.

10.4 Conclusion

We can conclude that we have made Cost analysis, Break Even analysis and Sensitivity analysis for our product for developing a better product design approach. Cost analysis helped us estimate the payback period by examining the break-even point. Sensitivity analysis helped us determine which parameters are sensitive (i.e. change in that parameter results in large change in break-even point) and which are not.

Conclusion

In Bangladesh, there are a huge number of ordinary wheelchair manufacturer. But there is no local manufacturer of stair climbing wheelchair. So, our manual stair climbing wheelchair, if produced efficiently by removing the design as well as other limitations that may still have, can be a solution to a lot of disabled people.

Product design is an important part of technology. It’s one of the first steps to many to creating a new product. Product design can simply be a solution to a flaw that needs redesigning or it could be a new idea that has the potential to succeed. This course has provided us with a comprehensive understanding of the process involved in product design and development of ideas from concept to implementation in the case of new or modified products.

RECOMMENDATIONS

Following recommendations are given for consideration with respect to Bangladesh and foreign countries

- Stair climbing wheelchair can be used to climb a few steps usually at the entrance of the building. This product can be made more effective if motor power is used as driving force instead of manual power. But this will increase the price of the product which is crucial keeping in mind the financial state of the majority of the disabled persons in our country.

- In future this product can be produced in 2 different categories: manual and automated. The automated wheelchairs use mainly electric motor rather than manual power. They are significantly more expensive than regular wheelchairs, and because everything is automated, it's much more user-friendly. This options can help customers choose the type of product they need keeping in mind their own financial state.

- In many foreign countries, automated stair climbing wheelchair are used. Many mechanisms for climbing the stairs are available. But our product is unique in the sense that it's the first product designed using manual power. So it is advisable that whenever someone is using a wheelchair to climb a few steps our manual stair climbing wheelchair is highly recommended in that case.

APPENDICES

Appendix A: Questionnaire for the Survey

Name:

Gender:

Address:

Age:

Date:

1. What type of wheelchair(s) do you currently use regularly?

    - Manual
    - Power-assisted
    - Scooter

2. Who paid for your current wheelchair?

    - National Pongu Hospital
    - National Institute Of Traumatology and Orthopedic Rehabilitation
    - Other organization
    - Self-pay

3. How many years have you used a wheelchair?

    - 0 - 5 years
    - 6 - 10 years
    - 11 - 15 years
    - 15 years or more

4. What activity are you involved in on a daily or regular basis?

    - Household activity
    - Go shopping
    - Go to school
    - Go to work

5. What kind of problem do you face during climbing up or downward to a stair?

- Need assistance
- Need extra support
- Require alternative (e.g- lift)

6. Who was present during your most current wheelchair assessment? (Select any one option)

- My child(ren)
- Occupational Therapist (OT)
- Friend
- Physician (MD)
- Spouse / Partner

7. Where was your most current wheelchair assessment?

- Home
- Hospital
- Wheelchair clinic
- Supplier's office or store

8. Did you have an opportunity to try one or more wheelchairs and/or configurations before your current wheelchair was ordered?

- Yes
- No

9. What was your level of decision making in the selection of your most recent wheelchair?

- Very involved
- Somewhat involved
- Hardly involved
- Not involved at all

10. Where did you accept delivery of your most recent wheelchair?

- Home
- Hospital
- Specialty wheelchair clinic
- Supplier's office or store

11. Are you satisfied with the manner that your current wheelchair was delivered?

- Very satisfied
- Somewhat satisfied
- Hardly satisfied
- Not satisfied at all

12. Who helped adjust your wheelchair when it was delivered?

- Physician (MD)
- Self (No one else.)
- Spouse / Partner
- Vendor / supplier Wheelchair technician
- Assistive Tech Provider (ATP)

13. How much time was spent on your most recent wheelchair fitting process?

- Less than 15 minutes
- 16 - 30 minutes
- 31 - 60 minutes
- 1 - 1.5 hours
- More than 1.5 hours

14. How much time was spent on your most recent wheelchair education and training process?

- Less than 15 minutes
- 16 - 30 minutes
- 31 - 60 minutes
- 1 - 1.5 hours
- More than 1.5 hours

15. How often assistance is available during climbing the stairs?

- Very often
- Often
- Rarely

16. How often you need to ascend or descend stairs?

- 3-5 times a day
- 6-8 times a day
- 9-12 times a day
- No need

17. How much additional payment you can afford for the special assembles or fittings (taka)?

- Less than 2000
- 2000
- 3000
- 4000
- More than 4000

Appendix B: Results of Tensile Tests of Some Metals

The following table was used during material selection using weighted average method for identifying different material property (as example: shear strength, yield strength etc.) values

			Strength (Tensile)					
Number	Material	Condition	Yield S_y, MPa (kpsi)	Ultimate S_u, MPa (kpsi)	Fracture, σ_f, MPa (kpsi)	Coefficient σ_0, MPa (kpsi)	Strain Strength, Exponent m	Fracture Strain ϵ_f
1018	Steel	Annealed	220 (32.0)	341 (49.5)	628 (91.1)	620 (90.0)	0.25	1.05
1144	Steel	Annealed	358 (52.0)	646 (93.7)	898 (130)	992 (144)	0.14	0.49
1212	Steel	HR	193 (28.0)	424 (61.5)	729 (106)	758 (110)	0.24	0.85
1045	Steel	Q&T 600°F	1520 (220)	1580 (230)	2380 (345)	1880 (273)	0.041	0.81
4142	Steel	Q&T 600°F	1720 (250)	1930 (210)	2340 (340)	1760 (255)	0.048	0.43
303	Stainless steel	Annealed	241 (35.0)	601 (87.3)	1520 (221)	1410 (205)	0.51	1.16
304	Stainless steel	Annealed	276 (40.0)	568 (82.4)	1600 (233)	1270 (185)	0.45	1.67
2011	Aluminum alloy	T6	169 (24.5)	324 (47.0)	325 (47.2)	620 (90)	0.28	0.10
2024	Aluminum alloy	T4	296 (43.0)	446 (64.8)	533 (77.3)	689 (100)	0.15	0.18
7075	Aluminum alloy	T6	542 (78.6)	593 (86.0)	706 (102)	882 (128)	0.13	0.18

Appendix C: Mechanical Properties of Some Aluminum Alloys

The following table was used during material selection using weighted average method for identifying different material property value

Aluminum Association Number	Temper	Yield, S_y, MPa (kpsi)	Strength Tensile, S_u, MPa (kpsi)	Fatigue, S_f, MPa (kpsi)	Elongation in 2 in, %	Brinell Hardness H_B
Wrought:						
2017	O	70 (10)	179 (26)	90 (13)	22	45
2024	O	76 (11)	186 (27)	90 (13)	22	47
	T3	345 (50)	482 (70)	138 (20)	16	120
3003	H12	117 (17)	131 (19)	55 (8)	20	35
	H16	165 (24)	179 (26)	65 (9.5)	14	47
3004	H34	186 (27)	234 (34)	103 (15)	12	63
	H38	234 (34)	276 (40)	110 (16)	6	77
5052	H32	186 (27)	234 (34)	117 (17)	18	62
	H36	234 (34)	269 (39)	124 (18)	10	74
Cast:						
319.0*	T6	165 (24)	248 (36)	69 (10)	2.0	80
333.0†	T5	172 (25)	234 (34)	83 (12)	1.0	100
	T6	207 (30)	289 (42)	103 (15)	1.5	105
335.0*	T6	172 (25)	241 (35)	62 (9)	3.0	80
	T7	248 (36)	262 (38)	62 (9)	0.5	85

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