Bangladesh University of Engineering & Technology

IPE 304

PRODUCT DESIGN-I SESSIONAL

A report on

Intelligent Automatic Plant Watering System with Air Humidifier

Submitted to

Dr. Shuva Ghosh

Associate Professor, Department of IPE, BUET

Dr. A. B. M. Mainul Bari

Assistant Professor, Department of IPE, BUET

Kaniz Fatema

Lecturer, Department of IPE, BUET

Submitted by

Group – A12

Name	**Student ID**
Minhaj Alam Dip	1808006
Md. Fahim Al Hasan Rafi	1808007
Maksud Bin Malik	1808008
Uthso Roy Shuvo	1808009
Ishmam Tasnim	1808010

Department of Industrial and Production Engineering, BUET

<u>Copyright Notice</u>

FORWARDING LETTER

February 25, 2023

Dr. Shuva Ghosh

Associate Professor, Department of IPE, BUET

Dr. A. B. M. Mainul Bari

Assistant Professor, Department of IPE, BUET

Kaniz Fatema

Lecturer, Department of IPE, BUET

Subject: A report on "Intelligent Automatic Plant Watering System with Air Humidifier".

Dear Teachers,

With due respect, we would like to submit you our report on "Intelligent Automatic Plant Watering System with Air Humidifier".

In our product, we have used an Arduino uno module along with a sensor probe and motor to automatically water plant pots along with an air humidifier. This product will ease urban planting and gardening along with purifying dry and dusty air. It is affordable, modular and easy to use. This report, it is presented how the plant watering and air humidifier system 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,

Minhaj Alam Dip - 1808006

Md. Fahim Al Hasan Rafi - 1808007

Maksud Bin Malik - 1808008

Uthso Roy Shuvo - 1808009

Ishmam Tasnim – 1808010

Level -3, Term -2

Department of Industrial and Production Engineering, BUET.

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 with multiple tasks and subtasks. Parts of the process often need to be repeated many times.

After presenting our initial concepts with our course teachers, we were assigned Intelligent Automatic Plant Watering System with Air Humidifier as our course project. This product will be plant watering source with humidifier that can sense moisture level and can automatically water plants without any human assistance, it additionally purifies dry and dusty air. 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 considered customer requirements, cost, and feasibility of the product prior to finalizing the design concept and process flow plan.

Summary

Intelligent Automatic Plant Watering System consists of a smart plant pot to sense the water level and indicate the condition of plants on attached LED screen based on level of hydration, along with automated system of plant watering based on level of hydration. The level of hydration is decided based on a moisture sensor and can operate sustainably without any human assistance.

The system will also include an automatic air humidifier to control a comfortable indoor environment which will be operated from the same water reservoir system. 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 make planting in urban life easy and which can also improve air quality of households.

Acknowledgement

This project would not be completed without the support, help and inspiration from well-wishers and mentors.

Firstly, we would like to wholeheartedly thank our course teachers - Dr. Shuva Ghosh, Associate Professor, Department of IPE, BUET, Dr. A. B. M. Mainul Bari, Assistant Professor, Department of IPE, BUET, Kaniz Fatema, Lecturer, Department of IPE, BUET, for their valuable advice, support, time, guideline and useful suggestions on product design. They guidance was pivotal from the concept development to the design execution of this product.

The financial support from the department of IPE, BUET helped us to manufacture the original product successfully. We would like to express our gratitude to the head of our department, Professor Dr. Ferdous Sarwar for his help regarding this fund. We would also like to express our gratitude to BUET authority for this support.

We would finally thank our classmates and lab personnel of department of IPE, BUET who have helped us with process designs and other resources.

Table of Contents

List of Tables

List of Figures

Chapter-1

Introduction

1.1 Product Design

Product design is the process that designers use to blend user needs with business goals to help brands make consistently successful products. It also describes the process of imagining, creating, and iterating products that solve users' problems or address specific needs in a given market. Product design must include the whole part of the product from the preliminary stages to its manufacturing and maintenance.

Product design is also a result of a plan or specification in the form of a prototype, product, or process. With a methodical approach, product designers conceptualize, evaluate and turn ideas into tangible products as well as satisfy certain goals and constraints.

The most important aspects of a product should be its functionality and productivity. Rather than functionality, it also should focus on its quality, reliability, sustainability, standardization, and so on. Also, the product should be designed such as it would be safe to use and economically stable.

The key to successful product design is understanding the end user customer, the person for whom the product is being developed. Product designers attempt to solve real problems for people by using empathy and knowledge of their perspective customer habits, behavior, frustration, needs, and wants. Product design plays an ongoing role in refining the customer experience and ensuring supplemental functionality and capabilities get added in a seamless, discoverable. Brand consistency and evolution remain essential product design responsibilities until the end of a product's lifespan.

1.2 Proposed Product Ideas

For the product design sessional, we proposed five ideas in different fields such as healthcare, environment, lifestyle, industrial production, etc. We planned the products considering demand, production and retail price, and scalability of the products. Following are the five ideas for our primarily proposed product.

1.2.1 Eco-Friendly Footpath Cycle

It is a pedal-based cyclic system with a rotating cleaning brush and dust disposable attached collector. As the driver paddles, the cycle moves forward, and the rotating cylindrical brush collects the dust and puts them in the disposable collector. It is a time and energy-efficient dustingsystem for dry hallways and footpaths.

1.2.2 Advanced Wheelchairs

Wheelchair with advanced carrier and trolley mechanism with staircase-friendly bumping-controlled wheels and electrical components to alert caretakers if the patient is in discomfort. It is conveniently usable in staircases. Additionally, there is a sensor-based push buttoned alarm and light switch system to alert for discomfort. Finally, it has cross-functional and easy to use - can be used in toilets as well.

1.2.3 Intelligent Automatic Plant Watering System with Air Humidifier

Smart plant pot to sense the water level and indicate the condition (“happy/sad”) of pots on the attached LED screen based on level of hydration and automated system of plant watering based on level of hydration. The level of hydration is decided based on a moisture sensor. If the moisturesensor indicates a value below the desired set value, the mechanical valve will automatically openand water the soil until the moisture level reaches the desired value.

The system will also include an automatic air humidifier to control a comfortable indoor environment which will be operated from the same water reservoir system.

1.2.4 Automatic nut extracting and processing machine

Motor-powered nut extraction system from nut peeling with peel separation system and an attachment for peanut butter processing at home. It has a space and energy-efficient design for the household and cottage industries. It is a compact 3-in-1 device for nut extracting, peel separation, and peanut butter processing

1.2.5 Automatic double hacksaw with a chips management system

Pneumatic or motor-powered double hacksaw system which can cut two similar pieces with no material wastage and a wood chip management system to thrash them into usable fuel cooking systems. It has an automatic system for evenly cutting wood, less waste. We added a double-cutting system for time efficiency. It also has a wood chip thrashing and compacting chamber foruse as fuel. The design is conveniently usable and affordable for small industry and household applications.

1.3 Selected Product

We proposed three different product designs for the Product Design Sessional-I. Among those, the Intelligent Automatic Plant Watering System' was selected as it is innovative, feasible, has new customer-oriented features, and is within our allotted budget.

1.3.1 Product Background

Humans are part of nature. One of the most significant parts of nature is trees. Also, it is importantto consider the dependencies of life on trees. People have been dependent on trees for food, shelter,and many other things since the prehistoric era. There have been signs of farm-based civilization all over the world. People still depend on farming for a major part of their food habits. But nowadays, farming is not only just a necessity but also considered a hobby. There is a huge demandfor indoor plants in this modern world. People are moving further from nature but to keep the 'Close to Nature' feeling alive, more and more people are considering indoor planting. But the common problem that everyone face is they often don't have time to water these plants. Moreover,if someone goes on a vacation or stays out of their residents for a couple of days, it gets nearly impossible for them to properly water the plants. As a result, their hobby or desire for planting getsnipped in the bud. To overcome this problem, we are introducing our intelligent plant care system.

Now let's explain how our product overcomes this problem. We are designing an intelligent pot.

We will install a moisture sensor in the pot. Whenever the moisture level of the soil drops below a certain critical point, the sensor will activate. Now comes the important part. We will attach a water reservoir through a pipe with the pot. There will be a servo-motor mechanism. This servo motor will be controlled by the signal received from the sensor. The servo motor itself will control a watering gate system. So, whenever the sensor is triggered, the servo-motor will be activated andit will maintain a steady flow of water to the pot until the moisture level reaches the desired value.

1.3.2 Product Features

1. **A moisture sensor:** A moisture sensor is used to detect the moisture content of the soil.
2. **A digital display:** A digital display will show the moisture state of the soil determined by the moisture sensor.
3. **A servo-motor:** A servo-motor will control the valve to regulate water flow as per the signal received from the moisture sensor.
4. **A reservoir-pipe system:** A reservoir to store water and a pipe to water the plants.

1.3.3 The motivation behind our Product

In our residential halls, a lot of students have a knack for indoor planting. They do it with enthusiasm and they also find it interesting. Moreover, these plants have aesthetic value. But during term breaks or other vacations, they face a huge problem. They can’t water their plants andas a result, most of the plants die.

Also, there is a Facebook group named ‘Indoor Plants Bangladesh’. In that group, we saw many posts regarding people’s inability of planting due to the above-mentioned reasons. These things motivated us to solve such a problem and hence led us to design our product.

Chapter-2

Understanding customer needs through survey

2.1 Introduction

With increasing industrialization, the environment has deteriorated considerably with high air pollution. Moreover, urban populations are getting less and less exposure to greeneries. Mass potted planting and gardening is a way to slowly and steadily eliminate the problem. However, sometimes it becomes difficult to look after saplings daily. Especially, it's difficult to regularly water plants especially if the user needs to travel for work/education purposes. Regular watering is a primary obstacle for many consumers to pursue planting. In this modern world of convenience, we are constantly looking for ways to make our daily lives more convenient. Any product that can save us time and effort is highly in demand.

Additionally, with increased dust concentration in the air, air humidifiers have become a necessity. Commercial air humidifiers are expensive and often not affordable by the regular mass. To solve both of these crucial problems, we designed our product plan. Quality is customer satisfaction - so, we set out to know what the possible customers think about this product and what their requirements are. Primarily, we conducted a consumer profile analysis so that we can point out exactly what is the requirement of the customers. We tried to make a well-structured and appropriately arranged questionnaire. Almost all the survey participants seemed to understand and answer our questions conveniently.

In the case of surveying the consumer insight for our product, two methods have been implemented.

i. Direct Interview

ii. Questionnaire

Variation in methods has led us to gather data from customers more efficiently. The total number of reviewers is 58. Important factors that we focused on during the survey are mentioned below:

1. Firstly, we made sure that the survey participant is appropriate because not everybody requires a device for gardening and nursing. So we asked them first whether they possess any interest in it or not.
2. If the consumer seemed enthusiastic about planting and indoor air quality, we asked them about lacking the current products they use and listed them.
3. At last, we asked them their expected price for such a product.

2.2 Areas and Locations of Survey

1. Sylhet Agricultural University (SAU)
2. Sher-E-Bangla Agricultural University (SBAU)
3. Nurseries around Doel Square, Dhaka University
4. Baldha Garden, Narinda, Wari, Dhaka.
5. Bangladesh University of Engineering and Technology
6. Facebook Group – Indoor Plants Bangladesh.

2.3 Survey Result

We got 58 responses from the survey. Response frequency from different survey areas is shown below:

Table 2.1: Survey response count per area

Survey area	**Response Count**
Sylhet Agricultural University (SAU)	12
Sher-E-Bangla Agricultural University (SBAU)	9
Nurseries around Doel Square, Dhaka University	7
Baldha Garden, Narinda, Wari, Dhaka	8
Bangladesh University of Engineering and Technology	8
Facebook Group – Indoor Plants Bangladesh.	14

The results of the survey are shown below with the help of pie charts along with percentages:

1. Have you considered planting in your home/office space to reduce carbon footprints?

a) Yes

b) No

c) Never thought about this

Table 2.2: Tendency of planting

Options	Response Count	Percentage (%)
Yes	44	75.9
No	4	6.9
Never thought about this	10	17.2

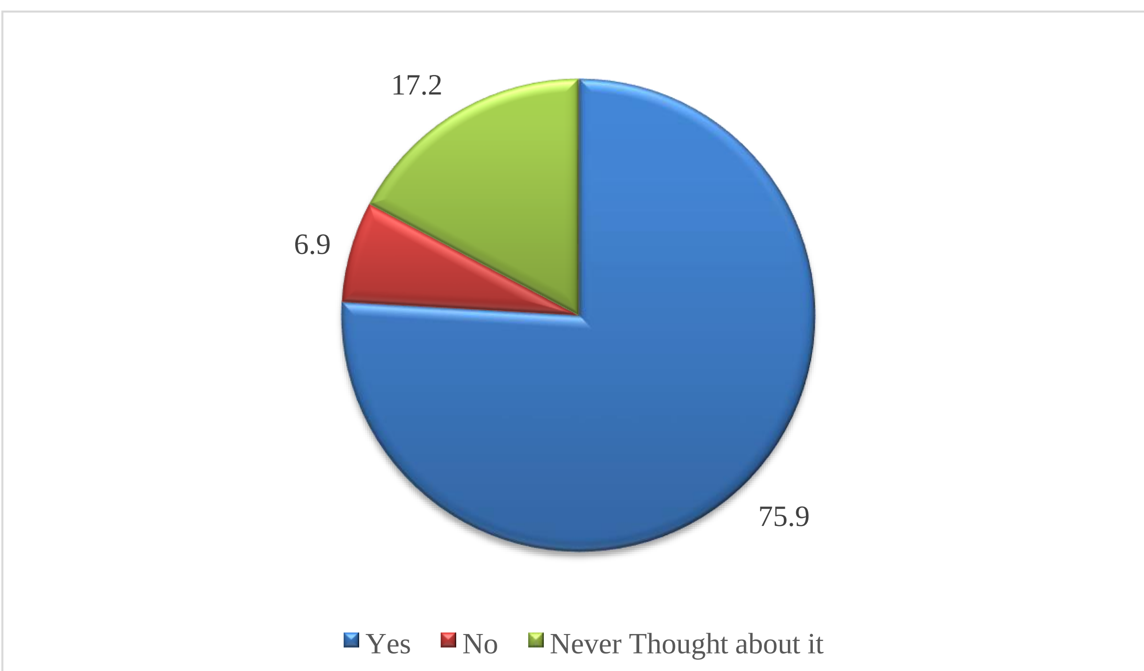


Figure 2.1: Tendency of planting

2. How many potted plants do you own?

a) 1-5

b) 5-10

c) More than 10

d) I don't own any

Table 2.3: Number of potted plants

Options	Response Count	Percentage (%)
1-5	16	27.6
5-10	16	27.6
More than 10	12	20.7
I don't own any	14	24.1

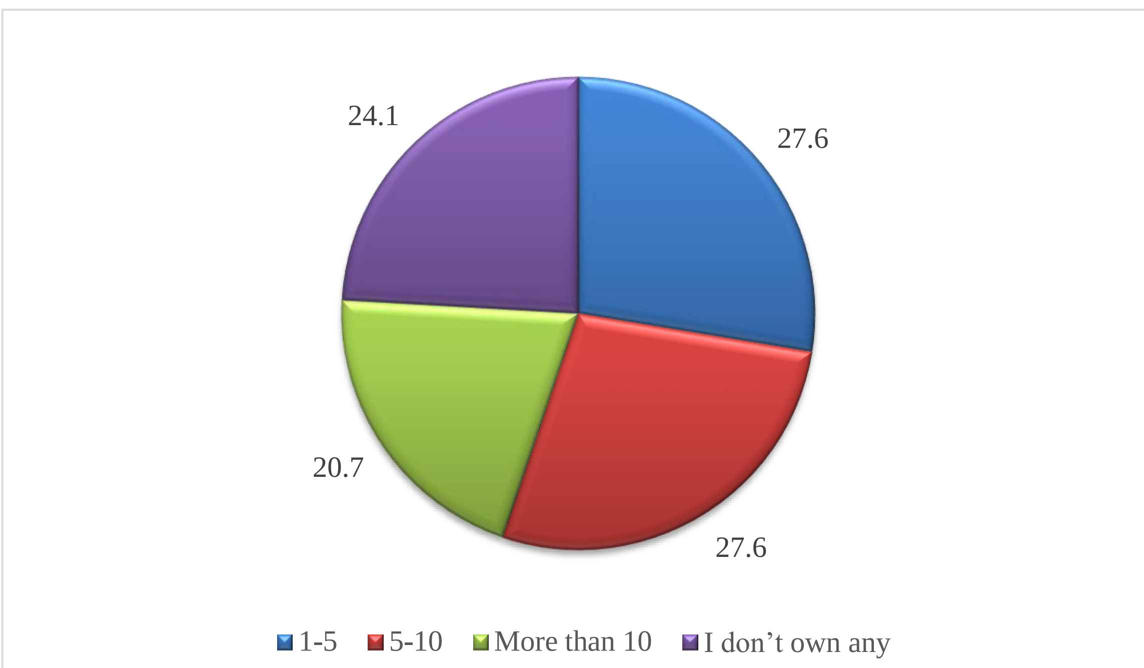


Figure 2.2: Number of potted plants

3. What do you consider the most while buying a potted plant?

a) Plant watering and spillage issue

b) Beautification of plants

c) Usefulness of plant

d) Other

Table 2.4: Customer preference for potted plants

Options	Response Count	Percentage (%)
Plant watering and spillage issue	20	34.4
Beautification of plants	30	51.8
Usefulness of plant	4	6.9
Other	4	6.9

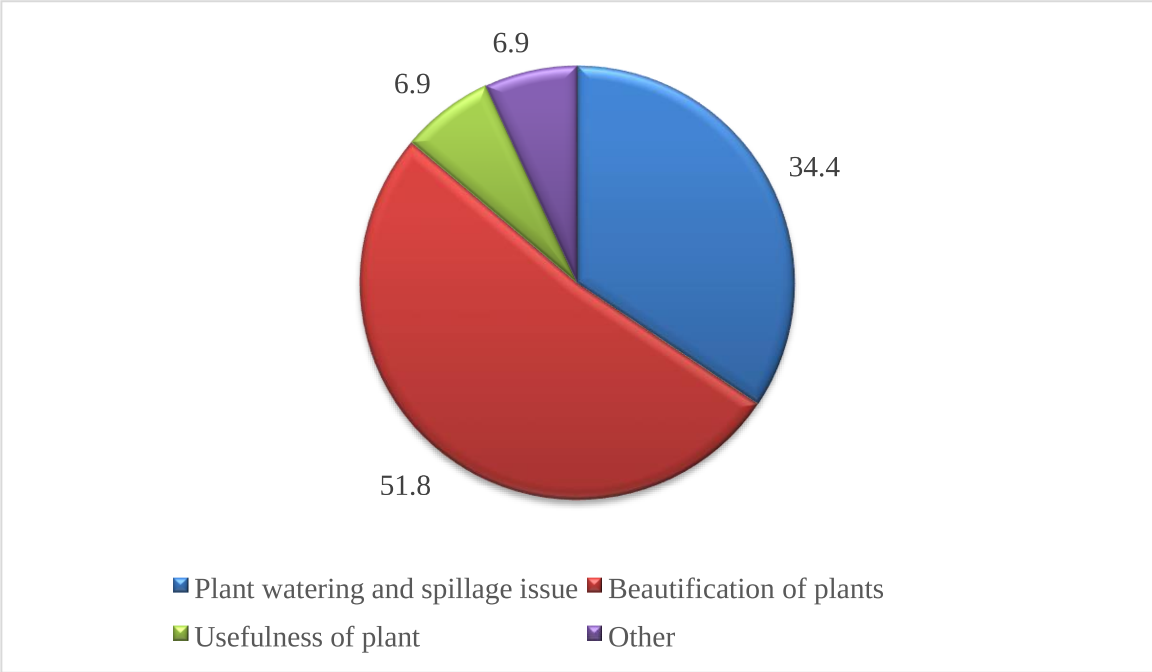


Figure 2.3: Customer preference for potted plants

4. How much time do you spend watering plants at your home/office space daily?

a) 5 - 10 minutes

b) 11 - 20 minutes

c) 20 - 30 minutes

d) More than 30 minutes

Table 2.5: Time spent on watering plants

Options	Response Count	Percentage (%)
5 - 10 minutes	38	65.6
11 – 20 minutes	16	27.6
20 - 30 minutes	2	3.4
More than 30 minutes	2	3.4

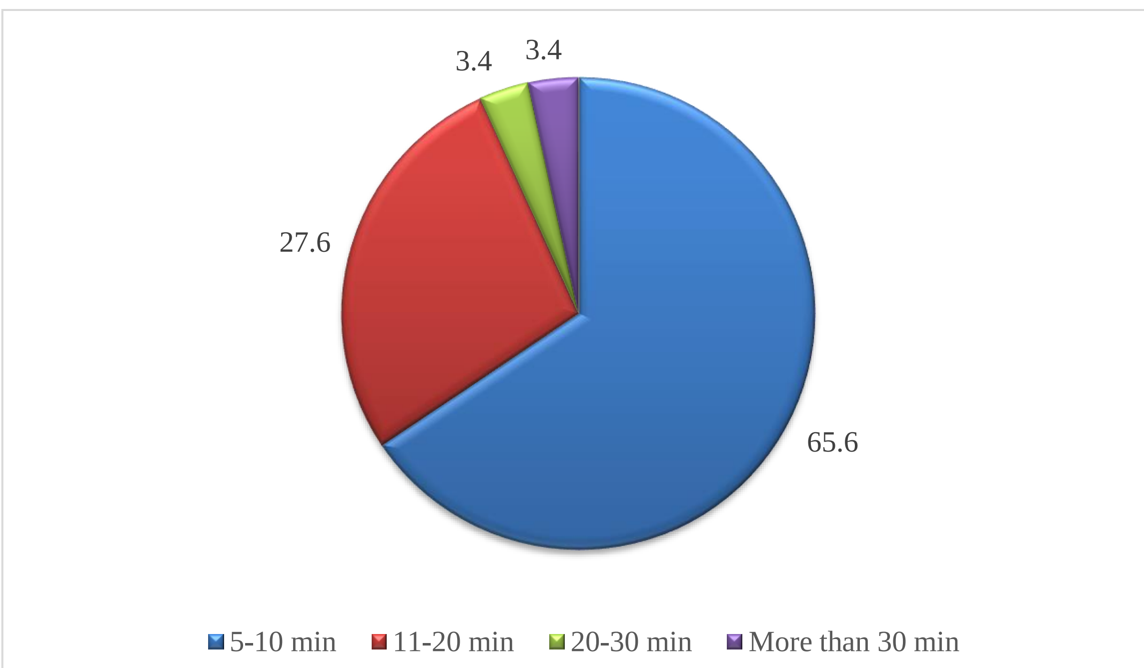


Figure 2.4: Time spent on watering plants

5. What are the obstacles to pursuing planting at home/office in your opinion?
a) Watering them every day
b) Plants dying out
c) Lack of space
d) Risk of mosquito and dengue

Table 2.6: Obstacles to planting

Options	Response Count	Percentage (%)
Watering them every day	24	41.4
Plants dying out	12	20.7
Lack of space	12	20.7
Risk of mosquito and dengue	10	17.2

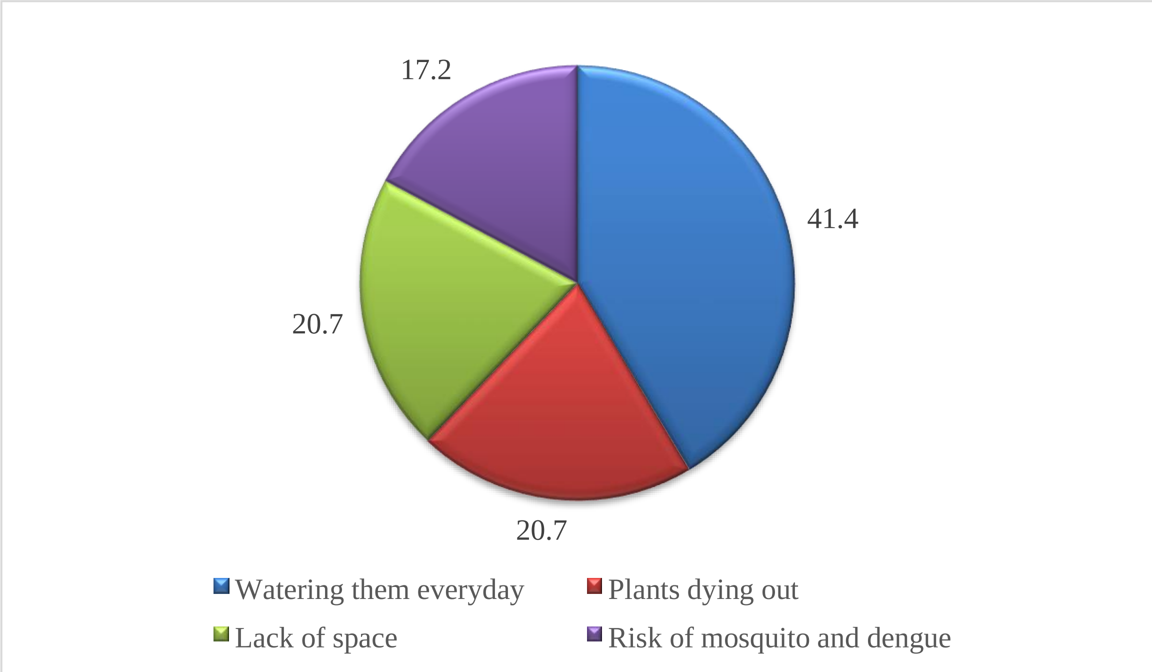


Figure 2.5: Obstacles to planting

6. How tiring do you feel about watering plants every day?
a) 1 (Enjoyable, not tiring at all)
b) 2
c) 3
d) 4
e) 5 (Monotonous and tiring)

Table 2.7: Feeling about watering the plants every day

Options	Response Count	Percentage (%)
1 (Enjoyable, not tiring at all)	14	24.1
2	14	24.1
3	12	20.7
4	6	10.3
5 (Monotonous and tiring)	12	20.7

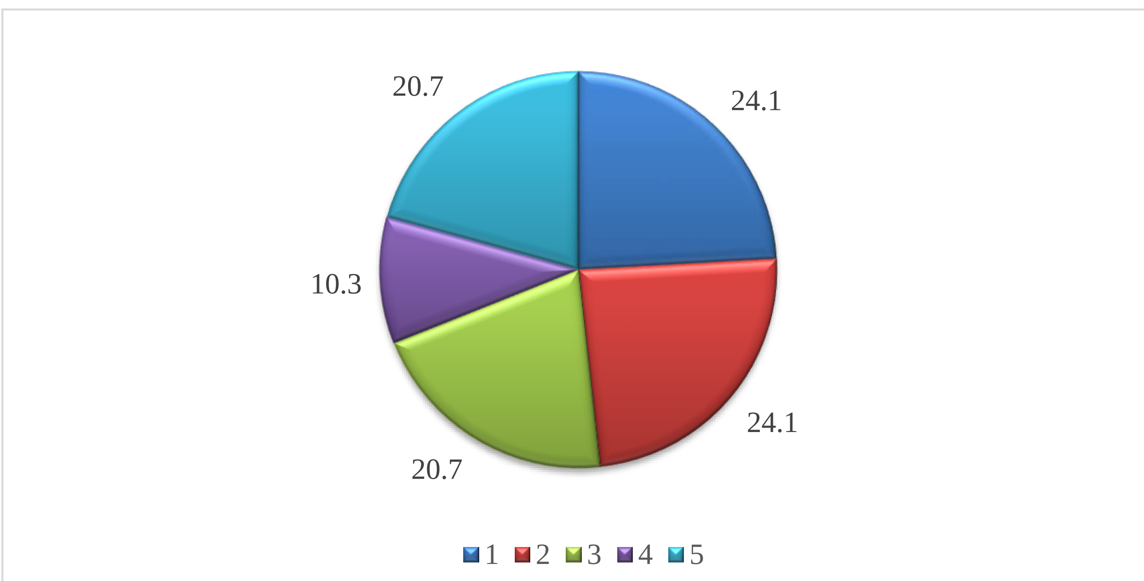


Figure 2.6: Feeling about watering the plants every day

7. How many times do you need to go out for a few days on a business trip/vacation leaving your plants unattended?

a) 1-2 times a year
b) 3-5 times a year
c) More than 5 times a year

Table 2.8: Frequency of leaving plants unattended

Options	Response Count	Percentage (%)
1-2 times a year	26	44.8
3-5 times a year	16	27.6
More than 5 times a year	16	27.6

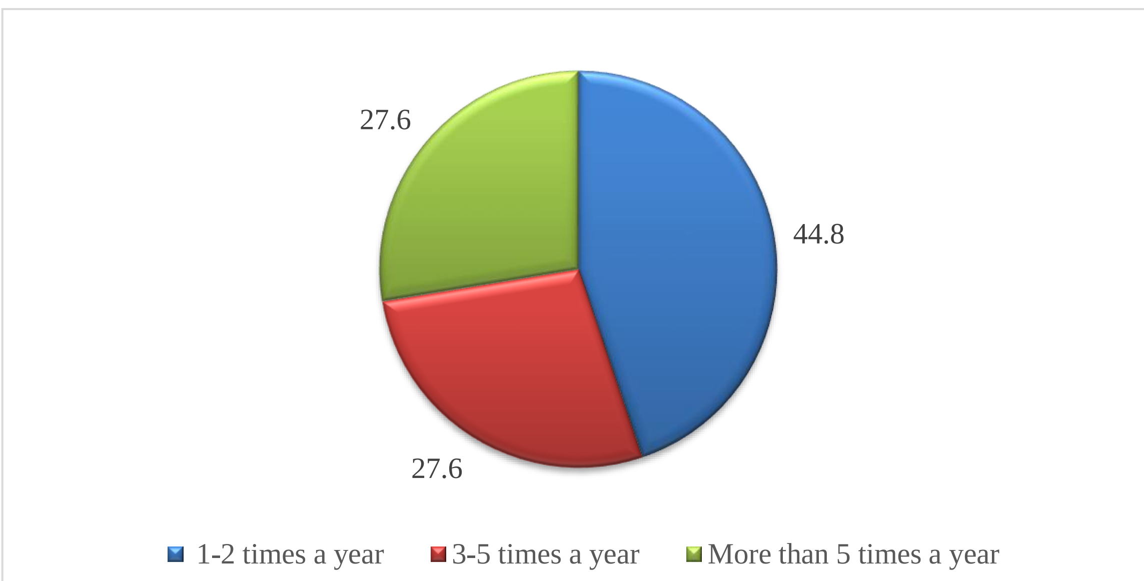


Figure 2.7: Frequency of leaving plants unattended

8. How often did you face difficulty in watering your plants while going away from home for a few days?

a) 1 (Never faced difficulty)

b) 2

c) 3

d) 4

e) 5 (Often faced difficulty)

Table 2.9: Difficulty in watering plants while away from home

Options	**Response Count**	**Percentage (%)**
1 (Never faced difficulty)	12	20.7
2	6	10.3
3	20	34.5
4	6	10.3
5 (Often faced difficulty)	14	24.1

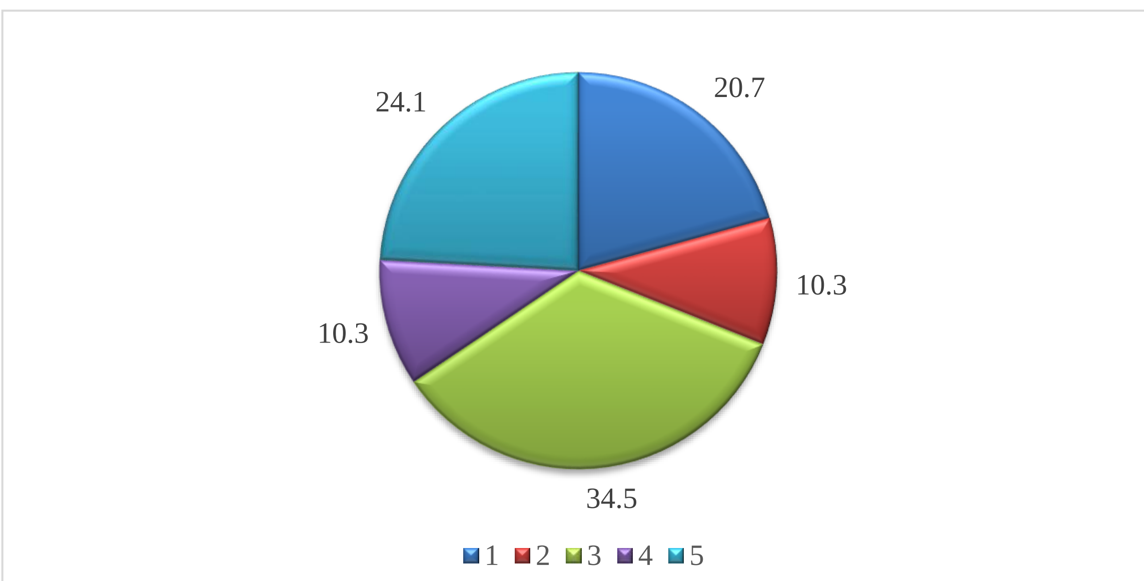


Figure 2.8: Difficulty in watering plants while away from home

9. Would you be interested in buying automatic watering pots for plants?

a) Yes

b) No

c) Maybe, depends on other features

Table 2.10: People's interest in our product

Options	Response Count	Percentage (%)
Yes	26	44.8
No	6	10.3
Maybe, depends on other features	26	44.8

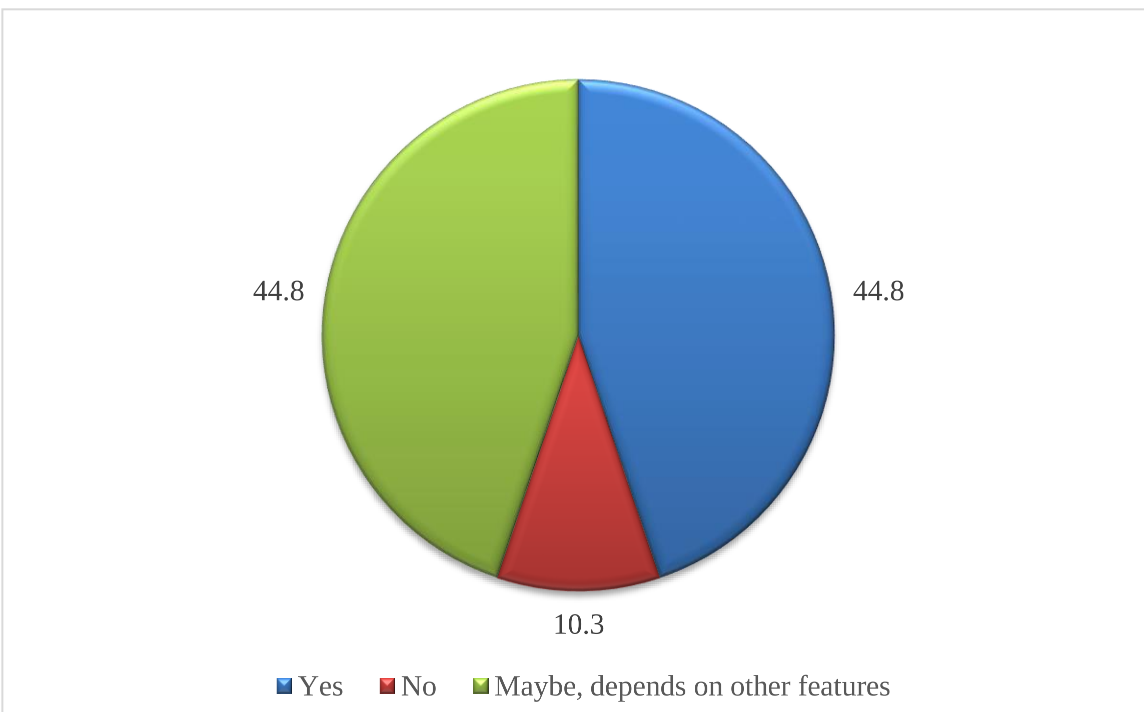


Figure 2.9: People's interest in our product

10. How much are you willing to spend on automatic watering plant pots?

a) 3000-4000

b) 4000-5000

c) 5000+

Table 2.11: Amount people willing to spend on our product.

Options	Response Count	Percentage (%)
3000-4000	48	82.8
4000-5000	8	13.8
5000+	2	3.4

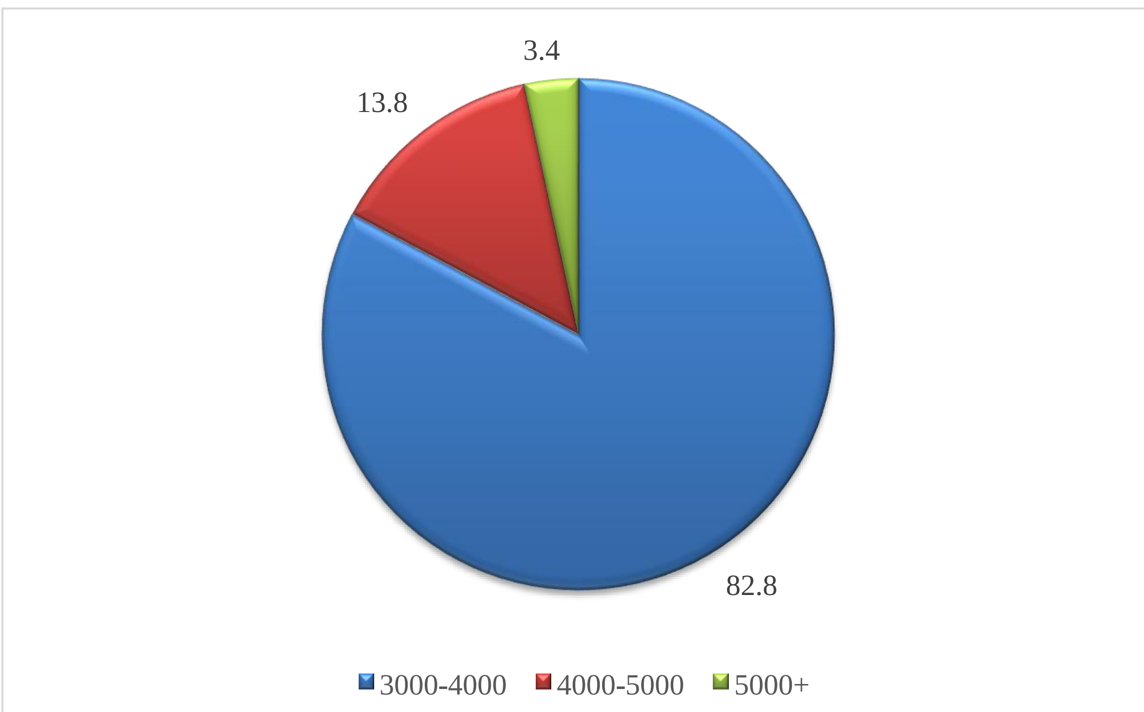


Figure 2.10: Amount people willing to spend on our product

11. Would you have more potted plants in your home/office space if regular watering wasn't an issue?

a) Yes

b) No

c) Maybe

Table 2.12: People’s tendency to have more plants after the problems are resolved

Options	Response Count	Percentage (%)
Yes	30	51.7
No	20	34.5
Maybe	8	13.8

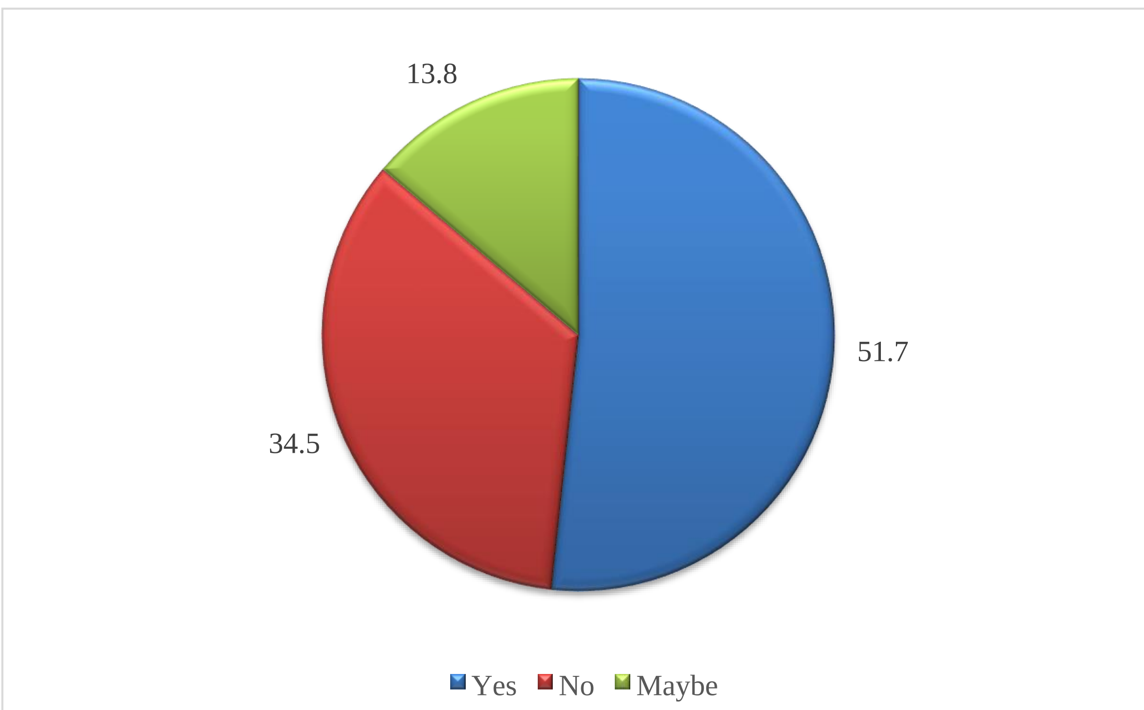


Figure 2.11: People’s tendency to have more plants after the problems are resolved

12. What features would you like to see in such automatic water plants?

a) An interactive screen indicating plant water level

b) Affordable price

c) Handy design

d) Multi-purpose

Table 2.13: Wanted features in our product

Options	**Response Count**	**Percentage (%)**
An interactive screen indicating plant water level	14	24.1
Affordable price	22	37.9
Handy design	10	17.2
Multi-purpose	12	20.7

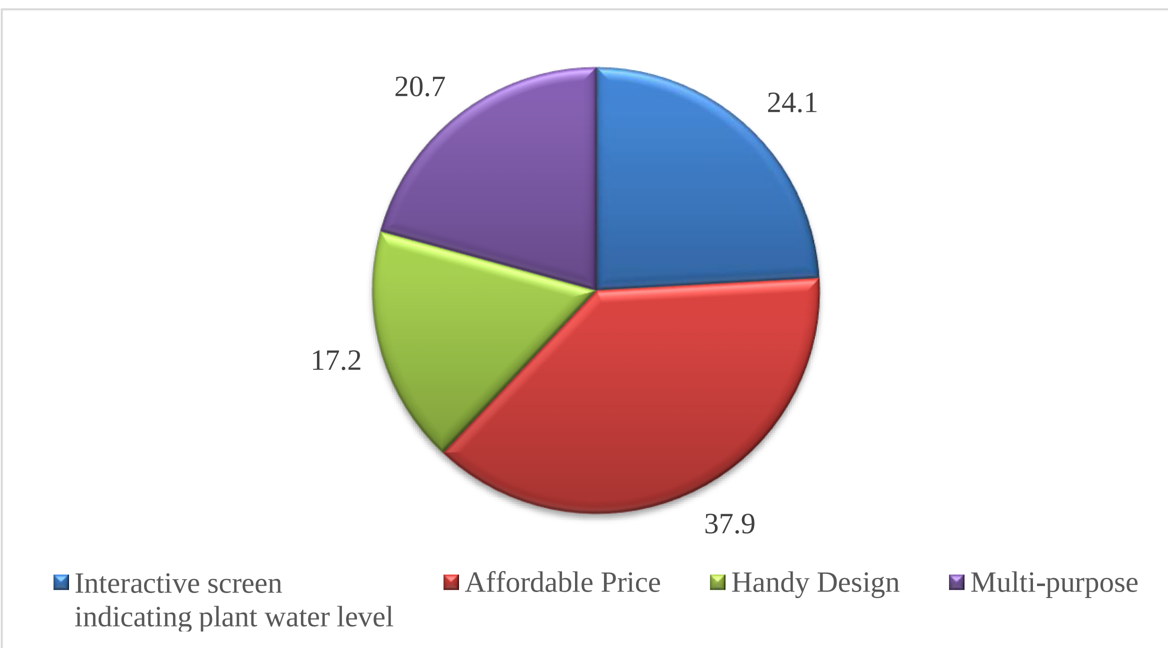


Figure 2.12: Wanted features in our product

13. Do you feel the air to be dry and dusty recently due to air pollution?

a) Yes

b) No

c) Maybe in some weather

Table 2.14: Presence of air pollution

Options	Response Count	Percentage (%)
Yes	44	75.9
No	6	10.3
Maybe in some weather	8	13.8

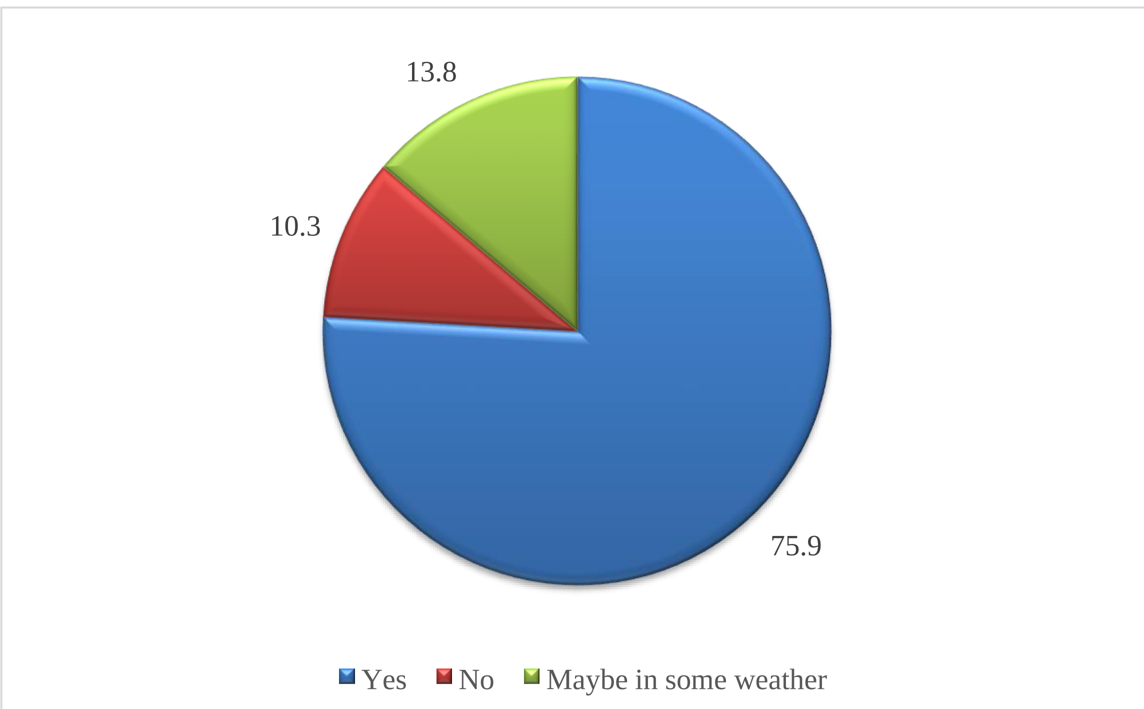


Figure 2.13: Presence of air pollution

14. How many hours a day you are exposed to dry/industry air in your home/workspace?

a) 2-4 hours

b) 5-10 hours

c) 11-14 hours

d) More than 15 hours

Table 2.15: People's exposure time to dry/industry air

Options	Response Count	Percentage (%)
2-4 hours	20	34.5
5-10 hours	30	51.7
11-14 hours	6	10.3
More than 15 hours	2	3.4

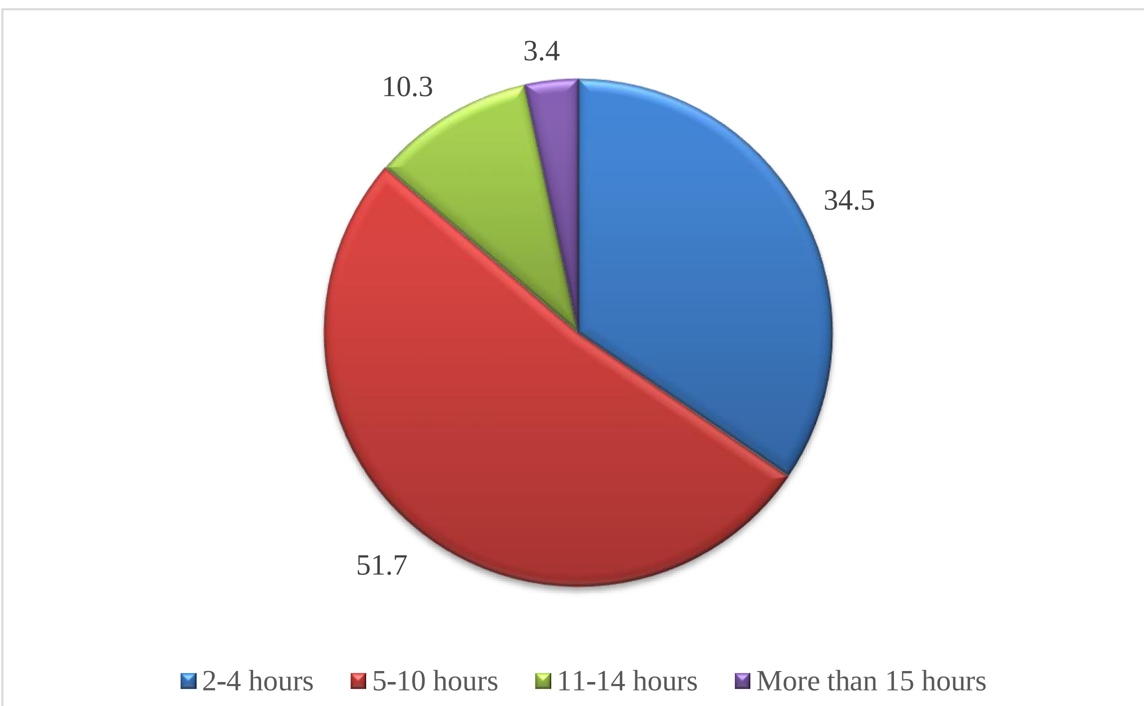


Figure 2.14: People's exposure time to dry/industry air

15. How strongly have you considered buying an air purifier/humidifier for your work/office space?

a) 1 (Never considered buying one)

b) 2

c) 3

d) 4

e) 5 (Strongly considered buying one)

Table 2.16: People's tendency to buy an air purifier

Options	**Response Count**	**Percentage (%)**
1 (Never considered buying one)	10	17.2
2	8	13.8
3	8	13.8
4	10	17.2
5 (Strongly considered buying one)	22	37.9

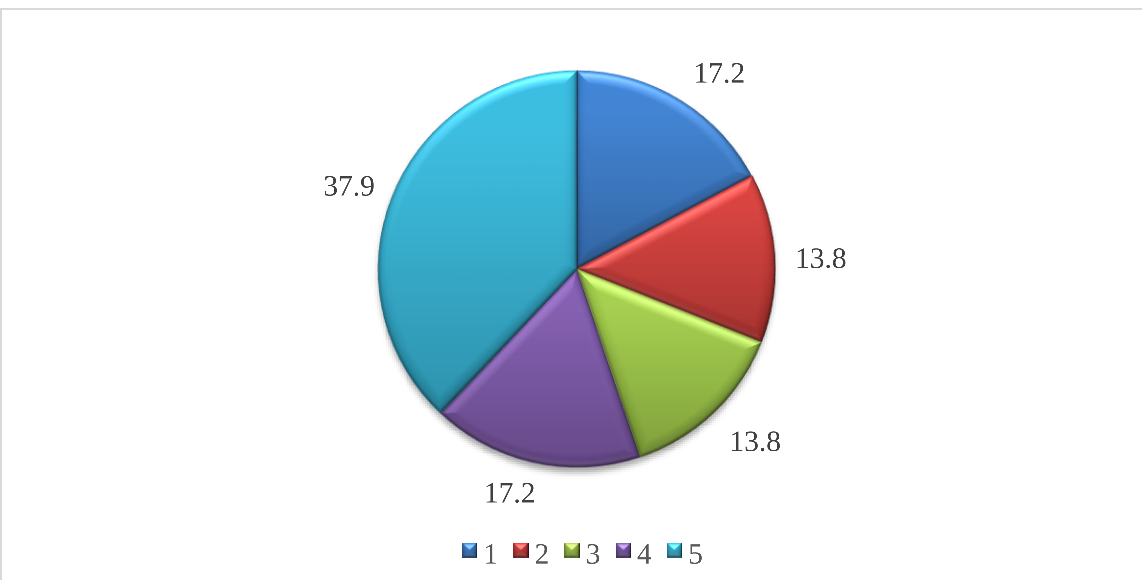


Figure 2.15: People's tendency to buy an air purifier

16. What do you think is the primary obstacle in buying an air humidifier/purifier?

a) High Price

b) Bulky Size for setup

c) High Electricity consumption

d) Lack of portability

Table 2.17: Price expectation for humidifier/purifier

Options	**Response Count**	**Percentage (%)**
High price	36	62.1
Bulky Size for setup	8	13.8
High Electricity consumption	8	13.8
Lack of portability	6	10.3

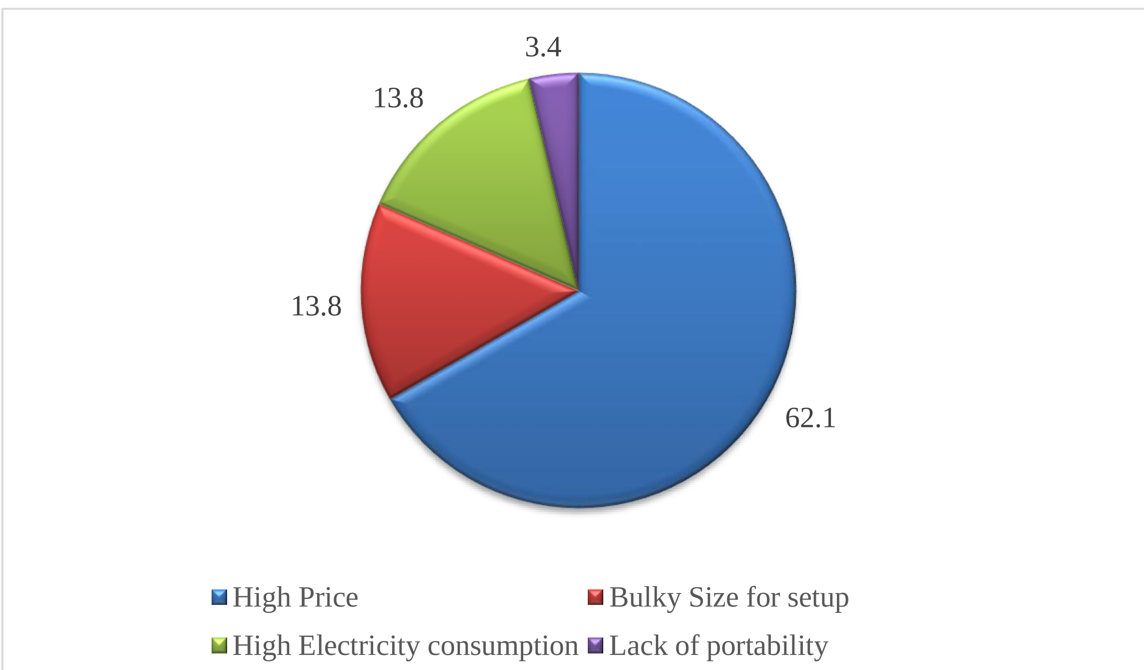


Figure 2.16: Price expectation for humidifier/purifier

17. Would you be more interested in buying an affordable air humidifier/purifier if it was compact in size and multi-purpose?

a) Yes

b) No

c) Maybe, depends on other features

Table 2.18: Interests in buying humidifier/purifier

Options	**Response Count**	**Percentage (%)**
Yes	36	62.1
No	4	6.9
Maybe, depends on other features	18	31

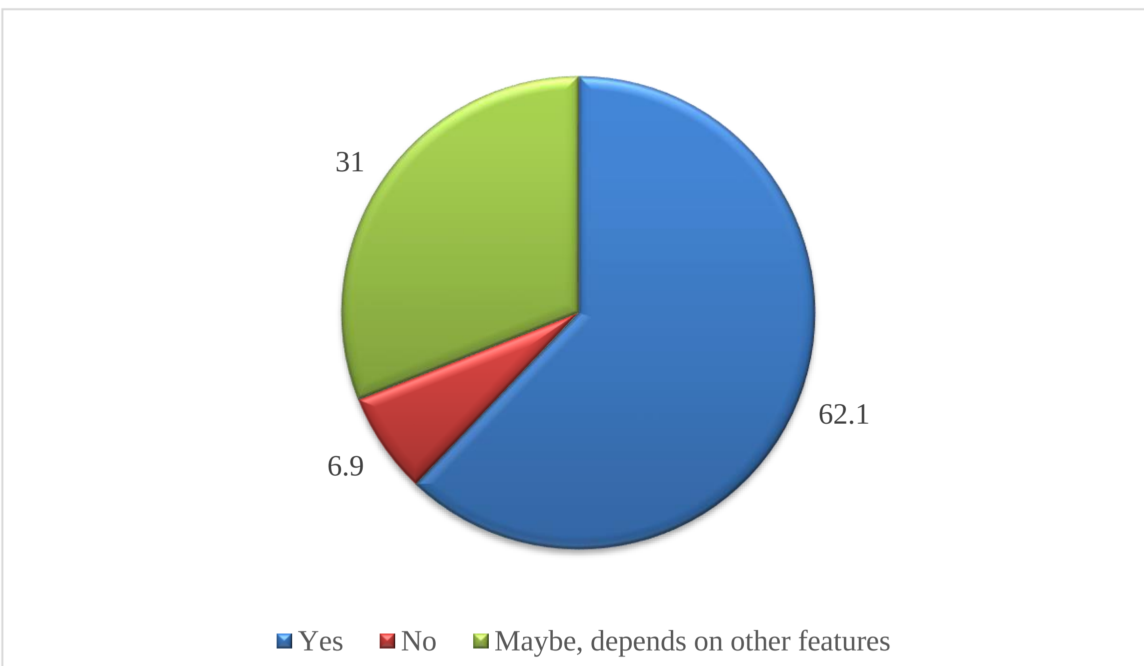


Figure 2.17: Interests in buying humidifier/purifier

18. How much are you willing to pay for such an air humidifier/purifier?

a) Less than 2000

b) 2000 - 3000

c) 3000 - 4000

d) More than 4000

Table 2.19: Price expectation of the buyer

Options	Response Count	Percentage (%)
Less than 2000	24	41.4
2000 - 3000	20	34.5
3000 – 4000	12	20.7
More than 4000	2	3.4

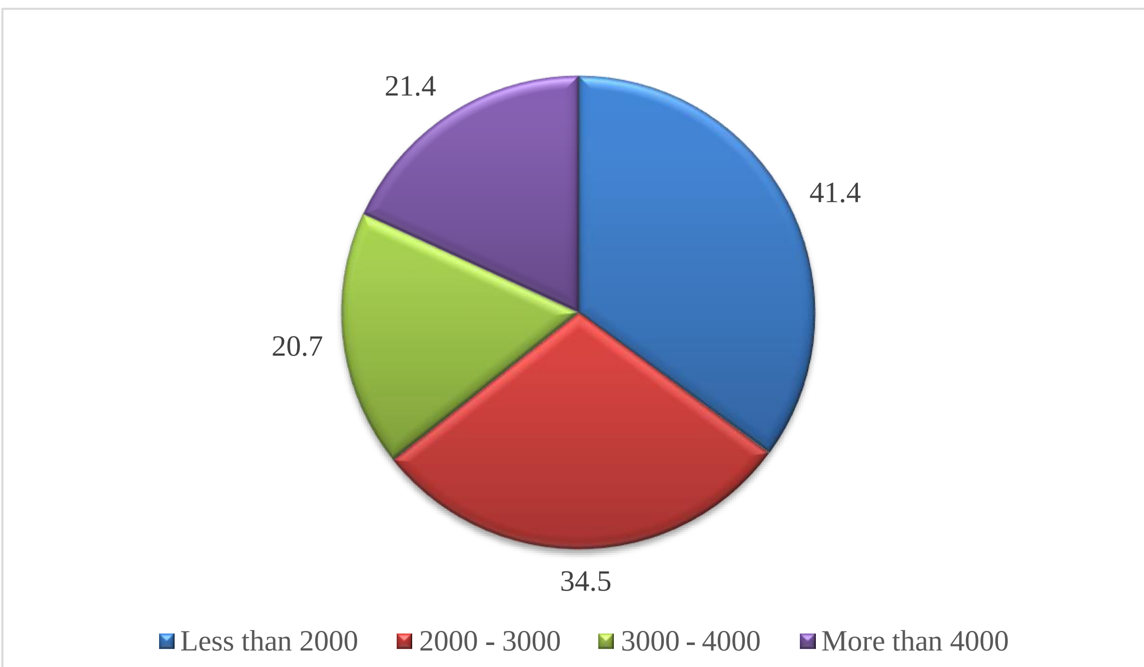


Figure 2.18: Price expectation of the buyer

19. Would you be more interested in buying a compact automatic plant watering pot with an air humidifier?

a) Yes

b) No

c) Maybe, depends on other features

Table 2.20: Interests in buying the product

Options	Response Count	Percentage (%)
Yes	40	69
No	6	10.3
Maybe, depends on other features	12	20.7

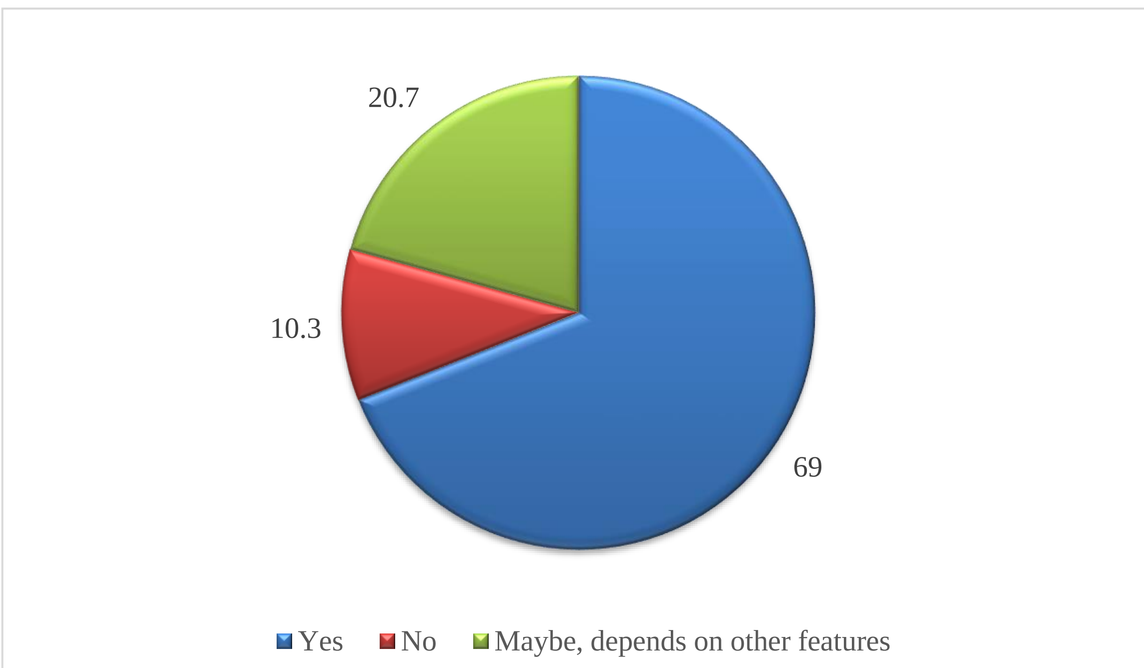


Figure 2.19: Interests in buying the product

20. What do you think would be most beneficial for an automatic plant watering pot with an air humidifier?

a) Multi-purpose

b) Compact in size

c) Comfort of use

d) Price

Table 2.21: Most beneficial aspect of the product

Options	Response Count	Percentage (%)
Multi-purpose	30	51.7
Compact in size	8	13.8
Comfort of use	8	13.8
Price	12	20.7

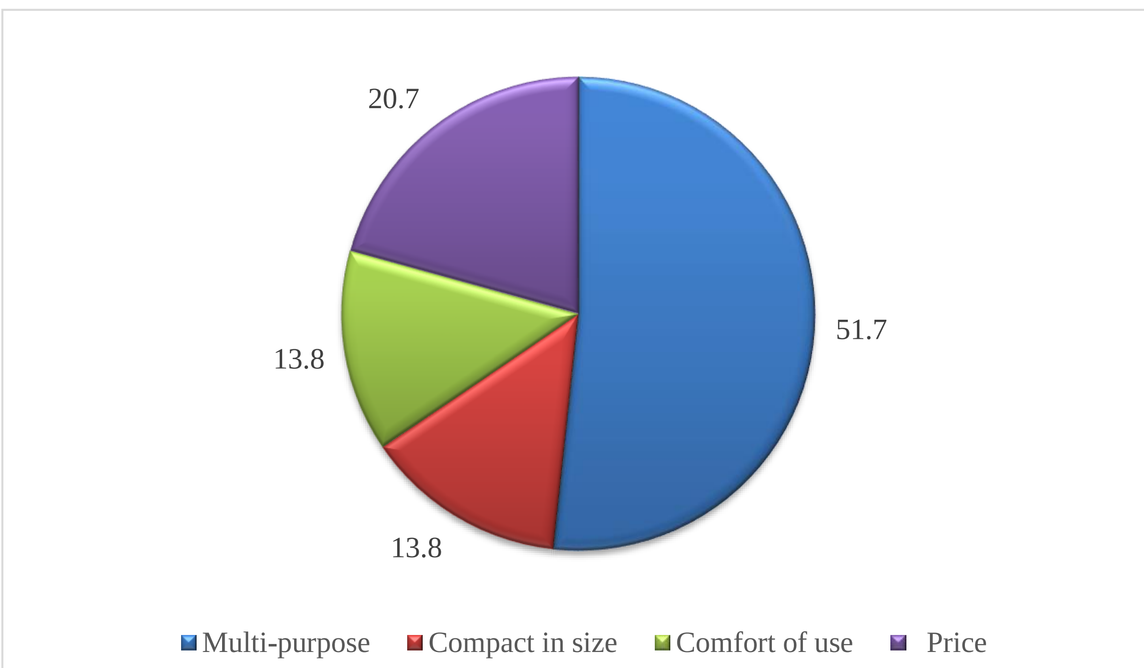


Figure 2.20: Most beneficial aspect of the product

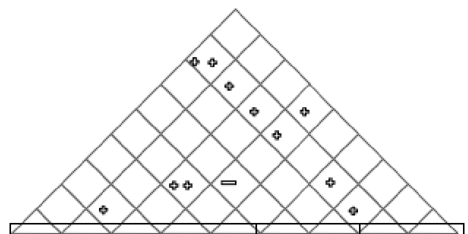
2.2 Customer Requirement Evaluation

This survey is primarily designed to gather customer feedback on the "Intelligent Automatic Plant Watering System". Customer survey results revealed that some significant product attributes are most valued by customers. As a result, we gave these characteristics relatively greater importance, while also considering other characteristics to enhance the product's quality. After compiling all the data from the survey Customer requirements were categorized into nine groups and each was evaluated on a relative importance scale of 10. The results are shown below:

3.2 House

Relationships	
Strong Relationship (6)	*
Moderate Relationship (3)	#
Weak Relationship (1)	^
No Relationship (0)	

Correlati
Strong Positiv
Weak Positive
No Relationshi
Weak Negative
Strong Negativ



		Engineering Requirements / Customer Requirements	Customer Rating	Mechanical & Electrical: 1 Motor	2 Pot with Attached Display	3 Moisture Sensor	4 Reservoir	5 Control Box	Physical: 6 Material	7 Design	Cost: 8 Manufacturing Cost	9 Operational Cost	Our Company	Treevaly	Sam's Solution
1	Functionality	Detachability	8		*		*	*		*			10	0	0
2		Portability	10						#	*		^	8	10	10
3		Flexibility	10			^		*		*			8	0	5
4	Appearance	Simple Design	8						#	*	*		8	10	10
5		Aesthetics	8		*					^	*		8	10	10
6	Maintainability	Less Space	10							*			8	10	10
7		Repairable	10		#			*		*	#	*	10	5	8
8	Cost	Maintenance Cost	10	*			^	*					8	10	8
9		Repairing Cost	8	*		*	^	*					10	0	8
		Performance Rating		108	126	58	66	284	102	344	126	70			

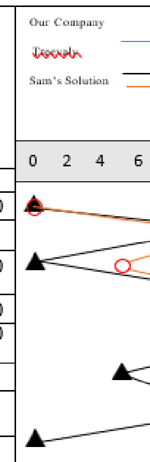


Table 2.22: Relative Importance of customer requirements

Customer Requirement	Relative Importance (Scale of 10)

Portability	8
Comfortable	7
Low Cost	9
Maintainability	6
Reliability	7
Environmental Benefit	10
High Capacity	8
Safety	7
Stability	6

After being finished with surveying, we now can move to the next step for developing the House of Quality.

Chapter – 3

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

3.1 Introduction

The voice of the customer is the collection and synthesis of the customers' ideas, concerns, priorities, and feedback, on a particular product, service, process, or project**.** The application voiceof the customer can and should be applied to most problem-solving that happens across an organization. A widely used form of VOC market research produces a detailed set of customer wants and needs, organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives. The Voice of the customer's studies typicallyconsist of both qualitative and quantitative research steps and are generally conducted at the start of any new product, process, or service design initiative to better understand the customer's wantsand needs, and as the key input for new product definition.

According to the Japanese Quality Function Deployment (QFD), "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. Manytechniques 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:

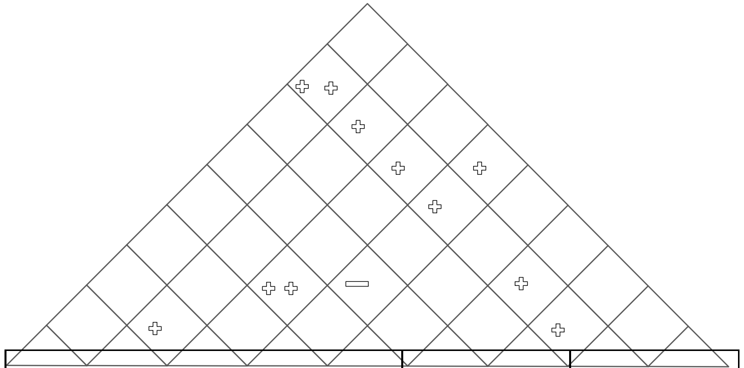
1. Listening to the voice of the customers
2. Improving teamwork
3. Improving production efficiency

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 and targets to work toward.

Since we have already collected customer needs by conducting the 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 House of Quality

Relationships	
Strong Relationship (6)	*
Moderate Relationship (3)	#
Weak Relationship (1)	^
No Relationship (0)	



Correlations	
Strong Positive	+ +
Weak Positive	+
No Relationship	
Weak Negative	−
Strong Negative	− −

		Engineering Requirements / Customer Requirements	Customer Rating	Mechanical & Electrical 1 Motor	2 Pot with Attached Display	3 Moisture Sensor	4 Reservoir	5 Control Box	Physical 6 Material	7 Design	Cost 8 Manufacturing Cost	9 Operational Cost	Our Company	Treevaly	Sam's Solution
1	Functionality	Detachability	8		*		*	*		*			10	0	0
2		Portability	10						#	*		^	8	10	10
3		Flexibility	10			^		*		*			8	0	5
4	Appearance	Simple Design	8						#	*	*		8	10	10
5		Aesthetics	8		*					^	*		8	10	10
6	Maintainability	Less Space	10							*			8	10	10
7		Repairable	10		#			*		*	#	*	10	5	8
8	Cost	Maintenance Cost	10	*			^	*					8	10	8
9		Repairing Cost	8	*		*	^	*					10	0	8
		Performance Rating		108	126	58	66	284	102	344	126	70			

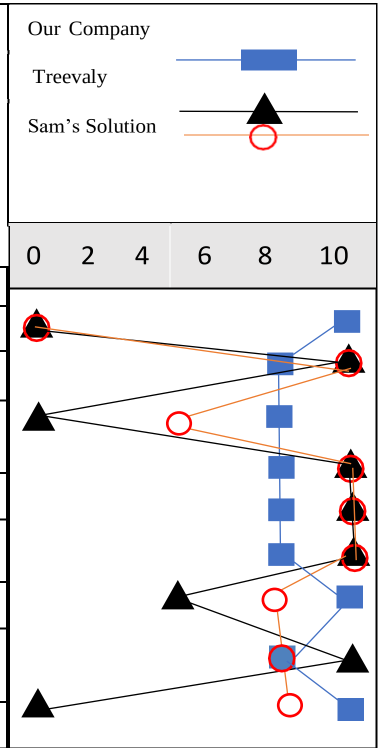


Figure 3.1: House of Quality for Intelligent Plant Watering System with Air Humidifier

3.3 Customer Requirements & Engineering Requirementsrelationship

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

Table 3.1: Relationship explanation

Customer Requirements	Engineering Requirements	Relationship	Explanation
Detachability	Design	Strong	The product is designed in such a way that its part can be detached also can be assembled.
	Black Box	Strong	Contains Arduino, a Motor, and also detachable
	Reservoir	Strong	Contains water that is also detachable
	Pot with display	Strong	Display, as well as pot, are also detachable
Portability	Design	Strong	The product is designed in such a way that it can be easily handled with less weight
	Material	Moderate	Material with moderate weight is used here
	Operational cost	Weak	Sometimes portability creates some cost
Flexibility	Design	Strong	Flexible Design and easy to set up
	Black Box	Strong	That contains Arduino, the motor is flexible enough to pour water for any condition
	Moisture Sensor	Weak	Flexible enough to calculate any range of moisture level

Customer Requirements	Engineering Requirements	Relationship	Explanation
Simple Design	Design	Strong	Design is simple and easy to manufacture
	Manufacturing Cost	Strong	The complexity of design comes with more cost
	Material	Moderate	Moderately priced material used in this product
Aesthetic	Design	Weak	Design can have little influence on a product's aesthetic
	Manufacturing Cost	Strong	Making eye-pleasing aesthetic products comes with more cost
	Pot with attached Display	Strong	Eye-pleasing, colorful products are more aesthetic looking
Less Space	Design	Strong	The design is compact so that it takes less space
	Manufacturing Cost	Moderate	The compact product takes less space and also sometimes comes with less cost
Repairable	Design	Strong	Design is made in such a way that it can be easily repaired
	Operational Cost	Strong	Repairing the product makes the operational cost higher
	Black Box	Strong	Arduino, sensors are repairable also can be easily replaced
	Motor	Strong	The motor also can be repaired easily
Maintenance Cost	Black Box	Weak	Arduino, sensors have strong relationships with the maintenance cost.
	Reservoir	Weak	The reservoir has little effect on cost as it also needs some maintenance.

Customer Requirements	Engineering Requirements	Relationship	Explanation
Repairing Cost	Pot with Display	Moderate	In case of our display or pot needs repairing there is some cost involved
	Black Box	Strong	Arduino and other things can have a great impact on cost in terms of repairing
	Reservoir	Weak	Even sometimes water reservoir needs repairing
	Motor	Strong	If the motor that will pump water doesn't work well, repairing is needed so the cost is involved here.
	Sensor	Strong	To make the sensor functional the whole time, it also needs repairing, therefore cost is involved here
Environmental Benefit	Design	Strong	Our design is environment friendly
	Material	Moderate	Material that is involved in this product has little or no bad impact on the environment
	Black Box	Weak	No bad impact on the environment

3.4 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	Motor	108
2	Pot with attached Display	126
3	Moisture Sensor	58
4	Reservoir	66
5	Control Box	284
6	Material	102
7	Design	344
8	Manufacturing Cost	126
9	Operational Cost	70

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 systems that 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 Intelligent Automatic Plant Watering System with Air Humidifier is given below:

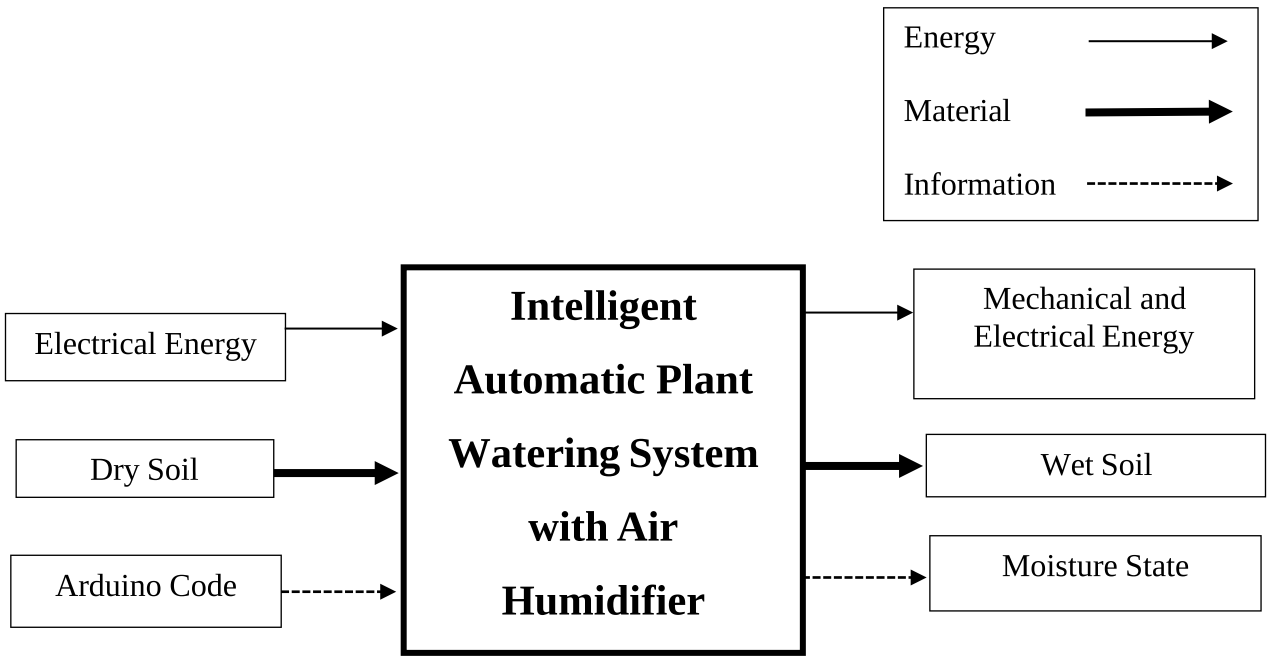


Figure 4.1: Black box model of Intelligent Automatic Plant Watering System with Air Humidifier

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

1. **Energy flow:** Our product will receive power from a DC source which will run the motor (mechanical energy) and power the Arduino (electrical energy)
2. **Material flow:** Considering the black box as a function our input is dry soil and our output will be wet soil.
3. **Information flow:** The moisture sensor will signal the Arduino which in response will regulate the moisture state. A digital display will show the moisture status.

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 sub-assembly. When the function of all sub-assemblies is satisfied, the prime function (compactingthe 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 atthe expense of understanding interactions between sub-assemblies.

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

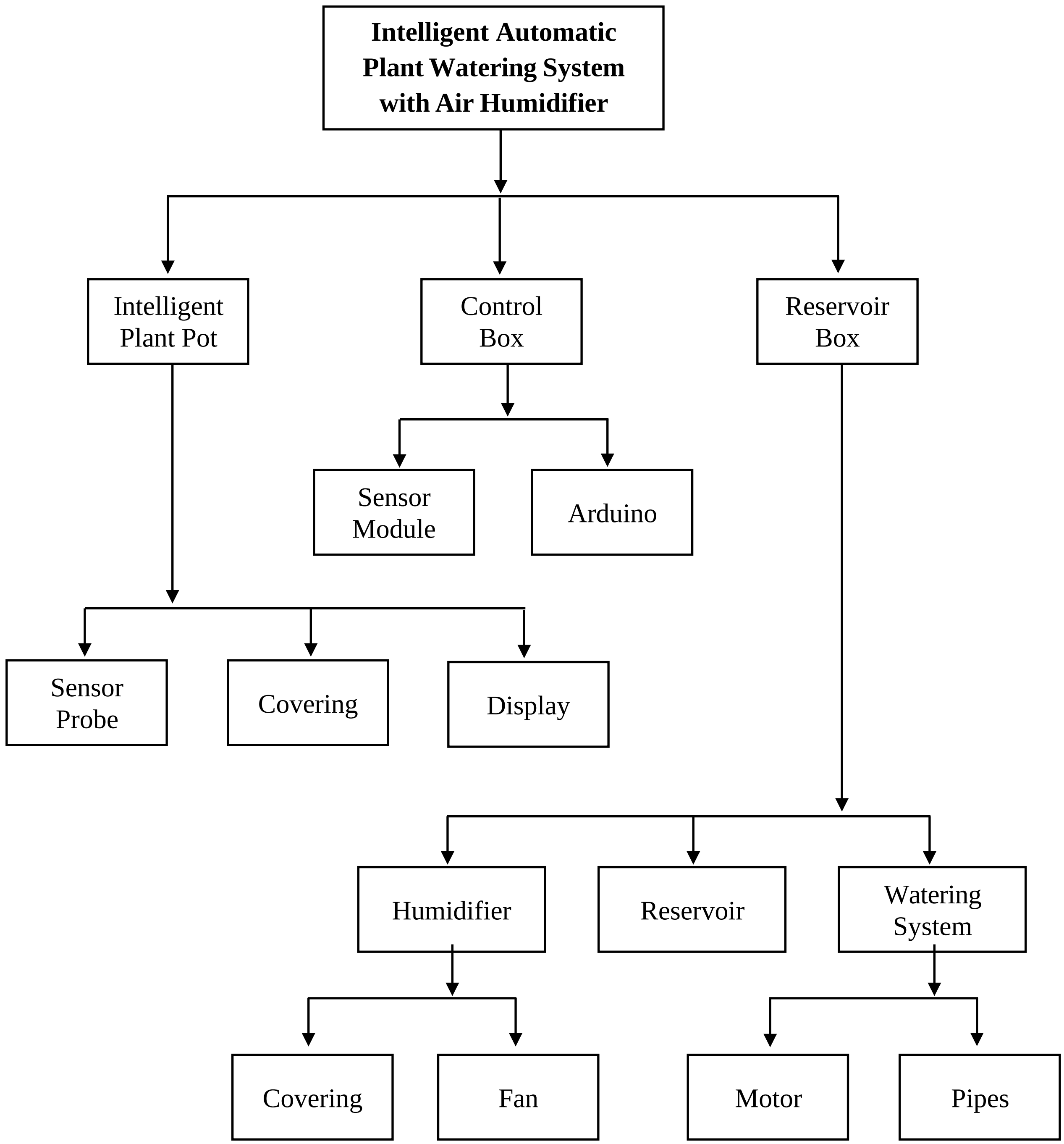


Figure 4.2: Component Hierarchy of Intelligent Automatic Plant Watering System with Air Humidifier

4.4 Cluster Function Structure of Intelligent Automatic Plant Watering System with Air Humidifier

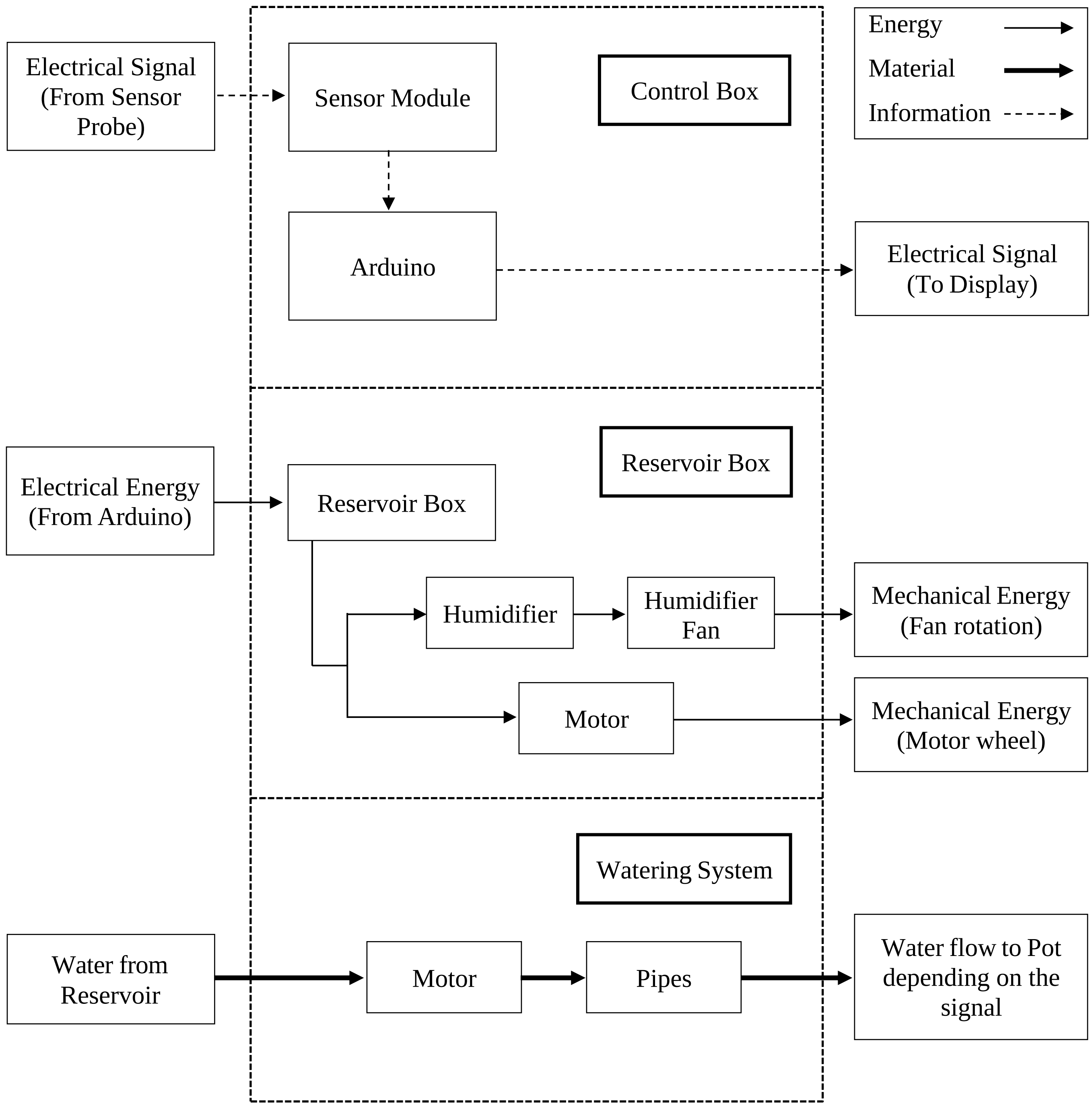


Figure 4.2: Cluster Function of Intelligent Automatic Plant Watering System with Air Humidifier

Chapter-5

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 Intelligent Automatic Plant watering system with air humidifier

5.2.1 Plant Pot

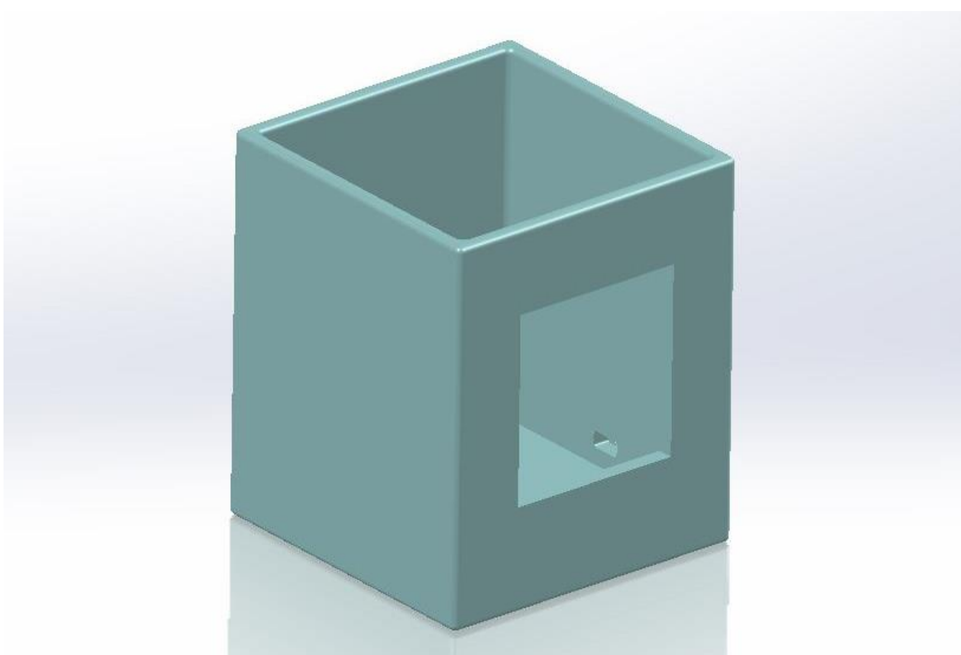


Figure 5.1 : Plant Pot

5.2.2 Sensor and Coverings

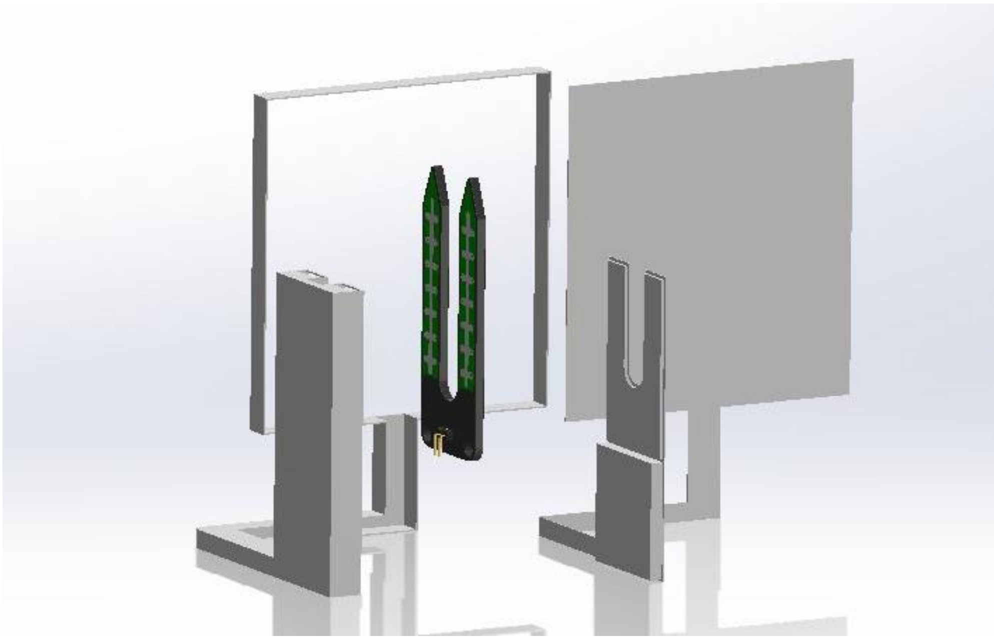


Figure 5.2: Sensor and Coverings

5.2.3 Plant Pot with sensor and display (Exploded View)

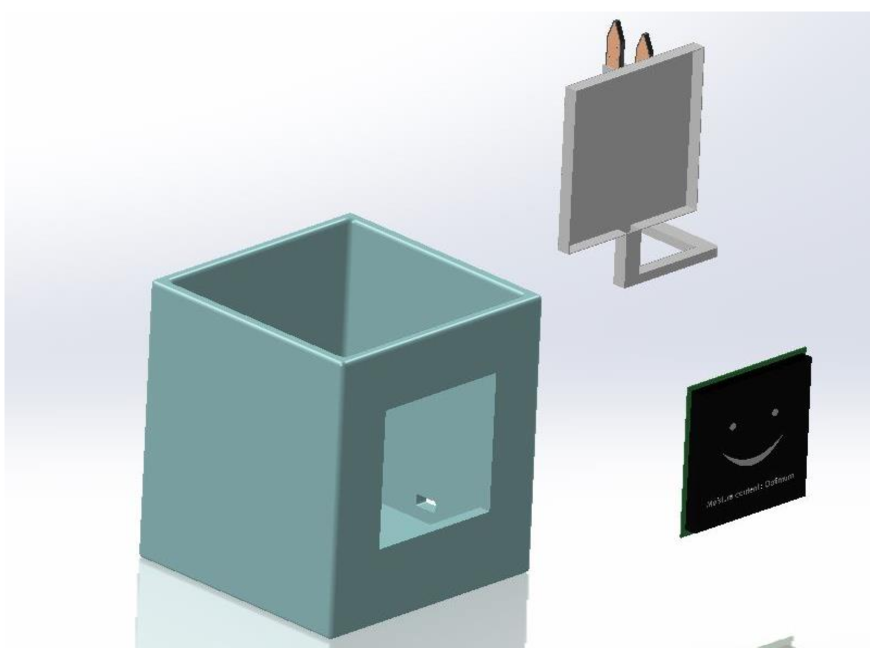


Figure 5.3: Plant Pot with sensor and display (Exploded View)

5.2.4 Control Box (Exploded View)

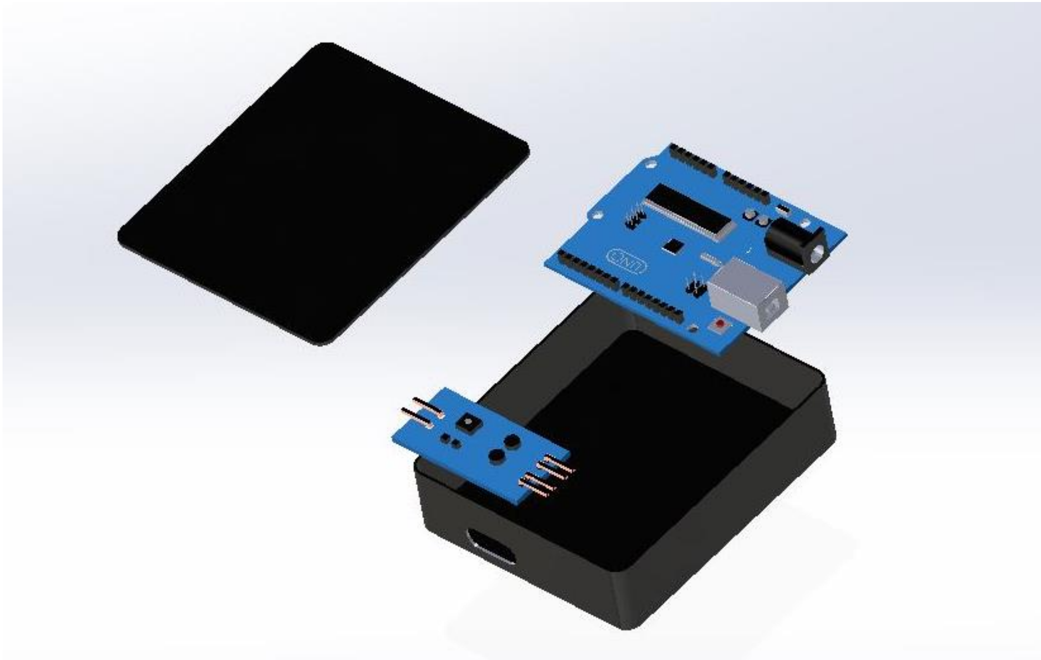


Figure 5.4: Control Box (Exploded View)

5.2.5 Humidifier Blower

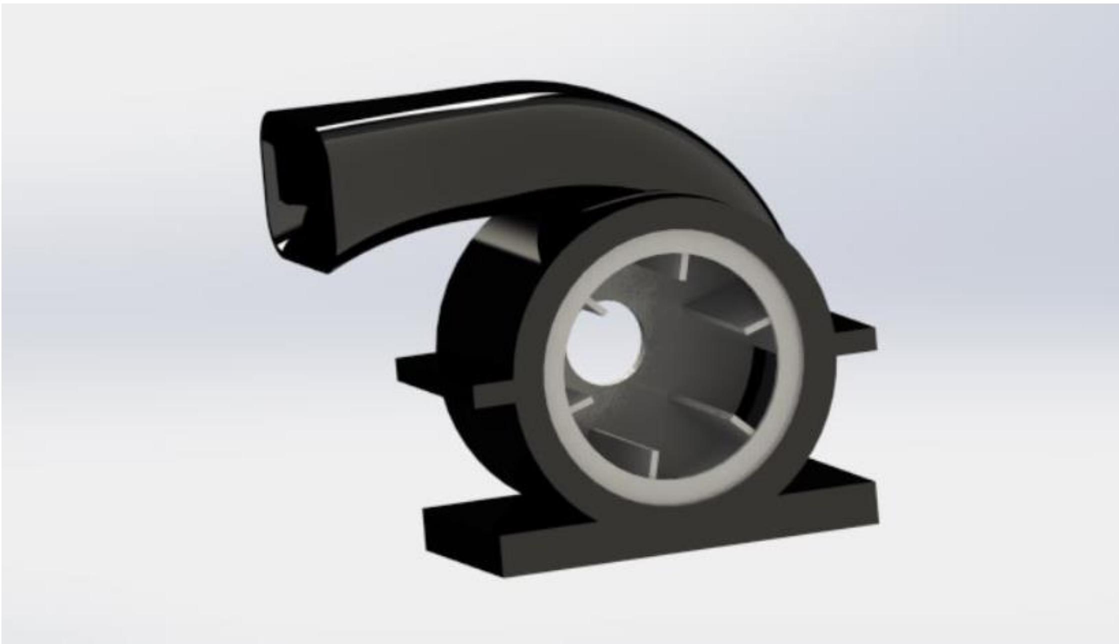


Figure 5.5: Humidifier Blower

5.2.6 Motor

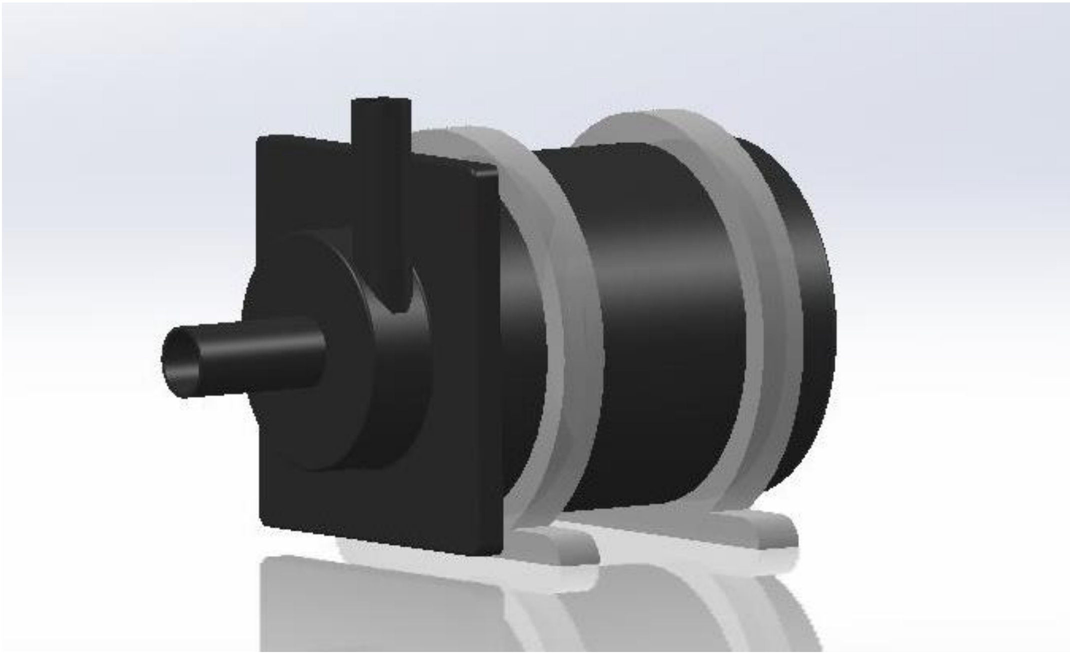


Figure 5.6: Motor

5.2.7 Reservoir with Humidifier and Control box (Exploded view)

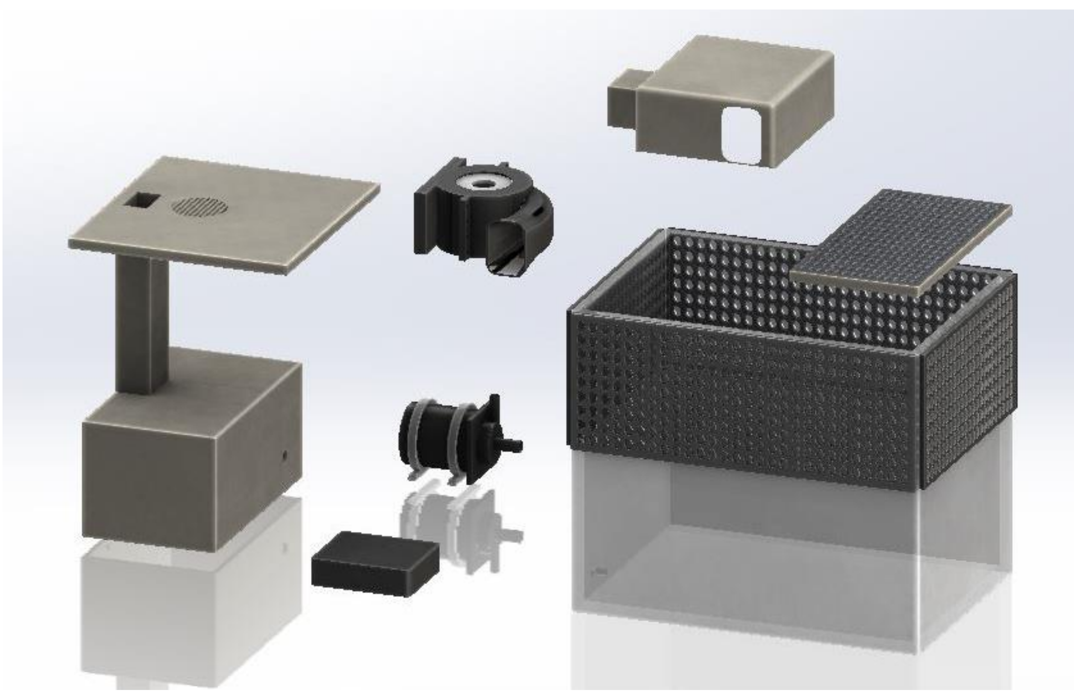


Figure 5.7: Reservoir with Humidifier and Control box (Exploded view)

5.2.8 Reservoir with Humidifier and Control box

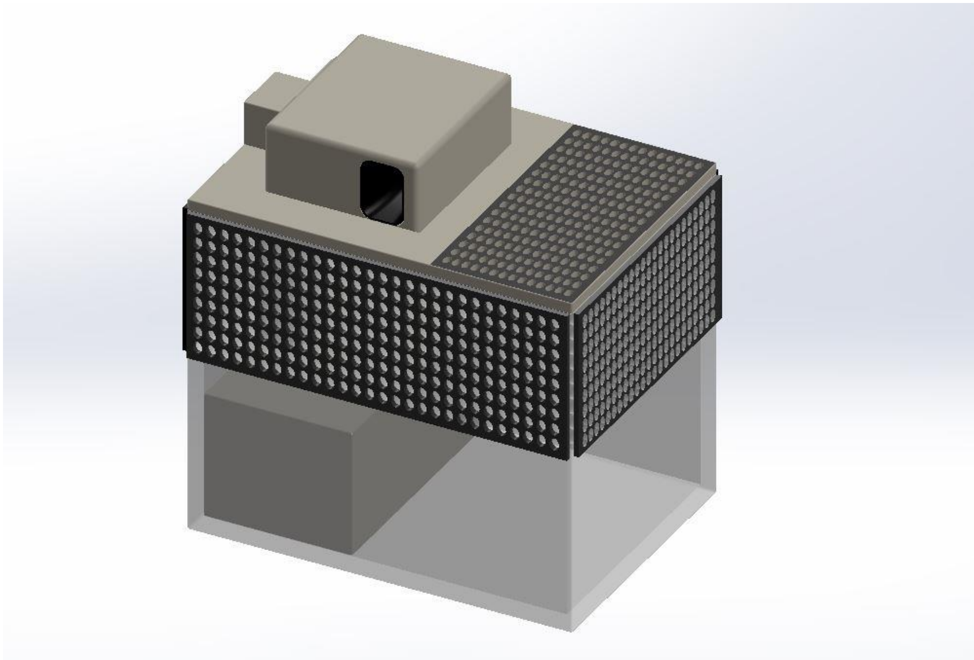


Figure 5.8: Reservoir with Humidifier and Control box

5.2.9 Final Assembly

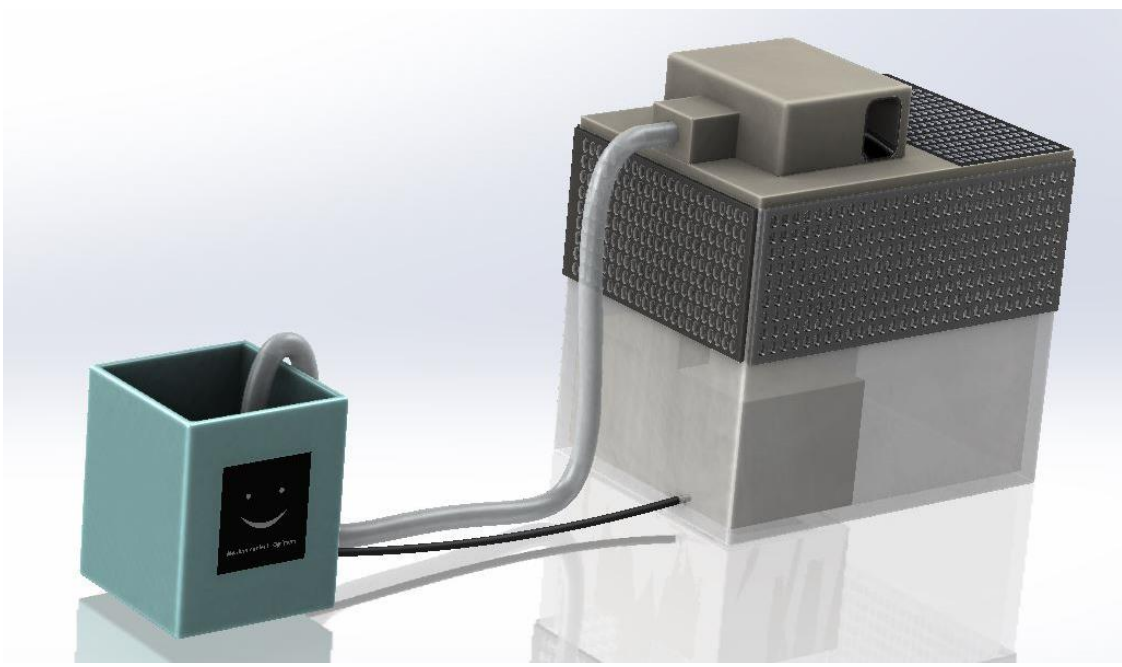


Figure 5.9: Final Assembly

Chapter-6

Qualitative Analysis of Material, Manufacturing Process &Joining Process Selection

As the conceptual design and development of our product are finalized, now it is important to find suitable material for every part of our product. A qualitative analysis of the material, manufacturing process also joining process is needed to find the best possible material and also its alternatives for every part of our product.

6.1 Selection of Materials for Different Sections

6.1.1 Intelligent Plant Pot

The qualitative analysis for the part of the intelligent plant pot of our product is given below:

Table 6.1: Qualitative Analysis of Material Selection of Intelligent Plant Pot

Section	Part	Material Selected	Alternative Options for Material	Reasons Behind Selection
Intelligent Plant Pot	Sensor Probe	Outsourced	-	-
	Covering	Plastic	Aluminum	Cost-effective, less in weight
	Display	LED Screen	LCD Screen	Cost-effective, Bright Resolution

6.1.2 Control Box

The qualitative analysis for the part of the Control Box of our product is given below:

Table 6.2: Qualitative Analysis of Material Selection of Control Box

Section	**Part**	**Material Selected**	**Alternatives Options for Material**	**Reasons Behind Selection**
Control Box	Sensor Module	Outsourced	-	-
	Arduino	Arduino Uno	Wemos 1 Mini	User-friendly, easy to handle coding, cost-effective

6.1.3 Reservoir Box

In our product, there is a section named "Reservoir Box". And that section consists of three different sub-sections. Those are given below:

1. Humidifier
2. Reservoir
3. Watering System

The qualitative analysis of these parts of the Reservoir section is given below:

Table 6.3: Qualitative Analysis of Material Selection of Reservoir Box

Section	**Part**	**Material Selected**	**Alternative Options for Material**	**Reasons Behind Selection**
Humidifier	Covering	Plastic	Aluminum	Cost-effective, less in weight
	Fan	Plastic	Stainless Steel	Cost-effective, easy to operate
Reservoir	Reservoir	Glass	Plastic	Not that costly, and aesthetically eye-soothing
Watering System	Motor	Outsourced	-	Easy to set up, Light in weight
	Pipes	Rubber	Plastic (PVC)	Cost-effective, Flexibility, High tensile strength

6.2 Selection of Manufacturing Processes for Different Sections

6.2.1 Intelligent plant pot and control box

The qualitative analysis of the manufacturing process selected for the parts of the intelligent plant pot and control box is given below:

Table 6.4: Qualitative analysis of the manufacturing process selected for the parts of the intelligent plant pot and control box

Process	**Manufacturing process selected**	**Options for other processes**	**Reasons behind selection**
Shaping of covering of plant pot	Outsourced	3D printing	Cost-effectiveness, ease of operation
Cutting digital display slot	Sawing	Scribing and breaking	Dimensional accuracy, Ease of operation
Creating holes in the control box	Drilling, Reaming	Broaching	Dimensional accuracy, availability
Cutting wiring port	Drilling	Laser cutting	Cost-effectiveness, availability
Filleting edges of covering	Sandpaper scribing	Shaping	Ease of operation, Cost efficiency
Cutting flow pipes	Sawing	Laser cutting	Cost-effectiveness, availability

6.2.2 Reservoir Box

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

Table 6.5: Qualitative analysis of the manufacturing process selected for the parts of the reservoir box

Process	**Manufacturing process selected**	**Options for other processes**	**Reasons behind selection**
Shaping of covering of reservoir box	Outsourced	3D printing	Cost-effectiveness, ease of operation
Cutting of covering lid	Sawing	Scribing and breaking	Dimensional accuracy, Ease of operation
Creating holes in reservoir box	Drilling, Reaming	Broaching	Dimensional accuracy, availability
Cutting of blower slot	Sawing	Laser cutting	Cost-effectiveness, availability
Filleting edges of covering lid	Sandpaper scribing	Shaping	Ease of operation, cost efficiency
Cutting of motor exhaust	Drilling	Laser cutting	Ease of operation, cost-effectiveness
Cutting flow pipes	Sawing	Laser cutting	Cost-effectiveness, availability
Coloring	Color Spraying	Brush Painting	Smoothness, ease of operation, durability

6.3 Qualitative Analysis of Parts Joining Method Selection

Joints are basically of three types- permanent, semi-permanent, and temporary. In the process of joining the parts of different sub-assemblies of our product, only permanent and temporary joints are required. Working knowledge on various manufacturing knowledge is implemented here to determine the joining methods qualitatively. The joining method selection tables are as follows.

6.3.1 Plant pot

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

Table 6.6: Qualitative analysis of joining process selection for the parts of the plant pot

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Sensor Probe	Semi-permanent	Screw Mechanism	Hot Glue	Cost-effective, better surface finish
Covering	Semi-permanent	Screw Mechanism	Hot Glue	Cost-effective, better surface finish
Display	Permanent	Hot Glue	Nut-bolt	Cost-effective, better surface finish

6.3.2 Control box

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

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

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Arduino	Temporary	Hot Glue	Screw Mechanism	Aesthetics
Sensor Module	Temporary	Hot Glue	Screw Mechanism	Cost-effective, better surface finish

6.3.3 Reservoir Box

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

Table 6.8: Qualitative analysis of joining process selection for the parts of the reservoir box

Joining Part(s)	Type of Joint	Joining Process	Alternative Process	Reasons Behind Selection
Humidifier & Fan	Permanent	Screw Mechanism	Nut-bolt	Cost-effective, Durability
Covering & Reservoir	Temporary	Screw Mechanism	Nut-bolt	Cost-effective
Covering & Motor	Temporary	Screw Mechanism	Nut-bolt	Durability
Covering & Humidifier	Temporary	Screw Mechanism	Nut-bolt	Cost-effective

6.3.4 Intelligent Plant Pot with Air Humidifier

The qualitative analysis of the joining process selection for the parts of the Intelligent Plant Pot with Air Humidifier is given below:

Table 6.9: Qualitative analysis of joining process selection for the parts of the Intelligent Plant Pot with Air Humidifier

Joining Part(s)	**Type of Joint**	**Joining Process**	**Alternative Process**	**Reasons Behind Selection**
Probe & Module	Semi-permanent	Soldering	Tape	Durability
Module & Arduino	Semi-permanent	Soldering	Tape	Durability
Arduino & Motor	Semi-permanent	Soldering	Tape	Durability
Pot & Reservoir	Temporary	Rubber Pipes	PVC Pipes	Ease of use

The qualitative analysis of the material, manufacturing process, and joining process selection will helpus 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, Manufacturing Process, and Joining Process Selection Using Weighted Average Method

7.1 Introduction

Material Selection is an important part of the product design process. But the design of the engineering components is limited by the available materials and the selection of the wrong material can lead to failure. In the previous chapter, a qualitative analysis of the material selection and the material joining process has been carried out. Now in this chapter, we are going to discuss the quantitative analysis of the material selection and also joining process.

There are several methods for the quantitative analysis of the process. We are here using the "Digital Logic Method" for selecting the material based on their performance rating.

7.2 List of Parts for Each Sub-assembly

7.2.1 Intelligent Plant Pot:

- Covering
- Display

7.2.2 Control Box:

- Arduino

7.2.3 Reservoir Box:

This section consists of three different parts:

1. Humidifier
    - Covering
    - Fan
2. Reservoir
3. Watering System
    - Pipes

7.3 Equations:

a) Relative Emphasis Coefficient, $\alpha = \dfrac{\text{No of positive decisions acquired by criteria.}}{\text{Total Number of Positive decisions}}$

b) For properties to be maximized,

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

c) For properties to be minimized,

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

d) Weighted Score = Relative Emphasis Coefficient (α) × Scaled Property (β)

e) Performance Index, $\gamma = \sum$ Weighted Score ($\alpha\beta$)

7.4 Likert Scale:

Likert Scale is a psychometric scale that is commonly used in research or design. Likert Scale mainly works on their level of agreement and disagreement on a symmetric agree or disagree scale. This scale mainly gives us a range based on requirements intensity.

So, in this chapter Likert scale is going to use where numerical values are not assigned with. The scale is given below:

Table 7.1: Likert Scale

Condition	**Rating**
Very Good	5
Good	4
Moderate	3
Poor	2
Very Poor	1

7.5 Quantitative Analysis of Material Selection of Intelligent Plant Pot with Air Humidifier

7.5.1 Material Selection for Intelligent Plant Pot & Humidifier (Covering):

Table 7.2: List of Selection Criteria with Numerical values or values of the Likert Scale

Selection Criteria	Plastic (Polycarbonate)	Aluminum
Fatigue Strength (MPa)	120	103
Cost (kg/BDT)	80	200
Corrosion Resistance (Likert Scale)	5	4
Vibration Resistance (Likert Scale)	5	4
Availability (Likert Scale)	4	3
Soldering (Likert Scale)	3	4

From these criteria, we want to maximize fatigue strength, corrosion resistance, and vibration resistance and also minimize cost.

Table 7.3: Determination of relative importance of material selection criteria for covering using the 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		
Fatigue Strength	1	1	1	1	1											5	0.333
Cost	0					1	0	0	0							1	0.067
Corrosion Resistance		0				0				0	1	0				1	0.067
Vibration Resistance			0				1			1			1	1		4	0.267
Availability				0				1			0		0		1	2	0.133
Soldering					0				1			1		0	0	2	0.133
Total Number of Positive Decisions																15	$\sum\alpha = 1$

Table 7.4: Calculation of the performance index for material selection of Covering

Selection Criteria	Relative Emphasis Coefficient, α	Plastic		Aluminum	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Fatigue Strength	0.333	100	33.3	85.33	28.4149
Cost	0.067	100	6.7	40	2.68
Corrosion Resistance	0.067	100	6.7	80	5.36
Vibration Resistance	0.267	100	26.7	80	21.36
Availability	0.133	80	10.64	60	7.98
Soldering	0.133	60	7.98	80	10.64
Material Performance Index			**92.02**		76.4349

So, from this table 7.4, we can easily see the weighted score comparison between the two materials. Among them, plastic gives us a better result. Therefore, for covering part plastic is the suitable material.

7.5.2 Material Selection for Display:

Table 7.5: List of selection criteria with numerical values or values from the Likert Scale

Selection Criteria	**LED Display**	**LCD Display**
Cost (per inch)	450	430
Resolution (Likert Scale)	5	3
Durability (Likert Scale)	5	4
Low Power Requirement (Likert Scale)	5	3
Availability (Likert Scale)	4	5

From these criteria, we want to maximize Resolution, Durability, Availability, and Low power requirement and also minimize cost.

Table 7.6: Determination of relative importance of material selection criteria for covering using the 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 (per inch)	1	0	1	0							2	0.2
Resolution (Likert Scale)	0				0	1	0				1	0.1
Durability (Likert Scale)		1			1			1	0		3	0.3
Low Power Requirement (Likert Scale)			0			0		0		1	1	0.1
Availability (Likert Scale)				1			1		1	0	3	0.3
Total Number of Positive Decisions											10	$\sum\alpha = 1$

Table 7.6 shows the selection criteria for display using the digital logic method.

Table 7.7: Calculation of the performance index for material selection of Display

Selection Criteria	Relative Emphasis Coefficient, α	LED Display		LCD Display	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost (per inch)	0.2	95.56	19.112	100	20
Resolution (Likert Scale)	0.1	100	10	60	6
Durability (Likert Scale)	0.3	100	30	80	24
Low Power Requirement (Likert Scale)	0.1	100	10	60	6
Availability (Likert Scale)	0.3	80	24	100	30
Material Performance Index			**93.112**		86

So, from this table 7.7, we can easily see the weighted score comparison between the two displays. Among them, LED Display gives us a better result. Therefore, for the Display part, LED Display is the most suitable one.

7.5.3 Material Selection for Control Box (Arduino):

Table 7.8: List of selection criteria with numerical values or values from the Likert Scale

Selection Criteria	**Arduino UNO**	**Wemos 1 Mini**
Cost (BDT)	1100	950
Durability (Likert Scale)	5	3
User-friendly (Likert Scale)	5	3
Availability (Likert Scale)	4	3

From these criteria, we want to maximize Durability, User-friendly, and Availability and also to minimize cost.

Table 7.9: Determination of relative importance of material selection criteria for Control Box 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 (BDT)	0	0	1				1	0.167
Durability (Likert Scale)	1			1	1		3	0.5
User-friendly (Likert Scale)		1		0		0	1	0.167
Availability (Likert Scale)			0		0	1	1	0.167
Total Number of Positive Decisions							6	∑α = 1

Table 7.9 shows the selection criteria of the Control Box using the digital logic method.

Table 7.10: Calculation of the performance index for material selection of Control Box

Selection Criteria	Relative Emphasis Coefficient, α	Arduino Uno		Wemos 1 Mini	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost (BDT)	0.167	95	15.865	100	16.7
Durability (Likert Scale)	0.5	100	50	60	30
User-friendly (Likert Scale)	0.167	100	16.7	60	10.02
Availability (Likert Scale)	0.167	80	13.36	60	10.02
Material Performance Index			**95.925**		66.74

So, from this table 7.10, we can easily see the weighted score comparison between the two Control Units. Among them, Arduino Uno gives us better results. Therefore, for Control Box Arduino Uno is the most suitable one.

7.5.3 Material Selection for Humidifier (Fan):

Table 7.11: List of selection criteria with numerical values or values from the Likert Scale

Selection Criteria	Plastic (Polycarbonate)	Stainless Steel
Fatigue Strength (MPa)	120	240
Cost (kg/bdt) (Likert Scale)	3	5
Corrosion Resistance (Likert Scale)	5	4
Vibration Resistance (Likert Scale)	5	3
Availability (Likert Scale)	4	3
Soldering	3	3

From these criteria, we want to maximize Fatigue Strength, Corrosion resistance, Vibration Resistance, and Availability, and also minimize cost.

Table 7.12: Determination of relative importance of material selection criteria for Humidifier 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		
Fatigue Strength	0	0	1	0	1											2	0.1333
Cost	1					0	0	1	0							2	0.1333
Corrosion Resistance		1				1				1	1	0				3	0.2
Vibration Resistance			0				1			0			0	0		1	0.0667
Availability				1				0			0		1		1	3	0.2
Soldering					0				1			1		1	0	3	0.2
Total Number of Positive Decisions																15	∑α =1

Table 7.12 shows the digital logic method for different components of the part Humidifier (Fan)

Table 7.13: Calculation of the performance index for material selection of Covering

Selection Criteria	Relative Emphasis Coefficient, α	Plastic		Stainless Steel	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Fatigue Strength	0.1333	50	6.665	100	13.33
Cost	0.1333	100	13.33	60	7.998
Corrosion Resistance	0.2	100	20	80	16
Vibration Resistance	0.0667	100	6.7	60	4.02
Availability	0.2	80	16	60	12
Soldering	0.2	60	12	60	12
Material Performance Index			**74.695**		65.348

So, from this table 7.13, we can easily see the weighted score comparison between the two Materials of the fan. Among them, Plastic gives us a better result. Therefore, for Humidifiers, Plastic is the most suitable one.

7.5.4 Material Selection for Reservoir Pot:

Table 7.14: List of selection criteria with numerical values or values from the Likert Scale

Selection Criteria	Glass	Plastic
Cost (Likert Scale)	4	3
Durability (Likert Scale)	4	4
Availability (Likert Scale)	5	4
Aesthetics (Likert Scale)	5	3

From these criteria, we want to maximize Durability, Aesthetics, and availability and also minimize cost.

Table 7.15: Determination of relative importance of material selection criteria for Reservoir Pot 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 (Likert Scale)	0	1	0				1	0.167
Durability (Likert Scale)	1			1	1		3	0.5
Availability (Likert Scale)		0		0		1	1	0.167
Aesthetics (Likert Scale)			1		0	0	1	0.167
Total Number of Positive Decisions							6	$\sum\alpha = 1$

Table 7.15 shows the digital logic method for different components of the part Reservoir Pot

Table 7.16: Calculation of the performance index for material selection of Control Box

Selection Criteria	Relative Emphasis Coefficient, α	Glass		Plastic	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost (Likert Scale)	0.167	75	12.525	100	16.7
Durability (Likert Scale)	0.5	100	50	100	50
Availability (Likert Scale)	0.167	100	16.7	80	13.36
Aesthetics (Likert Scale)	0.167	100	16.7	60	10.02
Material Performance Index			**95.925**		90.08

So, from this table 7.16, we can easily see the weighted score comparison between the two materials of the Reservoir Pot. Among them, Glass gives us a better result. Therefore, for Reservoir Pot, Glass is the most suitable one

7.5.5 Material Selection for Watering System (Pipes):

Table 7.17: List of selection criteria with numerical values or values from the Likert Scale

Selection Criteria	**Rubber**	**Plastic (PVC)**
Cost (Likert Scale)	4	5
Durability (Likert Scale)	5	4
Bending Quality (Likert Scale)	4	3
Availability (Likert Scale)	5	5
User-friendly (Likert Scale)	5	3

From these criteria, we want to maximize Durability, Bending Resistance, User-friendliness, and Availability and also to minimize cost.

Table 7.18: Determination of relative importance of material selection criteria for Watering System (Pipe) 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 (Likert Scale)	0	0	0	1							1	0.1
Durability (Likert Scale)	1				1	1	1				4	0.4
Bending Quality (Likert Scale)		1			0			1	0		2	0.2
Availability (Likert Scale)			1			0		0		1	2	0.2
User-friendly (Likert Scale)				0			0		1	0	1	0.1
Total Number of Positive Decisions											10	∑α =1

Table 7.18 shows the selection criteria for Watering System’s using the digital logic method.

Table 7.19: Calculation of the performance index for material selection of Watering System (Pipes)

Selection Criteria	Relative Emphasis Coefficient, α	Rubber		Plastic (PVC)	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Cost (Likert Scale)	0.1	100	10	80	8
Durability (Likert Scale)	0.4	100	40	80	32
Bending Quality (Likert Scale)	0.2	80	16	60	12
Availability (Likert Scale)	0.2	100	20	100	20
User-friendly (Likert Scale)	0.1	100	10	60	6
Material Performance Index			96		78

So, from this table 7.19, we can easily see the weighted score comparison between the two materials of the Watering System (Pipes). Among them, Rubber gives us a better result. Therefore, for Watering System (Pipes), Rubber is the most suitable one.

7.6 Quantitative Analysis of Manufacturing Process Selection of Intelligent Plant Pot with Air Humidifier

7.6.1 Manufacturing Process Selection for Cutting Display Slots in Intelligent Plant Pot:

Table 7.20: List of Selection Criteria with Numerical values or values of Likert Scale for cutting slots

Selection Criteria	Sawing	Scribing and breaking
Defect Rate (%)	4	15
Cost of operation (BDT/unit)	80	200
Time of Operation (sec)	90	150
Surface finish (Likert Scale)	5	4
Safety – Personal and Environment (Likert Scale)	4	3

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

Table 7.21: Determination of relative importance of process selection criteria for cutting display slots 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		
Defect Rate	1	1	1	1							4	0.4
Cost of Operation	0				0	1	1				2	0.2
Time of operation		0			1			0	0		1	0.1
Surface Finish			0			0		1		1	2	0.2
Safety				0			0		1	0	1	0.1
Total Number of Positive Decisions											10	$\sum\alpha = 1$

Table 7.21 shows the digital logic method for different manufacturing process for cutting display slots. Of these criteria, defect rate has the highest relative emphasis coefficient.

Table 7.22: Calculation of the performance index for manufacturing process selection of display slot cutting

Selection Criteria	Relative Emphasis Coefficient, α	Sawing		Scribing and breaking	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Defect Rate	0.4	100	40	26.67	10.68
Cost of Operation	0.2	100	20	40	8
Time of Operation	0.1	100	10	60	6
Surface Finish	0.2	100	20	80	16
Safety	0.1	100	10	75	7.5
Process Performance Index			**100**		48.17

So, from this table 7.22 we can easily see the weighted score comparison between two processes. Among them sawing gives us a better result. Therefore, for cutting display slots, sawing is the suitable process.

7.6.2 Manufacturing Process Selection for Creating Holes in Control Box

Table 7.23: List of Selection Criteria with Numerical values or values of Likert Scale for creating holes in control box

Selection Criteria	Drilling	Broaching
Defect Rate (%)	4	15
Cost of operation (BDT/unit)	80	160
Ease of operation (Likert Scale)	3	1
Surface finish (Likert Scale)	5	4
Compatibility (Likert Scale)	5	4

From these criteria, we want to maximize surface finish, safety and ease of operation and also want to minimize defect rate, cost of operation.

Table 7.24: Determination of relative importance of process selection criteria for cutting holes 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		
Defect Rate	1	1	1	1							4	0.4
Cost of Operation	0				0	1	1				2	0.2
Ease of operation		0			1			0	0		1	0.1
Surface Finish			0			0		1		1	2	0.2
Compatibility				0			0		1	0	1	0.1
Total Number of Positive Decisions											10	∑α =1

Table 7.24 shows the digital logic method for different manufacturing process for cutting holes. Of these criteria, defect rate has the highest relative emphasis coefficient.

Table 7.25: Calculation of the performance index for manufacturing process selection of cutting holes

Selection Criteria	Relative Emphasis Coefficient, α	Drilling		Broaching	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Defect Rate	0.4	100	40	26.67	10.68
Cost of Operation	0.2	100	20	50	25
Ease of Operation	0.1	100	10	33.33	3
Surface Finish	0.2	100	20	80	16
Compatibility	0.1	100	10	80	8
Process Performance Index			**100**		66.01

So, from this table 7.25 we can easily see the weighted score comparison between two processes. Among them sawing gives us a better result. Therefore, for cutting display slots, sawing is the suitable process.

7.6.3 Manufacturing Process Selection for Cutting wiring port holes

Table 7.26: List of Selection Criteria with Numerical values or values of Likert Scale for creating wiring port holes in control box

Selection Criteria	Drilling	Laser cutting
Defect Rate (%)	3	2
Cost of operation (BDT/unit)	70	330
Time of Operation (sec)	60	40
Surface finish (Likert Scale)	4	5
Safety – Personal and Environment (Likert Scale)	5	4

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

Table 7.27: Determination of relative importance of process selection criteria for cutting wiring port holes 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		
Defect Rate	0	0	1	1							2	0.2
Cost of Operation	1				1	1	1				4	0.4
Time of operation		1			0			0	0		1	0.1
Surface Finish			0			0		1		1	2	0.2
Safety				0			0		1	0	1	0.1
Total Number of Positive Decisions											10	$\sum\alpha = 1$

Table 7.27 shows the digital logic method for different manufacturing process for cutting wiring port holes. Of these criteria, Cost of operation has the highest relative emphasis coefficient.

Table 7.28: Calculation of the performance index for manufacturing process selection of cutting wiring port holes

Selection Criteria	Relative Emphasis Coefficient, α	Drilling		Laser Cutting	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Defect Rate	0.2	66.67	13.34	100	20
Cost of Operation	0.4	100	40	21.21	8.484
Time of Operation	0.1	66.67	6.67	100	10
Surface Finish	0.2	80	4	100	20
Safety	0.1	100	10	80	8
Process Performance Index			**74.01**		66.484

So, from this table 7.28 we can easily see the weighted score comparison between two processes. Among them drilling gives us a better result. Therefore, for cutting wiring port holes, drilling is the suitable process.

7.6.4 Manufacturing Process Selection for Filleting Edges

Table 7.29: List of Selection Criteria with Numerical values or values of Likert Scale for filleting edges of covering

Selection Criteria	Sandpaper scribing	Shaping
Defect Rate (%)	3	2
Cost of operation (BDT/unit)	20	100
Time of Operation (sec)	120	60
Surface finish (Likert Scale)	4	5
Safety – Personal and Environment (Likert Scale)	5	3

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

Table 7.30: Determination of relative importance of process selection criteria for filleting edges 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		
Defect Rate	0	0	1	1							2	0.2
Cost of Operation	1				1	1	1				4	0.4
Time of operation		1			0			0	0		1	0.1
Surface Finish			0			0		1		1	2	0.2
Safety				0			0		1	0	1	0.1
Total Number of Positive Decisions											10	$\sum\alpha = 1$

Table 7.30 shows the digital logic method for different manufacturing process for filleting edges. Of these criteria, Cost of operation has the highest relative emphasis coefficient.

Table 7.31: Calculation of the performance index for manufacturing process selection of filleting edges

Selection Criteria	Relative Emphasis Coefficient, α	Sandpaper scribing		Shaping	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Defect Rate	0.2	66.67	13.34	100	20
Cost of Operation	0.4	100	40	20	8
Time of Operation	0.1	50	5	100	10
Surface Finish	0.2	80	4	100	20
Safety	0.1	100	10	60	6
Process Performance Index			**72.34**		64

So, from this table 7.31 we can easily see the weighted score comparison between two processes. Among them sandpaper scribing gives us a better result. Therefore, for filleting edges, sandpaper scribing is the suitable process.

7.6.5 Manufacturing Process Selection for Cutting Flow Pipes

Table 7.32: List of Selection Criteria with Numerical values or values of Likert Scale for cutting flow pipes

Selection Criteria	**Sawing**	**Laser cutting**
Defect Rate (%)	3	2
Cost of operation (BDT/unit)	80	250
Time of Operation (sec)	120	80
Surface finish (Likert Scale)	4	5
Operational Complexity (Likert Scale)	2	4

From these criteria, we want to maximize surface finish and also want to minimize defect rate, cost of operation, operational complexity and time of operation.

Table 7.33: Determination of relative importance of process selection criteria for cutting flow pipes 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		
Defect Rate	0	0	1	1							2	0.2
Cost of Operation	1				1	1	1				4	0.4
Time of operation		1			0			0	0		1	0.1
Surface Finish			0			0		1		0	1	0.1
Operational Complexity				0			0		1	1	2	0.2
Total Number of Positive Decisions											10	$\sum\alpha = 1$

Table 7.33 shows the digital logic method for different manufacturing process for cutting flow pipes. Of these criteria, Cost of operation has the highest relative emphasis coefficient.

Table 7.34: Calculation of the performance index for manufacturing process selection of cutting flow pipes

Selection Criteria	Relative Emphasis Coefficient, α	Sawing		Laser Cutting	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Defect Rate	0.2	66.67	13.34	100	20
Cost of Operation	0.4	100	40	32	12.8
Time of Operation	0.1	66.67	6.67	100	10
Surface Finish	0.1	80	8	100	10
Safety	0.2	100	20	50	10
Process Performance Index			**88.01**		62.8

So, from this table 7.34 we can easily see the weighted score comparison between two processes. Among them sawing gives us a better result. Therefore, for cutting flow pipes, sawing is the suitable process.

7.6.6 Manufacturing Process Selection for Coloring

Table 7.35: List of Selection Criteria with Numerical values or values of Likert Scale for cutting flow pipes

Selection Criteria	Color spraying	Brush painting
Cost (BDT/Product)	30	25
Durability (Month)	60	48
Time of operation (sec)	120	300
Adhesiveness	5	4
Compatibility	5	4

From these criteria, we want to maximize durability, adhesiveness, compatibility and also want to minimize cost and time of operation.

Table 7.36: Determination of relative importance of process selection criteria for coloring 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	0	1	0	1							2	0.2
Durability	1				1	1	1				4	0.4
Time of operation		0			0			0	1		1	0.1
Adhesiveness			1			0		1		0	2	0.2
Compatibility				0			0		0	1	1	0.1
Total Number of Positive Decisions											10	∑α =1

Table 7.36 shows the digital logic method for different manufacturing process for coloring. Of these criteria, Durability has the highest relative emphasis coefficient.

Table 7.37: Calculation of the performance index for manufacturing process selection of coloring

Selection Criteria	Relative Emphasis Coefficient, α	Color Spraying		Brush Painting	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.2	83.33	16.66	100	20
Durability	0.4	100	40	80	32
Time of Operation	0.1	100	10	40	4
Adhesiveness	0.2	100	20	80	4
Compatibility	0.1	100	10	80	8
Process Performance Index			**96.66**		68

So, from this table 7.37 we can easily see the weighted score comparison between two processes. Among them sawing gives us a better result. Therefore, for coloring, color spraying is the suitable process.

7.7 Quantitative Analysis of Joining Process Selection:

7.7.1 Joining Process Selection for Permanent Joints:

Table 7.38: List of selection criteria with numerical values or values from the Likert Scale for Permanent Joints

Selection Criteria	Hot Glue	Screw Mechanism	Nut-bolt
Cost (BDT/Product)	6	8	30
Surface Finish	3	4	4
Strength (MPa)	15	240	400
Operational Time	5	4	3
Corrosion Resistant	5	4	3

From the criteria, we want to maximize Surface finish, Strength, and Corrosion Resistant and minimize Cost & Operational time.

Table 7.39: Calculation of the relative emphasis coefficient for joining process selection for Permanent Joints using the 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	1	1				2	0.2
Strength (MPa)		0			1			0	1		2	0.2
Operational Time			0			0			0	1	1	0.1
Corrosion Resistant				0			0	1		0	1	0.1
Total number of positive decisions											10	∑α=1

Table 7.40: Calculation of performance index for joining process selection of Permanent Joints

Selection Criteria	Relative Emphasis Coefficient, α	Hot Glue		Screw Mechanism		Nut-bolt	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.4	100	40	75	30	20	8
Surface Finish	0.2	75	15	100	20	100	20
Strength (MPa)	0.2	0.0375	0.0075	60	12	100	20
Operational Time	0.1	60	6	75	7.5	100	10
Corrosion Resistant	0.1	100	10	80	8	60	6
Material Performance Index, γ			71.0075		77.50		64

So, from this table 7.40**,** we can easily see the weighted score comparison between the three joining methods. Among them, Screw Mechanism gives us the best result. Hot glue gives a comparatively better result as well. Therefore, we will be focusing on the screw mechanism on permanent joints.

7.7.2 Joining Process Selection for Temporary Joints:

Table 7.41: List of selection criteria with numerical values or values from the Likert Scale for Temporary Joints

Selection Criteria	Rubber Pipes	PVC Pipes
Cost (BDT/feet)	30	200
Availability	5	4
Design Flexibility	5	2
Durability	4	5
Aesthetics	4	3
Indefectibility	3	4

From the criteria, we want to maximize Durability, Design Flexibility, Aesthetics, Indefectibility & Availability and Minimize Cost.

Table 7.42: Calculation of the relative emphasis coefficient for joining process selection for Temporary Joints using the Digital Logic Method

Selection criteria	Number of positive decisions, N = n(n-1)/2 = 6(6-1)/2=15																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Positive Decisions	Relative Emphasis Coefficient, α
Cost	1	1	0	1	1											4	0.267
Availability	0					1	0	0	0							1	0.067
Design Flexibility		0				0				1	0	1				2	0.133
Durability			1				1			0			1	1		4	0.267
Aesthetics				0				1			1		0		1	3	0.2
Indefectibility					0				1			0		0	0	1	0.067
Total number of positive decisions																15	∑α=1

Table 7.43: Calculation of performance index for joining process selection of Temporary Joints

Selection Criteria	Relative Emphasis Coefficient, α	Rubber Pipes		PVC pipes	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.267	100	26.667	15	4
Availability	0.067	100	6.667	80	5.333
Design Flexibility	0.133	100	13.333	40	5.333
Durability	0.267	80	21.333	100	26.667
Aesthetics	0.2	100	20	75	15
Indefectibility	0.067	75	5	100	6.667
Material Performance Index, γ			**93.00**		63.00

So, from this table 7.43**,** we can easily see the weighted score comparison between the two joining methods. Rubber pipes give us the best result. PVC pipe gives a comparatively better result as well. Therefore, we will be focusing on Rubber pipes on temporary joints.

Table 7.44: List of selection criteria with numerical values or values from the Likert Scale for Temporary Joints

Selection Criteria	Hot Glue	Screw Mechanism
Cost (BDT/Product)	6	8
Surface Finish	3	4
Strength (MPa)	15	235
Operational Time	5	4
Corrosion Resistant	5	4

From the criteria, we want to maximize Surface finish, Strength, and Corrosion Resistant and minimize Cost & Operational Time.

Table 7.45: Calculation of the relative emphasis coefficient for joining process selection for Temporary Joints using the 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	1	1				2	0.2
Strength		0			1			0	1		2	0.2
Operational Time			0			0			0	1	1	0.1
Corrosion Resistant				0			0	1		0	1	0.1
Total number of positive decisions											10	$\sum\alpha=1$

Table 7.46: Calculation of performance index for joining process selection of Temporary Joints

Selection Criteria	Relative Emphasis Coefficient, α	Hot Glue		Screw Mechanism	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.4	100	40	75	30
Strength	0.2	75	15	100	20
Surface finish	0.2	0.0375	0.0075	60	12
Corrosion Resistant	0.1	60	6	75	7.5
Operational Time	0.1	100	10	80	8
Material Performance Index, γ			71.0075		77.50

So, from this table 7.46, we can easily see the weighted score comparison between the two joining methods. The screw Mechanism gives us the best result. Hot glue gives a comparatively better result as well. Therefore, we will be focusing on the screw mechanism on temporary joints.

7.7.3 Joining Process Selection for Semi-Permanent Joints:

Table 7.47: List of selection criteria with numerical values or values from the Likert Scale for Semi-permanent Joints

Selection Criteria	Soldering	Tape
Cost	20	12
Surface Finish	5	3
Strength	5	2
Indefectibility	5	3
Corrosion Resistant	3	5
Operational Time	4	5

From the criteria, we want to maximize Surface finish, Strength, Indefectibility, Corrosion Resistant, and minimize Cost & Operational Time.

Table 7.48: Calculation of the relative emphasis coefficient for joining process selection for Semi-permanent Joints using the Digital Logic Method

Selection criteria	Number of positive decisions, N = n(n-1)/2 = 6(6-1)/2=15																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Positive Decisions	Relative Emphasis Coefficient, α
Cost	1	1	0	0	1											3	0.2
Surface Finish	0					0	0	0	1							1	0.067
Strength		0				1				1	0	0				2	0.133
Indefectibility			1				1			0			1	1		4	0.267
Corrosion Resistant				1				1			1		0		1	4	0.267
Operational Time					0				0			1		0	0	1	0.067
Total number of positive decisions																15	$\sum\alpha=1$

Table 7.49: Calculation of performance index for joining process selection of Semi-permanent Joints

Selection Criteria	Relative Emphasis Coefficient, α	Soldering		Tape	
		Scaled Property, β	Weighted Score, αβ	Scaled Property, β	Weighted Score, αβ
Cost	0.2	60	12	100	20
Surface Finish	0.067	100	6.667	60	4
Strength	0.133	100	13.333	40	5.333
Indefectibility	0.267	100	26.667	60	16
Corrosion Resistant	0.267	60	16	100	26.667
Operational Time	0.067	100	6.667	80	5.333
Material Performance Index, γ			81.333		77.333

So, from this table 7.49**,** we can easily see the weighted score comparison between the two joining methods. The Soldering gives us the best result. The tape gives a comparatively better result as well. Therefore, we will be focusing on Soldering on semi-permanent joints.

Chapter- 08

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, 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.

8.1 Demand Forecast

Forecasted Number of Products per Year: 10,000 units

8.2 Fixed Costs

Fixed costs are an initial investment in machinery and other accessories.

8.2.1 Machine Cost

1. Gorilla Dual Temp Mini Hot Glue Gun Kit

   Buying Cost: BDT 1,100

   Life: 20 years

   Quantity: 3

2. NEWACALOX Soldering Gun

   Buying Cost: BDT 6,000

   Life: 15 years

   Quantity: 1

3. Walnut Hollow Professional Hot Knife for Cutting & Carving

   Buying Cost: BDT 2,100

   Life: 15 years

   Quantity: 1

4. EASTVOLT 20V Max Cordless Power Drill

   Buying Cost: BDT 6,600

   Life: 20 years

   Quantity: 1

5. Westinghouse 12500 Watts Dual Fuel Portable Generator
   Buying Cost: BDT 90,000
   Life: 20 years
   Quantity: 1

The total cost of machinery: BDT 1,05,800

8.2.2 Cost of furniture, computer, and other accessories

1. Furniture and accessories
   Buying Cost: BDT 1,00,000
   Life: 15 years
2. Computer
   Buying cost: BDT 50,000
   Life: 15 years

The total cost of furniture, computer, and other accessories: BDT 1,50,000

8.2.3 Factory Insurance

Yearly payment for factory insurance: BDT 10,000

8.3 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.

8.3.1 Cost of Raw Materials (per unit of product)

1. Plastic Pot
   Quantity: 1
   Market Price: BDT 100
2. Moisture Sensor
   Quantity: 1
   Market Price: BDT 150

3. Motor

   Quantity: 1

   Market Price: BDT 150

4. Digital Screen

   Quantity: 1

   Market Price: BDT 850

5. Pipe

   Quantity: 3ft

   Market Price: BDT 45

6. Plastic Sheet

   Quantity: 1

   Market Price: BDT 200

7. Arduino

   Quantity: 1

   Market Price: BDT 1,000

8. Blower

   Quantity: 1

   Market Price: BDT 1,000

9. Glass Sheet

   Quantity: 4

   Market Price: BDT 800

Total Cost of Raw Material (Per unit of product): BDT 4,295

8.3.2 Manufacturing Costs of different operations (per month)

5. Joining and Assembly

   Number of Workers: 1

   Wage/Labor: 7,500

6. Shaping

   Number of Workers: 1

   Wage/Labor: 7,500

7. Setting up Arduino

   Number of Workers: 1

   Wage/Labor: 7,500

8. Sawing and Drilling

   Number of Workers: 1

   Wage/Labor: 7,500

9. Coloring

   Number of Workers: 1

   Wage/Labor: 7,500

10. Packaging

    Number of Workers: 1

    Wage/Labor: 7,500

Total labor cost: BDT 45.000 per month

Total labor cost per year: BDT 5,40,000

8.3.3 Purchasing cost

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

Component	Quantity	Market Price (BDT)	Total Cost (BDT)
Glue Stick	1/10	450	45
Color Spray	1/2	150	75
Cardboard Box	1	30	30
Screw	10	1	10
Wire	1 ft	5	5
Total Purchasing Cost (Per unit of Product)			165

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)
Manufacturing Engineer	1	30,000	30,000
Quality Control Engineer	1	30,000	30,000
Power Consumption		5,000	5,000
Factory Rent		15,000	15,000
		Total	80,000

Yearly manufacturing overhead: BDT 80,000 * 12 = 9,60,000

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. 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 (BDT)	Total Cost (BDT)
Chief Executive Officer	1	40,000	40,000
Accountant	1	20,000	20,000
Clerk	1	15,000	15,000
Guard	1	15,000	15,000
		Total	90,000

Yearly administrative cost BDT 90,000*12=10,80,000

9.4.2 Selling Expenses (per month)

Table 9.4: Selling Expenses

Cost Item	No. of post	Salary (BDT)	Total Cost (BDT)
Marketing Executive	1	30,000	30,000
Advertisement			20,000
		Total	50,000

Yearly Selling Expenses: BDT 50,000*12=6,00,000

Total Non-manufacturing cost: BDT 16,80,000

9.5 Break-Even analysis

For the first year,

Fixed Costs:

Table 8.5: An overview of fixed costs

Sector	Amount (BDT)
Machine Cost	1,05,800
Accessories Cost	1,50,000
Factory Insurance	10,000
Labor Cost	5,40,000
Manufacturing Overhead	9,60,000
Non-manufacturing Cost	16,80,000
Total Cost	34,45,800

Total Cost of Raw Material (Per unit of product): BDT 4,295

Total Purchasing Cost (Per unit of Product): BDT 165

Total Cost of manufacturing one unit of product (Variable cost): BDT 4,460

Selling Price of BDT 5,000

Let our Break-Even quantity be Q

So, we know,

$$Q = \frac{Fixed\ Cost}{(Revenue\ per\ unit - Variable\ cost\ per\ unit)}$$

$$Q = \frac{3445800}{5000 - 4460} \approx 6381 \text{ Units}$$

So, the break-even quantity for the first year is 33,855 units. The plot for the break-even analysis for the first year is shown below:

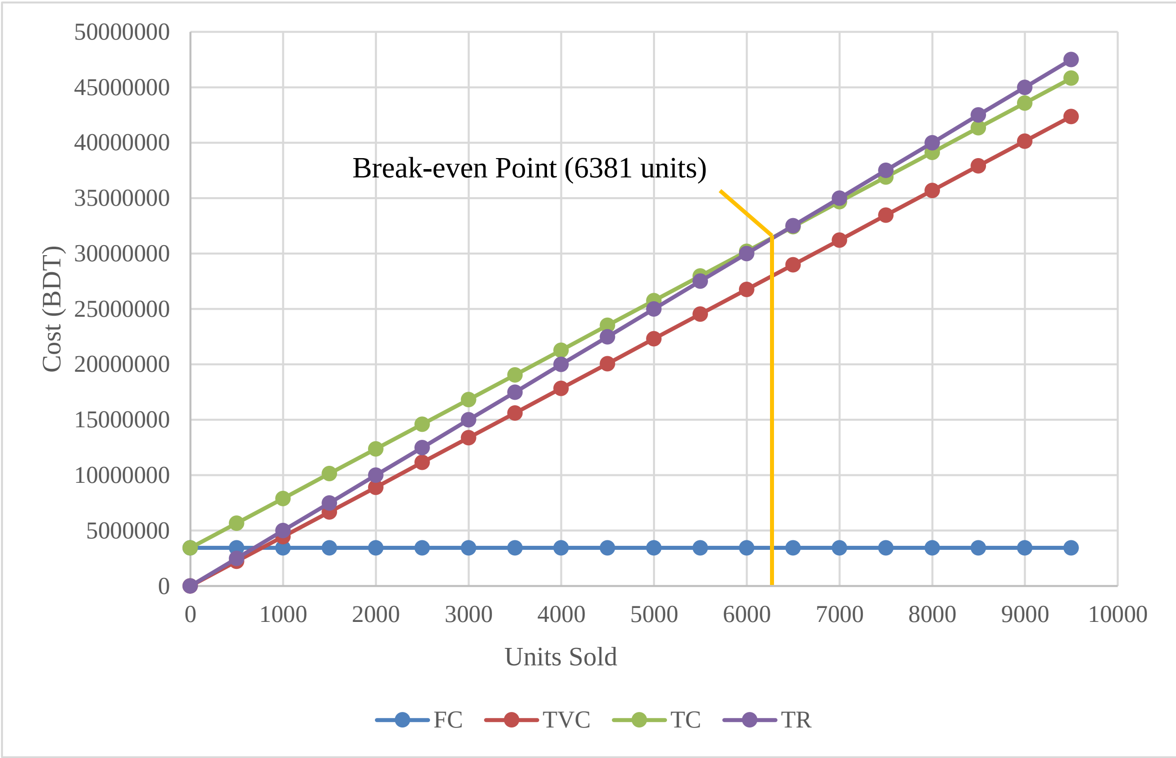


Figure 8.1: Graphical Representation of Break-even analysis

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 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.