



Bangladesh University of Engineering and Technology

IPE 304
PRODUCT DESIGN-I SESSIONAL

Report on
Mechanical Trash Compactor

Submitted to

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FORWARDING LETTER

December 07, 2020

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Subject: A report on “Mechanical Trash Compactor”.

Dear Teachers,

With due respect, we would like to submit you our report on “Mechanical Trash Compactor”.

In our product, we have used X-frame to Compact trash. This Mechanism will increase the capacity of the bin. It is flexible and easy to use. This report, it is presented how the Trash Compactor will work, its manufacturing process, and the overall costing of production.

We would like to thank you for helping us in completing this project. Due to time shortage, there might be some errors and lacking. We request you to kindly consider such cases and oblige thereby.

Sincerely yours,

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PREFACE

In Product Design-I Sessional we have learned how to design a product and how to perform all the corresponding analyses to manufacture the product.

The engineering design is a methodical series of steps that an engineer uses in creating functional products and processes. The process is iterative. Parts of the process often need to be repeated many times.

After consulting with our course teachers, we were given Mechanical Trash Compactor as our course project. This product will be a bin that can compact the trash and will give more space to dump more trash.

The objective of this project was to implement the knowledge we gained from Product Design I Sessional. Engineering design follows a series of processes to come up with a suitable solution. We have to consider customer requirements, cost, and feasibility of the product before designing it.

Summary

A trash compactor is a mechanical tool that can be used to compact the trash in a way creating more space for adding more garbage. But our mechanical trash compactor uses a general belt-pulley mechanism and does not use any electrical means for the compaction process. The X-frame by belt-pulley and paddle make a thruster ramming on the garbage in the bin creating compacted trash. As a result, cleanliness awareness is raised. As per identifying the customer requirements a prototype is meant to be built. For mass production cost analysis has been done. Our target is to manufacture a product which can be used to keep the city streets and even your households clean with classiness.

ACKNOWLEDGEMENT

This project would not be completed without the help and participation of many people.

Firstly, we would like to thank our course teachers for their valuable advice, support, guideline and useful suggestions on product design. They helped us very much with their experience. They gave us a lot of information which was helpful to design the product.

Table of Contents

Copyright Notice.....	i
FORWARDING LETTER.....	ii
PREFACE.....	iii
Summary.....	iv
ACKNOWLEDGEMENT.....	v
Chapter-01.....	1
Introduction.....	1
1.1 Product Design:.....	1
1.2 Proposed Product Ideas:.....	1
1.3 Selected Proposal:.....	1
1.3.1 Mechanical Trash Compactor:.....	1
1.3.2 Background that leads us to design waste compacting machines:.....	3
Chapter-02.....	4
Understanding Customer Needs Through Survey.....	4
2.1 Introduction:.....	4
2.2 Areas and Locations of Survey:.....	4
2.3 Survey Result:.....	5
2.4 Customer Requirement Evaluation:.....	19
Chapter-03.....	20
Incorporating the Voice of Customer in Product Design with Quality Function Deployment (QFD).....	20
3.1 Introduction:.....	20
3.2 Quality Function Deployment's House of Quality:.....	21
3.2 Customer Requirement & Engineering Requirement Relationship:.....	22
3.3 Importance Rating Table:.....	25

Chapter- 04.....	26
Functional Decomposition	26
4.1 Introduction:.....	26
4.2 Black Box Model of Functional Decomposition:	27
4.3 Component Hierarchy:	28
4.4 Cluster Function Structure of Trash Compactor:	30
Chapter 05	32
Design Analysis	32
5.1 Introduction:.....	32
5.2 Parts of Mechanical Trash Compactor:.....	33
5.3 Static Structural Analysis (ANSYS):.....	36
Chapter- 06.....	56
Qualitative Analysis of Material, Manufacturing Process & Joining Process Selection	56
6.1 Selection of Materials for Different Sections:	56
6.2 Selection of Manufacturing Processes for Different Sections	59
6.3 Selection of Joining Process	62
Chapter- 07.....	65
Material Selection Using Weighted Average method	65
7.1 Introduction:.....	65
7.2 List of Parts for Each Sub-assembly:.....	65
7.3 Equations:	66
7.4 Likert Scale:	66
7.5 Quantitative Analysis of Material Selection for Mechanical Trash Compactor Parts:	67
Chapter - 08.....	73
Manufacturing Process and Joining Process Selection Using Weighted Average Method: 73	
8.1 Introduction:.....	73

8.2 List of Manufacturing Processes and Joining Processes:	73
8.3 Quantitative Analysis of Manufacturing Process Selection:	74
8.4 Quantitative Analysis of Joining Process Selection:	84
Chapter- 09.....	86
Cost Analysis	86
9.1 Demand Forecast:	86
9.2 Fixed Cost.....	86
9.3 Manufacturing Cost:	88
9.4 Non-manufacturing Costs	92
9.5 Break Even Analysis:.....	93
Conclusion:	96
Appendix.....	97
References.....	100

List of Table

Table 2.1: The number of dustbins in a customer’s house/workplace.....	5
Table 2.2: Amount of daily trash in a customer’s dustbin.....	6
Table 2.3: Approximate volume of customer’s dustbin.....	7
Table 2.4: Approximate price of a customer’s dustbin.....	8
Table 2.5: Response count for the frequency of taking out the trash in a day.....	9
Table 2.6: Frequency of customers getting annoyed when the dustbin gets filled up.....	10
Table 2.7: Frequency of customer responses for having an option to compact trash.....	11
Table 2.8: Type of trash in a customer’s dustbin.....	12
Table 2.9: Frequency of customers according to the smelliness of their dustbins	13
Table 2.10: Frequency of customers willing/not willing to buy a dustbin with a lid	14
Table 2.11: Customer preference for the type of compactor	15
Table 2.12: Customer’s expected price of the trash compactor.....	16
Table 2.13: Preferred mode of getting trash compactor	17
Table 2.14: Customer response about learning the basics of the trash compactor	18
Table 2.15: Relative importance of customer requirements	19
Table 3.1: Relationship Explanation.....	22
Table 3.2: Importance Rating	25
Table 6.1: Qualitative analysis of material selection for the parts of housing:.....	56
Table 6.2: Qualitative analysis of material selection for parts of the relay system	57
Table 6.3: Qualitative analysis of material selection for the parts of the compacting system.....	58
Table 6.4: Qualitative analysis of the manufacturing process selected for the parts of the housing.....	59
Table 6.5: Qualitative analysis of the manufacturing process selected for the parts of the relay System.....	60
Table 6.6: Qualitative analysis of manufacturing process selection for parts of the compacting system	61
Table 6.7: Qualitative analysis of joining process selection for the parts of the housing.....	62
Table 6.8: Qualitative analysis of joining process selection for the parts of the relay system	63

Table 6. 9: Qualitative analysis of joining process selection for parts of the compacting system	63
Table 7.1: Likert Scale	66
Table 7.2: List of selection criteria with numerical values or values from Likert Scale for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster:.....	67
Table 7.3: Determination of relative importance of material selection criteria for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster using Digital Logic Method:.....	68
Table 7.4: Calculation of the performance index for material selection of Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster:.....	69
Table 7.5: List of selection criteria with numerical values or values from Likert Scale for body and lid.....	70
Table 7.6: Calculation of the performance index for material selection of body and lid using Digital Logic Method:.....	71
Table 7.7: Calculation of the performance index for material selection of Body and Lid:	72
Table 8.1: List of selection criteria with numerical values or values from Likert Scale for cutting mild steel blanks:	74
Table 8.2: Calculation of the performance index for manufacturing process selection for cutting of mild steel blanks using Digital Logic Method:	74
Table 8.3: Calculation of performance index for manufacturing process selection of cutting mild steel blanks:	75
Table 8.4: List of selection criteria with numerical values or values from Likert Scale for cutting HDPE sheets:	75
Table 8.5: Calculation of the performance index for manufacturing process selection for cutting of HDPE sheets using Digital Logic Method:	76
Table 8.6: Calculation of performance index for manufacturing process selection of cutting HDPE sheets:	76
Table 8.7: List of selection criteria with numerical values or values from Likert Scale for forming operations (for shafts):	77
Table 8.8: Calculation of the performance index for manufacturing process selection for forming operations (for shafts) using Digital Logic Method:.....	78

Table 8.9: Calculation of performance index for manufacturing process selection of forming operation (for Shafts):	79
Table 8.10: List of selection criteria with numerical values or values from Likert Scale for forming operations (for X-frame, Thruster):	79
Table 8.11: Calculation of the performance index for manufacturing process selection for forming operations (for X-frame, Thruster) using Digital Logic Method:	80
Table 8.12: Calculation of performance index for manufacturing process selection of forming operation (for X-frame, Thruster):	81
Table 8.13: List of selection criteria with numerical values or values from Likert Scale for cutting slots (for trash slot, housing):	81
Table 8.14: Calculation of the performance index for manufacturing process selection for cutting slots (for trash slot, housing) using Digital Logic Method:	82
Table 8.15: Calculation of performance index for manufacturing process selection of cutting slots (for housing and trash slot):	82
Table 8.16: List of selection criteria with numerical values or values from Likert Scale for Coloring Process:	83
Table 8.17: Calculation of the performance index for manufacturing process selection for coloring system using Digital Logic Method:	83
Table 8.18 Calculation of performance index for manufacturing process selection of Coloring System:	84
Table 8.19: List of selection criteria with numerical values or values from Likert Scale for Permanent Joint:	84
Table 8.20: Calculation of the relative emphasis coefficient for joining process selection for Permanent Joints using Digital Logic Method:	85
Table 8.21: Calculation of performance index for joining process selection of Permanent Joints:	85
Table 9.1: Purchased parts and their cost (per unit of product)	90
Table 9.2: Manufacturing Overhead Costs	91
Table 9.3: Administrative costs	92
Table 9.4: Selling Expenses	93

List of Figure

Figure 2.1: Split of customers according to the number of dustbins in their house/workplace.	5
Figure 2.2: Split of customers according to the amount of trash in their dustbins	6
Figure 2.3: Split of customers according to the approximate volume of their dustbins	7
Figure 2.4: Split of customers according to the approximate price of their dustbins	8
Figure 2.5: Split of customers according to the number of time they take out the trash daily ..	9
Figure 2.6: Split of customers according to their response when their dustbins get filled	10
Figure 2.7: Split of customers according to their will of compacting trash.....	11
Figure 2.8: Split of customers according to their trash type	12
Figure 2.9: Split of customers accruing to the smelliness of their dustbins	13
Figure 2.10: Split of the customer according to their will to buy a dustbin with a lid	14
Figure 2.11: Split of customers according to their preference for the type of compactor.	15
Figure 2.12: Split of customers according to their expected price of the trash compactor.....	16
Figure 2.13: Split of customers according to their preferred mode of getting trash compactor	17
Figure 2.14: Split of customers according to their will to learn the basics from a technician.	18
Figure 3.1: House of Quality of Mechanical Trash Compactor.....	21
Figure 4.1: Black Box Model of the Mechanical Trash Compactor.....	27
Figure 4.2: Component Hierarchy of trash compactor	29
Figure 4.3: Cluster Function of Trash Compactor	30
Figure 5.1: Bin	33
Figure 5.2: Pedal	33
Figure 5.3: Housing	34
Figure 5.4: Press Plate.....	34
Figure 5.5: X-frame and Pulley System.....	35
Figure 5.6: Top X-frame Holder.....	35
Figure 5.3.1: Holder.....	36
Figure 5.3.2: Total Deformation	37
Figure 5.3.3: Equivalent Stress	38

Figure 5.3.4: Safety factor	39
Figure 5.3.5: Fatigue Life	40
Figure 5.3.6: Housing	41
Figure 5.3.7: Total deformation	42
Figure 5.3.8: Equivalent Stress	43
Figure 5.3.9: Safety Factor.....	44
Figure 5.3.10: Press Plate.....	45
Figure 5.3.11: Total Deformation	46
Figure 5.3.12: Equivalent Stress	47
Figure 5.3.13: Safety Factor.....	48
Figure 5.3.14: Fatigue Life	49
Figure 5.3.15: X-frame	50
Fig 5.3.16: Total Deformation	51
Fig 5.3.17: Equivalent Stress	52
Figure 5.3.18: X-frame Bar.....	53
Figure 5.3.19: Total Deformation	54
Figure 5.3.20: Equivalent Stress	55
Figure 9.1: Graphical Representation of the Break-even Analysis.....	94

Chapter-01

Introduction

1.1 Product Design:

Design is a plan or specification for the construction of an object or system or the implementation of an activity or process, or the result of the plan or specification in the form of a prototype, product, or process. The design usually has to satisfy certain goals and constraints, may take into account aesthetic, functional, economic, or socio-political consideration, and is expected to interact with a certain environment.

Developing a design concept is the initial phase of design engineering. Designing a new product goes through an analytical process and relies on a problem-solving approach to improve the quality of life of the end-user and his or her interaction with the environment. It is about problem-solving, visualizing the needs of the user, and bringing a solution.

1.2 Proposed Product Ideas:

In the beginning, we have selected these three designs which included:

1. Modular Design for Electric Bicycles
2. Ergonomic Wheelchair
3. Mechanical Trash Compactor

1.3 Selected Proposal:

After proposing three different products for Product Design Sessional-I, the 'Mechanical Trash Compactor' was selected as our project after analyzing it's feasibility, design, the demand for the features we are bringing to the product.

1.3.1 Mechanical Trash Compactor:

Waste management has always been a problem in Commercial and Residential uses. The currently large-sized dustbin is used in commercial places and residential use, the small-sized dustbin is used. The wastebasket can contain only a limited volume of waste and has no compacting capabilities. The waste compactor is a great way to cut down on waste. Compacting waste has a lot of benefits. It makes waste management hygienic and convenient, reduces the

transportation cost of waste materials, and also it can contain a large volume of waste in a single bin. On a large scale, a baller-wrapper compactor is used for compacting wastes. This has very little or no use in commercial uses like restaurants, offices, hospitals, schools, etc. Waste compactor on a smaller scale can make the best use of spaces in the kitchen, restaurants, offices, etc.

The compactor will be separate from the dustbin and will use a small ram to compress waste. There will be a bin cover to keep the smell out.

Currently, there is no local manufacturer for ‘Mechanical Trash Compactor’, so we have to import from other countries with a huge cost. Manufacturing it locally could reduce the cost a lot.

Features:

- The trash will be compacted by the ram using the X Frame mechanism which will be controlled with a lever. Hence, anyone can easily use it.
- The container of the box can be closed with a lid. So, the trash will not stink.
- The ram cannot be pressed when the compactor is open; which ensures the safety of the user.
- The cost of the product will be within the range of common people.

Description:

The product consists of three parts. The first one is the container. It will be made of metal/high-density plastic (based on the type of use) so that it can withstand the pressure of the trash. The second part of the container is the lid of the container which has a snap latch lock. And the final part is the compactor which consists of a ram to presses the trash. The compactor will be separate from the bin. The ram is controlled with the X Frame mechanism which is connected to a lever attached to the compactor.

Improvements:

Current dustbins take a lot of space but their full capacity is not fully used. So compacting wastes can increase dustbin's capacity and that means in commercial places like restaurants, hotels, offices, fewer dustbins will be required and regular trash pickup won't be necessary.

1.3.2 Background that leads us to design waste compacting machines:

Most people do not think of a waste compactor as an essential item to have a clean kitchen. The current waste bin takes a lot of space but its full capacity is not fully used. If there is one thing that is inevitable in the kitchen but which we wish we could get away with executing less, it is certainly emptying the trash. We want to solve this problem by designing a waste compacting machine by reducing waste volume. It can reduce the daily chore of taking the garbage out to once a week. In commercial uses, the volume of wastes very high where a waste compacting machine can reduce the total space taken by a large waste bin. In many areas in Dhaka city where trash pickup is not regular, a waste compacting machine can be very helpful.

Chapter-02

Understanding Customer Needs Through Survey

2.1 Introduction:

In this modern world of convenience, we are constantly looking for ways to make our daily lives more convenient. Any product that can save our time and effort is high in demand. Our product is a trash compactor bin that enables its user to manage waste efficiently while saving valuable time needed to take out the trash. Compacted trash takes up less space in municipal dumps and landfills, reducing a household's environmental footprint.

The total waste collection rate in major cities of Bangladesh such as Dhaka is only 37%. When waste is not properly collected, it will be illegally disposed of and this will pose serious environmental and health hazards to the Bangladeshis. So, any improvement in this sector is much needed.

As primary research, we identified our target customers are:

- Households
- Government's City Corporations
- Other Private Organizations such as Schools, Colleges, Universities, Malls, Restaurants, etc.

We surveyed developing customer requirements for our trash compactor bin among some of the above customers in a very short time.

2.2 Areas and Locations of Survey:

01. Some of the restaurants of Dhaka (Mirpur), Chittagong, and Faridpur.
02. Bangladesh University of Engineering and Technology

2.3 Survey Result:

The survey was done among 30 people. The results of the survey are shown below with the help of pie charts along with percentage:

1. How many dustbins do you have in your house/workplace?
 - a) 1
 - b) 2
 - c) More than 2

Table 2.1: The number of dustbins in a customer's house/workplace

Option	Response Count	Response Percent (%)
1	6	20
2	14	47
More than 2	10	33

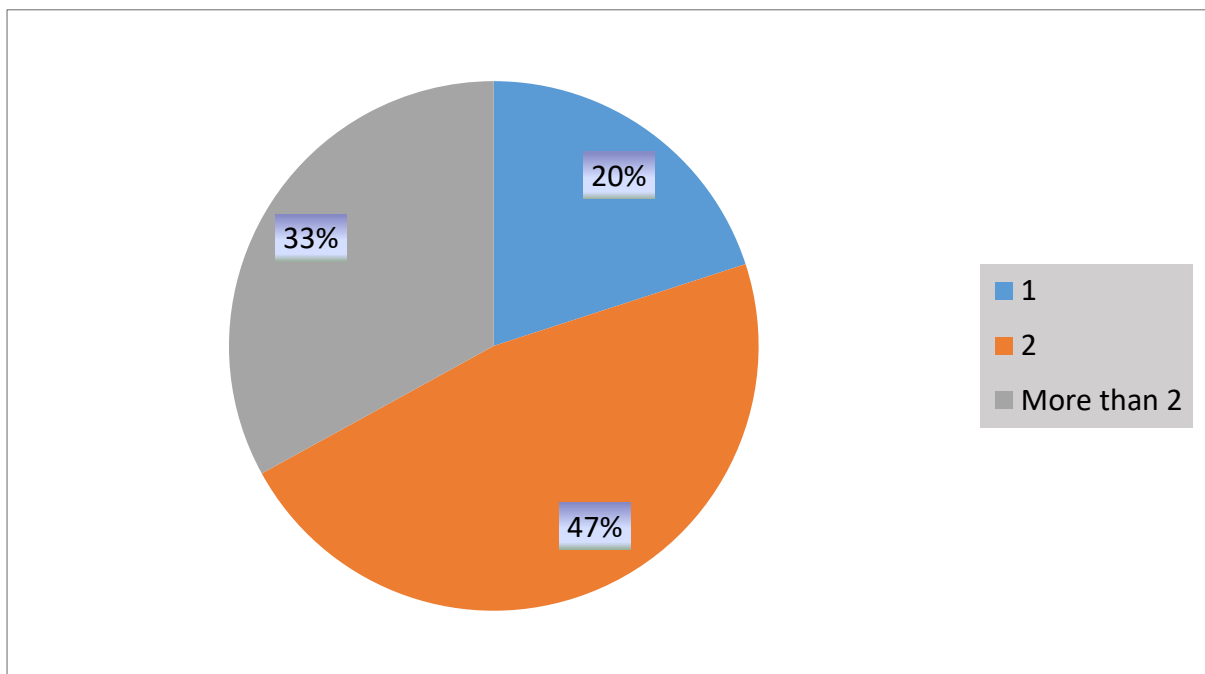


Figure 2.1: Split of customers according to the number of dustbins in their house/workplace

2. The amount of trash in your dustbin daily-

- a) Full bucket
- b) Half Bucket
- c) Not Sure

Table 2.2: Amount of daily trash in a customer's dustbin

Option	Response Count	Response Percent (%)
Full Bucket	10	33
Half Bucket	17	57
Not Sure	3	10

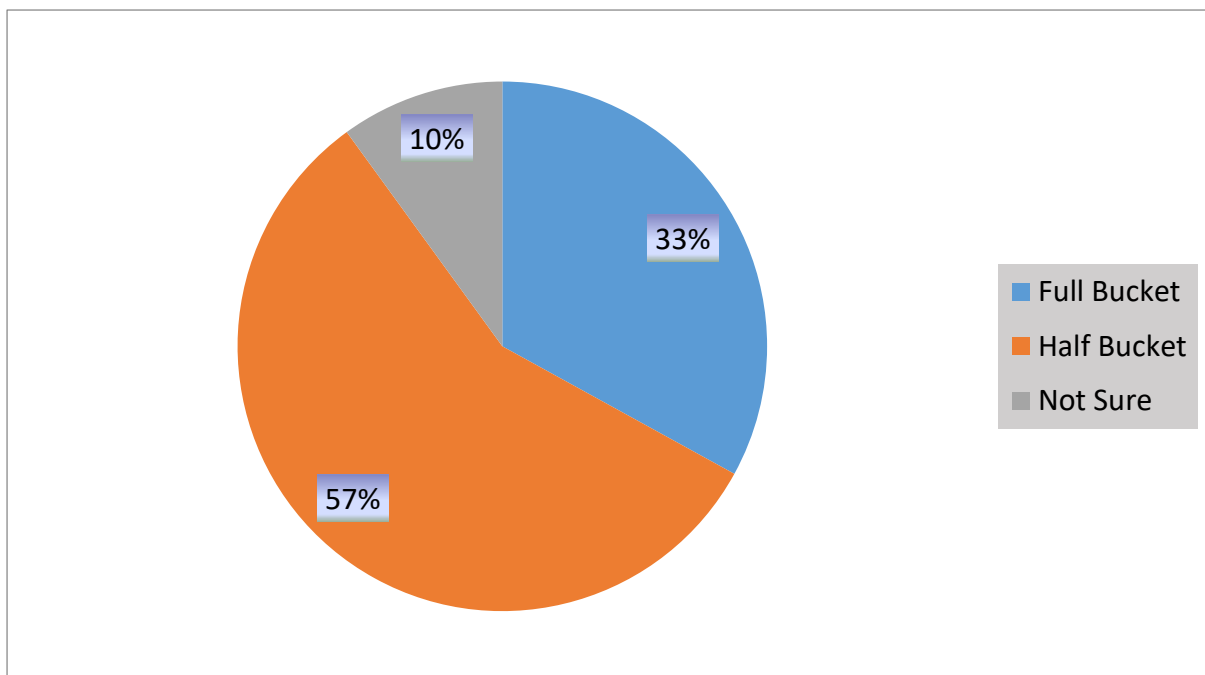


Figure 2.2: Split of customers according to the amount of trash in their dustbins

3. What is the approximate volume of your dustbin?

- a) 10L
- b) 10-50L
- c) More than 50L

Table 2.3: Approximate volume of customer's dustbin

Option	Response Count	Response Percent (%)
10L	15	50
10-50L	13	43
More than 50L	2	7

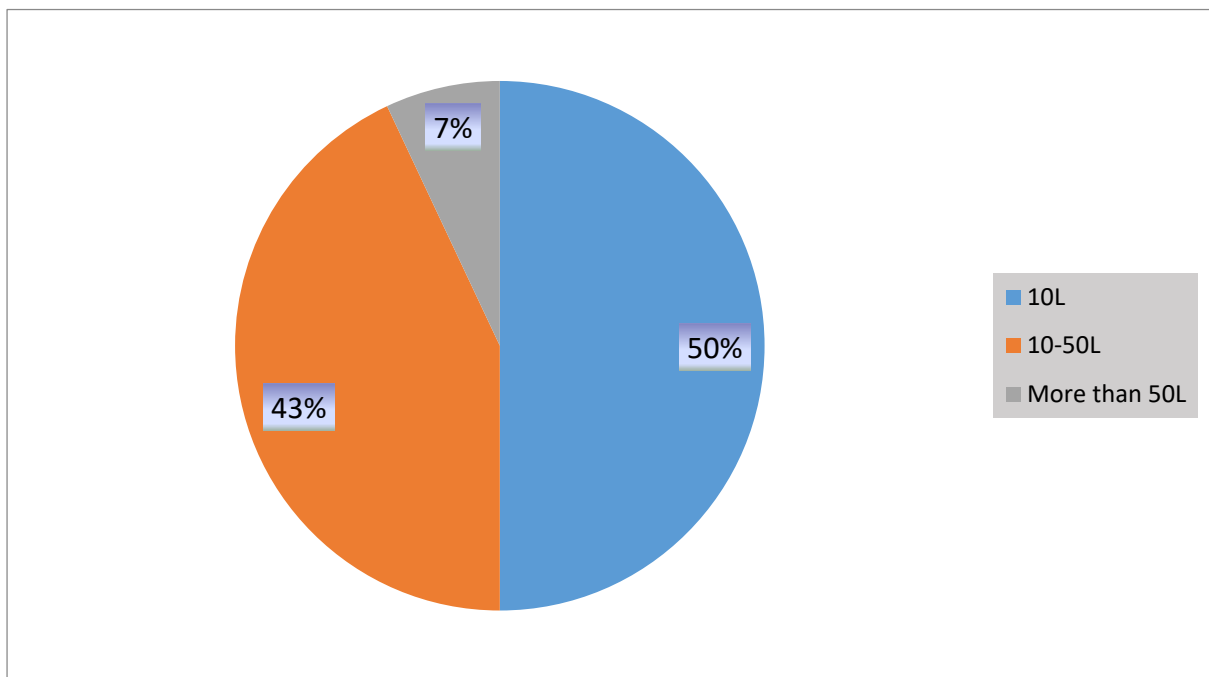


Figure 2.3: Split of customers according to the approximate volume of their dustbins

4. What was the approximate price of your dustbin?

- a) Below 500 TK
- b) 500-1000 TK
- c) More than 1000 TK

Table 2.4: Approximate price of a customer's dustbin

Option	Response Count	Response Percent (%)
Below 500 TK	20	67
500-1000 TK	7	23
More than 1000 TK	3	10

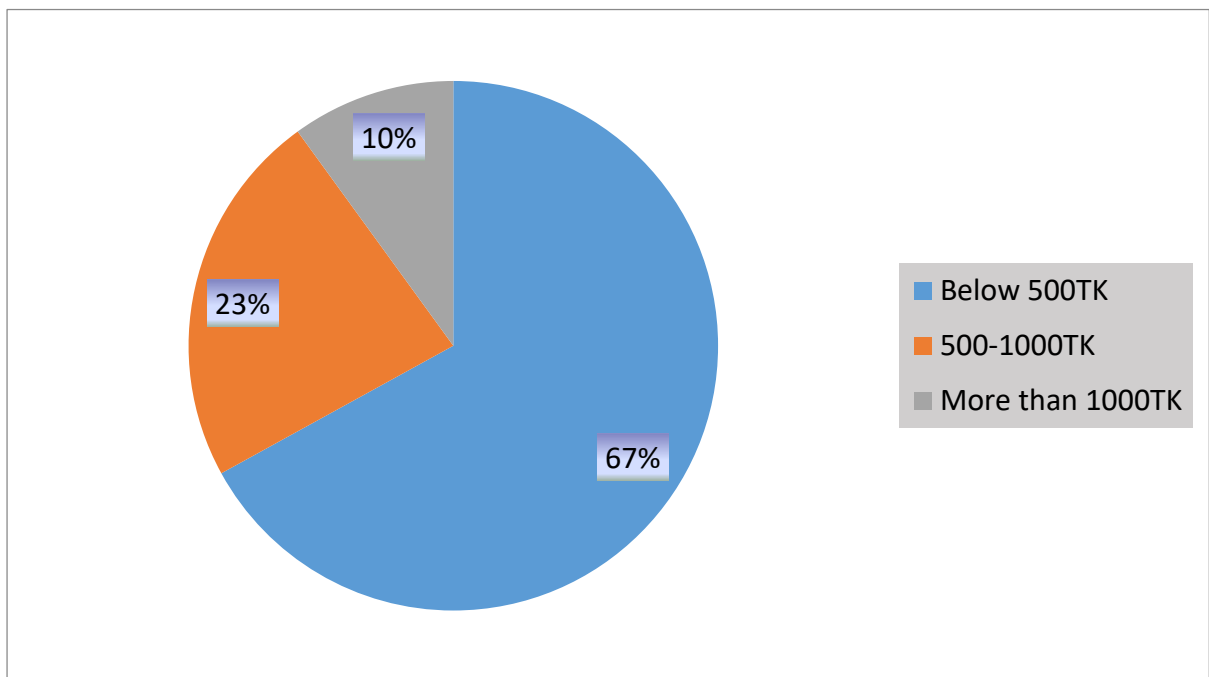


Figure 2.4: Split of customers according to the approximate price of their dustbins

5. How frequently you take out your trash in a day?

- a) 0 times
- b) 1 time
- c) 2-3 times
- d) More than 3 times

Table 2.5: Response count for the frequency of taking out the trash in a day

Option	Response Count	Response Percent (%)
0 times	2	7
1 time	19	63
2-3 times	5	17
More than 3 times	4	13

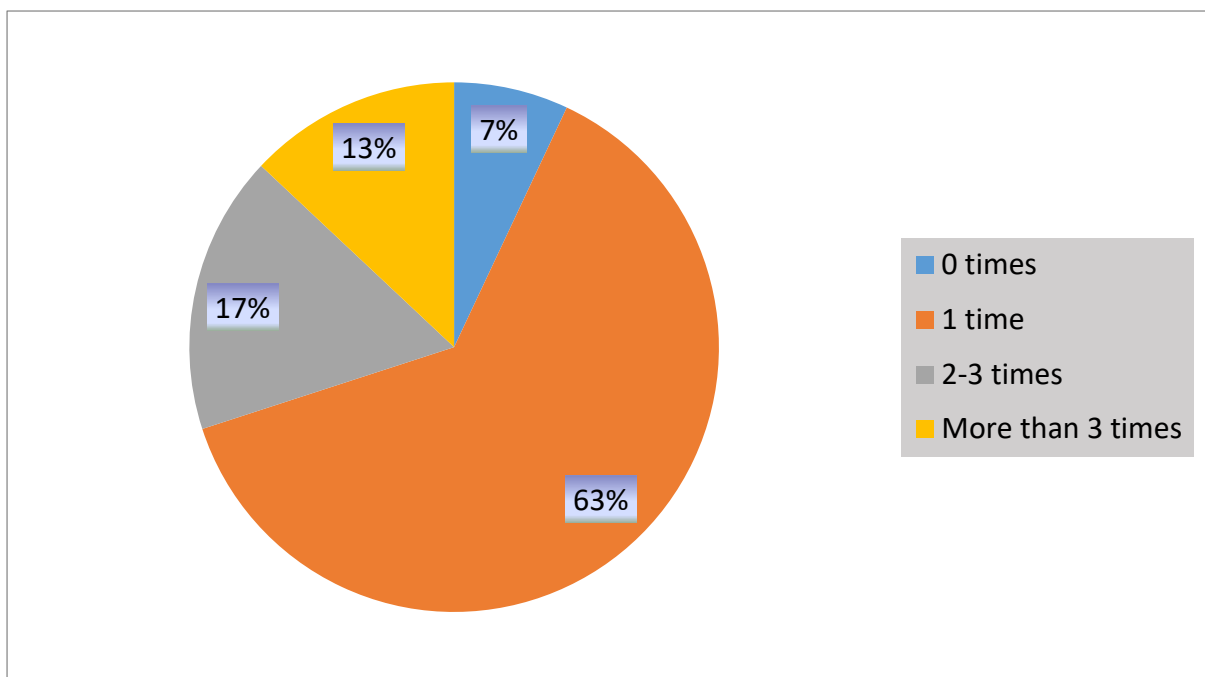


Figure 2.5: Split of customers according to the number of time they take out the trash daily

6. When your household/workplace/roadside dustbin gets filled with trash, do you feel annoyed not being able to dump your trash?

- a) Yes, very annoyed
- b) No, I just throw it somewhere

Table 2.6: Frequency of customers getting annoyed when the dustbin gets filled up

Option	Response Count	Response Percent (%)
Yes, very annoyed	27	90
No, I just throw it somewhere	3	10

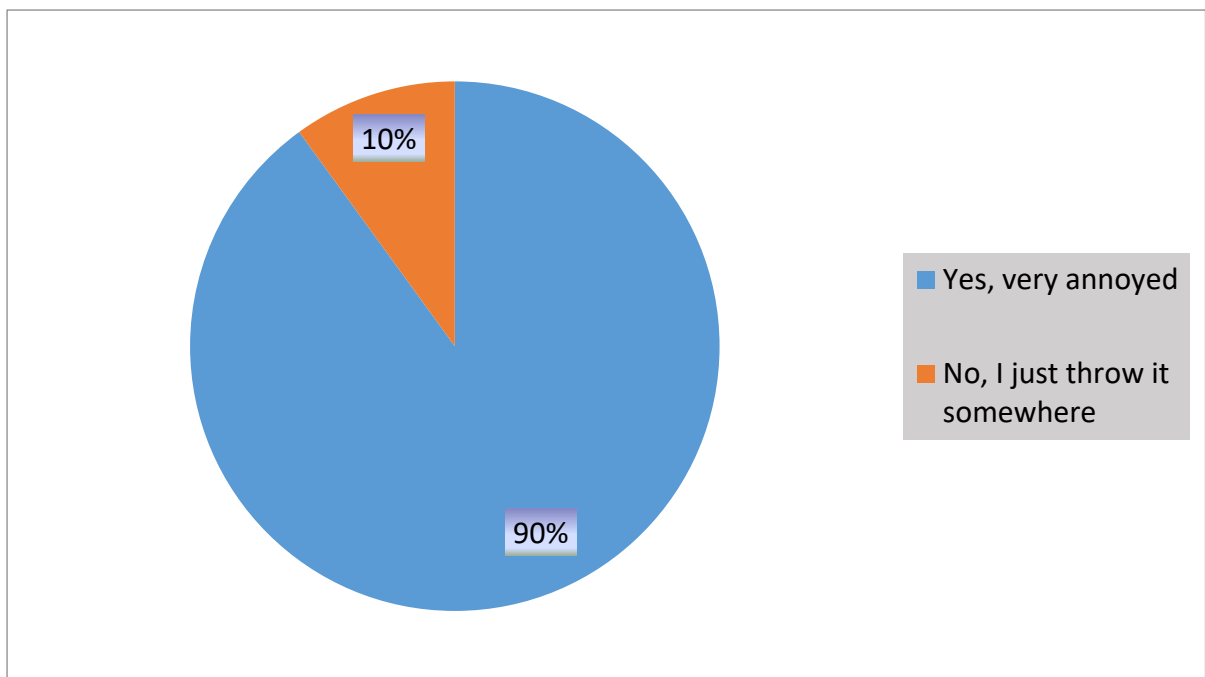


Figure 2.6: Split of customers according to their response when their dustbins get filled

7. Compaction of the trash will increase the capacity of the dustbin. Are you willing to have an option to compact your trash in a dustbin?

- a) Yes
- b) No

Table 2.7: Frequency of customer responses for having an option to compact trash

Option	Response Count	Response Percent (%)
Yes	24	80
No	6	20

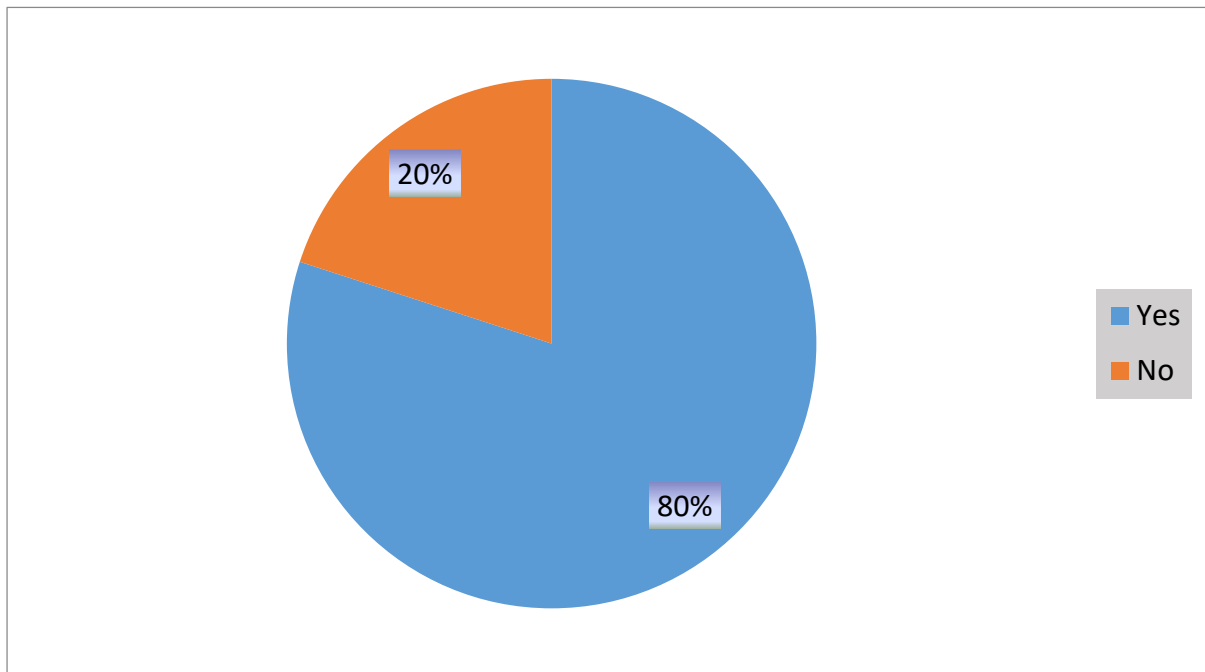


Figure 2.7: Split of customers according to their will of compacting trash

8. What type of trash you usually dump in your dustbin?

- a) Dry
- b) Wet
- c) Both

Table 2.8: Type of trash in a customer's dustbin

Option	Response Count	Response Percent (%)
Dry	3	10
Wet	2	7
Both	25	83

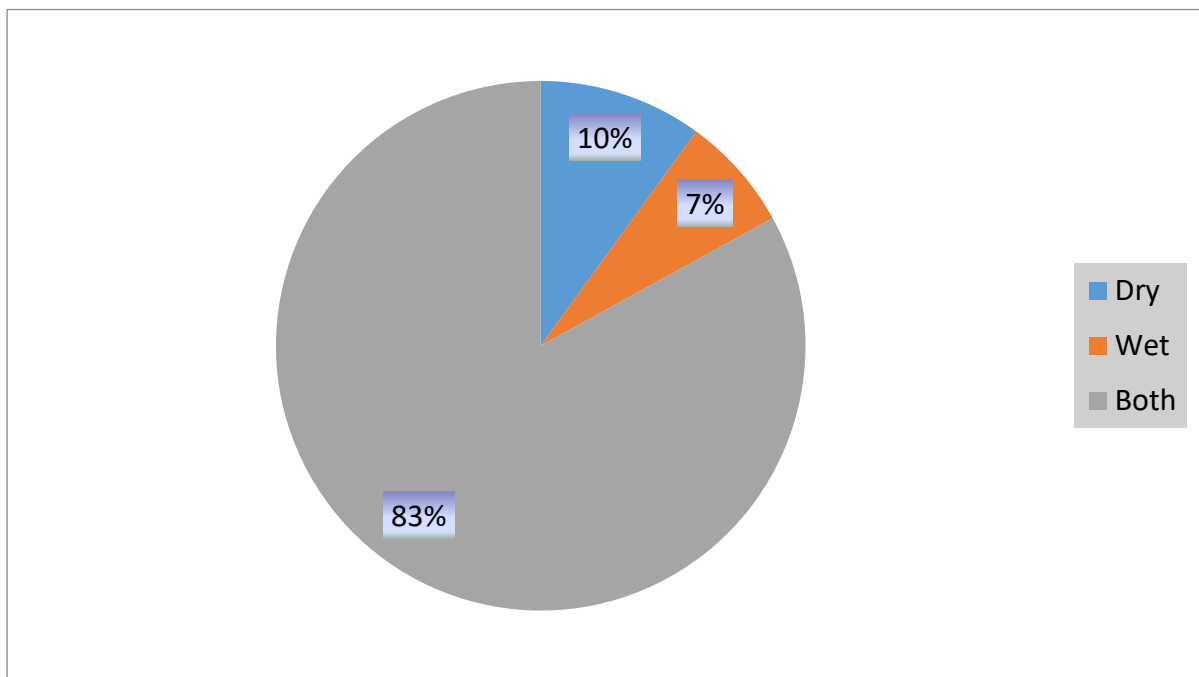


Figure 2.8: Split of customers according to their trash type

9. After decomposition some trash stink. How smelly your household/workplace becomes because of your dustbin?

- a) Smelly, but tolerable
- b) Very smelly, can't deal with it
- c) Not so much smelly to notice

Table 2.9: Frequency of customers according to the smelliness of their dustbins

Option	Response Count	Response Percent (%)
Smelly, but tolerable	12	40
Very smelly, can't deal with it	9	30
Not so much smelly to notice	9	30

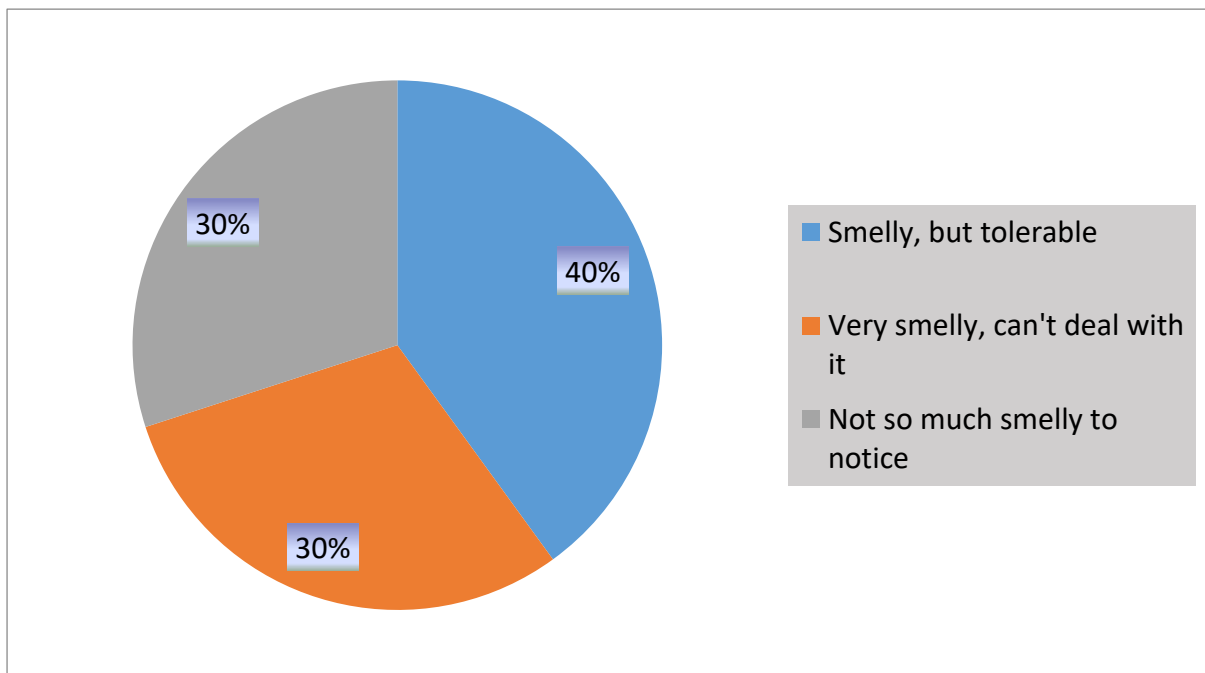


Figure 2.9: Split of customers accruing to the smelliness of their dustbins

10. Adding a lid can be a remedy to smell. Are you willing to buy a dustbin with a lid?

- a) Yes
- b) No

Table 2.10: Frequency of customers willing/not willing to buy a dustbin with a lid

Option	Response Count	Response Percent (%)
Yes	27	90
No	3	10

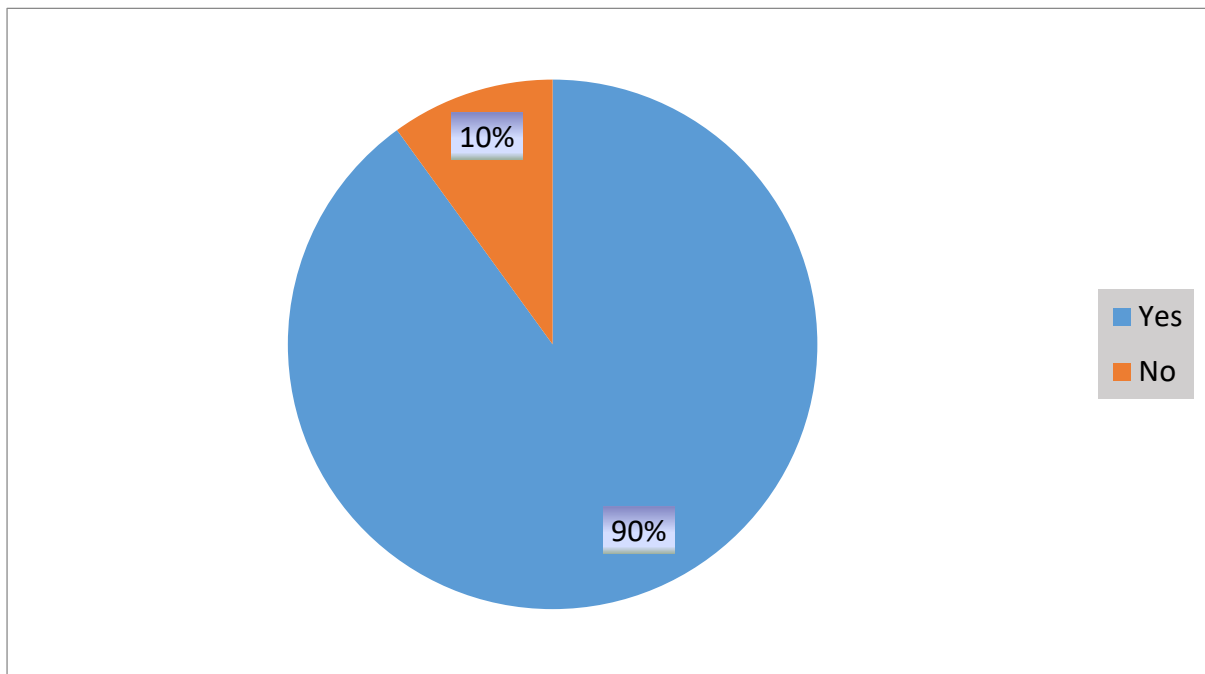


Figure 2.10: Split of the customer according to their will to buy a dustbin with a lid

11. What type of trash compactor would you prefer?

- a) Manual
- b) Automatic
- c) Both manual and automatic in one

Table 2.11: Customer preference for the type of compactor

Option	Response Count	Response Percent (%)
Manual	8	27
Automatic	9	30
Both manual and automatic in one	13	43

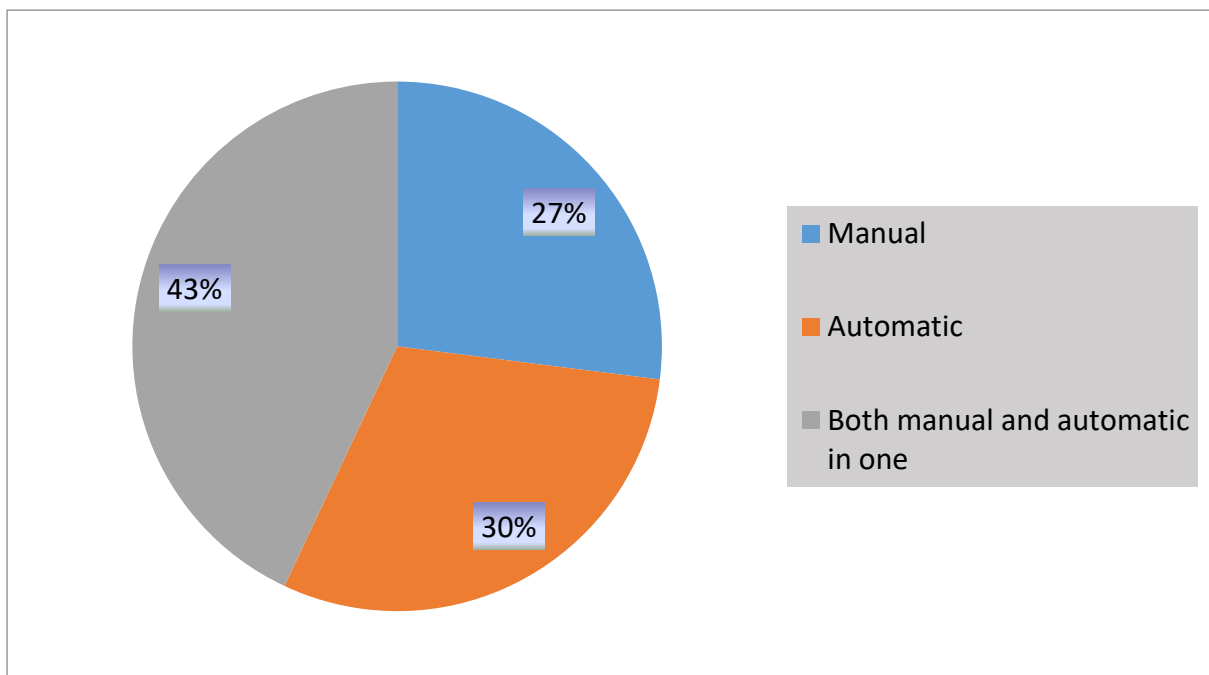


Figure 2.11: Split of customers according to their preference for the type of compactor.

12. How much are you willing to pay for a trash compacting dustbin?

- a) Below 1000 TK
- b) Below 2000 TK
- c) Below 3000 TK

Table 2.12: Customer's expected price of the trash compactor

Option	Response Count	Response Percent (%)
Below 1000 TK	21	70
Below 2000 TK	9	30
Below 3000 TK	0	0

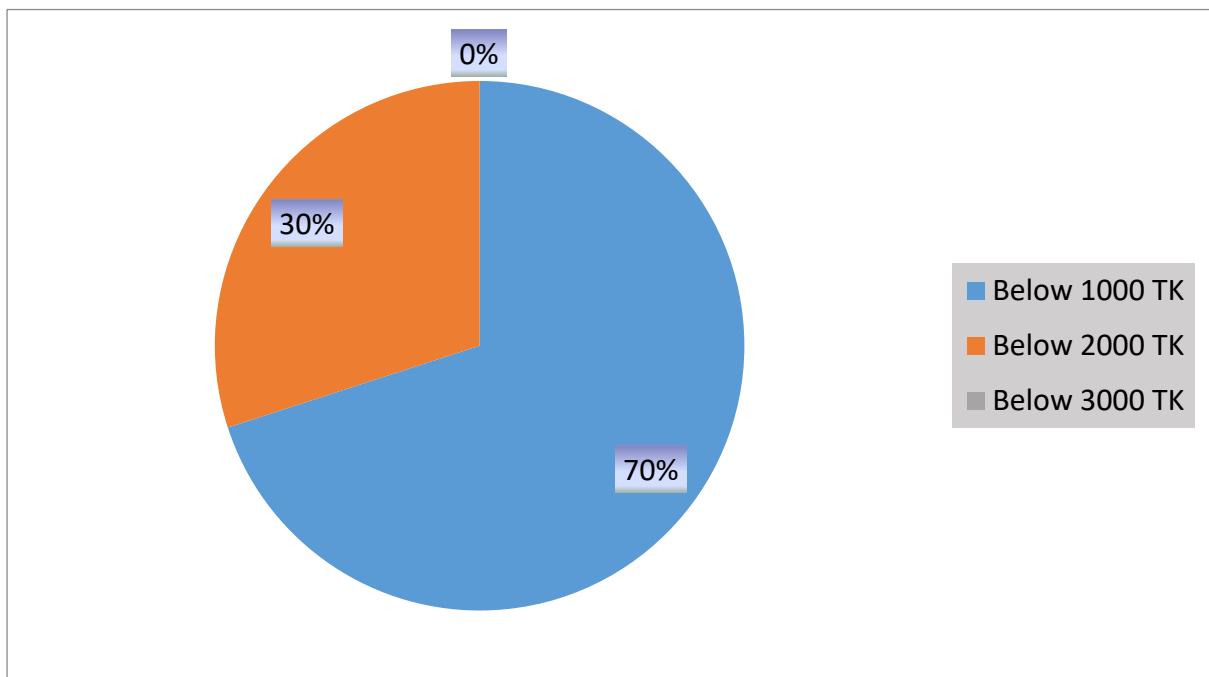


Figure 2.12: Split of customers according to their expected price of the trash compactor

13. How would you like to get your trash compactor?

- a) Buy from shop
- b) Buy from dealer
- c) Home delivery

Table 2.13: Preferred mode of getting trash compactor

Option	Response Count	Response Percent (%)
Buy from shop	9	30
Buy from dealer	7	23
Home delivery	14	47

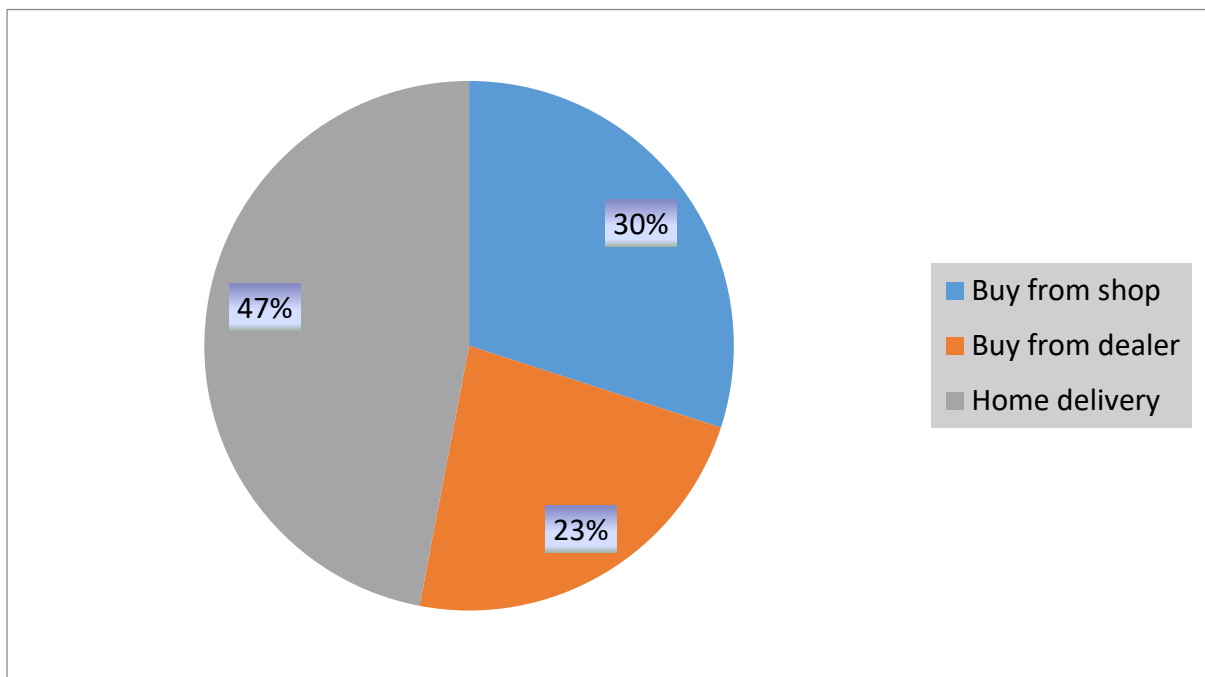


Figure 2.13: Split of customers according to their preferred mode of getting trash compactor

14. Would you want a technician to teach you the basics of the trash compactor?

- a) Yes
- b) No, I can handle it myself
- c) No, rather I want a YouTube tutorial

Table 2.14: Customer response about learning the basics of the trash compactor

Option	Response Count	Response Percent (%)
Yes	12	40
No, I can handle it myself	6	20
No, rather I want a YouTube tutorial	12	40

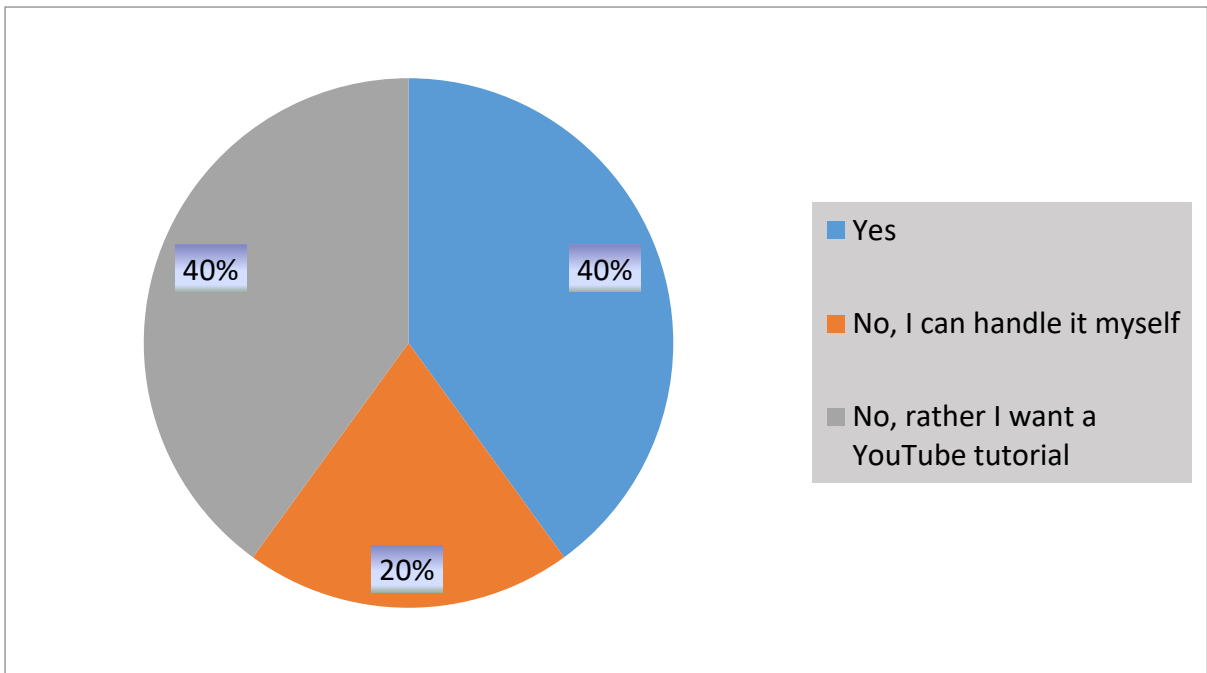


Figure 2.14: Split of customers according to their will to learn the basics from a technician

2.4 Customer Requirement Evaluation:

Through our survey, we have found that our customers mostly value a compacting dustbin that has easier compressibility, higher capacity, low cost, stability, and safety. So we have given these characteristics relatively higher importance along with considering other features as well.

Table 2.15: Relative importance of customer requirements

Customer Requirement	Relative Importance (Scale of 10)
Easy To Compress	10
Stability	8
Easy Trash Dumping	7
Prevention of Smell	9
Low cost	9
Low Maintenance Cost	7
Repairable	8
High Capacity	10
Safety	8

This survey is a list of carefully constructed questions aimed at a specific group of people for extracting specific data. Some of them were conducted face-to-face and some of them via the internet. A survey plays an important role in the initial stages of the product development process. After conducting the survey, we can now move on to the next stage of the product development process.

Chapter-03

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

3.1 Introduction:

The “voice of the customer” is a process used to capture the requirements/feedback from the customer (internal or external) to provide the customers with the best in class service/product quality. This process is all about being proactive and constantly innovative to capture the changing requirements of the customers with time. The “voice of the customer” is the term used to describe the stated and unstated needs or requirements of the customer. The voice of the customer can be captured in a variety of ways: Direct discussion or interviews, Surveys, Focus groups, Customer specifications, Observation, Warranty data, Field reports, Complaint logs, etc.

The house of quality is a voice of customer analysis tool and a key component of the quality function deployment technique. It starts with the voice of the customer. It is a tool to translate what the customer wants into products or services that meet the customer wants in terms of engineering design values by way of creating a relationship matrix.

House of Quality is a part of a larger process called **QFD**, which stands for **Quality, Function, Deployment**. QFD is a planning process with a quality approach to new product design, development, and implementation driven by customer needs and values.

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

3.2 Customer Requirement & Engineering Requirement Relationship:

From the house of quality, we can explain the relationship between customer requirements & engineering requirements.

Table 3.1: Relationship Explanation

Customer Requirement	Engineering Requirement	Relationship	Explanation
Easy to compress	X-frame	Strong	X-frame helps to compress the trash
	Moving shaft	Strong	Compression depends on the smoothness of the moving shaft
	Spring	Moderate	Recoil control
	Tension belt	Strong	The quality of the tension belt affects the compression of trash
Stability	Moving shaft	Moderate	An increase in the speed of the moving shaft decreases stability
	Strength of the main body	Strong	Strength of the main body increases stability
	Tension belt	Strong	Strength of the tension belt increases stability
	Material	Strong	Quality of material increases stability
Smell prevention	Housing design	Moderate	Compact design reduces smell
	Operational cost	Moderate	Extra bucket increases cost
Simple design	X-frame	Moderate	Higher compressibility
	Strength of the main body	Moderate	Complex design reduces the strength of the main body
	Material	Moderate	Lower machinability requires for a simple design
	Housing design	Strong	Less machining requires a simple design
	Manufacturing cost	Strong	Simple design reduces manufacturing cost

Customer Requirement	Engineering Requirement	Relationship	Explanation
Aesthetics	Material	Moderate	Better surface finish increases aesthetics
	Manufacturing cost	Strong	Aesthetics increases the manufacturing cost
Easy trash dumping	X-frame	Moderate	X-frame helps to dump trash easily
	Housing design	Moderate	Proper positioning of the lid in housing ease dumping
Repairable	Moving shaft	Moderate	Easily replaceable after break-down
	Spring	Weak	Easily replaceable after break-down
	Tension belt	Weak	A strained belt can be replaced
	Operational cost	Moderate	Service cost for repairing
Easy to clean	Housing design	Strong	The simple design helps to cleans easily
	Operational cost	Moderate	Less cost required for cleaning
High capacity	X-frame	Strong	Higher compressibility increases capacity
	Moving shaft	Weak	Smooth moving of shaft increases capacity
	Strength of the main body	Strong	High capacity requires higher strength of the main body
	Housing design	Weak	High trash dumping capability
	Manufacturing cost	Moderate	High capacity requires higher manufacturing cost

Customer Requirement	Engineering Requirement	Relationship	Explanation
Safety	Moving shaft	Weak	Break-down of the moving shaft can cause an accident
	Tension belt	Moderate	Strain can cause an accident as a projectile
Low cost	Strength of the main body	Weak	High strength material requires a higher cost
	Material	Strong	Higher quality material requires higher cost
	Housing design	Moderate	Simple design requires a lower cost
	Manufacturing cost	Strong	Selection of the proper manufacturing process can reduce cost
	Operational cost	Weak	Lower operational cost minimizes total cost
Low maintenance cost	X-frame	Moderate	X-frame joints require lubrication
	Housing design	Weak	Simple housing design requires a low maintenance cost
	Operational cost	Weak	Higher operational cost increases maintenance cost

3.3 Importance Rating Table:

From the house of quality, we arranged the technical requirements by their importance.

Table 3.2: Importance Rating

Observation Number	Engineering Requirements	Importance Rating
1	X frame	30
2	Moving shaft	19
3	Strength of the main body	23
4	Spring	5
5	Tension belt	23
6	Material	26
7	Housing design	32
8	Manufacturing cost	31
9	Operational cost	14

QFD reduces the likelihood of late design changes by focusing on product features and improvements based on customer requirements. Effective QFD methodology prevents valuable project time and resources from being wasted on the development of non-value-added features or functions.

Chapter- 04

Functional Decomposition

4.1 Introduction:

Functional decomposition is a method that decomposes a system into smaller subsystems and removes the complexity of the system. By decomposing, it fosters a better understanding of the overall system. Functional decomposition takes something complicated and simplifies it. A good functional decomposition is very useful for complex systems. A functional decomposition diagram contains the overall function or task as well as the necessary sub-functions or tasks needed to achieve the overall object.

There are four basic steps in applying the techniques and several guidelines for a good functional decomposition. These are given below:

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

All design problems have one or two major functions. These are reduced to a simple clause and put in a black box. The inputs to this box are all 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 that will be needed.

Step 3: Order the Sub-functions

The goal is to add order to the function generated in the previous 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. Here we examine each sub-function if it can be further divided into more sub-functions.

4.2 Black Box Model of Functional Decomposition:

The black box model is an abstraction representing a class of concrete open system which can be viewed solely in terms of its stimuli inputs and output reactions without any knowledge of its internal working. Its implementation is “opaque”. The flow of inputs (material, energy, and information) to outputs is sufficient to describe a technical system or product.

The Black Box Model for Mechanical Trash Compactor is given below:

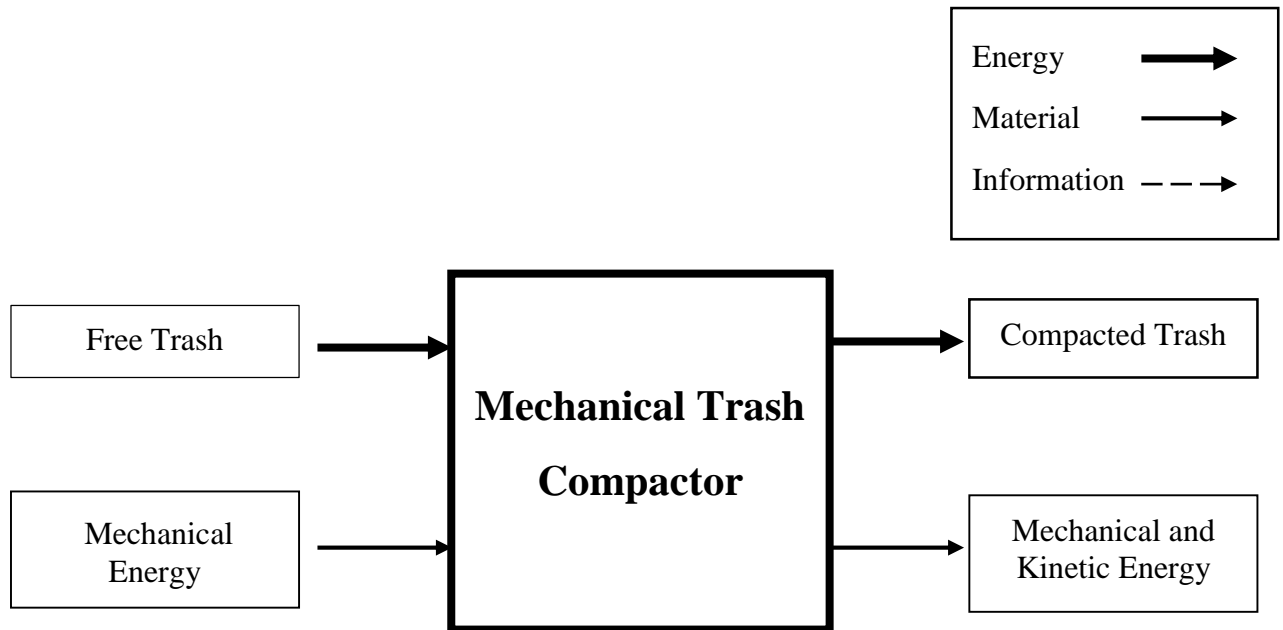


Figure 4.1: Black Box Model of the Mechanical Trash Compactor

There are generally three types of flows that are shown in the black-box model. These are:

1. Energy flow
2. Material flow
3. Information flow

Our product has no Information flow. The other two types of flow are discussed below:

1. Energy flow: Our product will receive maneuvering from the operator and the received mechanical energy will be used to compact the trash.

2. Material flow: There will be a trash throwing slot in the bucket through which trash will enter the compactor and then be compressed by the thruster with the help of mechanical energy.

Our product will take free trash as input and give compacted trash as output.

4.3 Component Hierarchy:

Component hierarchy is a very effective method of listing the components required to design a product. The component hierarchy methodology simply distinguishes between the core portions of the product and then lists the components for those portions. The portions are simply termed as sub-assembly. When the function of all sub-assemblies are satisfied, the prime function (compacting the trash in our case) 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-assemblies.

The component hierarchy of our trash compactor is shown on the following page:

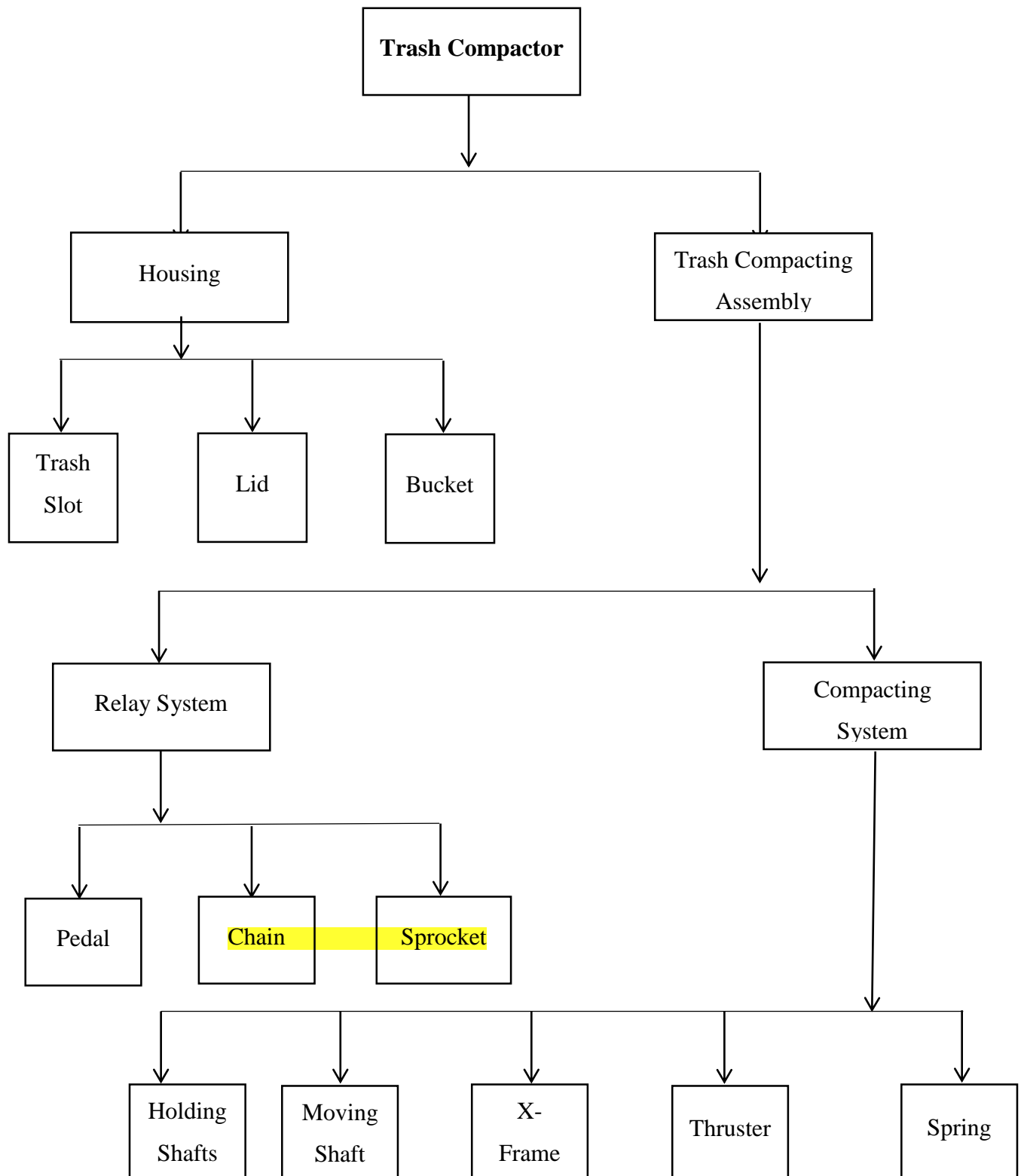


Figure 4.2: Component Hierarchy of trash compactor

4.4 Cluster Function Structure of Trash Compactor:

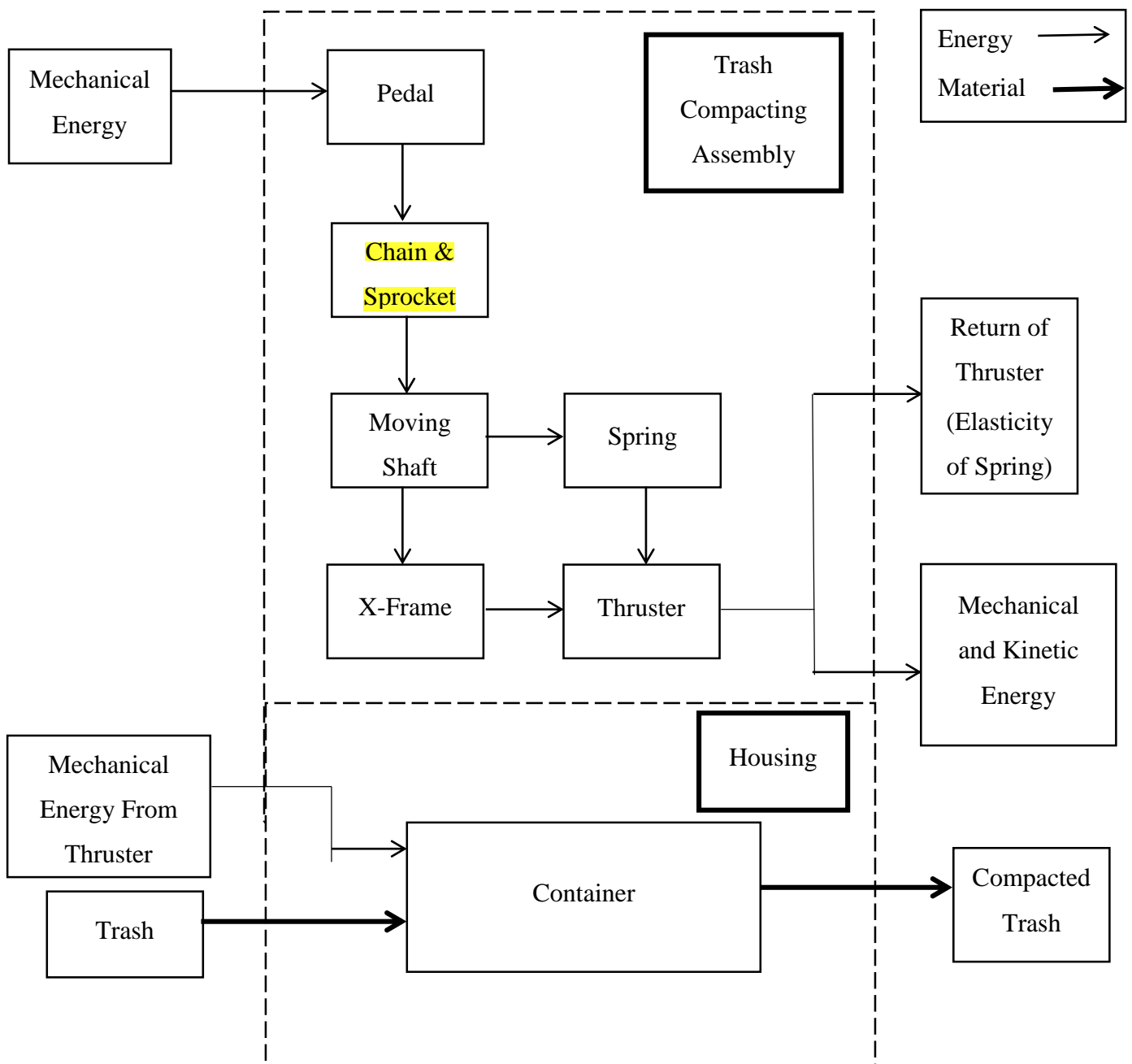


Figure 4.3: Cluster Function of Trash Compactor

These three methods are very useful for the functional decomposition of a product. The Black Box model gives an idea about three types of inputs and outputs but without the knowledge of internal workings. The component hierarchy and cluster function show detailed processes within the system with the material, energy, and information flow.

Chapter 05

Design Analysis

5.1 Introduction:

The goal of this chapter is to establish an intelligent support system to design a product through managing variety. The Interpretive Structural Model (ISM) technique is applied to visualize the hierarchy of component interactions within a product. To fulfill different market requests this approach renders the design priority and related design dimensions for helping designers to create variant design solutions in a product.

The designer must define the specific motion of each part and the sequence in which components are added to the base, they are more likely to understand how parts fit together as well as realize the purpose of the assembly.

5.2 Parts of Mechanical Trash Compactor:

1. Bin



Figure 5.1: Bin

2. Pedal

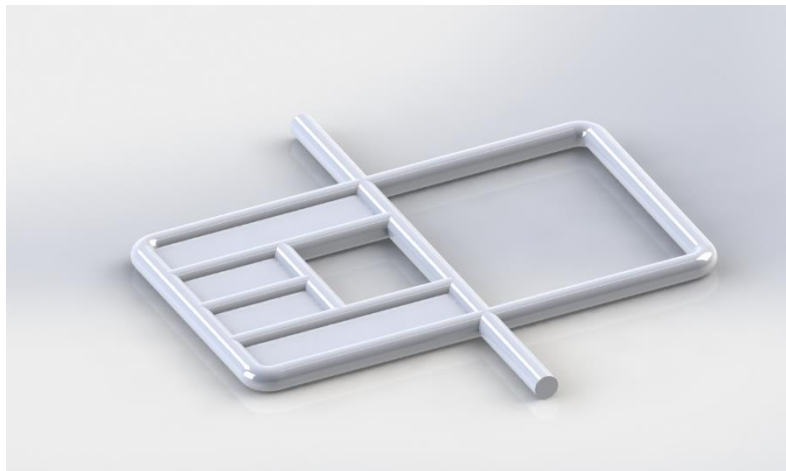


Figure 5.2: Pedal

3. Housing



Figure 5.3: Housing

4. Press Plate



Figure 5.4: Press Plate

5. X-frame and Pulley System

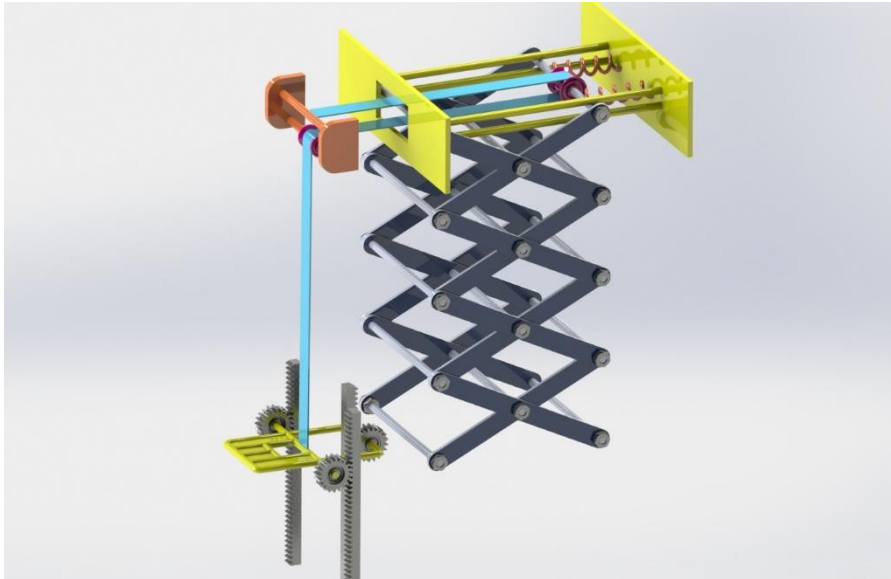


Figure 5.5: X-frame and Pulley System

6. Top X-frame Holder

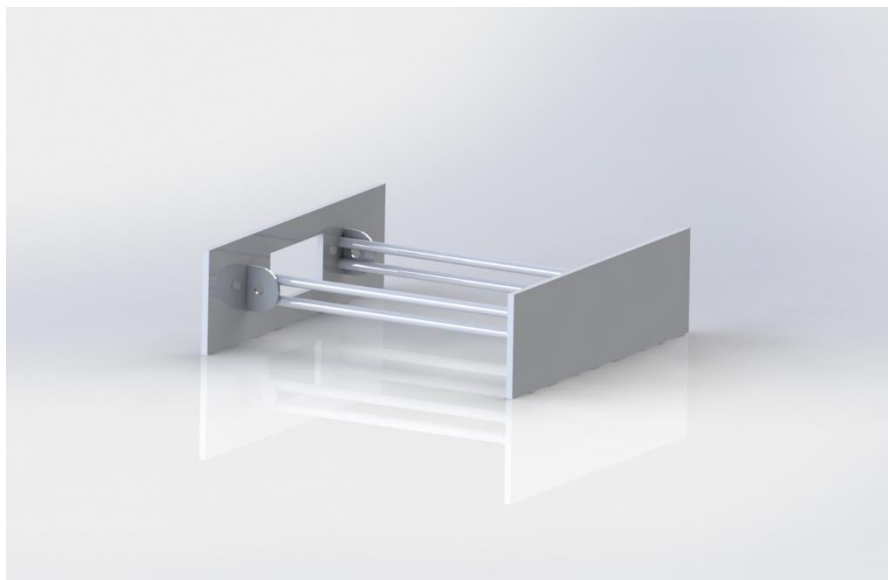


Figure 5.6: Top X-frame Holder

5.3 Static Structural Analysis (ANSYS):

5.3.1 Static Structural Analysis of Holder:

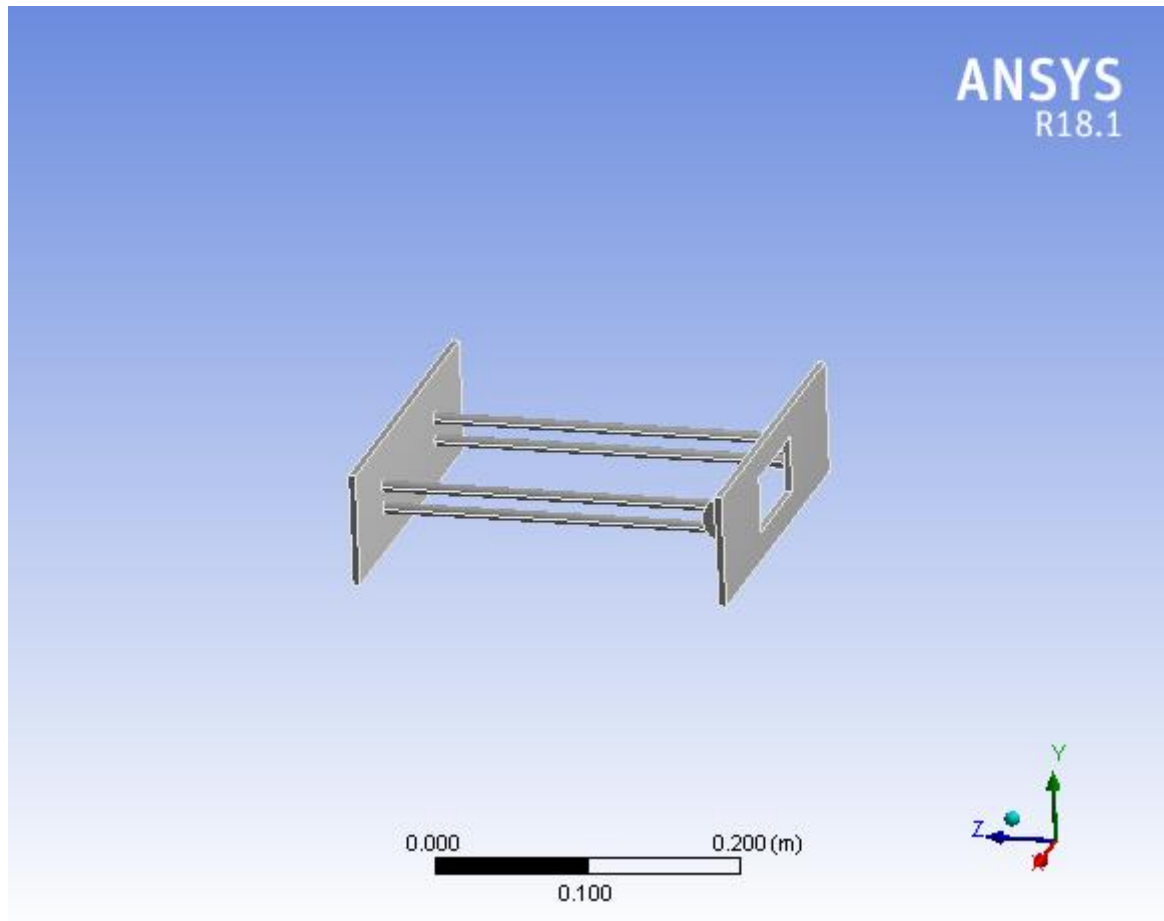


Figure 5.3.1: Holder

Load:

Types	Force
X-Component	0 N (ramped)
Y-Component	0 N (ramped)
Z-Component	-10000 N(ramped)

I. Total deformation

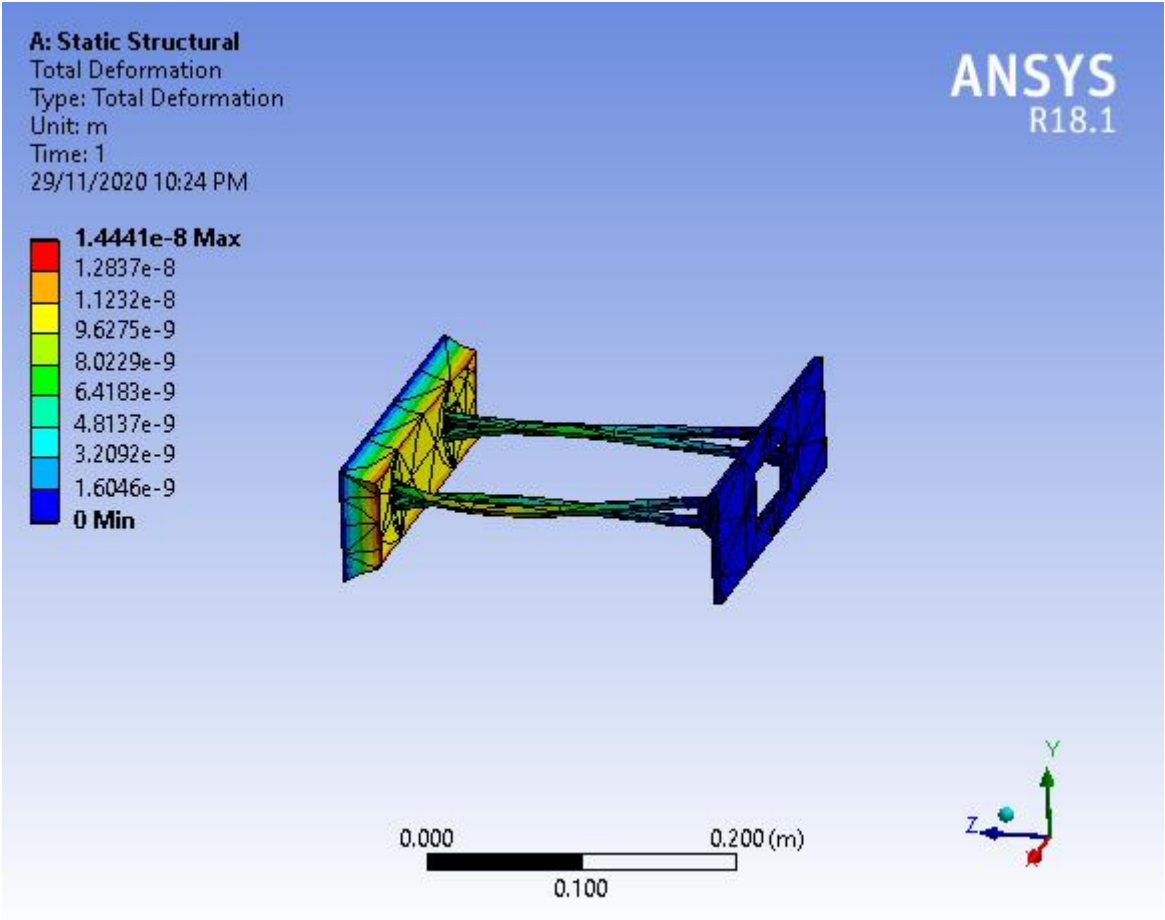


Figure 5.3.2: Total Deformation

Result:

	Total Deformation
Minimum	0 m
Maximum	1.4441e-8 m

II. Equivalent Stress

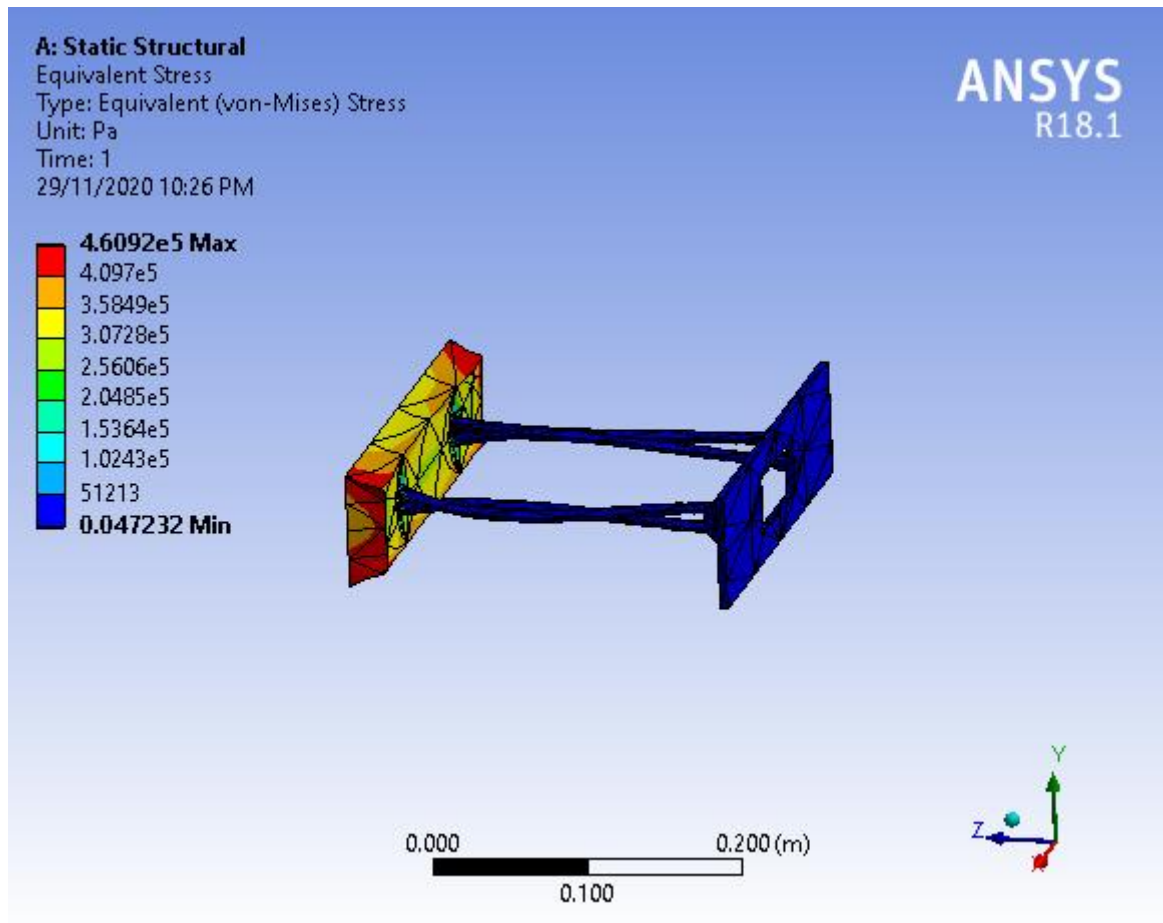


Figure 5.3.3: Equivalent Stress

Result:

	Equivalent (von-Mises) Stress
Minimum	0.047232 Pa
Maximum	4.6092e5 Pa

III. Safety Factor

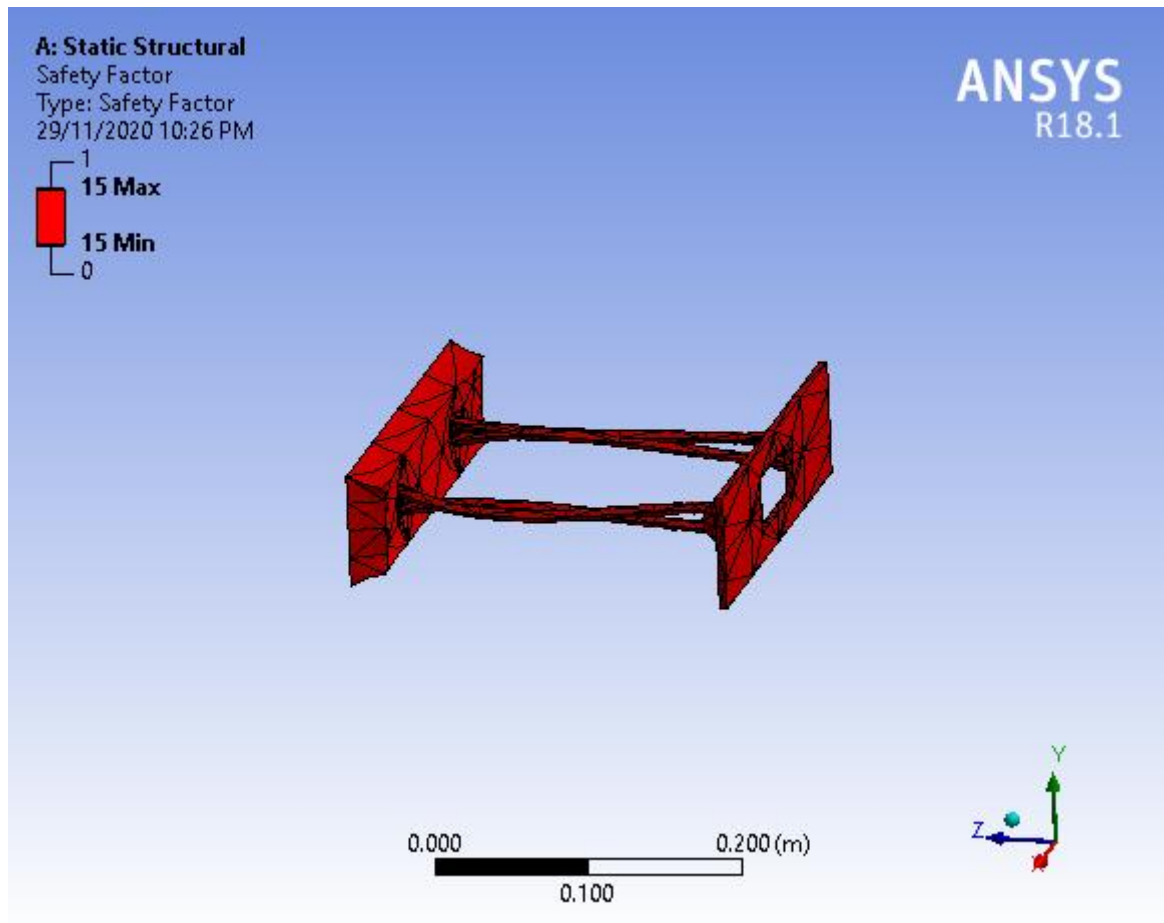


Figure 5.3.4: Safety factor

Result:

	Safety Factor
Minimum	15
Maximum	15

IV. Fatigue Life

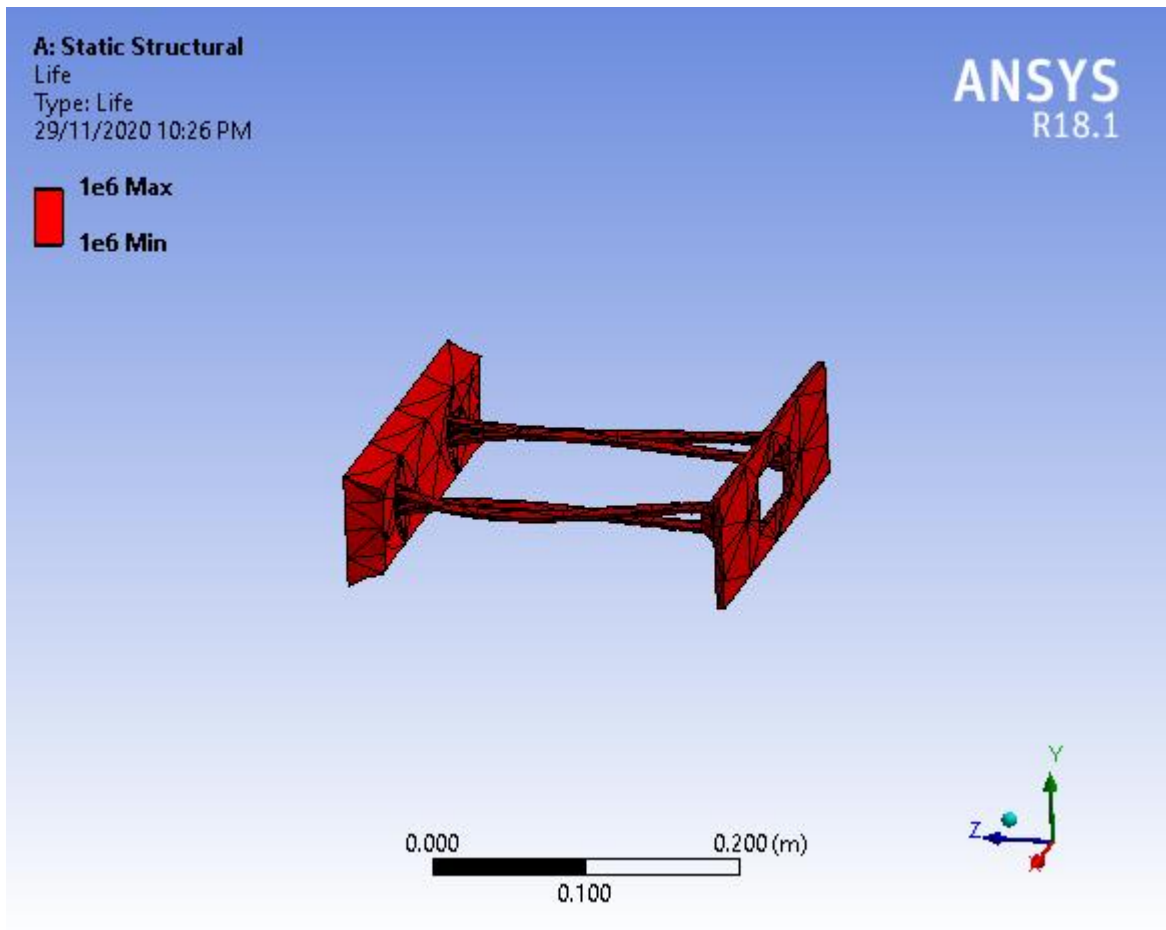


Figure 5.3.5: Fatigue Life

Result:

	Life
Minimum	1e6 cycles
Maximum	1e6 cycles

Discussion:

The part will sustain that force successfully.

5.3.2 Static Structural Analysis of Housing:

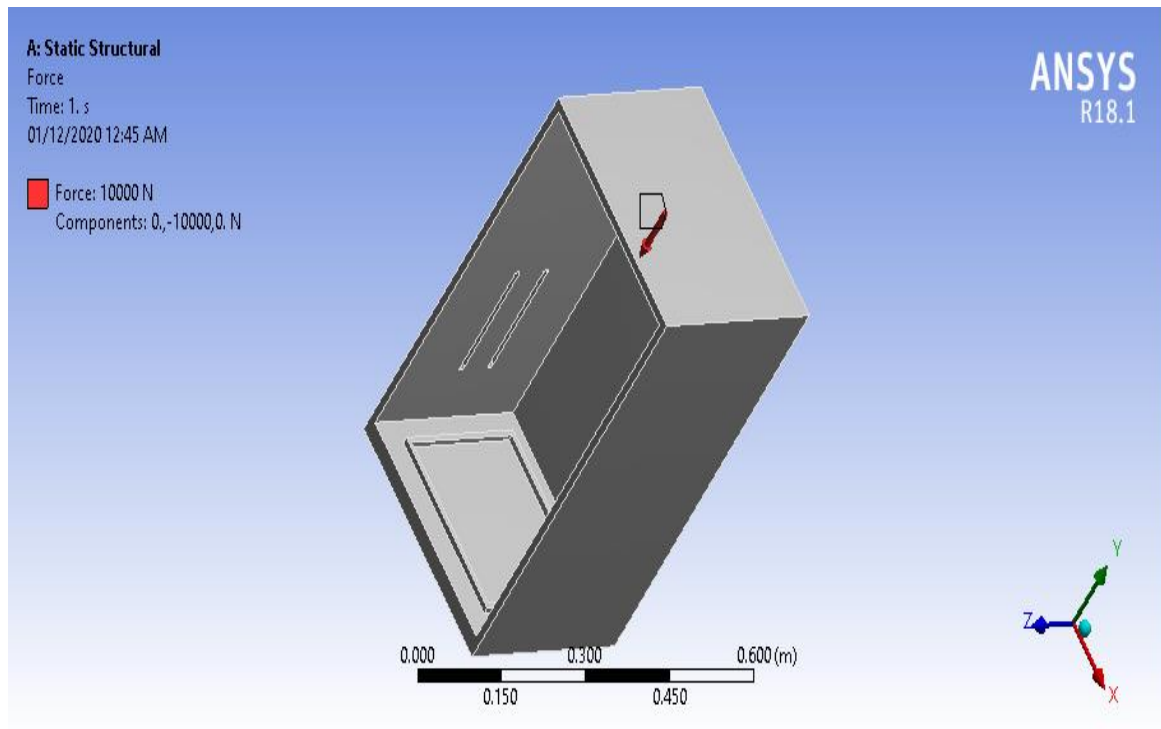


Figure 5.3.6: Housing

Load:

Types	Force
X-Component	0 N (ramped)
Y-Component	-10000 N(ramped)
Z-Component	0 N (ramped)

I. Total Deformation

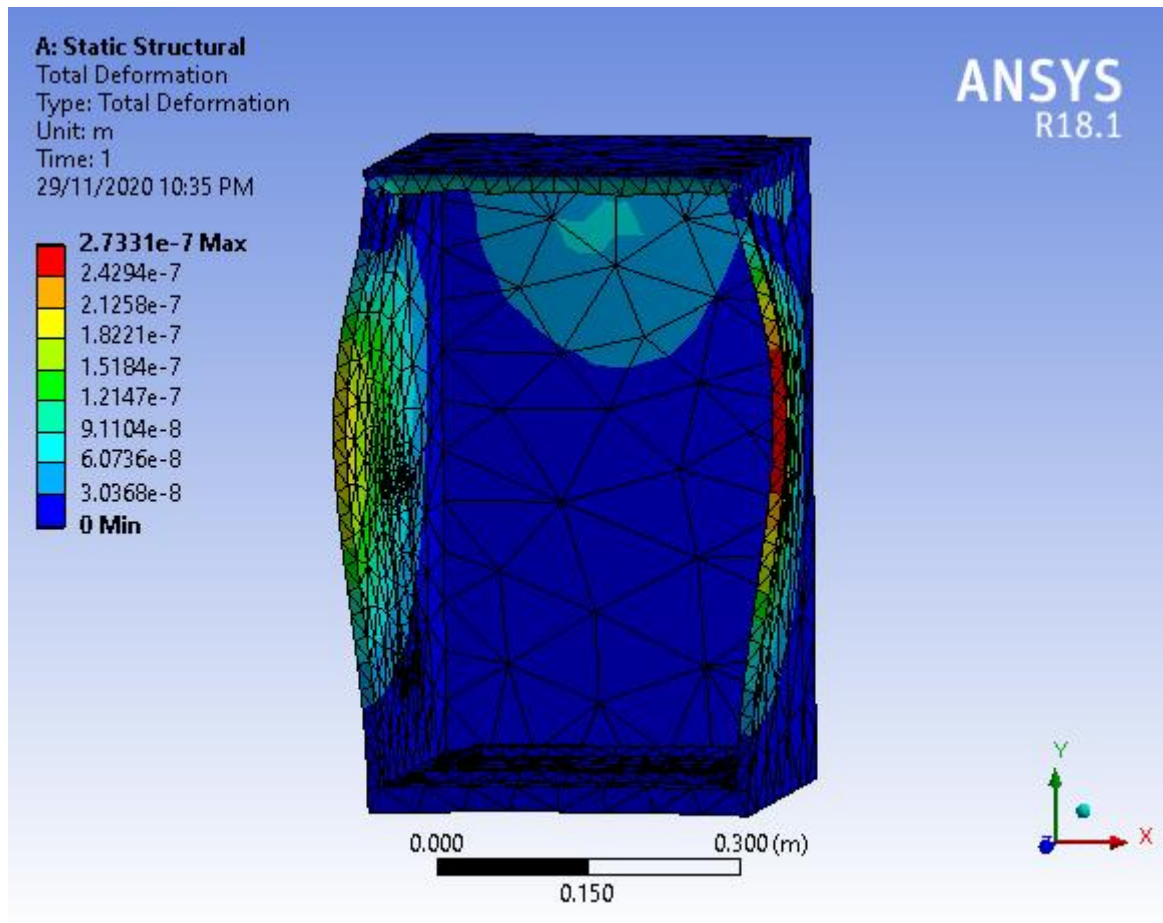


Figure 5.3.7: Total deformation

Result:

	Total Deformation
Minimum	0 m
Maximum	2.7331e-7 m

II. Equivalent Stress

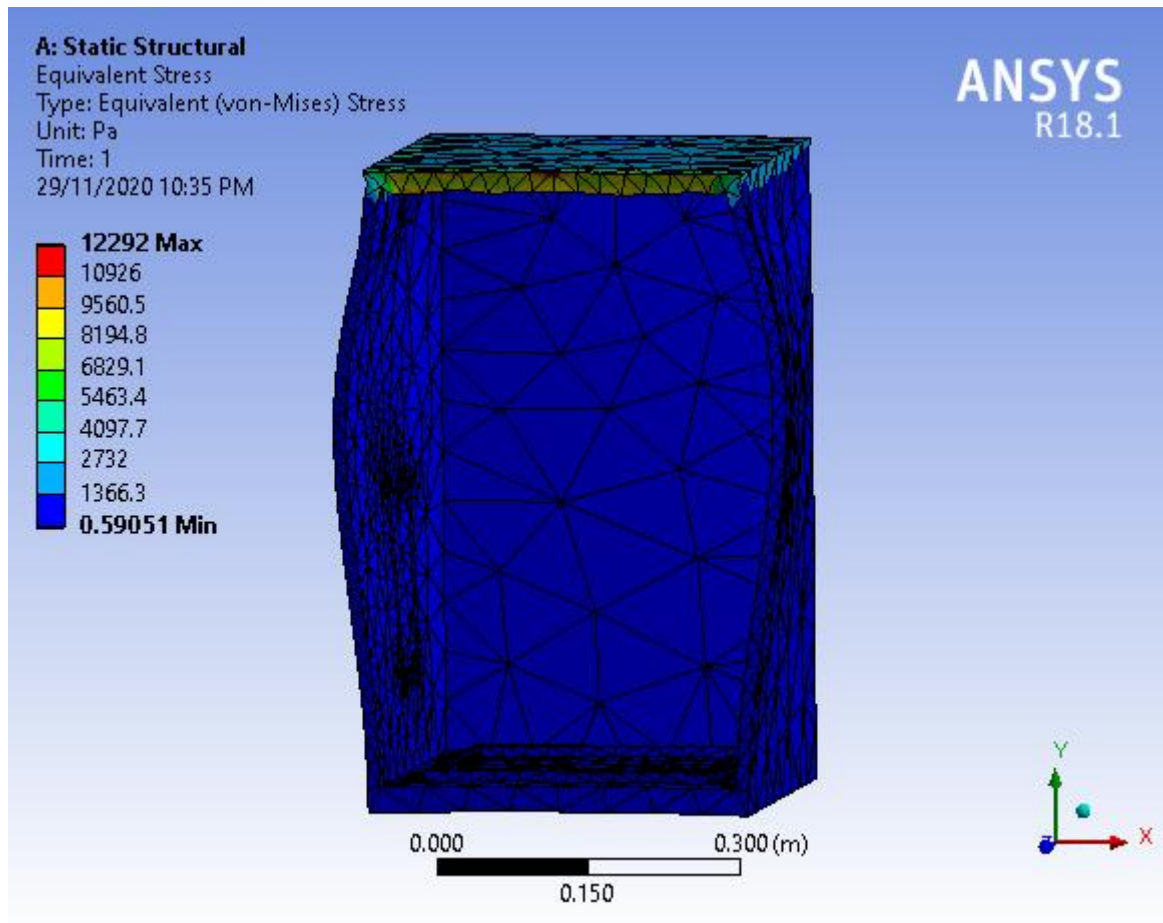


Figure 5.3.8: Equivalent Stress

Result:

	Equivalent (von-Mises) Stress
Minimum	0.59051 Pa
Maximum	12292 Pa

III. Safety Factor

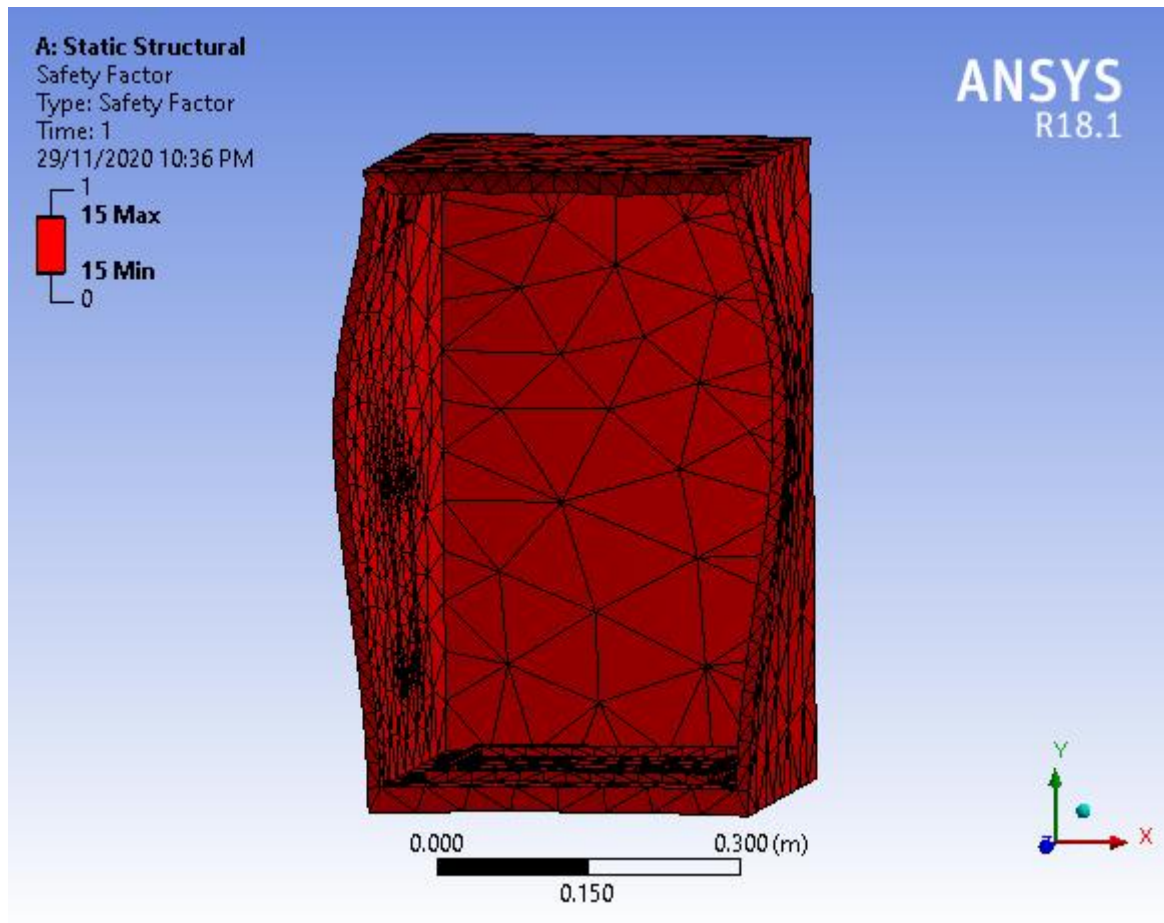


Figure 5.3.9: Safety Factor

Result:

	Safety Factor
Minimum	15
Maximum	15

Discussion:

The part will sustain that pressure successfully.

5.3.3 Static Structural analysis for Press Plate

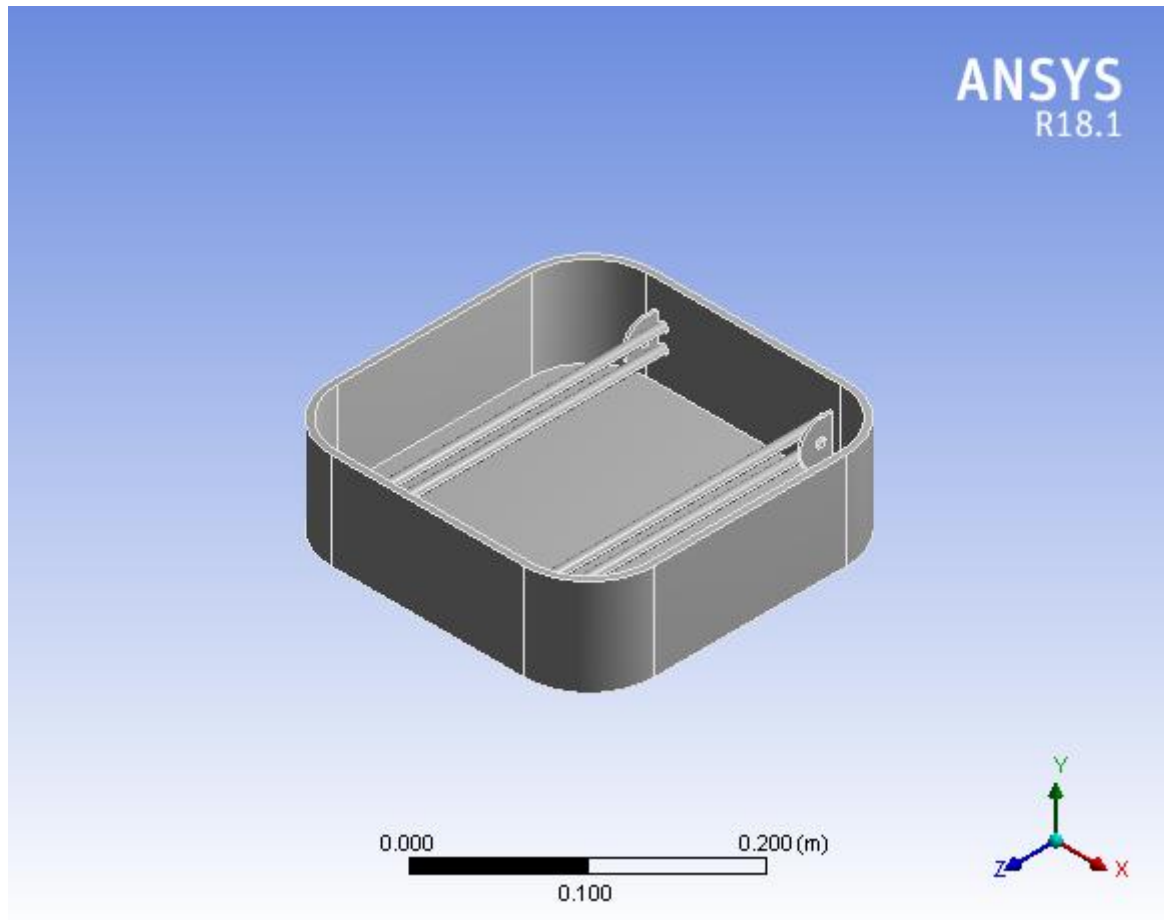


Figure 5.3.10: Press Plate

Load:

Types	Force
X-Component	0 N (ramped)
Y-Component	10000 N(ramped)
Z-Component	0 N (ramped)

I. Total Deformation

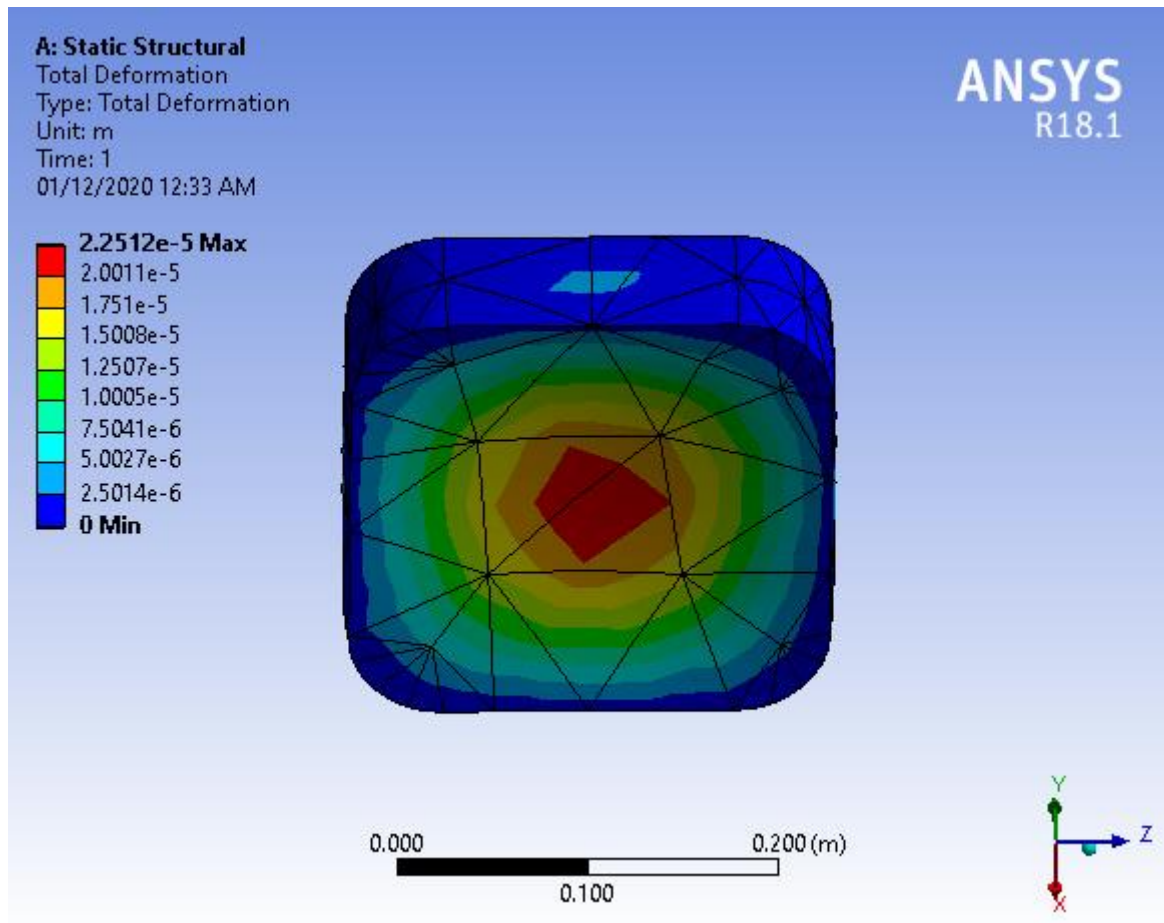


Figure 5.3.11: Total Deformation

Result:

	Total Deformation
Minimum	0 m
Maximum	2.2512e-5 m

II. Equivalent Stress

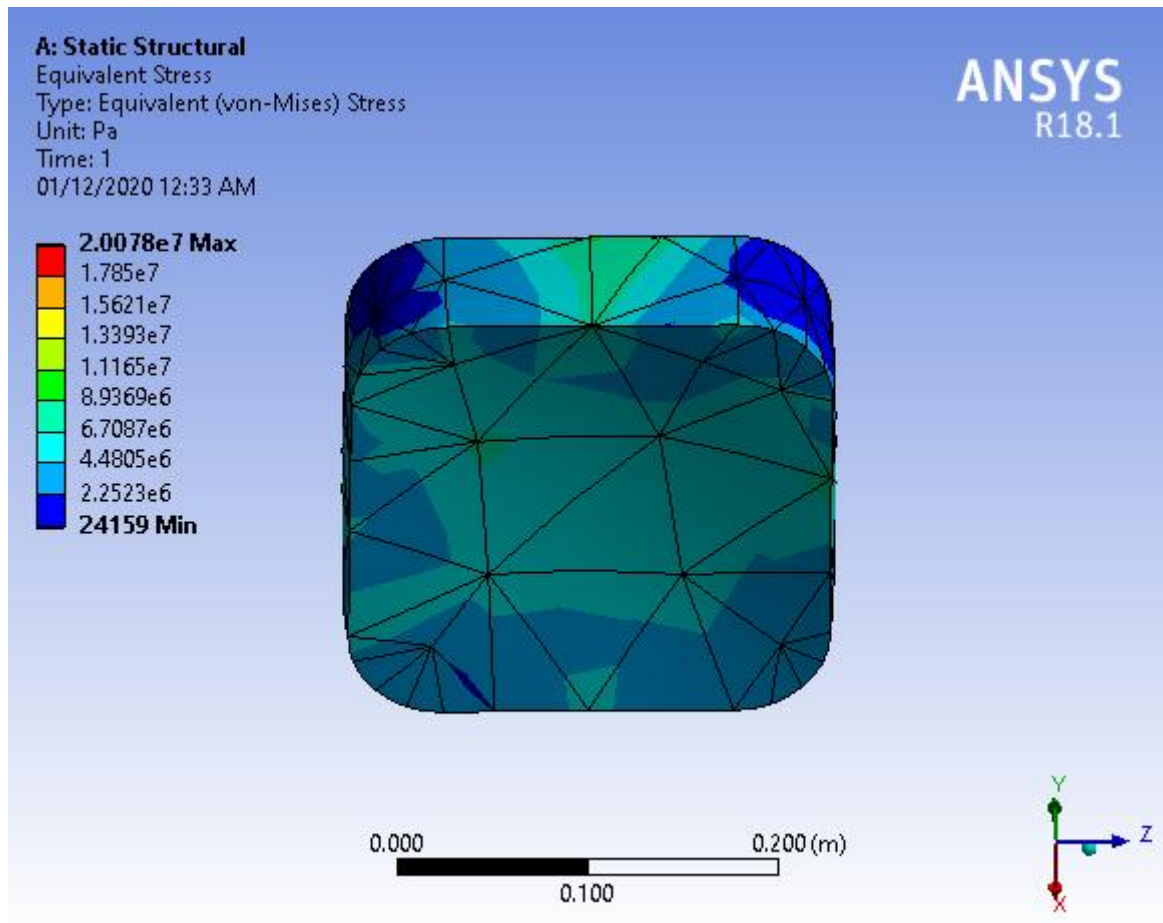


Figure 5.3.12: Equivalent Stress

Result:

	Equivalent (von-Mises) Stress
Minimum	24159 Pa
Maximum	2.0078e7 Pa

III. Safety Factor

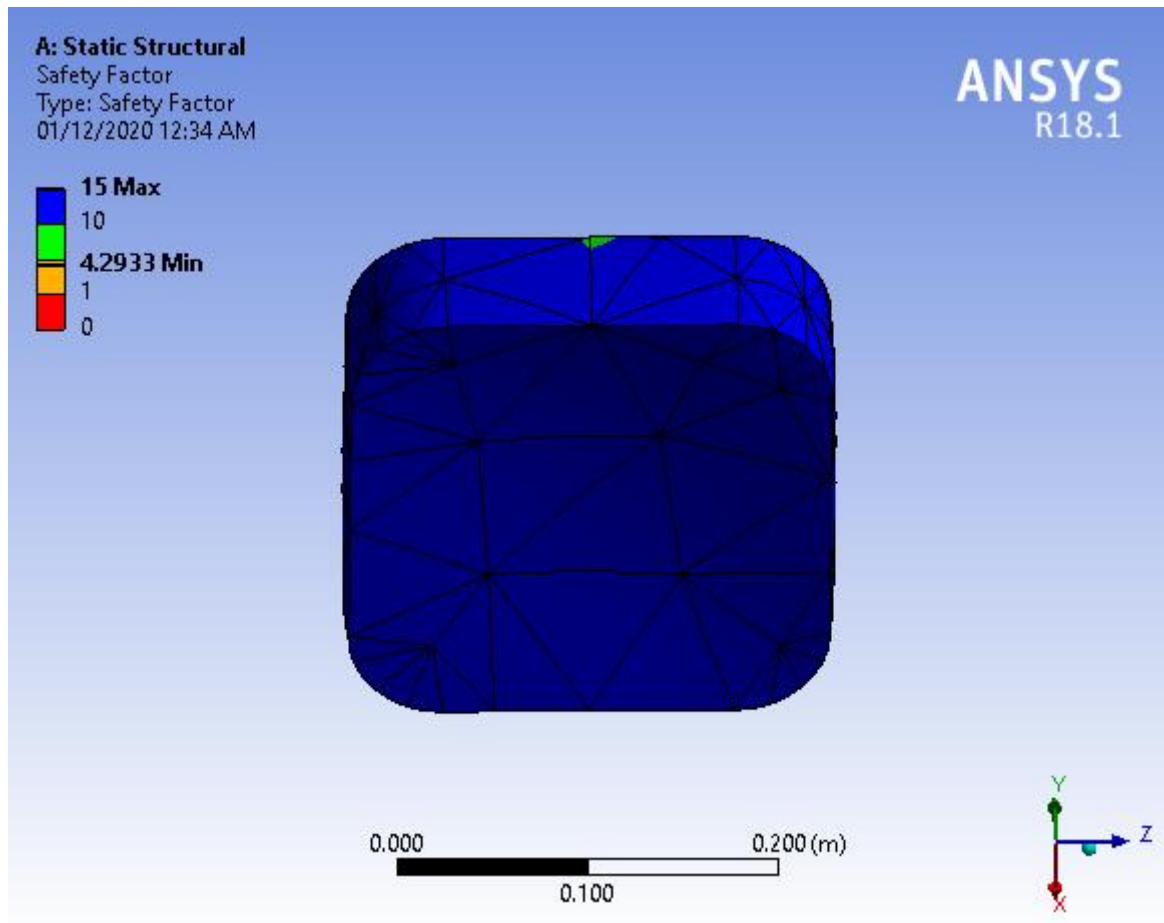


Figure 5.3.13: Safety Factor

Result:

	Safety Factor
Minimum	4.2933
Maximum	15

IV. Fatigue Life

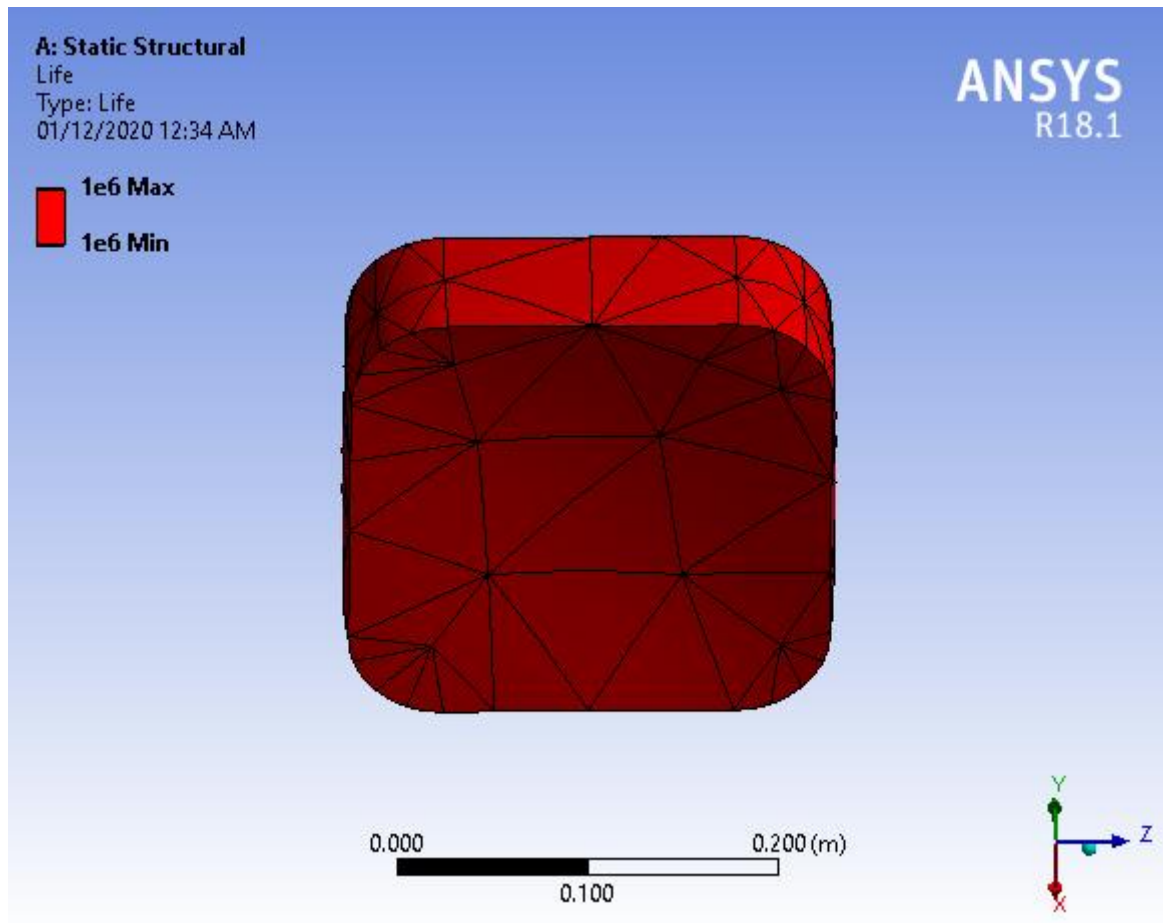


Figure 5.3.14: Fatigue Life

Result:

	Fatigue Life
Minimum	1e6 Cycles
Maximum	1e6 cycles

Discussion:

The part will sustain that force successfully.

5.3.4 Static Structural analysis for X-frame

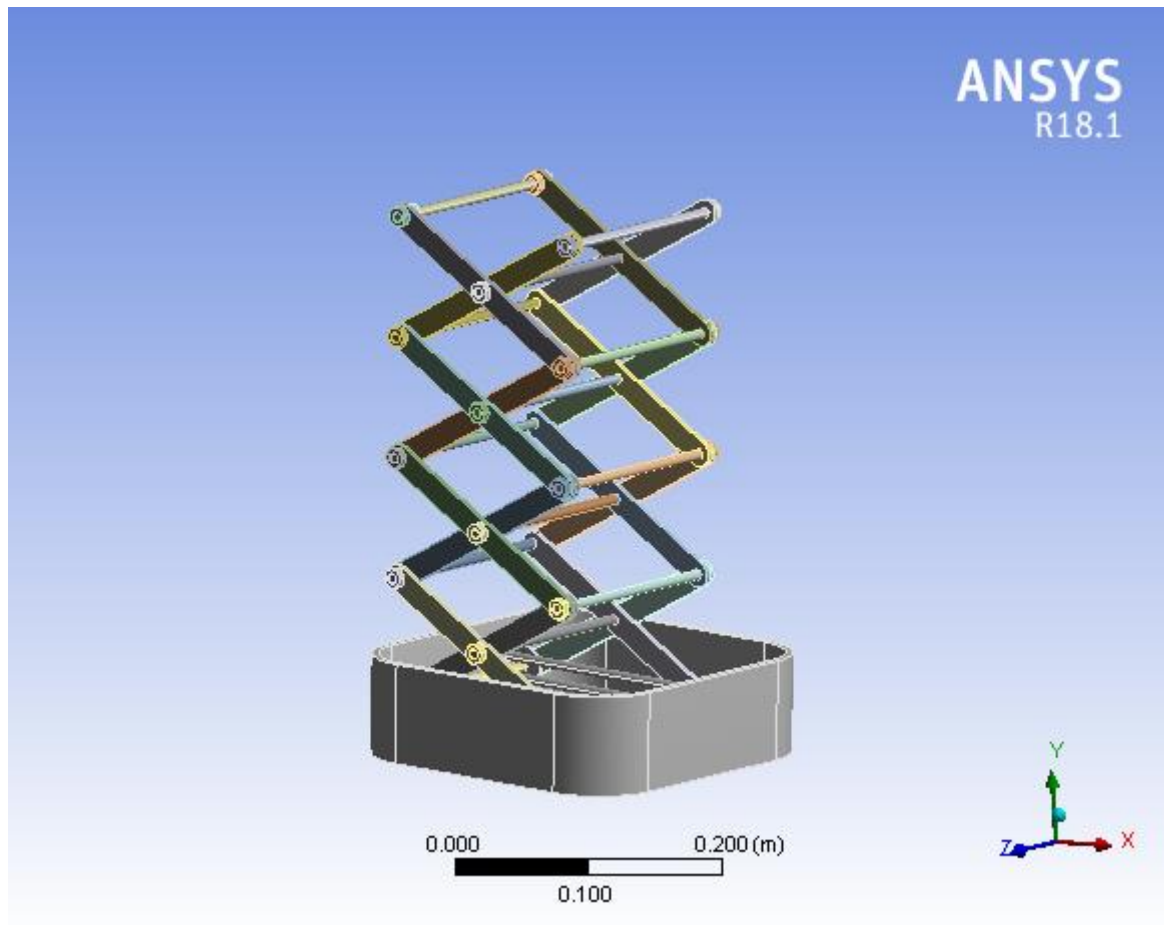


Figure 5.3.15: X-frame

Load:

Types	Force
X-Component	0 N (ramped)
Y-Component	10000 N(ramped)
Z-Component	0 N (ramped)

I. Total Deformation

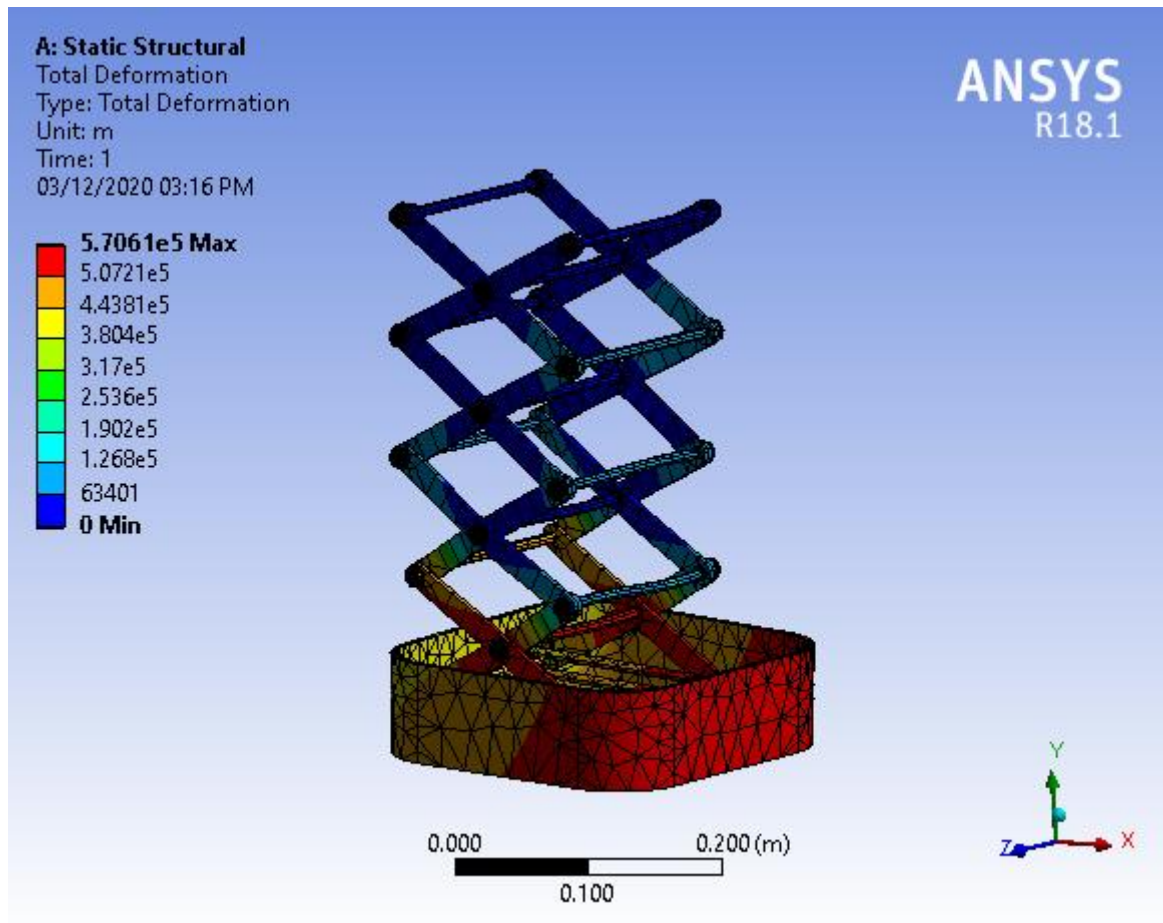


Fig 5.3.16: Total Deformation

Result:

	Total Deformation
Minimum	0 m
Maximum	5.7061e5 m

II. Equivalent Stress

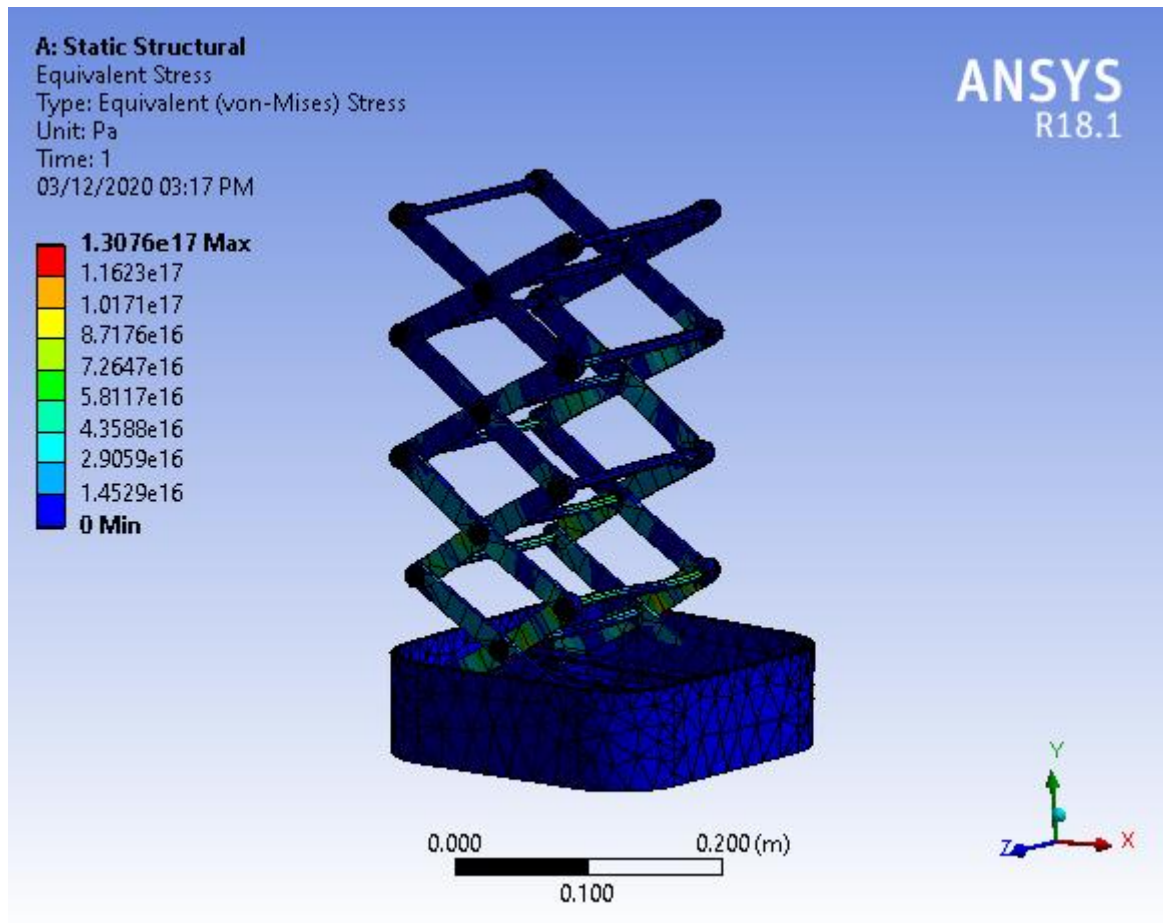


Fig 5.3.17: Equivalent Stress

Result:

	Equivalent (von-Mises) Stress
Minimum	0 Pa
Maximum	1.3076e17 Pa

Discussion:

The part will sustain that force successfully.

5.3.5: Static Structural analysis for X-frame Bar

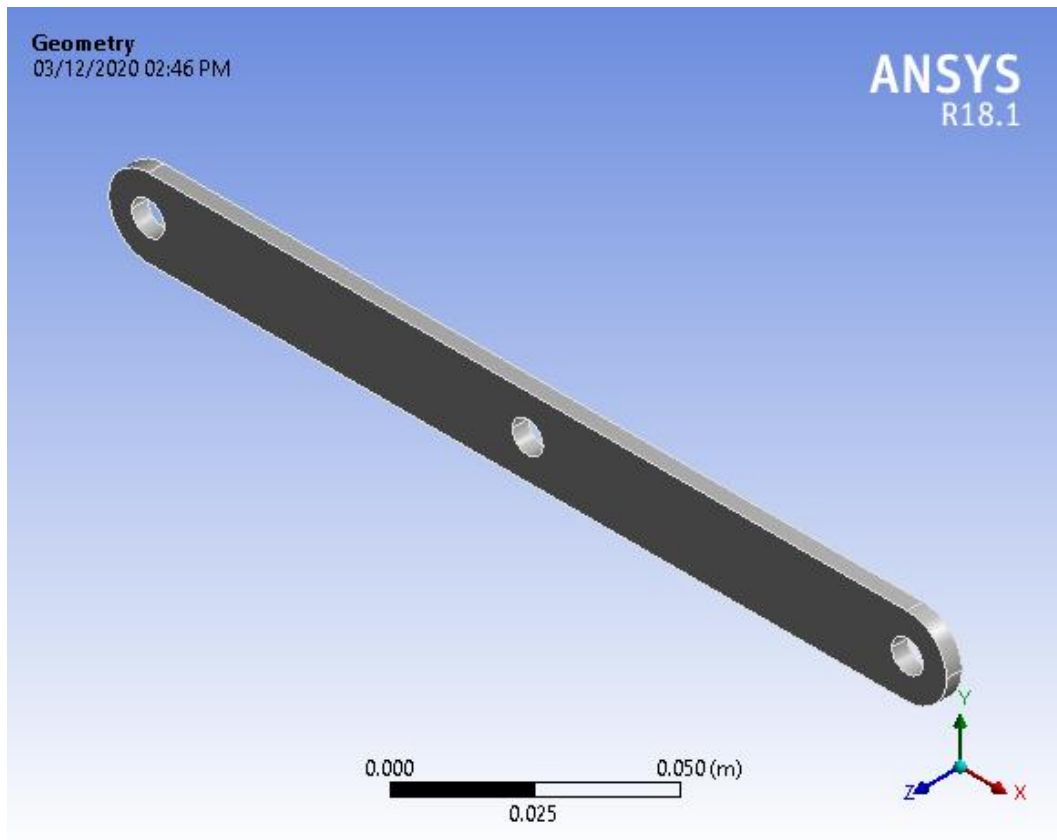


Figure 5.3.18: X-frame Bar

Load:

Types	Force
X-Component	-10000 N (ramped)
Y-Component	0 N(ramped)
Z-Component	0 N (ramped)

I. Total Deformation

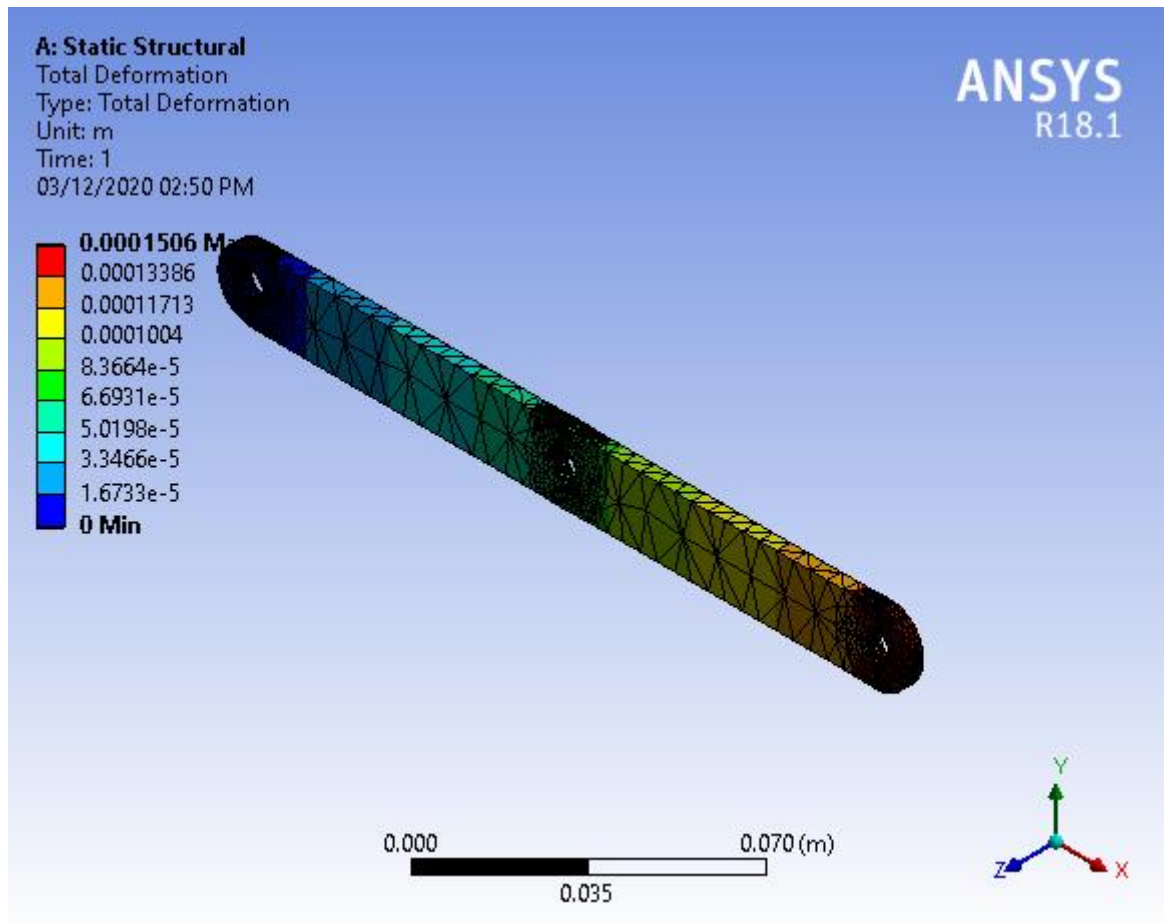


Figure 5.3.19: Total Deformation

Result:

	Total Deformation
Minimum	0 m
Maximum	0.0001506 m

II. Equivalent Stress

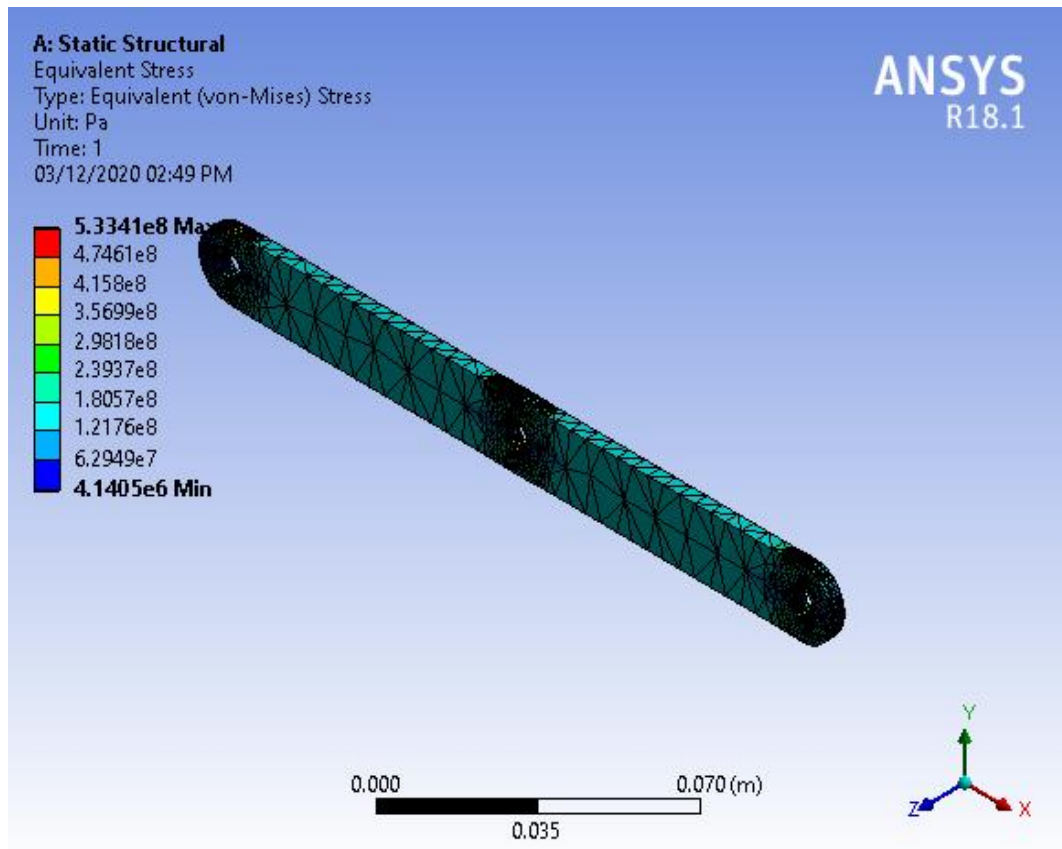


Figure 5.3.20: Equivalent Stress

Result:

	Equivalent (von-Mises) Stress
Minimum	4.1405e6 Pa
Maximum	5.3341e8 Pa

Discussion:

The part will sustain that force successfully.

Chapter- 06

Qualitative Analysis of Material, Manufacturing Process & Joining Process Selection

As the conceptual development and design are finalized for the Mechanical Trash Compactor, now it is important to assign specific materials and their manufacturing process for every part of the product. A qualitative analysis of the material, manufacturing process, and joining method selection is performed with the basic knowledge of material properties, manufacturing process, and their availability among the possible alternatives.

6.1 Selection of Materials for Different Sections:

6.1.1 Housing

The qualitative analysis of material selection for the parts of housing is given below:

Table 6.1: Qualitative analysis of material selection for the parts of housing:

Section	Parts	Material Selected	Options for Other Material	Reasons Behind Selection
Housing	Frame	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	Body	High-Density Polyethylene (HDPE) Grade-500	Grade 304 Stainless Steel Sheet metal, 1100-H14 Aluminum Sheet Metal	Cost-effective, lightweight, no corrosion, better strength
	Lid	High-Density Polyethylene (HDPE) Grade-500	Grade 304 Stainless Steel Sheet metal, 1100-H14 Aluminum Sheet Metal	Cost-effective, lightweight, no corrosion, better strength
	Bin	Outsourced		Cost-effective

6.1.2 Relay System

The qualitative analysis of material selection for the parts of the relay system is given below:

Table 6.2: Qualitative analysis of material selection for parts of the relay system

Section	Parts	Material Selected	Options for Other Material	Reasons Behind Selection
Relay system	Pedal	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	Pulley	Outsourced		Cost-effective
	Rack and Pinion	Outsourced		Cost-effective
	Belt	Outsourced		Cost-effective
	Connecting rod	AISI-1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability

6.1.3 Compacting System

The qualitative analysis of material selection for the compacting system are given below:

Table 6.3: Qualitative analysis of material selection for the parts of the compacting system

Section	Parts	Material Selected	Options for Other Material	Reasons Behind Selection
Compacting System	Holding Shaft	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	Moving Shaft	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	X-Frame	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	Thruster	AISI 1020 Mild Steel	A48 class 30 Cast Iron, 5052 Aluminum	Cost-effective, available, flexible, high tensile strength, machinability
	Spring	Outsourced		Cost-effective

6.2 Selection of Manufacturing Processes for Different Sections

6.2.1 Housing

The qualitative analysis of the manufacturing process selected for the parts of housing is given below:

Table 6.4: Qualitative analysis of the manufacturing process selected for the parts of the housing

Process	Manufacturing Process selected	Options for Other Processes	Reasons Behind Selection
Cutting of Mild Steel Blanks	Gas Cutting	Laser Cutting	Cost-effective, availability, power requirement
Cutting HDPE Sheets	Sawing with Circular Saw	Scribing and Breaking	Dimensional Accuracy, Ease of operation
Creating Hole for Rivets	Drilling, Boring, Reaming	Broaching	Dimensional accuracy, availability
Deforming the Head of Rivet Shank	Heading	Upsetting	Cost-Effective, Availability
Cutting Trash Slot	End Milling	Electrical Discharge Machining (EDM)	Cost-effectiveness, availability
Cutting Slot for Relay System Parts	End Milling	Electrical Discharge Machining (EDM)	Cost-effectiveness, availability
Coloring	Color Spraying	Brush Painting	Smoothness, ease of operation, durability

6.2.2 Relay System

The qualitative analysis of the manufacturing process selected for the parts of relay system is given below:

Table 6.5: Qualitative analysis of the manufacturing process selected for the parts of the relay System

Process	Manufacturing Process selected	Options for Other Processes	Reasons Behind Selection
Cutting of Mild Steel Blanks	Gas Cutting	Laser Cutting	Cost-effective, availability, power requirement
Shaft forming	Turning	Extrusion, Casting	Cost-effective, easy to perform, dimensional accuracy
Finishing process	Non-precision finishing (Grinding)	Precision finishing	Cost-effective, easy to perform, availability
Coloring	Color Spraying	Brush Painting	Smoothness, ease of operation, durability

6.2.3 Compacting System

The Qualitative analysis of the manufacturing process selected for the parts of the compacting system is given below:

Table 6.6: Qualitative analysis of manufacturing process selection for parts of the compacting system

Process	Manufacturing Process selected	Options for Other Processes	Reasons Behind Selection
Forming of shafts	Turning	Extrusion	Cost-effective, low power requirement, low defect rate, availability
Process	Manufacturing Process selected	Options for Other Processes	Reasons Behind Selection
Forming of X-frame	Casting	Powder Metallurgy	Cost-effective, availability
Forming of Thruster	Casting	Powder Metallurgy	Cost-effective, availability
Finishing process	Non-precision finishing (Grinding)	Precision finishing	Cost-effective, easy to perform, availability

6.3 Selection of Joining Process

6.3.1 Housing

The qualitative analysis of joining process selection for the parts of housing is given below:

Table 6.7: Qualitative analysis of joining process selection for the parts of the housing

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Frame	Permanent	Arc Welding	TIG Welding	Cost-effective
HDPE Sheets	Permanent	Mechanical Fasteners (Self-tapping Metal Screws)	Abrasive Welding	Cost-effective, better surface finish
Frame and HDPE Sheets	Temporary	Riveting	Nut-bolt	Aesthetics
Lid and Frame	Semi-Permanent	Hinge	Sliding Lid, Magnetic Joints	Cost-Effective

6.3.2 Relay System

The qualitative analysis of joining process selection for the parts of relay system is given below:

Table 6.8: Qualitative analysis of joining process selection for the parts of the relay system

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Pedal and connecting rod	Permanent	Arc Welding	TIG Welding	Cost-effective
Gear rack and housing	Temporary	Nut-bolt	Arc Welding	Cost-effective, strength, reliability, flexibility

6.3.3 Compacting System

The qualitative analysis of joining process selection for the parts of the compacting system is given below:

Table 6. 9: Qualitative analysis of joining process selection for parts of the compacting system

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Shafts	Permanent	Arc Welding	TIG Welding	Cost-effective
X-frame	Temporary	Nut-bolt		Cost-effective, strength, reliability, flexibility
Thruster	Permanent	Arc Welding	TIG Welding	Cost-effective
Spring	Permanent	Arc Welding	TIG Welding	Cost-Effective

The qualitative analysis of material, manufacturing process, and joining process selection will help us in taking initial decisions among the alternatives and provide us an insight into the overall production process of the Mechanical Trash Compactor. Before moving to quantitative analysis, a qualitative discussion helps to reduce computational effort in the further stages by eliminating erroneous choices for materials, manufacturing process, and joining method.

Chapter- 07

Material Selection Using Weighted Average method

7.1 Introduction:

Material selection is an important part of the product design process. The design of engineering components is limited by the available materials and selection of the wrong material can lead to catastrophic failures. In the previous chapter, a qualitative analysis of material, manufacturing process, and joining method selection has been carried out. But qualitative analysis is nothing but applying intuitive knowledge. Therefore, quantitative analysis for selection criteria is imperative to manufacture a good product.

There are several methods for quantifying the properties of a material or manufacturing process. Here, in this chapter, we are using the “Digital Logic Method” for selecting material based on their performance indices.

7.2 List of Parts for Each Sub-assembly:

7.2.1 Housing:

- Frame
- Body
- Lid
- Bin

7.2.2 Relay System:

- Pedal
- Pulley
- Rack and Pinion
- Belt
- Connecting Rod

7.2.3 Compacting System:

- Holding Shaft
- Moving Shaft
- X-frame
- Thruster
- Spring

7.3 Equations:

- Relative Emphasis Coefficient, $\alpha = \frac{\text{No. of positive decisions acquired by a criteria}}{\text{Total no. of positive decisions}}$
- For properties to be maximized,
Scaled Property, $\beta = \frac{\text{Numerical Value of the property}}{\text{Maximum value in the list}} \times 100$
- For properties to be minimized,
Scaled property, $\beta = \frac{\text{Minimum value in the list}}{\text{Numerical Value of the property}} \times 100$
- Weighted Score = Relative Emphasis Coefficient (α) \times Scaled Property (β)
- Performance Index, $\gamma = \sum \text{Weighted Score } (\alpha\beta)$

7.4 Likert Scale:

Likert scale is a psychometric scale commonly involved in research that employs questionnaires. This scale is used for rating different categories according to their significance or intensity. When responding to a Likert item, respondents specify their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements. Thus the range captures the intensity of their feelings for the given item.

In this chapter, we are going to use the Likert scale for those criteria that can't be assigned with numerical values. The scale is given below:

Table 7.1: Likert Scale

Very Good	5
Good	4
Moderate	3
Poor	2
Very poor	1

7.5 Quantitative Analysis of Material Selection for Mechanical Trash

Compactor Parts:

7.5.1 Material Selection for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster:

Table 7.2: List of selection criteria with numerical values or values from Likert Scale for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster:

Selection Criteria	Mild Steel	Cast Iron	Aluminum
Tensile Strength (MPa)	420	207	240
Compressive Strength	250	650	400
Corrosive Resistance	4	2	4
Surface Finish	5	2	5
Density (Kg/m ³)	7870	7150	2680
Cost (BDT/Kg)	65	60	180
Elastic Modulus (GPa)	205	90	69.3
Weldability	5	2	4

From these selection criteria, we want to maximize Tensile Strength, Compressive Strength, Corrosive Resistance, Surface Finish, Elastic Modulus, and Weldability; and to minimize Density (for lightweight) and Cost.

Table 7.3: Determination of relative importance of material selection criteria for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 8(8 - 1)/2 = 28$																												Positive Decisions	Relative Emphasis Coefficient, α	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
Tensile Strength	0	1	1	0	0	0	0																							2	0.071
Compressive Strength	1							1	1	1	0	1	0																	5	0.179
Corrosive Resistance		0						0						1	0	0	1	0												2	0.071
Surface Finish			0						0					0						0	0	1	0							1	0.036
Density				1						0					1					1				0	1	0				4	0.143
Cost					1						1					1					1					1		1	1	7	0.250
Elastic Modulus						1						0					0					0			0		0		0	1	0.036
Weldability							1						1					1					1			1		0	1	6	0.214
Total Number of Positive Decisions																												28	$\sum \alpha = 1$		

Table 7.3 shows the digital logic method for different components of the Mechanical Trash Compactor. Of these criteria, the cost has the highest number of positive decisions i.e. highest relative co-efficient.

Table 7.4: Calculation of the performance index for material selection of Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster:

Selection Criteria	Relative Emphasis Coefficient, α	Mild Steel		Cast Iron		Aluminum	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Tensile Strength	0.071	100	7.1	49.29	3.50	57.14	4.06
Compressive Strength	0.179	38.46	6.88	100	17.9	61.54	11.02
Corrosive Resistance	0.071	100	7.1	50	3.55	100	7.1
Surface Finish	0.036	100	3.6	40	1.44	100	3.6
Density	0.143	34.05	4.87	37.48	5.36	100	14.3
Cost	0.250	92.3	23.08	100	25	33.33	8.33
Elastic Modulus	0.036	100	3.6	43.9	1.58	33.8	1.21
Weldability	0.214	100	21.4	40	8.56	80	17.12
Material Performance Index			77.63		66.89		66.74

Table 7.4 shows the weighted score for different selection criteria for three different materials and the performance index for each of the materials. Among the three materials, mild steel has a maximum performance index. Therefore, for Frame, Pedal, Connecting Rod, Holding Shaft, Moving Shaft, X-frame, and Thruster mild steel should be selected as material which we also selected in the previous chapter.

7.5.2 Material Selection for Body and Lid:

Table 7.5: List of selection criteria with numerical values or values from Likert Scale for body and lid

Selection Criteria	High-Density Polythene (HDPE) Grade-500	Stainless steel	Aluminum
Tensile Strength (MPa)	40	480	240
Corrosion Resistance	5	4	4
Surface Finish	5	4	4
Toughness(MPa/m ²)	600	250	45
Density (Kg/m ³)	958	7950	2680
Cost (BDT/Kg)	100	220	180
Machinability	2	4	5

From these selection criteria, we want to maximize Tensile Strength, Corrosive Resistance, Surface Finish, Toughness, and Machinability; and to minimize Density (for lightweight) and Cost.

Table 7.6: Calculation of the performance index for material selection of body and lid using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $n(n - 1)/2 = 7(7 - 1)/2 = 21$																				Positive Decisions	Relative Emphasis Coefficient, α	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			21
Tensile Strength	0	0	1	0	0	0																1	0.048
Corrosion Resistance	1						1	1	1	0	0											4	0.190
Surface Finish		1					0					1	1	0	0							3	0.143
Toughness			0					0				0				1	0	0				1	0.048
Density				1					0				0			0			0	1		2	0.095
Cost					1					1				1			1		1		0	5	0.238
Machinability						1					1				1			1		0	1	5	0.238
Total Number of Positive Decisions																					21	$\sum \alpha = 1$	

Table 7.6 shows the digital logic method for the body and lid of the Mechanical Trash Compactor. Of these criteria, cost and machinability has the highest number of positive decisions i.e. highest relative co-efficient

Table 7.7: Calculation of the performance index for material selection of Body and Lid:

Selection Criteria	Relative Emphasis Coefficient, α	HDPE		Stainless Steel		Aluminum	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Tensile Strength	0.048	8.33	0.40	100	4.8	50	2.4
Corrosive Resistance	0.190	100	19	80	15.2	80	15.2
Surface Finish	0.143	100	14.3	80	11.44	80	11.4
Toughness	0.048	100	4.8	41.67	2.00	7.5	0.36
Density	0.095	100	9.5	12.05	1.14	35.75	3.40
Cost	0.238	100	23.8	45.45	10.82	55.55	13.22
Machinability	0.238	40	9.52	80	19.04	100	23.8
Material Performance Index			81.32		64.44		69.78

Table 7.7 shows the weighted score for three different materials for the body and lid. Among these three, HDPE has the highest performance index. Therefore, for the body and lid of the Mechanical Trash Compactor HDPE should be used.

Chapter - 08

Manufacturing Process and Joining Process Selection Using Weighted Average Method:

8.1 Introduction:

Manufacturing is the center of any production system. Therefore, the selection of a manufacturing method is very imperative for better efficiency in terms of design parameters. In the previous chapter, a quantitative analysis of material selection has been carried out using the “Digital Logic Method” and performance index. A similar approach has been followed in this chapter for the selection of manufacturing and joining processes. Also, the same formulas are used for determining relative emphasis coefficient, α , and scaled property, β . Instead of the material performance index, we will determine the process performance index as a summation of the weighted score.

8.2 List of Manufacturing Processes and Joining Processes:

8.2.1 Manufacturing Processes:

- Cutting of Mild Steel Blanks
- Cutting of HDPE sheets
- Cutting of Slots
- Coloring
- Forming Operation

8.2.2 Joining Processes:

- Permanent Joining
- Temporary Joining

8.3 Quantitative Analysis of Manufacturing Process Selection:

8.3.1 Manufacturing Process Selection for Cutting of Mild Steel Blanks (for Frame):

Table 8.1: List of selection criteria with numerical values or values from Likert Scale for cutting mild steel blanks:

Selection Criteria	Gas Cutting	Laser Cutting
Cost (BDT/Product)	5	50
Surface Finish	4	5
Operation Time (Sec)	30	20
Defect Rate (%)	5	1
Safety (Personal and Environmental)	4	5

From these criteria, we want to maximize surface finish and safety; and minimize cost, operation time, and defect rate.

Table 8.2: Calculation of the performance index for manufacturing process selection for cutting of mild steel blanks using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 5(5 - 1)/2 = 10$										Positive decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	1	1	1	1							4	0.4
Surface Finish	0				0	0	1				1	0.1
Operation Time		0			1			0	1		2	0.2
Defect Rate			0			1		1		0	2	0.2
Safety				0			0		0	1	1	0.1
Total Number of Positive Decisions											10	$\sum \alpha = 1$

Table 8.2 shows the digital logic method for cutting mild steel blanks for frames. Of these criteria, the cost has the highest relative emphasis coefficient.

Table 8.3: Calculation of performance index for manufacturing process selection of cutting mild steel blanks:

Selection Criteria	Relative Emphasis Coefficient, α	Gas Cutting		Laser Cutting	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.4	100	40	10	4
Surface Finish	0.1	80	8	100	10
Operation Time	0.2	66.67	13.33	100	20
Defect Rate	0.2	20	4	100	20
Safety	0.1	80	8	100	10
Process Performance Index			73.33		64

Table 8.3 shows the weighted score for gas cutting and laser cutting. Since the performance index of gas cutting is higher, it should be selected as the process for cutting mild steel blanks.

8.3.2 Manufacturing Process Selection for Cutting of HDPE sheets (for Body and Lid)

Table 8.4: List of selection criteria with numerical values or values from Likert Scale for cutting HDPE sheets:

Selection Criteria	Sawing (with Circular Saw)	Scribing and Sawing
Cost (BDT/Product)	5	2
Finishing	5	2
Operation Time (Sec)	10	30
Safety	5	4
Defect Rate (%)	5	3

From these criteria, we want to maximize surface finish and safety; and minimize cost, operation time, and defect rate.

Table 8.5: Calculation of the performance index for manufacturing process selection for cutting of HDPE sheets using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 5(5 - 1)/2 = 10$										Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	1	0	1	0							2	0.2
Finishing	0				0	1	0				1	0.1
Operation Time		1			1			0	1		3	0.3
Safety			0			0		1		0	1	0.1
Defect Rate				1			1		0	1	3	0.3
Total Number of Positive Decisions											10	$\sum \alpha = 1$

Table 8.5 shows the digital logic method for cutting HDPE sheets. Of these criteria, operation time and defect rate have the highest relative emphasis coefficient.

Table 8.6: Calculation of performance index for manufacturing process selection of cutting HDPE sheets:

Selection Criteria	Relative Emphasis Coefficient, α	Sawing		Scribing and Breaking	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.2	40	8	100	20
Finishing	0.1	100	10	40	4
Operation Time	0.3	100	30	33.33	10
Safety	0.1	100	10	80	8
Defect Rate	0.3	100	30	60	18
Process Performance Index			88		60

Table 8.6 shows the weighted score for sawing and scribing. Since the performance index of sawing is higher, it should be selected as the process for cutting HDPE sheets.

8.3.3 Manufacturing Process Selection for Forming Operations (for moving shaft, holding the shaft and connecting rod):

Table 8.7: List of selection criteria with numerical values or values from Likert Scale for forming operations (for shafts):

Selection Criteria	Turing	Extrusion
Surface Roughness (μ Inch)	16-125	100-250
Tolerance (μ Inch)	0.001	0.03
Cost	5	15
Operation Complexity	2	5
Dimensional Accuracy	5	3
Material Compatibility	5	3

From these criteria, we want to maximize tolerance, dimensional accuracy, and material compatibility; and minimize surface roughness, cost, and operation complexity.

Table 8.8: Calculation of the performance index for manufacturing process selection for forming operations (for shafts) using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 6(6 - 1)/2 = 15$															Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Surface Roughness	1	0	0	0	1											2	0.133
Tolerance	0					1	1	0	0							2	0.133
Cost		1				0				1	0	1				3	0.200
Operation Complexity			1				0			0			0	1		2	0.133
Dimensional Accuracy				1				1			1		1		1	5	0.334
Material Compatibility					0				1			0		0	0	1	0.067
Total number of positive decisions															15	$\sum \alpha = 1$	

Table 8.8 shows the digital logic method for forming operations. Of these criteria, dimensional accuracy has the highest relative emphasis coefficient.

Table 8.9: Calculation of performance index for manufacturing process selection of forming operation (for Shafts):

Selection Criteria	Relative Emphasis Coefficient, α	Turning		Extrusion	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Surface Roughness	0.133	100	13.3	40	5.32
Tolerance	0.133	3.33	0.44	100	13.3
Cost	0.200	100	20	33.33	6.67
Operation Complexity	0.133	100	13.3	40	5.32
Dimensional Accuracy	0.334	100	33.4	60	20.4
Metal Compatibility	0.067	100	6.7	60	4.02
Process Performance Index			87.14		55.03

Table 8.9 shows the weighted score for turning and extrusion for forming of different shafts (e.g. moving shaft, connecting rod, holding shaft). Since the turning process has a higher performance index it is selected as the manufacturing process for forming shafts.

8.3.4 Manufacturing Process Selection for Forming Operations (for X-frame, Thruster):

Table 8.10: List of selection criteria with numerical values or values from Likert Scale for forming operations (for X-frame, Thruster):

Selection Criteria	Casting	Forging
Cost (BDT/Product)	30	50
Operation Complexity	3	5
Dimensional Accuracy	3	5
Strength	4	5
Defect Rate (%)	5	3
Surface Roughness (μ Inch)	300-600	150-200

Of these criteria, we want to maximize strength and dimensional accuracy; and minimize cost, operations complexity, defect rate, surface roughness.

Table 8.11: Calculation of the performance index for manufacturing process selection for forming operations (for X-frame, Thruster) using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 6(6 - 1)/2 = 15$															Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	1	0	0	1	1											3	0.200
Operation Complexity	0					1	0	0	1							2	0.133
Dimensional Accuracy		1				0				0	1	1				3	0.200
Strength			1				1			1			1	0		4	0.267
Defect Rate				0				1			0		0		1	2	0.133
Surface Roughness					0				0			0		1	0	1	0.067
Total Number of Positive Decisions																15	$\sum \alpha = 1$

Table 8.11 shows the calculation of the relative emphasis coefficient for different selection criteria using the digital logic method. Of these entire selection criteria, strength has the highest relative emphasis coefficient.

Table 8.12: Calculation of performance index for manufacturing process selection of forming operation (for X-frame, Thruster):

Selection Criteria	Relative Emphasis Coefficient, α	Casting		Forging	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.200	100	20	60	12
Operation Complexity	0.133	100	13.3	60	7.98
Dimensional accuracy	0.200	60	12	100	20
Strength	0.267	80	21.36	100	26.7
Defect Rate	0.133	60	7.98	100	13.3
Surface Roughness	0.067	55.55	3.72	100	6.7
Process Performance Index			78.36		86.68

As shown in table 8.12 casting has a smaller performance index than forging. Therefore, forging should be selected as the manufacturing process for the forming of X-frame and Thruster. But Forging requires a lot higher initial investment than casting. Therefore, for manufacturing parts with such simple designs as X-frame and Thruster, casting is often preferred.

8.3.5 Manufacturing Process Selection for cutting slots (for trash slot and parts of a relay system in housing body):

Table 8.13: List of selection criteria with numerical values or values from Likert Scale for cutting slots (for trash slot, housing):

Selection Criteria	End Milling	Electrical Discharge Machining (EDM)
Cost (BDT/Product)	5	30
Surface Finish	4	5
Operation Time (Sec)	60	900
Operation Complexity	3	5
Environmental Hazards	1	3

Of these properties, we want to maximize surface finish and minimize cost, operation time, operation complexity, and Environmental Hazards.

Table 8.14: Calculation of the performance index for manufacturing process selection for cutting slots (for trash slot, housing) using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 5(5 - 1)/2 = 10$										Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	1	0	1	1							3	0.3
Surface Finish	0				0	1	0				1	0.1
Operation Time		1			1			1	1		4	0.4
Operation Complexity			0			0		0		1	1	0.1
Environmental Hazards				0			1		0	0	1	0.1
Total Number of Positive Decisions											10	$\sum \alpha = 1$

Table 8.15: Calculation of performance index for manufacturing process selection of cutting slots (for housing and trash slot):

Selection Criteria	Relative Emphasis Coefficient, α	End Milling		EDM	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.3	100	30	16.67	5
Surface Finish	0.1	80	8	100	10
Operation Time	0.4	100	40	6.67	2.67
Operation Complexity	0.1	100	10	60	6
Environmental Hazards	0.1	100	10	33.33	3.33
Process Performance Index			98		27

From Table 8.15 it can be seen that End Milling has a complete advantage over EDM. Hence, End Milling should be selected as the manufacturing process for cutting slot.

8.3.6 Manufacturing Process Selection for Coloring:

Table 8.16: List of selection criteria with numerical values or values from Likert Scale for Coloring Process:

Selection Criteria	Spraying	Brush Painting
Cost (BDT/Product)	15	10
Durability (Month)	12	8
Adhesiveness	5	4
Compatibility	5	4

Of these criteria, we want to maximize durability, adhesiveness, compatibility, and minimize cost.

Table 8.17: Calculation of the performance index for manufacturing process selection for coloring system using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 4(4 - 1)/2 = 6$						Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6		
Cost	0	1	1				2	0.333
Durability	1			1	0		2	0.333
Adhesiveness		0		0		1	1	0.167
Compatibility			0		1	0	1	0.167
Total No. of Positive Decisions							6	$\sum \alpha = 1$

Table 8.18 Calculation of performance index for manufacturing process selection of Coloring System:

Selection Criteria	Relative Emphasis Coefficient, α	Spraying		Brush Painting	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.333	66.67	22.2	100	33.3
Durability	0.333	100	33.3	66.67	22.2
Adhesiveness	0.167	100	16.7	80	13.36
Compatibility	0.167	100	16.7	80	13.36
Process Performance Index			88.9		82.22

Since the performance index for Spraying is higher than Brush Painting; it is selected as the manufacturing process for color spraying.

8.4 Quantitative Analysis of Joining Process Selection:

8.4.1 Joining Process Selection for Permanent Joints:

Table 8.19: List of selection criteria with numerical values or values from Likert Scale for Permanent Joint:

Selection Criteria	Arc Welding	TIG welding
Cost (BDT/Product)	15	35
Surface Finish	3	5
Strength	4	5
Operation Time (Sec)	30	40
Defect Rate (%)	3	1

Table 8.20: Calculation of the relative emphasis coefficient for joining process selection for Permanent Joints using Digital Logic Method:

Selection Criteria	Number of Positive Decisions, $N = n(n - 1)/2 = 5(5 - 1)/2 = 10$										Positive Decisions	Relative Emphasis Coefficient, α
	1	2	3	4	5	6	7	8	9	10		
Cost	1	0	1	1							3	0.3
Surface Finish	0				0	1	0				1	0.1
Strength		1			1			1	1		4	0.4
Operation Time			0			0		0		1	1	0.1
Defect Rate				0			1		0	0	1	0.1
Total No. of Positive Decisions											10	$\sum \alpha = 1$

Table 8.21: Calculation of performance index for joining process selection of Permanent Joints:

Selection Criteria	Relative Emphasis Factor, α	Arc Welding		TIG welding	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost	0.3	100	30	42.85	12.71
Surface Finish	0.1	60	6	100	10
Strength	0.4	80	32	100	40
Operation Time	0.1	100	10	75	7.5
Defect Rate	0.1	33.33	3.33	100	10
Process Performance Index			81.33		80.21

Since the performance index for arc welding is larger than TIG welding, arc welding will be selected as our joining process for permanent joints.

Chapter- 09

Cost Analysis

Cost is directly related to a product's design because the cost largely varies with the decision related to its design. Apart from technologies and aesthetics, the cost is the main driving agent in this era of competition. Therefore, a successful product development organization must give more attention to the cost to make the product affordable for customers.

9.1 Demand Forecast:

Forecasted Number of Products per Year: 6500 units

9.2 Fixed Cost

Fixed costs are initial investments for types of machinery and other accessories.

9.2.1 Machine cost:

1. ***Horizontal Conventional Lathe Machine*** (Brand name: Shandong Schuler, China, Model NO: CA6150 CA 6250 Turning Machine)
Buying Cost: BDT 6, 50,000
Salvage: BDT 30,000
Life: 10 years
Quantity: 1
2. ***Gas Welding Machine*** (Brand name: Welding Equipment India, Faridabad (India) Model NO: RDH1100)
Buying Cost: BDT 3500
Salvage: BDT 500
Life: 5 years
Quantity: 2
3. ***Permanent Mold Casting Machine*** (Brand Name: Zhejiang, China, Model NO: 718-SKD65)
Buying Cost: BDT 10, 00,000
Salvage: BDT 50,000
Life: 15 years
Quantity: 1

4. ***Permanent Mold Casting Die***
Buying Cost: BDT 1, 50,000
Salvage: BDT 1000
Life: 7 years
Quantity: 2
5. ***Mini Milling Machine*** (Brand Name: Amit Engineering Co. (India), Model: AEC 4890073548)
Buying Cost: BDT 80,000
Salvage: BDT 3,000
Life: 10 years
Quantity: 1
6. ***Non-precision Grinding Machine***
Buying Cost: BDT 3, 50,000
Salvage: BDT 7000
Life: 10 years
Quantity: 1
7. ***Bench Drilling Machine*** (Brand Name: Shori Exim India Private Ltd, Punjab, Model NO: SEI 32090045)
Buying Cost: BDT 8000
Salvage: BDT 500
Life: 8 years
Quantity: 1
8. ***Circular Sawing Machine*** (Brand Name: Ningbo, Zhejiang, China, Model NO: MCS012-B)
Buying Cost: BDT 80,000
Salvage: BDT 1000
Life: 10 years
Quantity: 2
9. ***Rivet Gun (Hand Riveter):***
Buying Cost: BDT 1000
Life: 5 years
Quantity: 2

10. *Polishing and Coloring Equipment*

Buying Cost (Yearly): BDT 1, 00,000

The total cost of pieces of machinery: BDT 77, 95,000

9.2.2 Cost of furniture, computer, and other accessories:

1. *Total furniture and accessories cost for office:*

Buying Cost: BDT 3, 00,000

Life: 10 years

2. *Computer Cost:*

Buying Cost: 4, 50,000

Life: 15 years

The total cost of Furniture, Computer, and other Accessories: BDT 7, 50,000

9.2.3 Factory Insurance:

For factory insurance yearly payment: BDT 25,000

9.3 Manufacturing Cost:

Manufacturing cost is the cost of production that is directly incurred during the production process. It includes direct labor, direct material, and manufacturing overhead costs.

9.3.1 Cost of Raw Materials (Per unit of Product):

1. AISI 1020 Mild steel:

The raw material required: 3 Kg

Market price: BDT 120/Kg

Total raw material cost: BDT 360

2. HDPE (Grade-500) sheets

The raw material required: 6 Sheets

Market price: BDT 100/Sheet

Total raw material cost: BDT 600

Total Cost of Raw Material (Per unit of product): BDT 960

Total Raw Material Cost per Year: BDT 62, 40,000

9.3.2 Manufacturing Costs of different operations (Per month):

1. **Casting:**

Number of worker: 2

Wage/Labor: BDT 15,000

Total cost: BDT 30,000

2. **Milling**

Number of worker: 1

Wage/Labor: BDT 15,000

Total cost: BDT 15,000

3. **Drilling:**

Number of worker: 1

Wage/Labor: BDT 15,000

Total Cost: BDT 15,000

4. **Turning:**

Number of worker: 1

Wage/Labor: 16,000

Total cost: 16,000

5. **Cutting:**

Number of worker: 2

Wage/Labor: BDT 20,000

Total cost: BDT 40,000

6. **Joining and assembly:**

Number of worker: 3

Wage/Labor: BDT 15,000

Total cost: BDT 45,000

7. **Finishing:**

Number of worker: 1

Wage/Labor: BDT 18,000

Total cost: BDT 18,000

8. **Coloring:**

Number of worker: 1

Wage/Labor: BDT 16,000

Total Cost: BDT 16,000

Total Labor Cost: BDT 1, 95,000 per month

Total Labor Cost: BDT 23, 40,000 per year

9.3.3 Purchasing Cost:

Table 9.1: Purchased parts and their cost (per unit of product)

Component	Quantity	Market Price (BDT)	Total Cost (BDT)
Bin	1	100 each	120
Pulley	1	80 each	100
Rack and Pinion	3	40/each	120
Belt	1	800/meter	50
Spring	2	70 each	140
Nut-Bolt	12	10 each	120
Rivet	8	2.5 each	20
Total Purchasing Cost (Per unit of Product)			670

Since we are going to buy these parts in bundle offer we can get plenty of discounts. After analyzing the current market we estimated that about 30% discount will be available.

So, total purchasing costs of outsourced parts (per unit product): $BDT\ 670 \times 0.7 \approx BDT\ 469$

Total purchasing costs of outsourced parts per year: $BDT\ 469 \times 6500 = BDT\ 30,48,500$

9.3.4 Manufacturing Overhead Cost (per month):

Table 9.2: Manufacturing Overhead Costs

Cost Item	No. of Post	Salary/person (BDT)	Total cost (BDT)
Production Manager	1	50,000	50,000
Manufacturing Engineer	2	40,000	80,000
Design Engineer	1	40,000	40,000
Quality Control Engineer	1	45,000	45,000
Power Consumption		15,000	15,000
Factory Rent		30,000	30,000
		Total	2,60,000

Yearly manufacturing overhead: $\text{BDT } 2,60,000 \times 12 = \text{BDT } 31,20,000$

9.4 Non-manufacturing Costs

Non-manufacturing costs are the costs that are not directly related to manufacturing, but these are needed to maintain the supply chain properly. Generally, these include selling and administrative cost. Non-manufacturing costs are generally incurred at the later portion of the supply chain.

9.4.1 Administrative Cost (per month):

Table 9.3: Administrative costs

Post	No. of post	Salary/person (BDT)	Total Cost (BDT)
Chief Executive Officer	1	80,000	80,000
HR Manager	1	35,000	35,000
Accountant	1	25,000	25,000
Secretary	1	15,000	15,000
Clerk	2	6000	12,000
Guard	1	5000	5,000
Office rent			15,000
Power consumption			2000
Water bill			1000
		Total	1,90,000

Yearly administrative cost: $BDT\ 1,90,000 \times 12 = BDT\ 22,80,000$

9.4.2 Selling Expenses (per month):

Table 9.4: Selling Expenses

Cost Item	No. of post	Salary/person (BDT)	Total Cost (BDT)
Marketing Executive	2	30,000	60,000
Advertisement			20,000
		Total	80,000

Yearly Selling Expenses: $\text{BDT } 80,000 \times 12 = \text{BDT } 9,60,000$

Total Selling and Administrative cost (or non-manufacturing cost): $\text{BDT } 32,40,000$

9.5 Break Even Analysis:

For the first year,

Fixed Cost:

Machine Cost: $\text{BDT } 77,95,000$

Furniture, computer and accessories cost: $\text{BDT } 7,50,000$

Factory Insurance: $\text{BDT } 25,000$

Manufacturing Overhead: $\text{BDT } 31,20,000$

Selling and Administrative Costs: $\text{BDT } 32,40,000$

Total amount of fixed costs: $\text{BDT } 149,30,000$

Total raw material cost: $\text{BDT } 62,40,000$

Total purchase cost of outsourced parts: $\text{BDT } 30,48,500$

Total labor cost: $\text{BDT } 23,40,000$

Total variable cost: $\text{BDT } 116,28,500$

Variable cost per unit: BDT 116, $28,500 \div 65000 = \text{BDT } 1789$

Selling Price: $\text{BDT } 1789 + 25\% \text{ of } 1789 \approx \text{BDT } 2230$

At break even,

$$\text{Selling price} \times \text{break even unit (x)} = \text{Fixed cost} + \text{Variable cost}$$

$$\text{Or, } 2230x = 149,30,000 + 1789x$$

$$\text{Or, } x \approx 33,855 \text{ units}$$

So, the break even quantity for the first year is 33,855 units.

The plot for break-even analysis for the first year is shown below:

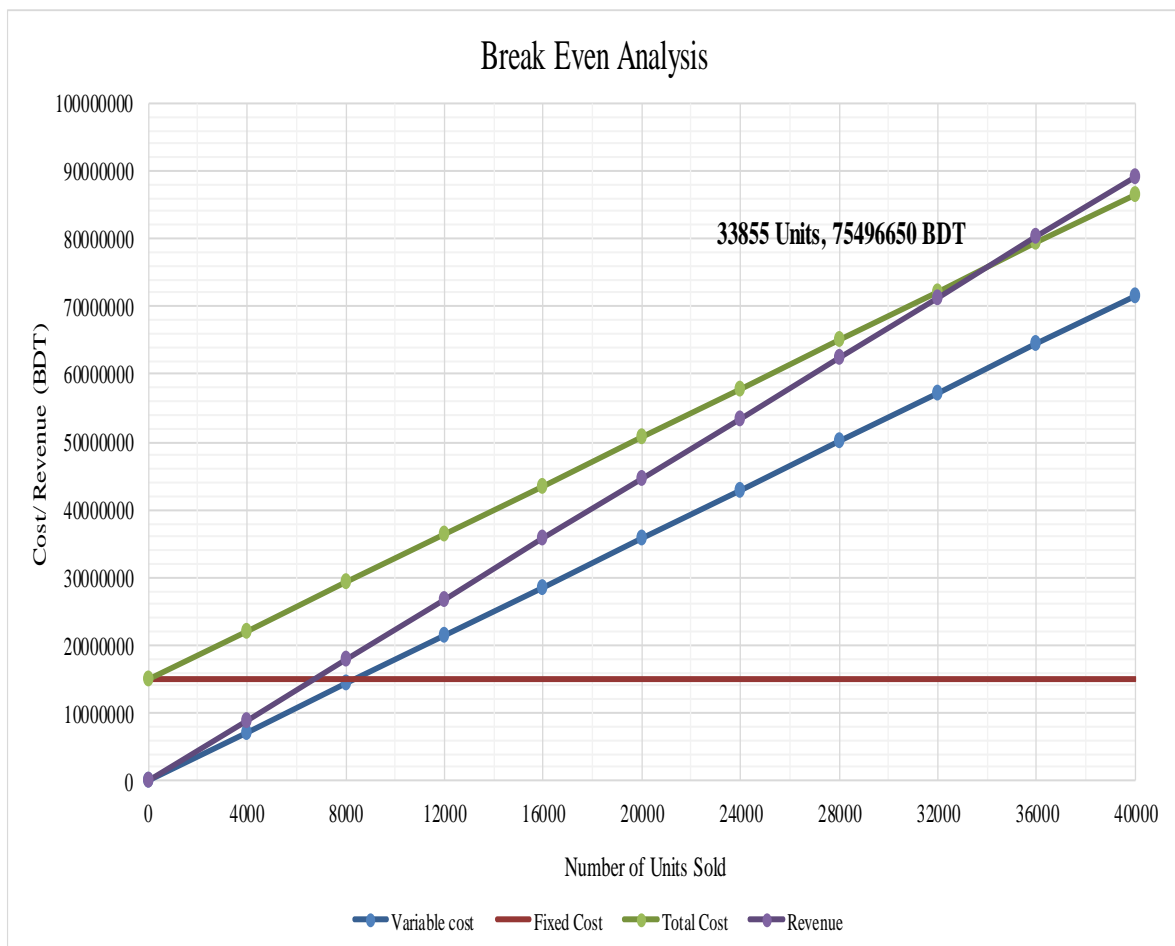


Figure 9.1: Graphical Representation of the Break-even Analysis

Here, we have only considered the first year where we had a major investment in machinery and other accessories. That's why the break-even is very large. But for the following years, there will be a very small amount of fixed cost (comprising of only factory insurance, manufacturing overhead, and non-manufacturing costs) compared to the first year. So, with the proper marketing strategy and quality products, our company can hope for crossing the break-even point and gain profit.

Conclusion:

In the current scenario of Bangladesh where the government is willing to keep the city streets clean and is raising cleanliness awareness through the works of city corporations due to the ongoing pandemic situation, our mechanical trash compactor can serve a greater purpose. Not only this but also the ongoing food business boom will be helpful as there is a lack of coordination between the city corporation and food trash from these businesses. The compactor we are willing to build is capable of holding three times more trash than the conventional one. A clean street is a necessity for a healthy environment as well as for households. That is why we are trying to provide a classy solution to the problem of waste management.

It has been a privilege for us to be a part of the course where we learned to connect a dot between the customer and engineers. Also, this course offered us the to utilize our theoretical knowledge in practical life, analyze a market situation, and putting our potential together to bring out something useful for the welfare of humankind.

Appendix

1. Appendix A: Results of Tensile Tests of Some Metals

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

Number	Material	Condition	Strength (Tensile)					Strain Exponent m	Fracture Strain ϵ_f
			Yield S_y MPa (kpsi)	Ultimate S_u MPa (kpsi)	Fracture, σ_f MPa (kpsi)	Coefficient σ_c MPa (kpsi)			
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 (280)	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	

2. Appendix B: Mechanical Properties of Some Aluminum Alloys

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

Aluminum Association Number	Temper	Strength			Elongation in 2 in, %	Brinell Hardness H_B
		Yield, S_y , MPa (kpsi)	Tensile, S_u , MPa (kpsi)	Fatigue, S_f , MPa (kpsi)		
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

3. Appendix C: Chart for Different Grade

ASTM Minimum Tensile and Yield Strengths for Some Hot-Rolled (HR) and Cold-Drawn (CD) Steels [The strengths listed are estimated ASTM minimum values in the size range 18 to 32 mm (3/4 to 1 1/4 in). These strengths are suitable for use with the design factor.

1	2	3	4	5	6	7	8
UNS No.	SAE and/or AISI No.	Process- ing	Tensile Strength, MPa (kpsi)	Yield Strength, MPa (kpsi)	Elongation in 2 in, %	Reduction in Area, %	Brinell Hardness
G10060	1006	HR	300 (43)	170 (24)	30	55	86
		CD	330 (48)	280 (41)	20	45	95
G10100	1010	HR	320 (47)	180 (26)	28	50	95
		CD	370 (53)	300 (44)	20	40	105
G10150	1015	HR	340 (50)	190 (27.5)	28	50	101
		CD	390 (56)	320 (47)	18	40	111
G10180	1018	HR	400 (58)	220 (32)	25	50	116
		CD	440 (64)	370 (54)	15	40	126
G10200	1020	HR	380 (55)	210 (30)	25	50	111
		CD	470 (68)	390 (57)	15	40	131
G10300	1030	HR	470 (68)	260 (37.5)	20	42	137
		CD	520 (76)	440 (64)	12	35	149
G10350	1035	HR	500 (72)	270 (39.5)	18	40	143
		CD	550 (80)	460 (67)	12	35	163
G10400	1040	HR	520 (76)	290 (42)	18	40	149
		CD	590 (85)	490 (71)	12	35	170
G10450	1045	HR	570 (82)	310 (45)	16	40	163
		CD	630 (91)	530 (77)	12	35	179
G10500	1050	HR	620 (90)	340 (49.5)	15	35	179
		CD	690 (100)	580 (84)	10	30	197
G10600	1060	HR	680 (98)	370 (54)	12	30	201
G10800	1080	HR	770 (112)	420 (61.5)	10	25	229
G10950	1095	HR	830 (120)	460 (66)	10	25	248

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