Concept Design

Group Project No. 02

Faculty of Technology and Bionics

PickIT

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Cleve,
25.10.2022

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Executive Summary

PickIT is a semi–automated fruit picker that is being developed to introduce effortless harvesting of fruits from trees which is usually a very tedious process done manually. Despite having home grown, organic fruits, many people prefer buying them from supermarkets just to avoid the manual task of picking them from trees. Further, every year during the harvesting season, tons of fruits grown in backyards and gardens go waste in several households due to lack of accessible equipment to pluck them easily from heights. PickIT therefore, aims to provide its users with a safe and easy mechanism that helps in plucking fruits from trees with minimal human effort and maximum efficiency. The machine consists of a telescopic rod made of PVC attached to a gripper that uses a rotating mechanism with the help of motors and gears to grab and detach fruits from trees. A basket along with an attached net, inclined at an angle is also provided with the device to collect the plucked fruits without causing any damage to them. The device is carefully and ergonomically designed imbibing a mechanical – electrical system to control the speed of the rotating mechanism as well as to hold onto the fruit precisely without any safety hazards. PickIT aims to promote agricultural enthusiasts in enjoying their garden-grown fruits without compromising on time or effort.

Keywords:
Semi-automated picker, telescopic fruit plucker, PVC fruit picker, picker with inclined net

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Introduction

Apple pickers are in high demand as today's people are moving at a faster pace towards increased consumption of home-grown fruits and vegetables, than ever before. People are more health conscious presently and prefer eating home-grown / home-cooked food as compared to fast food and unhealthy restaurant food. A study shows that the number of organic farming businesses has increased from 19,500 in 2008 to 35,000 in 2021[1]. A lot of people that once worked in the IT and other tech sectors have now moved towards organic farming because of the growing demand for organic fruits and vegetables and also because it serves as a great eco-friendly side business.
A lot of these agricultural enthusiasts are looking for technologically advanced farming techniques and devices as increasing the efficiency of their farms is a priority for them. Hence, to cater to this need of farmers, we have developed a device that not only semi automates the process of plucking fruits from trees but also reduces the effort and time taken for this process.
PickIT is being developed to introduce an efficient and safer alternative to the market, a specialized, semi-automated device that can be used to pluck multiple fruits from a tree without tiring the person picking the fruits. This has been developed for typically small to medium-sized gardens. Under normal conditions, the traditional pure mechanical fruit pickers have to be brought back down to the ground after picking 2-3 fruits as it gets too heavy for a person to hold such a device up in the air for long. Barring that, there is also the risk of the fruit dropping onto the ground and getting damaged. In conclusion, the goal of PickIT is not only to reduce picking time but also to offer an ergonomic and easy-to-use device to the new generation of small to medium-scale agricultural enthusiasts.

Figure 1:Generic Fruit Picker

Figure 2: Robotic Fruit Picker

Market Size

Meyve GmbH is a firm based in Germany planning to begin its manufacturing and distribution of high-tech farming equipment in the German market in 2023.
According to publicly available data, 47.64% of land area in Germany was reported to be Agricultural land [2]. Germany's agricultural sector is among the four largest producers in the European Union. There are around 630,000 farms just in Germany which is a lot compared to other countries all over the world [3]. Since apples are the most planted fruit trees and account for 68% of the total fruit tree area in Germany[4], it is important to analyze this market in detail, as compared to the statistics of other similarly sized fruits that are produced in much lower numbers. Around 1 million tons of apples were harvested in Germany in 2021[5]. Upon dividing this total weight by the average weight of an apple, this translates to approximately 5 billion apples being harvested every year. The price of apples in Germany is approximately 2.99 EUR / kg. This makes apple farming approximately a 3 billion Euro industry.
Considering the large disparity between the prices of the more advanced robotic apple pickers used on large-scale farms that cost around 50,000€ to 80,000€ and the generic apple picker that costs 20€ to 80€, we can assume that at least 99% of these apples come from state of the art large scale farms while the remaining 1% comes from rural gardens that have a few apple trees. Thus, the market that we would like to venture into is a 30 million Euro industry.
Germany has a rural population of around 18 million [6]. A survey shows that there are approximately 2 people per household [7]. Thus giving us an approximation of 9 million rural households. Assuming that only 20% of the 9 million gardens have apple trees, thus only 1.8 million households have apple trees. In such cases, the number of apple trees might vary from 1 to 15 apple trees per garden. Only 15% or 270,000 of such households may have enough apple trees to actually consider buying an apple picker. Upon considering 4 years as the average life of an apple picker, approximately 67,500 households buy an apple picker every year.
An average person living in a rural home with a garden will think twice before investing in an apple picker that is priced on the higher side of the market. The whole purpose of semi-automating our apple picker is to cater to the needs of 2 types of people that are in the market for an apple picker. First being the younger ones in their 20s and 30s that have taken up organic farming as their secondary source of income. Second being the senior citizens who are in their 60s and 70s, for whom the harvest from their garden would help carry out basic everyday expenses. For both groups of people, manually harvesting is not an option due to lack of time in the first group and lack of energy in the second. Opting for hourly paid labor is what they would lean towards and hence, reducing man hours would be their primary goal. Hence, for them, buying PickIT would be eyed as a one-time investment rather than an expenditure or liability.

Having considered this, we can approximate that we would be expecting around 10% of the 67,500 rural homes to buy our product every year, thus bringing our Market size to 6,750.
Additionally, food inflation in Germany is predicted to be approximately 18.20% by the end of 2022 according to Trading Economics global macro models and expert predictions; which if estimated correctly is expected to be 5.10% in 2023 and 2.10% in 2024[8].

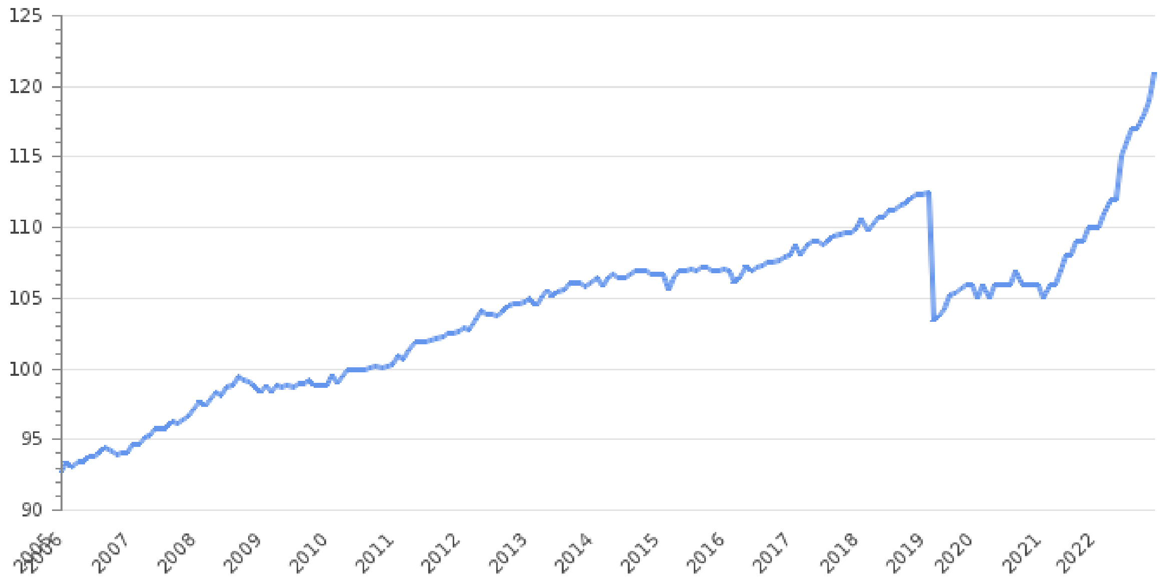


Figure 3: Projection of Food Inflation in Germany(Index Points vs Years)

This information is of great importance to us as it helps us understand how the price of food products and other relatable services will behave in the future. As inflation falls, consumers will start spending more, allowing farming businesses to increase their revenues and as a result, make them more willing to acquire new technologies such as PickIT.

Price

PickIT is projected to cost approximately 220€ per piece based on the cost of the parts required to produce one unit, prototyping costs, marketing costs, and other overhead expenses. A table with a rough estimation of each of these costs is given below (not accurate and will change upon detailed analysis of each cost in the future).

Type of Cost	Price per unit
Raw Materials	80€
Design and Manufacturing	50€
Prototyping	5€
Marketing	5€
Labor and Overhead	10€
Miscellaneous	15€

Table 1: Rough Estimation of Cost Price of PickIT

This makes the total cost of production approximately 165€. Upon adding a net profit of 30%, we can mark up the price to almost 220€.

Our aim at PickIT is to develop a product of very high quality that can be used all year round for different fruits, a product that is not just ergonomic in its use but also makes plucking fruits an easy and efficient task. Thus cutting down the average time for picking by approximately 3 times. This helps reduce the wages paid to the worker as we save on time.

The cost of a traditional, full mechanical apple picker may vary between 20€ to 80€ depending on quality. Upon taking an average price for such devices as 50€, our product is 4.4 times more expensive with a difference of 170€. However, for our target customers, 170€ is approximately 13.6 man-hours (considering minimum wage of 12.5€ / hour). Hence, the 170€ would be viewed as a one-time investment rather than an expense.

Planned Sales Volume

Our goal at PickIT is to capture at least 10% of the market share in the first three years of launching our product. We intend on concentrating on reaching our products out to the rural homes present predominantly in the central and southern parts of West Germany. We intend on setting up sales Outlets in Baden-Württemberg, Schleswig-Holstein, eastern Lower Saxony, and parts of North-Rhein Westphalia. To achieve our goal of capturing the market, we estimate the production and sales of approximately 15,700 units in the three-year time-span.

Units	Total Revenue
1	220€
15,700	3,454,000€

Table 2: Sales Volume

Acquiring sales of at least 6,750 products in the first year might be difficult although that is our expected market share as we are a new brand and need a minimum of 6 months to 1 year to be recognized and have a firm market share. Hence, it is only reasonable to project our sales of 15,700 units over the first 3 years.
An annual growth of about 40% in sales is expected for the first 3 years as we lay the foundation to acquire 10-15% of the market and then a stable growth of 3% of market share every year for the following years.

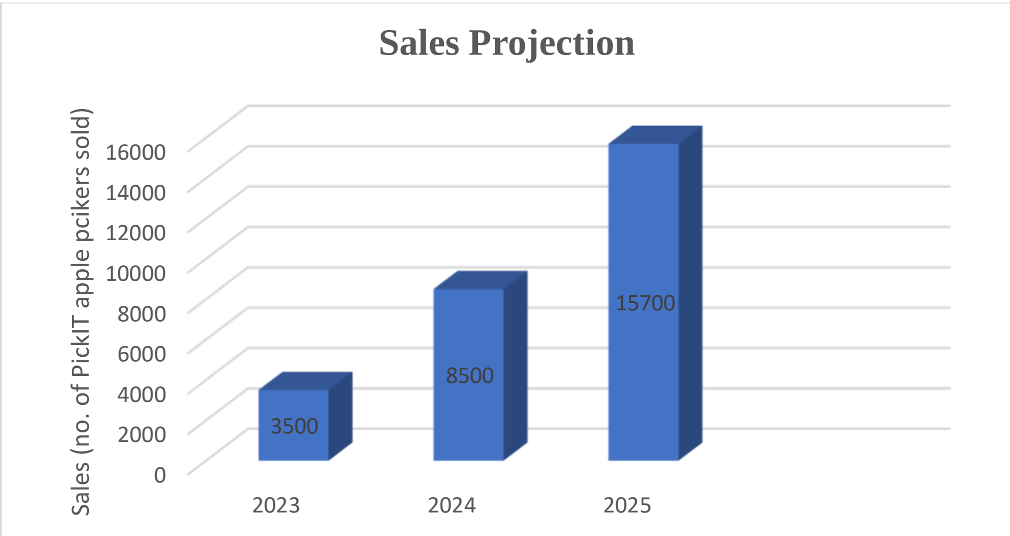


Figure 4: Sales Projection (3-year period)

Product Concept

The following section consists of the product description which provides some insight into the functioning of the equipment. It also includes a detailed technical sketch and a list of required components.

Product Description

PickIT is a semi-automated ergonomic fruit-picking device used to pluck fruits from trees. It is comprised of a telescopic PVC rod that can be extended or retracted easily using a lever lock mechanism. The height of the rod needs to be manually adjusted by the user accordingly. The rod further consists of two housings that secure the batteries, the gears, and the motors. The first housing is on the gripper, it consists of a motor connected to a rack and pinion gear that helps extend and retract the claws of the gripper. In the second housing which is at the end of the telescopic rod, a motor is connected to a straight bevel gear to which the gripper is attached. This helps rotate the gripper, which in turn rotates the fruit, thus plucking the fruit efficiently without damaging the branches of the tree. The two claws of the gripper are covered with thick rubber pads to ensure a firm and strong grip on the fruit. To provide easy accessibility, a pushbutton and a switch are attached at the bottom of the machine for convenience. The product is also equipped with a rope that could be used for wrapping around the wrist for easy handling while in use or for handing on the wall when not in use.

Operation: The user has to position the net roughly under the tree where he wishes to pluck the fruits. Next, he will have to extend the rod keeping a rough estimation of the height of the fruits in mind. Then he will slowly have to move the device towards the fruit and turn the switch to close position to close the claw so that the fruit is gripped firmly. Following this, he will have to press the push button which rotates the claw which in turn will safely detach the fruit from its stem. Then he will have to turn the switch to open position to open the claw, thus letting the fruit drop onto the net. The net reduces the momentum of the fruit and safely drops it into the soft padding in the cart, thus storing all the plucked fruits.

Product Sketch

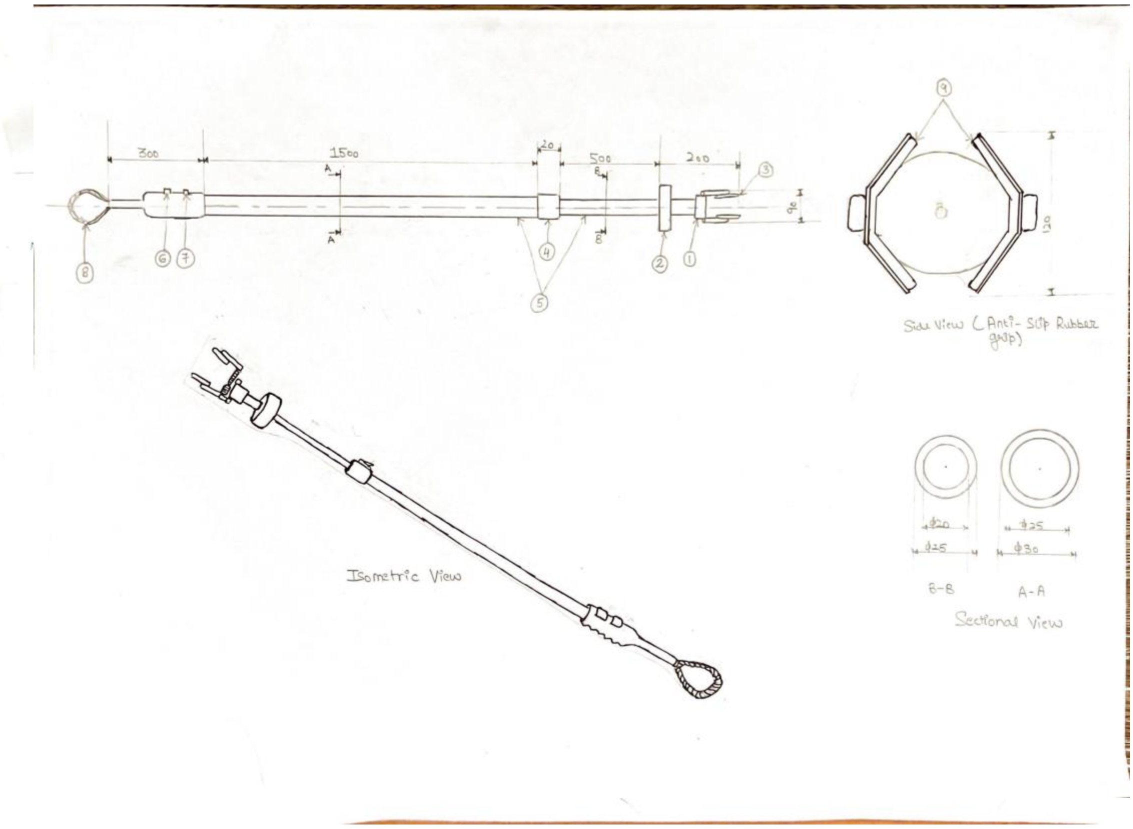


Figure 5: Technical drawing of PickIT

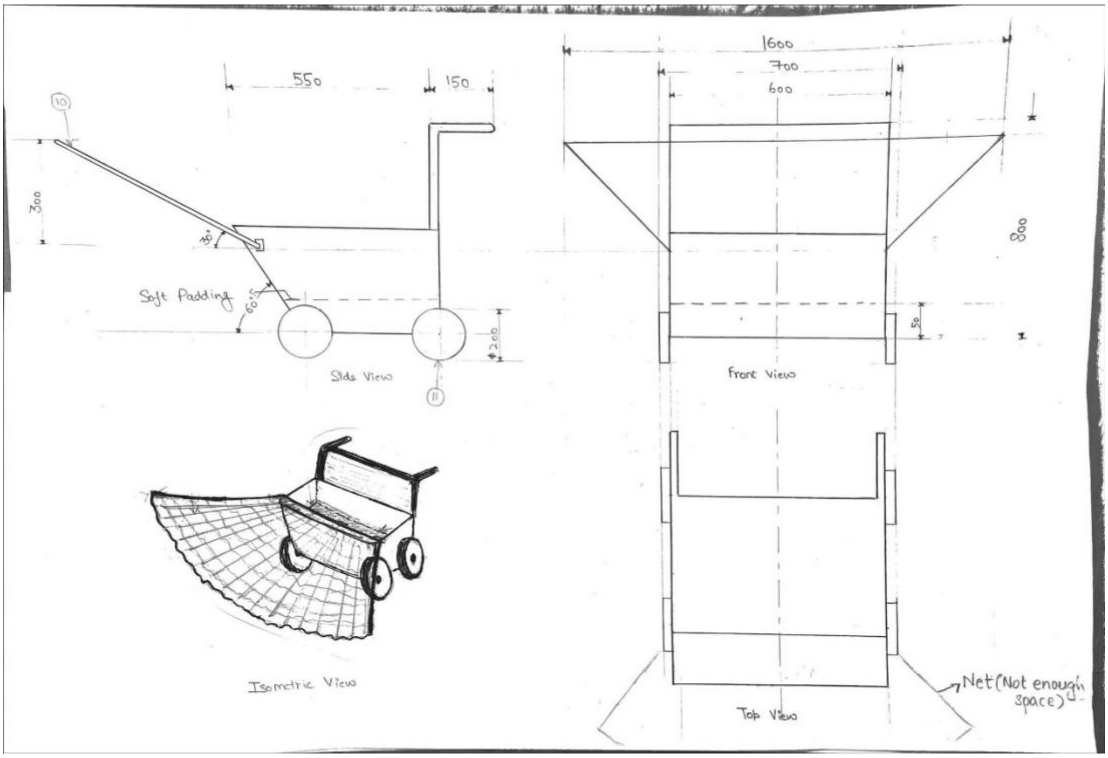
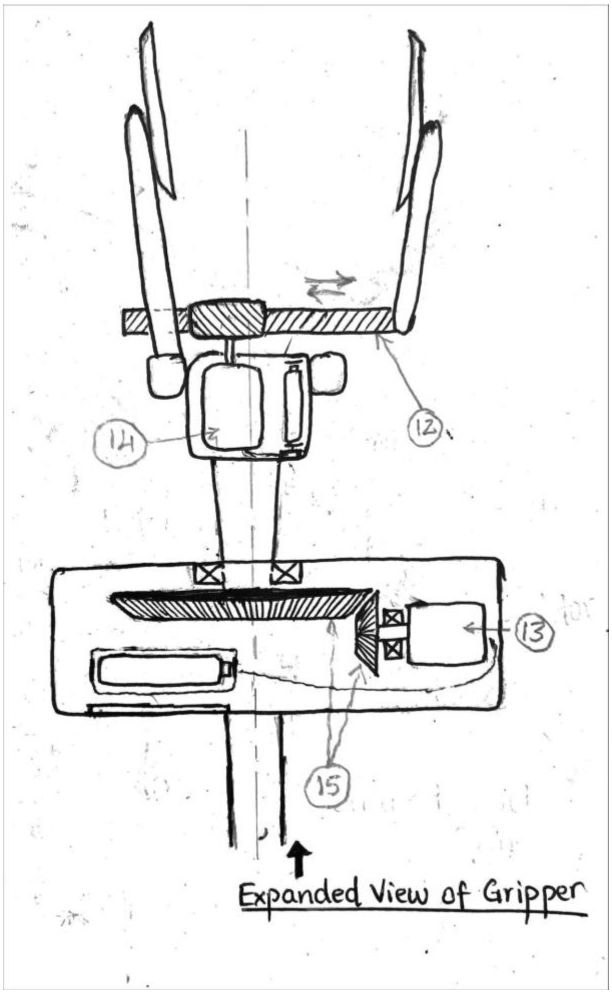


Figure 6: Technical Drawing of cart



Number of Bearings used still not decided (Minimum 2)

Figure 7: Expanded View of Gripper

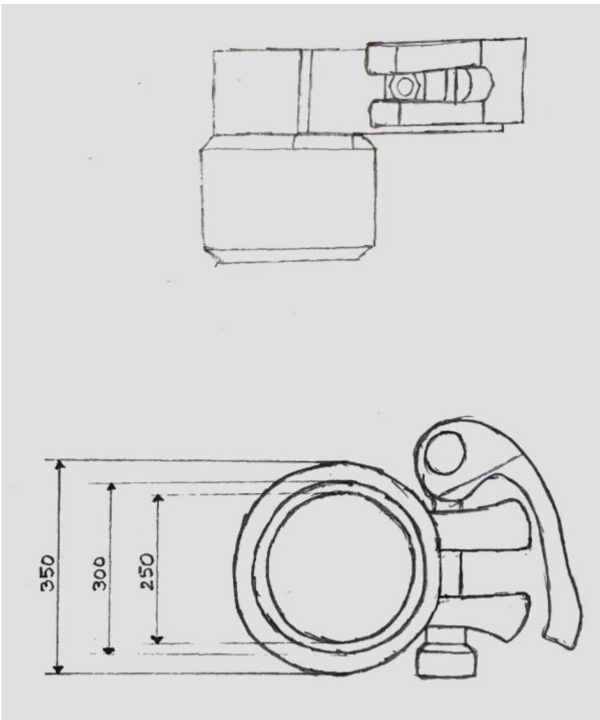


Figure 8: Mechanism to extend and retract Telescopic Rod (Flip Lock)

Sketch Description

Part	Description
1	Housing for Rack & Pinion gear, battery, and motor (Linear movement of the claws)
2	Housing for bevel gear, battery, and motor (Rotational movement of the gripper)
3	Gripper
4	Stopper which works on the lever mechanism
5	Telescopic rod
	Pushbutton for rotating
7	Pushbutton for linear movement
8	Rope
9	Gripper thick rubber pads
10	Net with outer radius of 1600 mm (Couldn’t draw the technical drawing of it because of not enough space)
11	Wheels
12	Rack & Pinion gear
13	Motor connected Bevel gear
14	Motor connected Rack & Pinion gear
15	Bevel gear

Table 3: Sketch Description

List of Main Components

The following section provides the list of components required to assemble one unit of PickIT. Along with the components and their function, an estimated price of each part is provided.

PART	FUNCTION	ESTIMATED PRICE
Gripper + Rubber Padding	Holds onto the fruit firmly without slipping	50€
Motor & Gear with Housing	To grab and rotate the fruit for plucking	60€
Telescopic Rod + Stopper/Lever	User can change the length of rod accordingly	8€
Arduino UNO + Pushbutton + Switch	To control machine functioning after user input	5€
Basket + Soft Padding + Wheels	To collect plucked fruits without damaging them	10€
Stainless Steel Rod/ Channel + Net	Holds the net at desired angle to control the pace of falling fruits	3€
Battery (x2)	Power supply for the system	5€

Table 4: Required Components

Preliminary Strength Assessment of Apple Picker

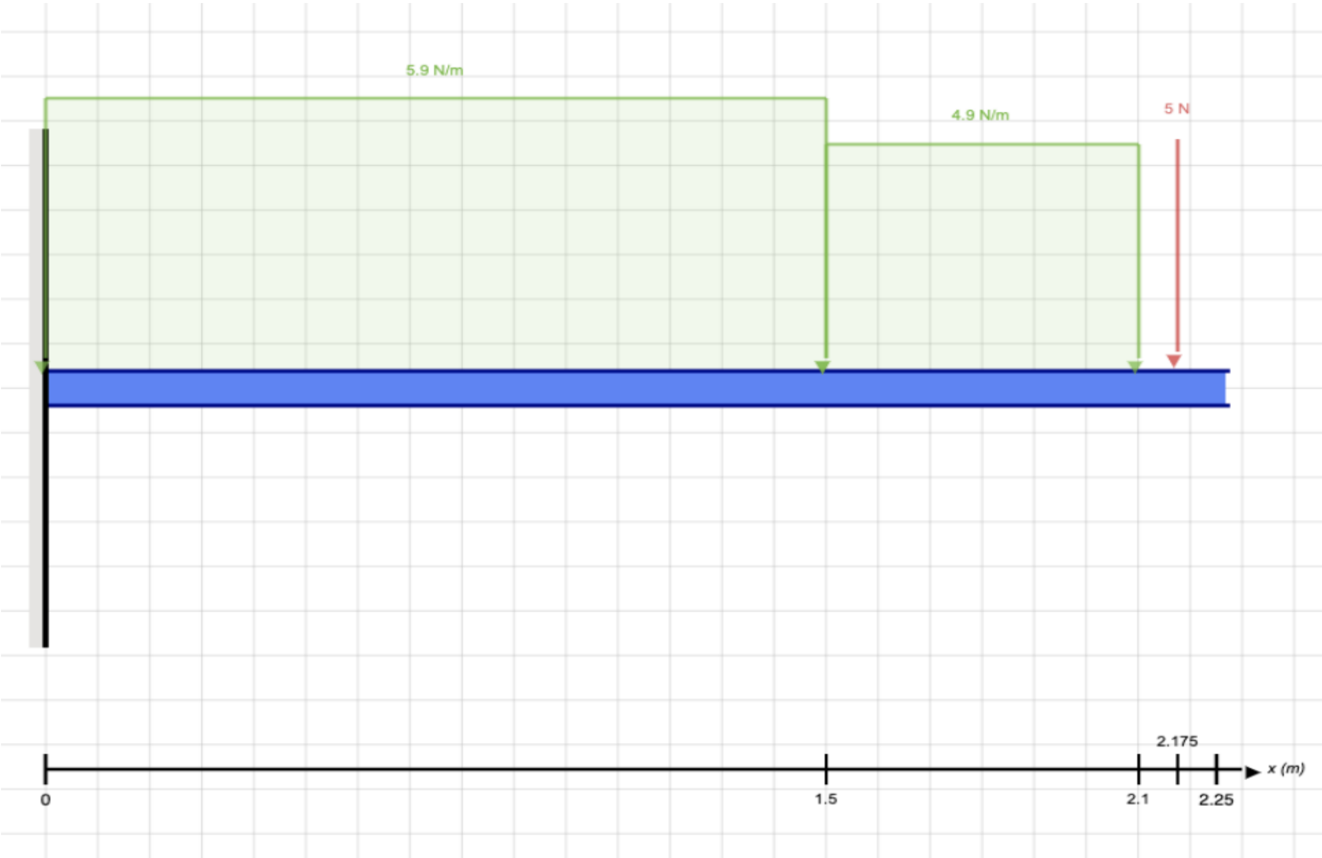


Figure 9: Distribution of Loads acting on the Fruit Picker (PickIT)

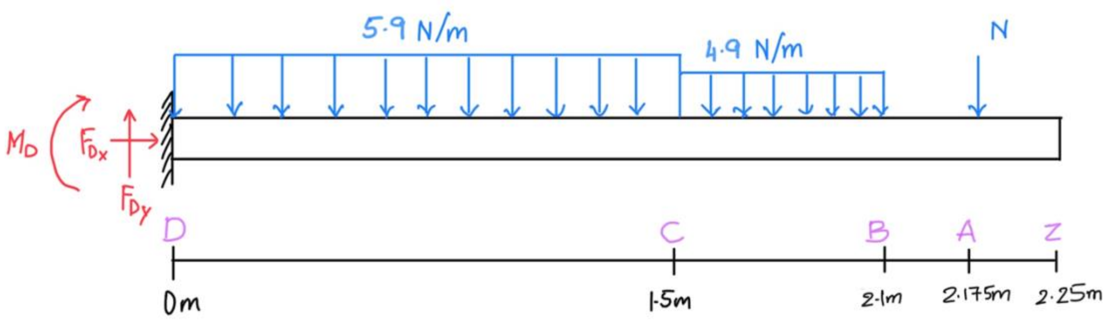


Figure 10: Free Body Diagram of Beam

Approximate weight of rod from D to C: 0.880kg
Approximate weight of rod from C to B: 0.295kg
Approximate weight of gripper: 0.5kg

(i) To Find forces at Cantilever Support:

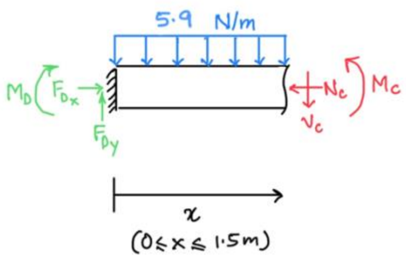
- $\sum F_{\{x\}} = 0$
  $\Rightarrow \boldsymbol{F_{D_x} = 0}$

- $\sum F_{\{y\}} = 0$
  $\Rightarrow F_{D_y} - 8.85N - 2.94N - 5N = 0$
  $\Rightarrow \boldsymbol{F_{D_y} = 16.79N}$

- $\sum M = 0$
  $\Rightarrow -M_D - (8.85N * 0.75m) - (2.94N * 1.8m) - (5N * 2.175m) = 0$
  $\Rightarrow \boldsymbol{M_D = -22.8Nm}$

(ii) To Find Internal forces, we take sections of the beam :

Section 1:



- $\sum F_x = 0$
  $\Rightarrow \boldsymbol{N_c = 0}$

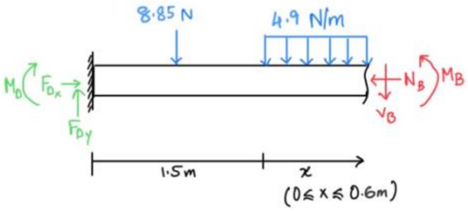
- $\sum F_y = 0$
  $\Rightarrow F_{D_y} - V_c - 5.9x = 0$
  $\Rightarrow \boldsymbol{V_c = (16.79 - 5.9x)N}$

  At point D, $V_c = 16.79N$
  At point C, $V_c = 7.94N$

- $\sum M = 0$
  $\Rightarrow -M_d + M_c - F_{D_y}x + 5.9x(\frac{x}{2}) = 0$
  $\Rightarrow \boldsymbol{M_c = \left(-22.8 + 16.79x - 5.9x\left(\frac{x}{2}\right)\right) Nm}$

  At point D, $M_c = -22.8Nm$
  At point C, $M_c = -4.25Nm$

<u>Section 2:</u>



- $\sum F_x = 0$
  $\Rightarrow \boldsymbol{N_b = 0}$

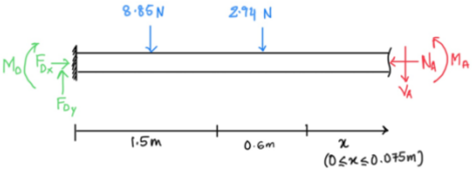
- $\sum F_y = 0$
  $\Rightarrow F_{D_y} - V_B - 8.85N - 4.9x = 0$
  $\Rightarrow \boldsymbol{V_B = (7.94 - 4.9x)N}$

  At point C, $V_B = 7.94N$
  At point B, $V_B = 5N$

- $\sum M = 0$
  $\Rightarrow -M_d + M_B - F_{D_y}(1.5 + x) + 8.85(0.75 + x) + 4.9x(\frac{x}{2}) = 0$
  $\Rightarrow \boldsymbol{M_B = (-22.8 + 16.79(1.5 + x) - 8.85(0.75 + x) - 2.45x^2)\ Nm}$

  At point C, $M_B = -4.25Nm$
  At point B, $M_B = -0.37Nm$

<u>Section 3:</u>



- $\sum F_x = 0$
  $\Rightarrow \boldsymbol{N_A = 0}$

- $\sum F_y = 0$
  $\Rightarrow F_{D_y} - V_A - 8.85N - 2.94N = 0$
  $\Rightarrow \boldsymbol{V_A = 5N}$

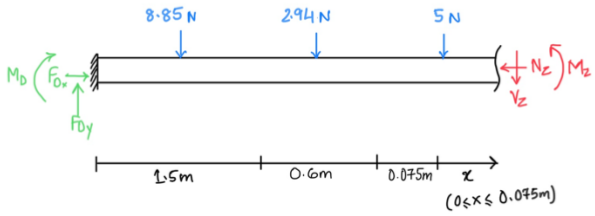
  At point B, $V_A = 5N$
  At point A, $V_A = 0N$

- $\sum M = 0$
  $\Rightarrow -M_d + M_A - F_{D_y}(x + 2.1) + 8.85(1.35 + x) + 2.94(0.3 + x) = 0$
  $\Rightarrow \boldsymbol{M_A = (-22.8 + 16.79(2.1 + x) - 8.85(1.35 + x) - 2.94(0.3 + x))\ Nm}$

  At point B, $M_A = -0.37Nm$

At point A, $M_A = 0Nm$

Section 4:



- $\sum F_x = 0$
  $\Rightarrow \boldsymbol{N_A = 0}$

- $\sum F_y = 0$
  $\Rightarrow F_{D_y} - V_Z - 8.85N - 2.94N - 5N = 0$
  $\Rightarrow \boldsymbol{V_Z = 0N}$

  At point A, $V_Z = 0N$
  At point Z, $V_Z = 0N$

- $\sum M = 0$
  $\Rightarrow -M_d + M_Z - F_{D_y}(x + 2.175) + 8.85(1.425 + x)$
  $+ 2.94(0.375 + x) + 5x = 0$
  $\Rightarrow \boldsymbol{M_Z = (-22.8 + 16.79(2.175 + x) - 8.85(1.425 + x) - 2.94(0.375 + x) - 5x)\ Nm}$

  At point A, $M_Z = 0Nm$
  At point Z, $M_Z = 0Nm$

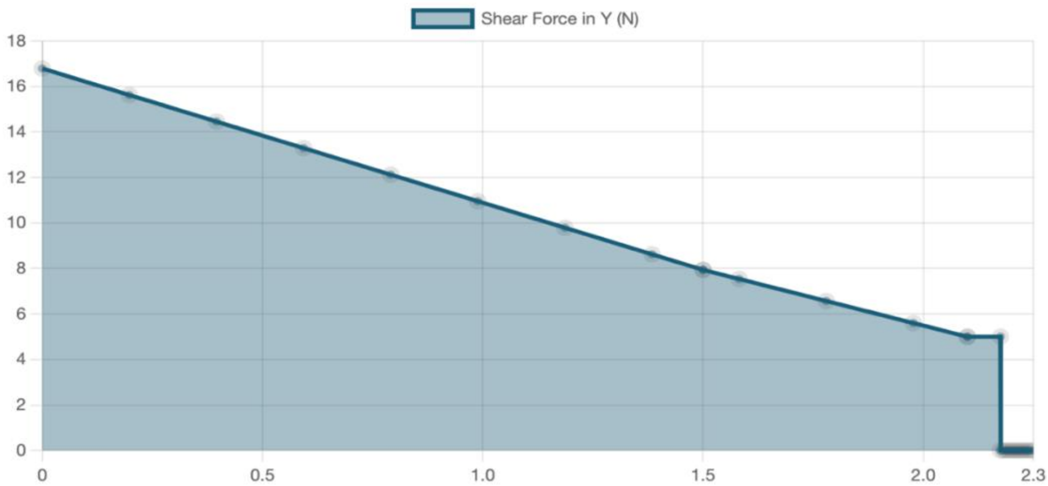


Figure 11: Shear Force Diagram of Apple Picker

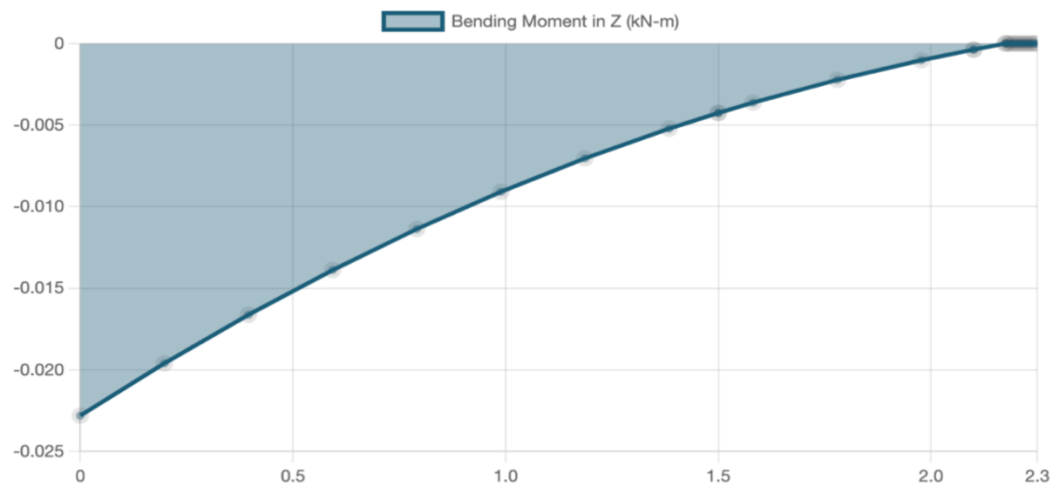


Figure 12: Bending Moment Diagram of Apple Picker

Thus, the highest Bending moment is **22.8Nm** and highest Shear Stress is **16.79N**, both acting at the point where the telescopic rod is attached to the handle.

Preliminary Strength Assessment of Cart:

Approximate mass of 1 apple: **0.25kg**

Approximate mass of cart: **20kg**

$$Load\ on\ each\ wheel = \frac{Mass\ of\ 25\ fruits + Mass\ of\ cart}{Number\ of\ Wheels} * g$$

$$= \frac{25 * 0.25kg + 20kg}{4} * \frac{9.81m}{s^2} = \mathbf{64.38N}$$

Functional Structure

Diagram:

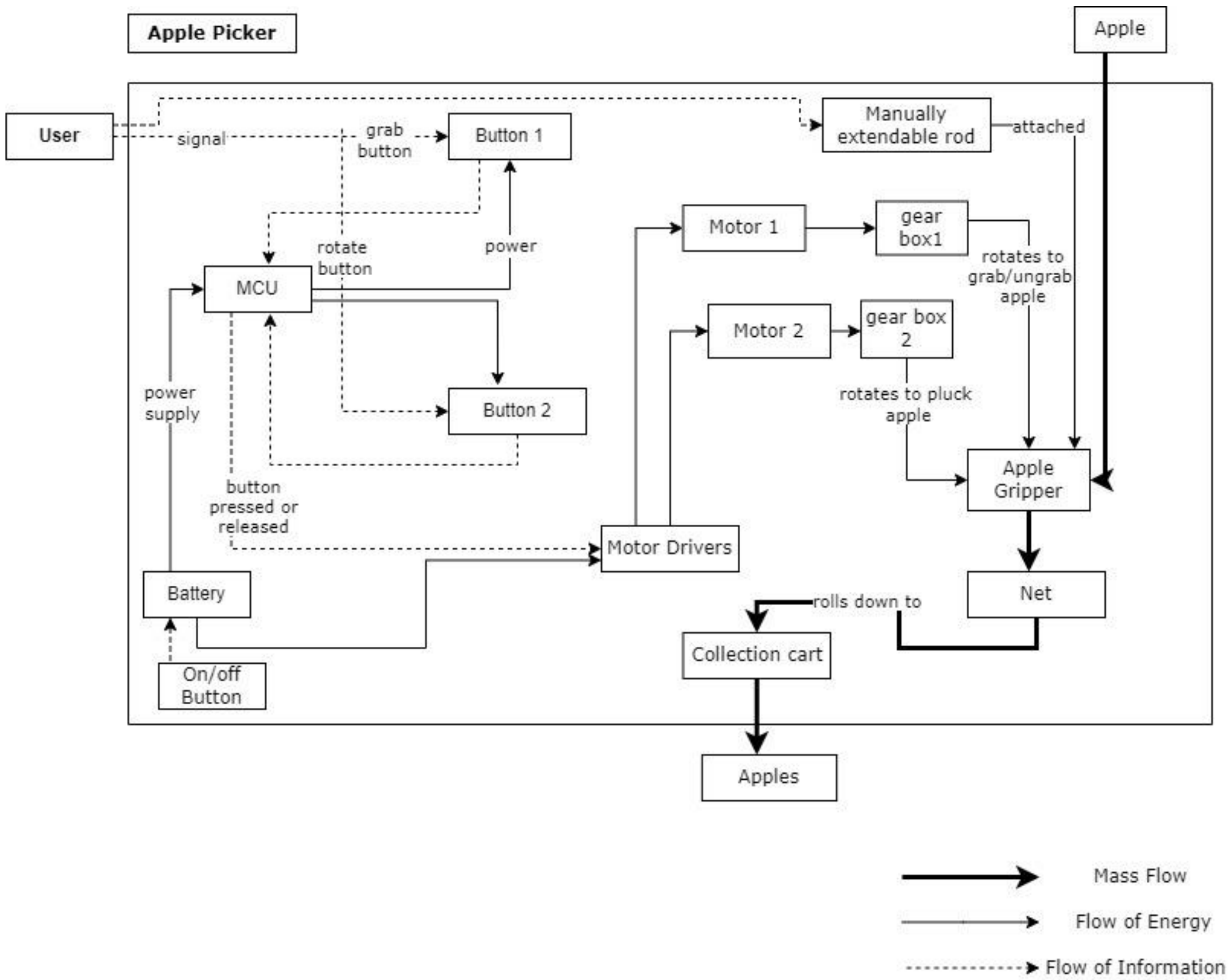


Figure 13: Functional Structure Diagram

Design- Failure Modes and Effects Analysis (D-FMEA)

D-FMEA is a type of Failure mode and effect analysis that is used to examine and identify potential risks and failures involved in the design of the product or system. This is a very useful qualitative tool as it helps the designer know where and how the component could fail and how to mitigate the likelihood of such failure. It, therefore, results in a much improved and efficient design by rectifying the potential flaws. With D-FMEA, we can achieve improved performance and safety of the product.
There is a certain set of guidelines to follow as mentioned below.
For the full breakdown table, **refer to Appendix A**

Severity Guidelines

10	Hazardous- no warning
9	Hazardous- with warning
8	Very high
7	High
6	Moderate
5	Low
4	Very low
3	Minor
2	Very minor
1	none

Table 5: D-FMEA Severity Guidelines

Occurrence Guidelines

Ranking	Effect	Failure Rates	Percent Defective
10	Extremely high	>1 in 2	50%
9	Very high	1 in 3	33%
8	Very high	1 in 8	10-15%
7	High	1 in 20	5%
6	Marginal	1 in 100	1%
5	Marginal	1 in 400	0.25%
4	Unlikely	1 in 2000	0.05%
3	Low	1 in 15,000	0.01%
2	Very low	1 in 150,000	0.00%
1	Remote	<1 in 1,500,000	0.000007

Table 6: D-FMEA Occurrence Guidelines

Detection Guidelines

Ranking	Effect
10	Absolute uncertainty
9	Very remote
8	Remote
7	Very low
6	Low
5	Moderate
4	Moderately high
3	High
2	Very high
1	Almost certain

Table 7: D-FMEA Detection Guidelines

Project Plan

The project plan elaborates on how the project will be executed and controlled. This is achieved with the help of the work packages that display the breakdown of every task and the expected duration for successfully completing them, the responsibility chart that depicts the breakdown of how the tasks will be divided amongst the group members according to each department of engineers and, the Gantt chart which illustrates the project timeline for each milestone present in the project.

Work Packages

Project Name	Duration	Start Date	End Date
PickIT	14 weeks	01.10.22	16.01.23

Task No.	WBS	Task Description	Start Date	End Date	Responsibility	Duration (Days)	Workload (hours)
1	1	Concept Design	1/10/22	23.10.22	All	22	138
2	1.1	Marketting Decision	1/10/22	07.10.22	Anagh	5	15
3	1.1.1	Market Size	1/10/22	03.10.22	Anagh	2	6
4	1.1.2	Pricing	3/10/22	05.10.22	Anagh	1	3
5	1.1.3	Planned sales volume	4/10/22	07.10.22	Anagh	2	6
6	1.2	Overall product concept	1/10/22	17.10.22	Shreenithi & Anagh	16	54
7	1.2.1	Sketch	1/10/22	15.10.22	Anagh & Shreshth	14	42
8	1.2.2	Written description	15/10/22	17.10.22	Shreenithi	2	6
9	1.2.3	List of main components	15/10/22	17.10.22	Shreenithi	2	6
10	1.3	Preliminary strength assessment	09.10.22	19.10.22	Anagh	9	27
11	1.4	Functional Structure	17.10.22	21.10.22	Lovepreet & Shreshth	4	15
12	1.4.1	System diagram	17.10.22	20.10.22	Lovepreet	3	9
13	1.4.2	Interdependencies between components	19.10.22	21.10.22	Lovepreet	2	6
14	1.5	D-FMEA	17.10.22	23.10.22	Shreshth	5	15
15	1.6	Project Plan	16.10.22	18.10.22	Shreenithi	2	12
16	1.6.1	Work package & Resposibilities	16.10.22	18.10.22	Shreenithi	2	6
17	1.6.2	GANTT-chart	16.10.22	18.10.22	Shreenithi	2	6
18	2	Product Design	25.10.22	18.11.22	All	24	120
19	2.1	Complete 3D CAD model	25.10.22	15.11.22	Shreshth & Shreenithi	10	30
20	2.2	Electric Drives	26.10.22	08.11.22	Lovepreet	13	39
21	2.2.1	Load calculation	26.10.22	02.11.22	Lovepreet	7	21
22	2.2.2	Decision on motor & electronics	02.11.22	08.11.22	Lovepreet	6	18
23	2.3	Circuit diagram	08.11.22	11.11.22	Shreshth	3	9
24	2.4	Make or Buy decision	11.11.22	15.11.22	Anagh	4	12
25	2.5	Technology selection for making parts	15.11.22	18.11.22	Lovepreet	3	9
26	2.6	Requirements manual for "buy" (CotS) parts	11.11.22	18.11.22	Shreenithi	7	21
27	3	Complete Project Documentation	30.11.22	23.12.22	All	23	69
28	3.1	Technical Drawings of Parts	30.11.22	10.12.22	Shreshth & Shreenithi	10	30
29	3.2	Program flow chart	05.12.22	10.12.22	Lovepreet	5	15
30	3.3	Bill Of Materials	10.11.22	15.11.22	Anagh & Shreshth	5	30
31	3.3.1	Bill of materials - Mechanical	10.12.22	15.12.22	Anagh	5	15
32	3.3.2	Bill of materials - Electrical	10.12.22	15.12.22	Shreshth	5	15
33	3.4	Production Planning	01.12.22	08.12.22	Shreenithi	7	21
34	3.5	Cost calculation	05.12.22	12.12.22	Anagh	7	21
35	3.6	Documentation	16.12.22	23.12.22	Lovepreet	7	21
36	4.1	Video Presentation	23.12.22	05.01.23	All	13	39
37	4.2	Poster Making	23.12.22	05.01.23	All	13	39

Figure 14: Work Distribution

Responsibilities Chart

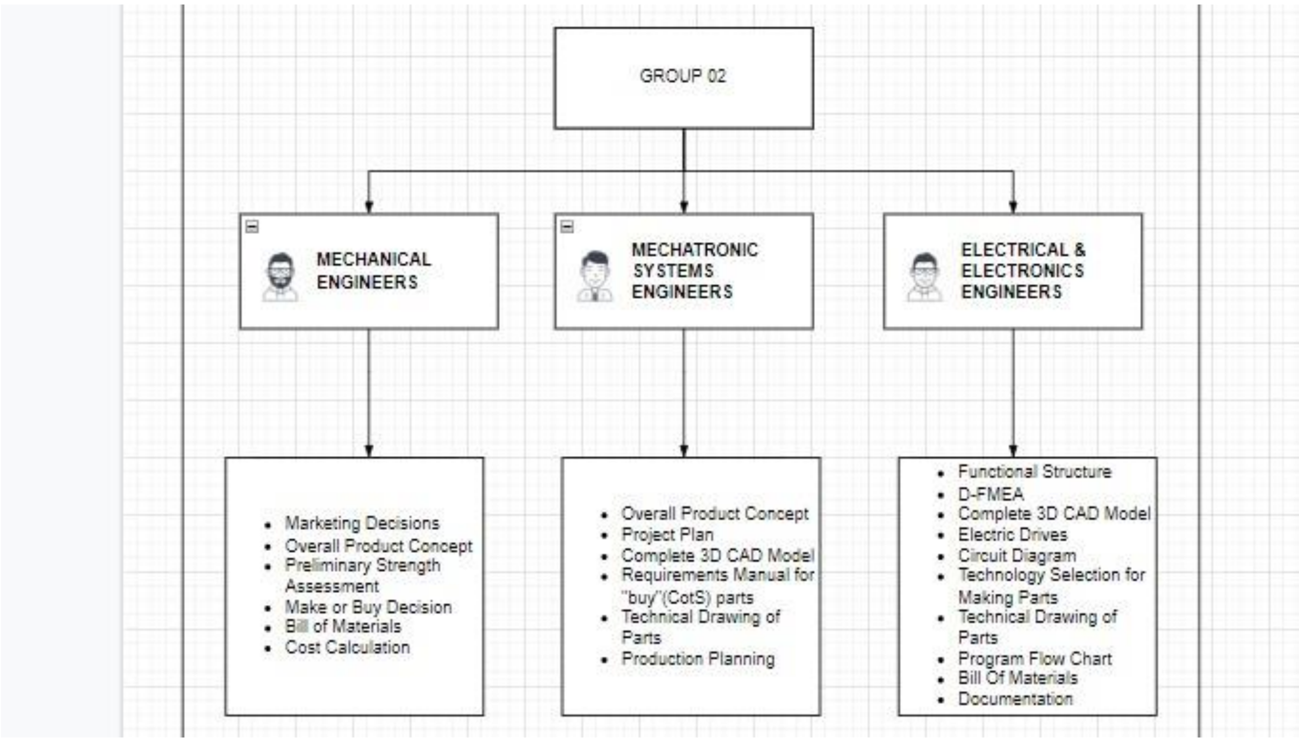


Figure 15: Responsibilities breakdown

GANTT-Chart

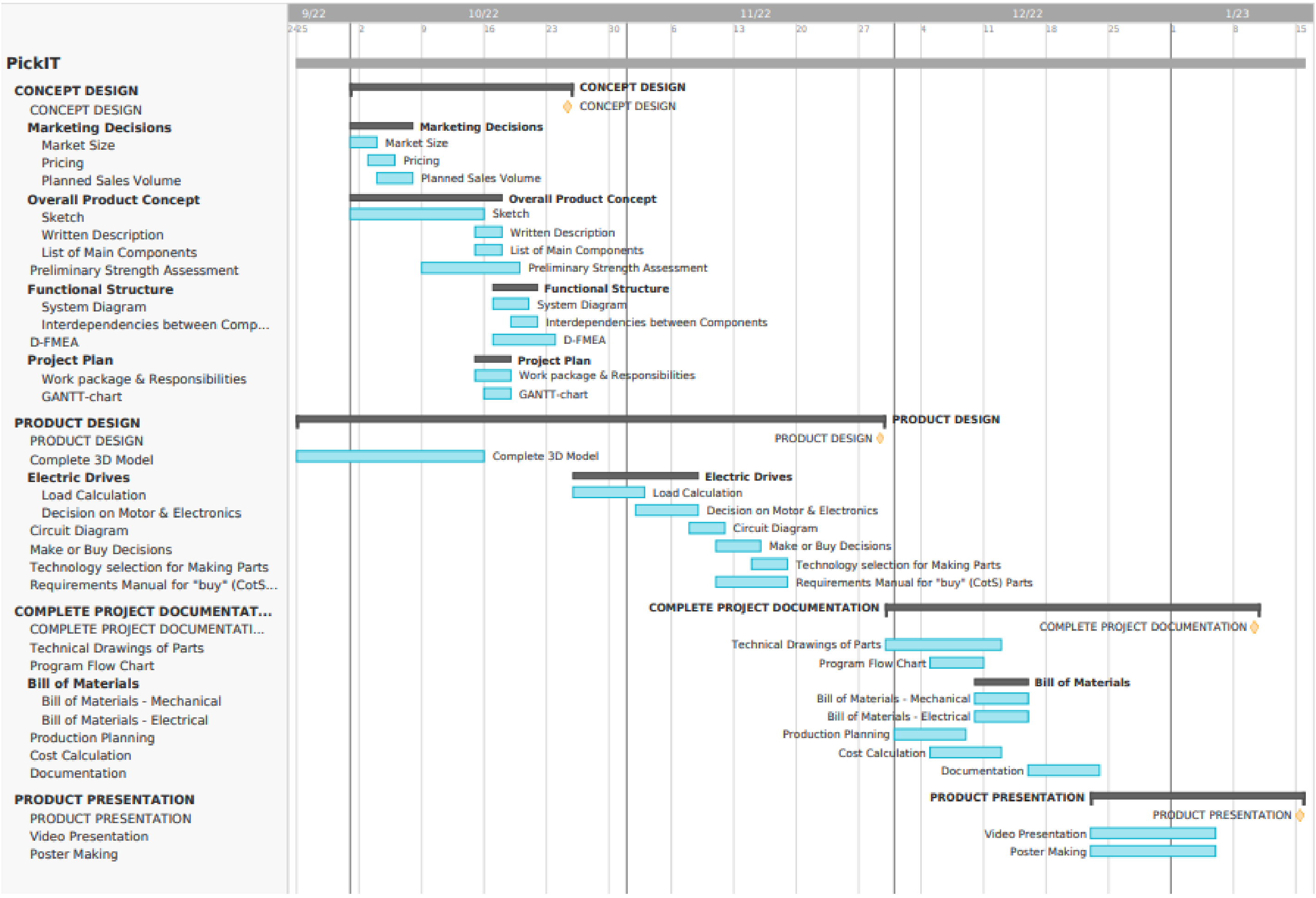


Figure 16: Gantt-Chart

Complete 3D Model (CAD) of PickIT

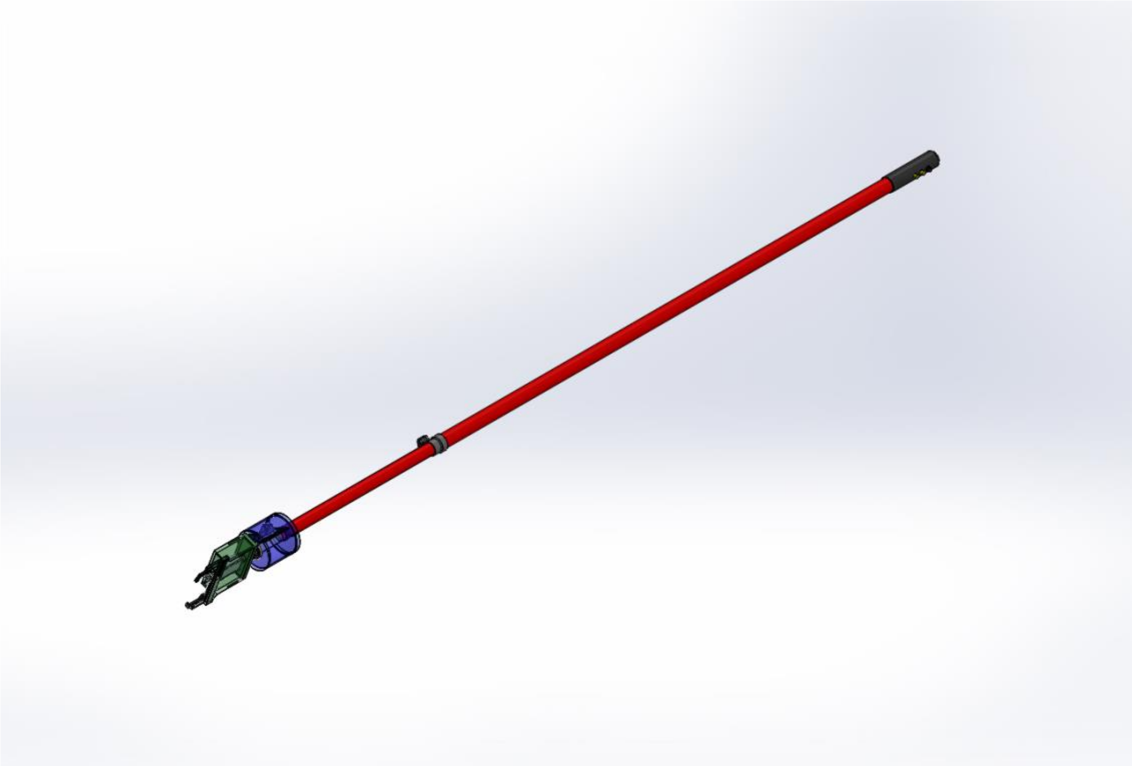


Figure 17: Assembly of PickIT

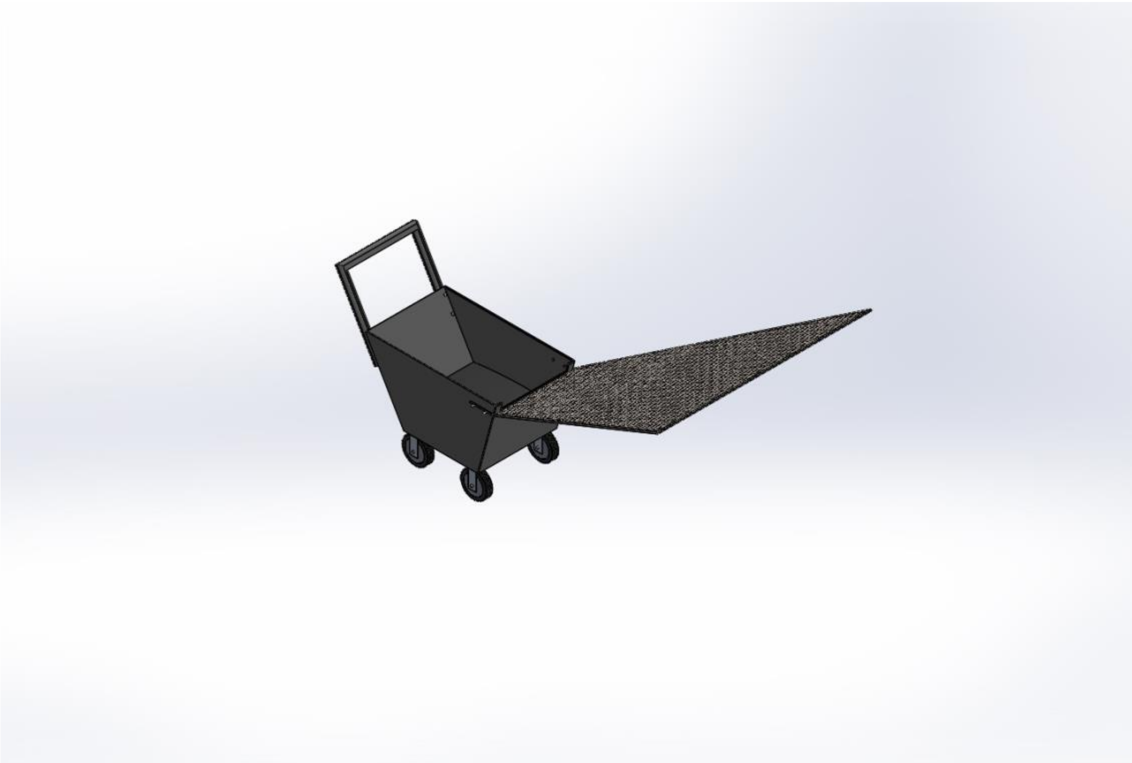


Figure 18: Assembly of the cart

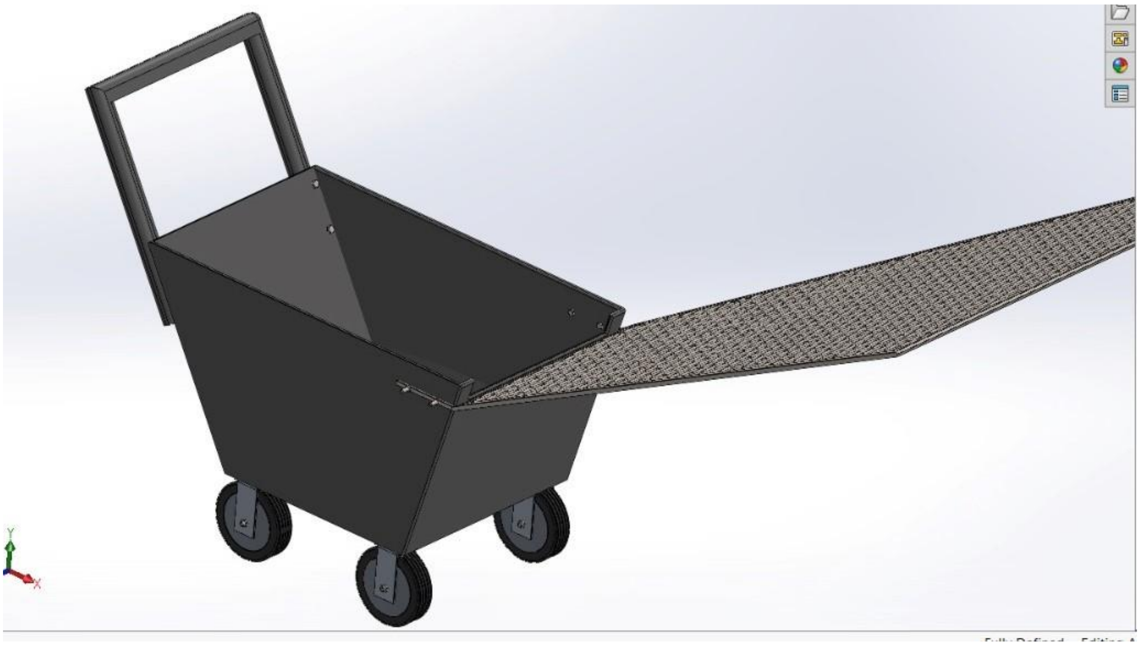


Figure 19: Zoomed view of the cart

Functional Principles

In the following section, the detailed description of each component of PickIT and its purpose is mentioned. The mechanism below allows PickIT to completely function, from twisting and plucking the fruit to dropping it to the basket without causing damage.

Name of Component	Feature
Handle of Fruit Picker	Provides user with grip to hold the fruit picker

Table 8: Handle - CAD

Name of Component	Feature
Pushbuttons (x2), Switch (x1)	The switch is used to turn on/off the entire system. The first button is used to expand/retract the claw of the gripper. The second one is used for the rotation of the claw.

Table 9: Input - CAD

Figure 20: Handle

Name of Component	Feature
Telescopic rods with flip-lock mechanism	The gripper and motor housings rest on the extendable rod. The flip -lock is used to lock the rod so that the length does not change.

Table 10: Telescopic Rod - CAD

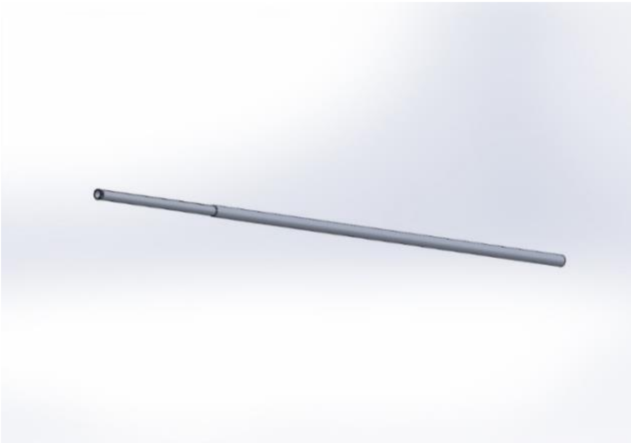


Figure 21: Telescopic rod

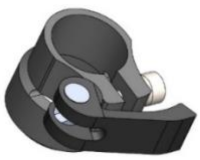


Figure 22: Flip-lock

Name of Component	Feature
Housing of the rotational mechanism	A cylindrical housing for positioning the geared motor, battery, and the microcontroller. The lid of housing is screwed into the body for accessibility.

Table 11: Housing of rotational mechanism

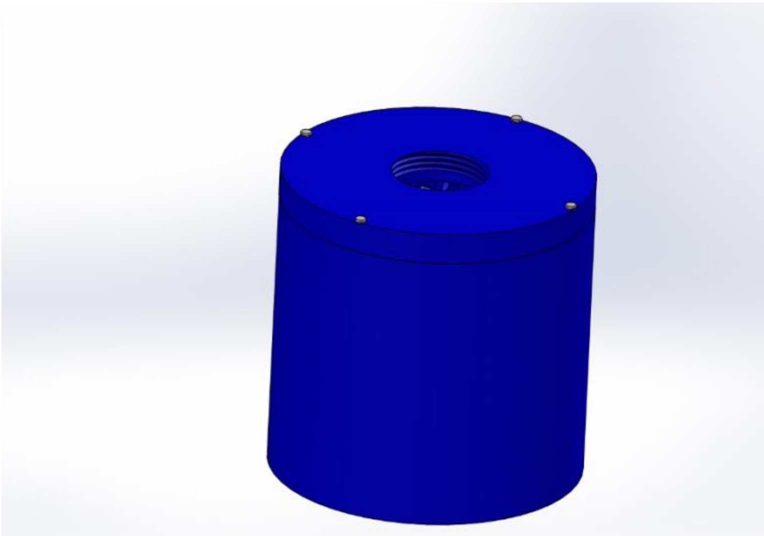


Figure 23: Rotational mechanism housing- CAD

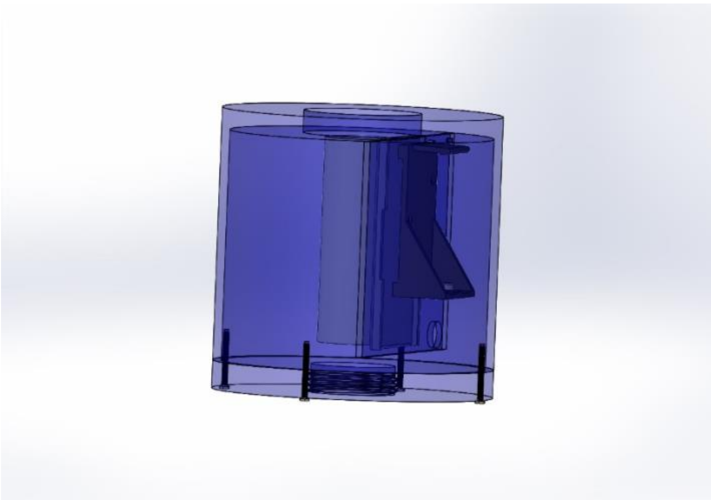


Figure 24: Transparent view of the housing- CAD

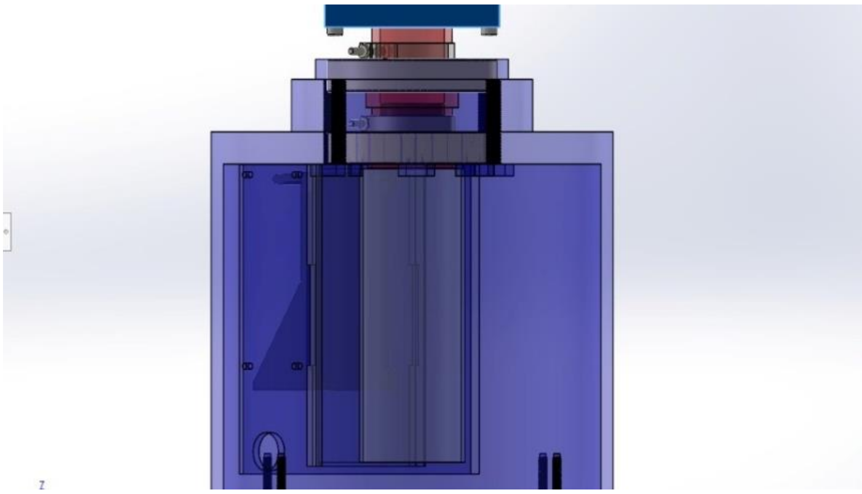


Figure 25: Housing attachment to ball bearing and shaft

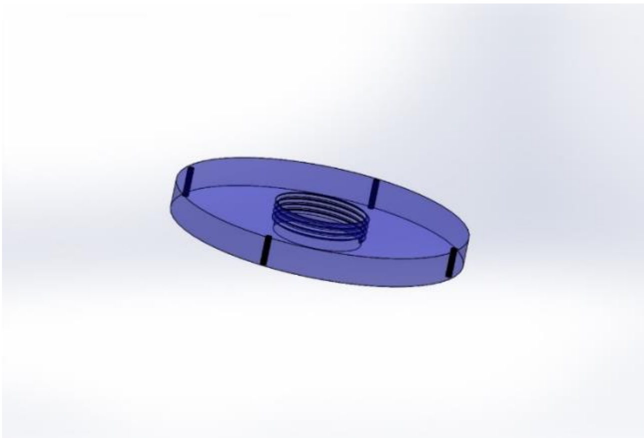


Figure 25: Lid of the housing- CAD

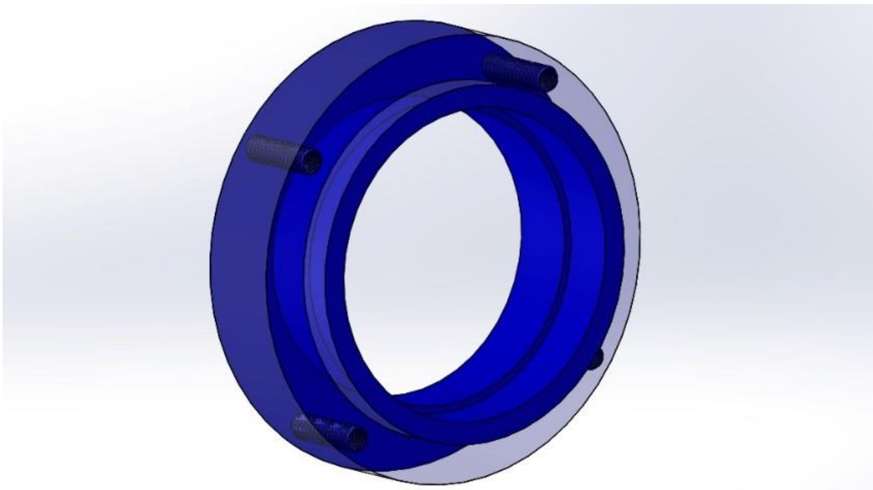


Figure 26: Extended housing to position the bearings securely- CAD

Name of Component	Feature
Housing plate	This plate is installed inside the rotational housing to place the battery holder, the motor housing and Arduino Nano.

Table 12: Housing plate

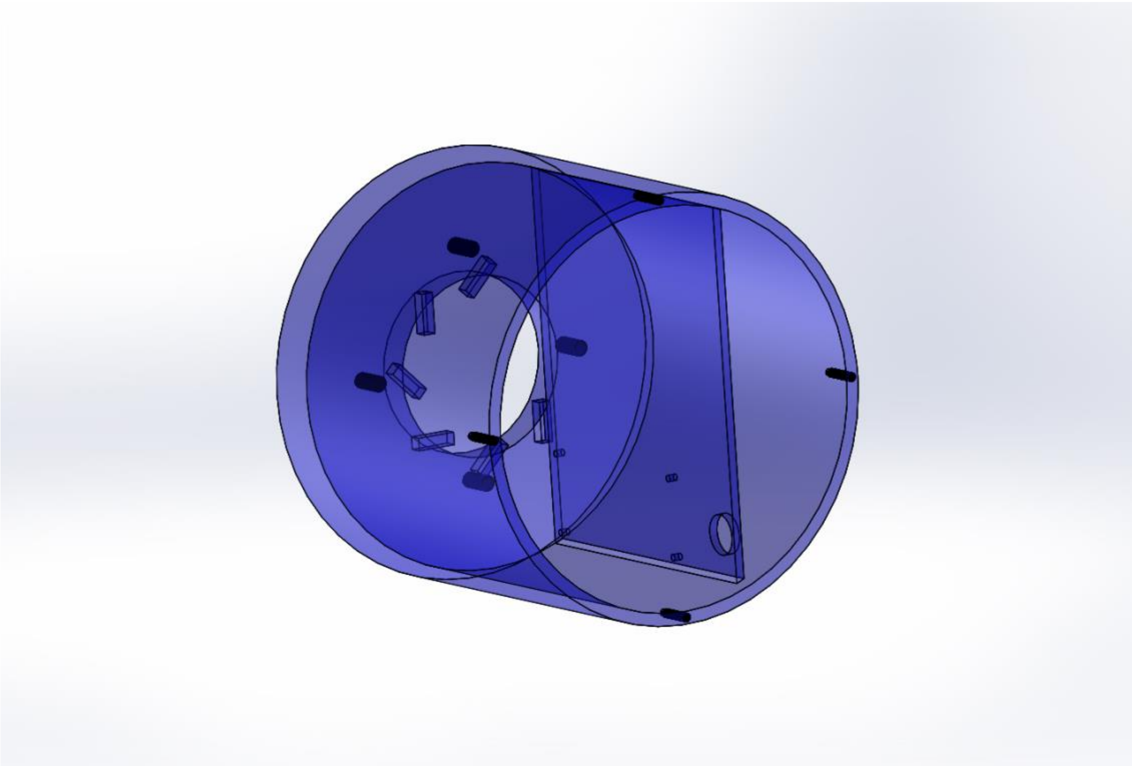


Figure 27: Transparent view of the housing- CAD

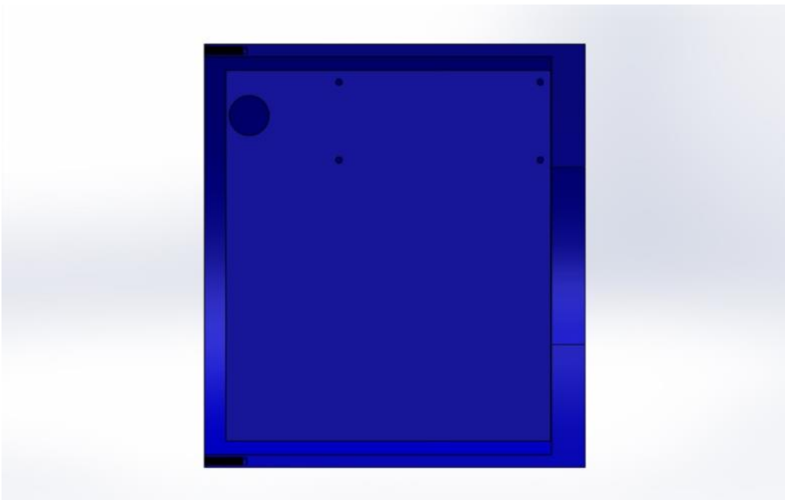


Figure 28: Plate inside the housing- CAD

Name of Component	Feature
Battery Holder	Battery is fixed in the battery holder and wires are connected to it.

Table 13: Battery holder

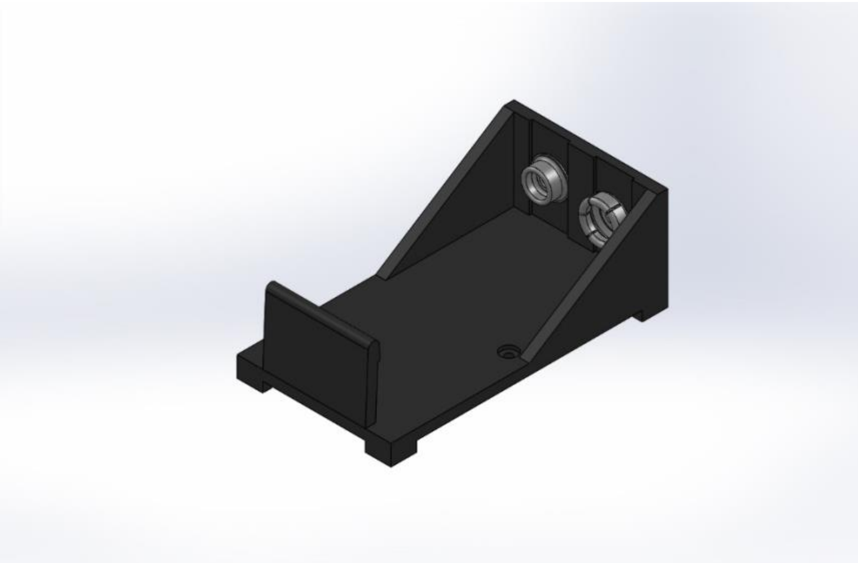


Figure 29: Battery Holder- CAD

Name of Component	Feature
Geared motor covering with shaft sleeve	Used to place the motor securely inside the rotational housing. The spindle of the motor rests inside the shaft sleeve to connect it to the output shaft.

Table 14: Handle - CAD

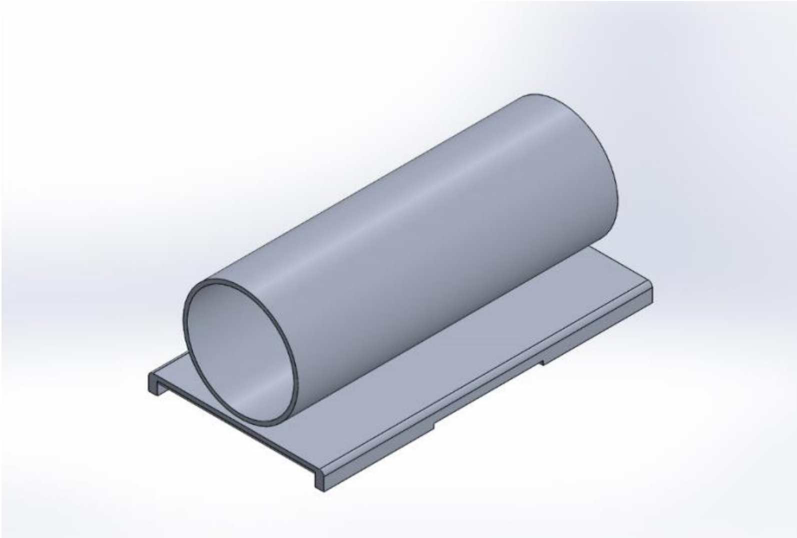


Figure 30: Motor covering - CAD

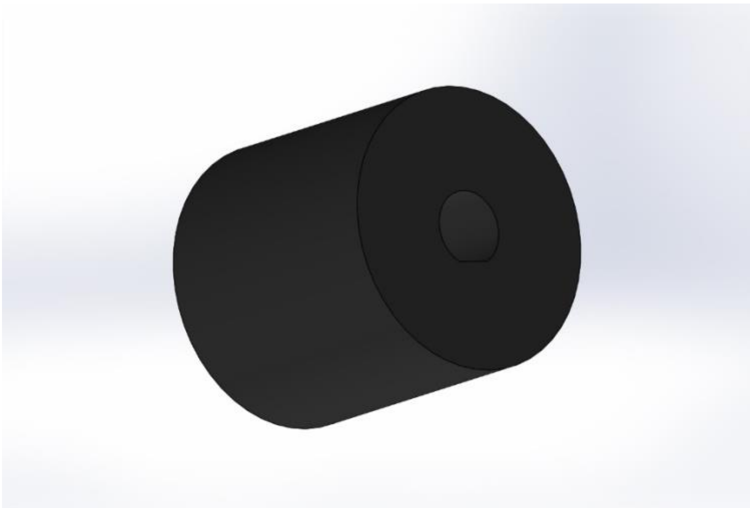


Figure 31: Motor shaft sleeve- CAD

Name of Component	Feature
Radial ball bearing	To eliminate eccentricity in the single-axis rotation of the output shaft of motor and to provide frictionless rotation.

Table 15: Radial ball bearing - CAD

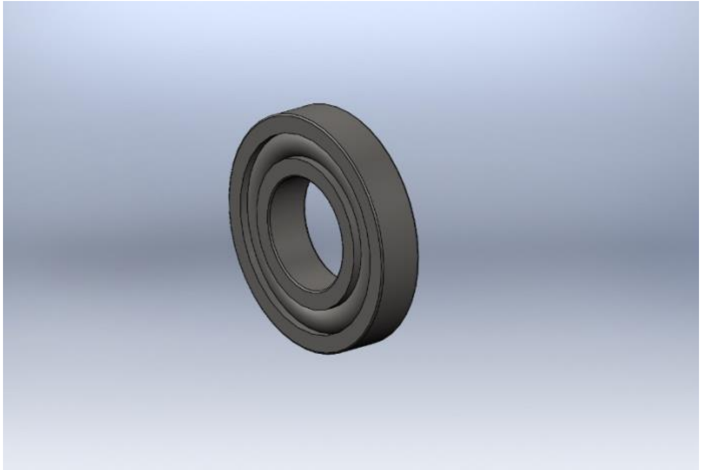


Figure 32: Radial ball bearing – CAD

Figure 33: Circlip to hold bearing in place – CAD

Name of Component	Feature
Output shaft of motor	Used to connect the motor to the gripper housing.

Table 16: Output shaft of motor - CAD

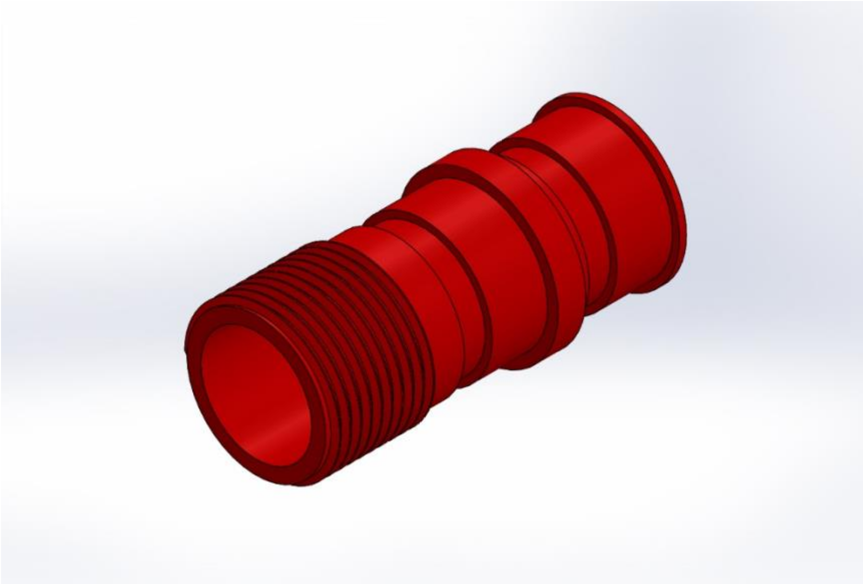


Figure 34: Output shaft of motor – CAD

Name of Component	Feature
Gripper housing	The second motor rests in the gripper's housing. It is attached to a slot for holding the rack which in turn is attached to one of the claws.

Table 17: Gripper housing - CAD

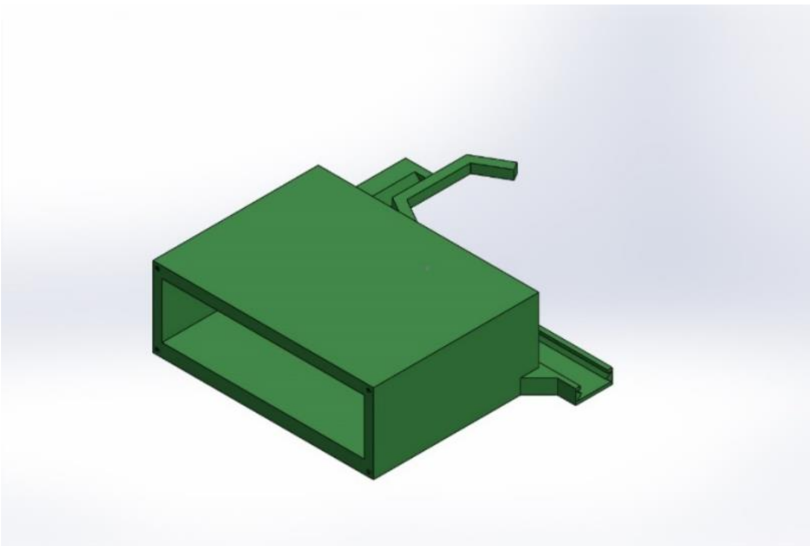


Figure 35: Gripper housing - CAD

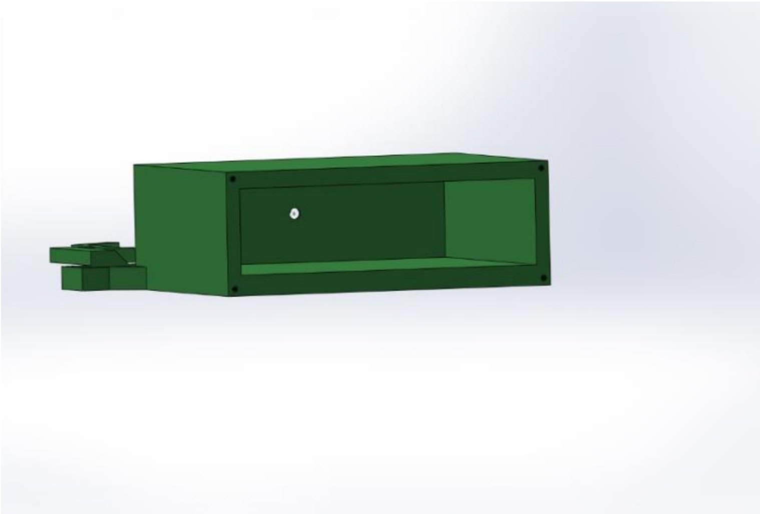


Figure 36: Inside the Gripper housing - CAD

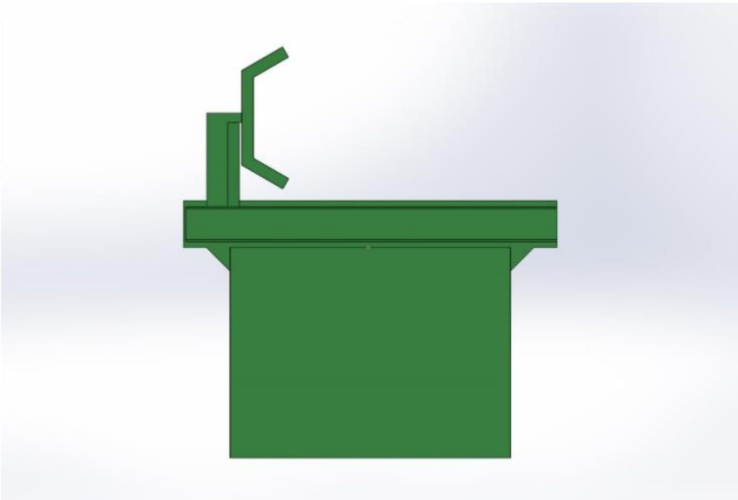


Figure 37: Top view of gripper housing

Name of Component	Feature
Motor covering	The second motor for opening and closing the claw is placed securely inside the motor covering.

Table 18: Motor covering

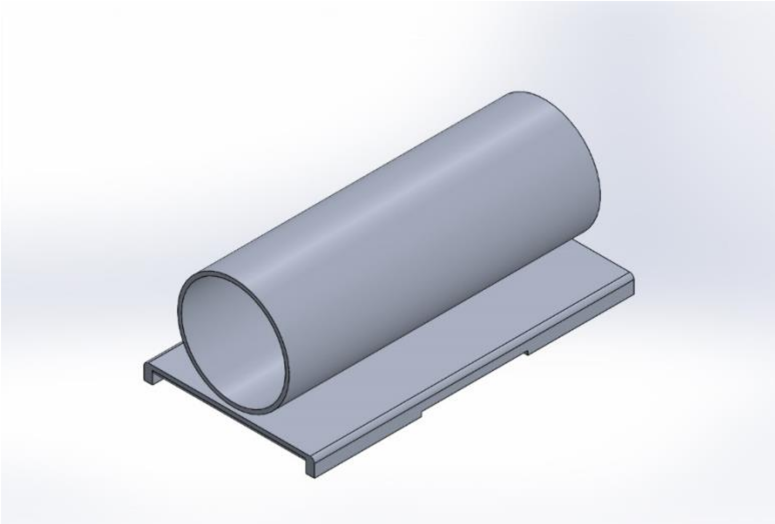


Figure 38: Motor covering-CAD

Name of Component	Feature
Rack & Pinion	Used to open and close the claw. One end of the rack is attached to the claw.

Table 19: Rack & Pinon

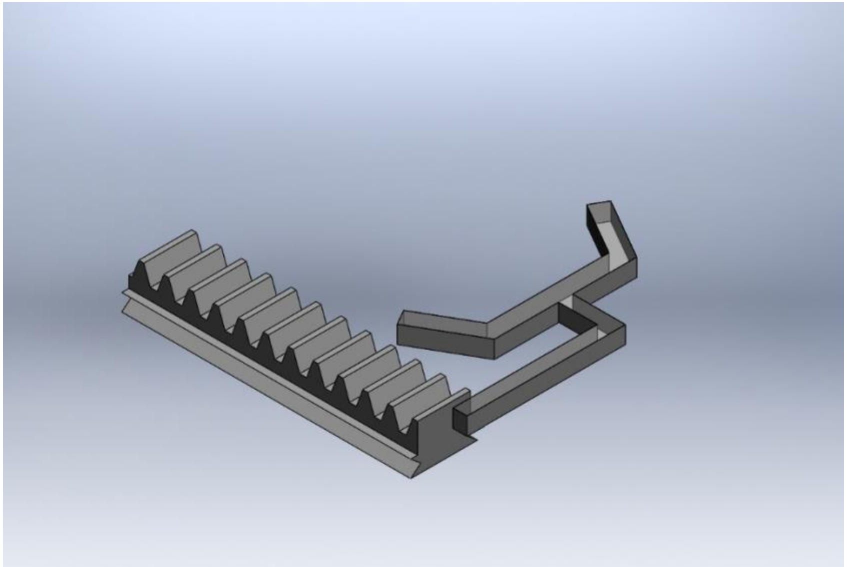


Figure 39: Rack attaching to one of the claws - CAD

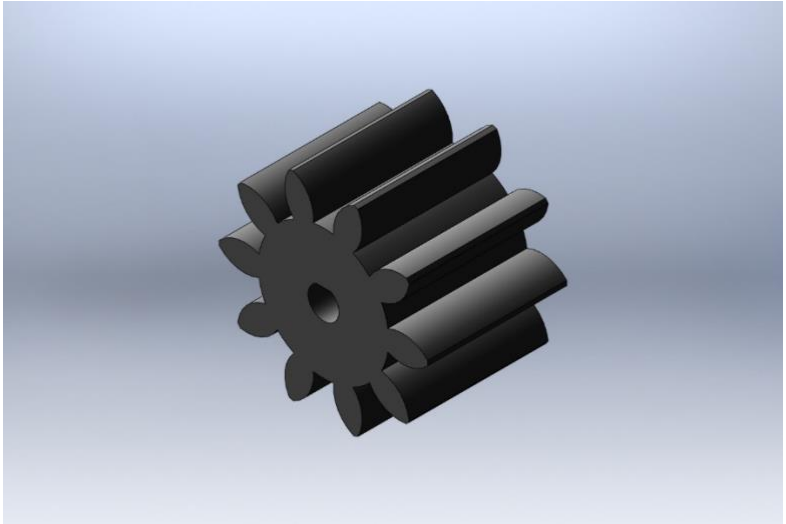


Figure 40: Pinion-CAD

Name of Component	Feature
Anti-slip rubber padding	Used to hold onto the fruit firmly without slipping away

Table 20: Anti-slip rubber padding

Figure 41: Anti-slip rubber padding-CAD

Name of Component	Feature
Basket and handle	Used to store the plucked fruits.

Table 21: Basket and Handle- CAD

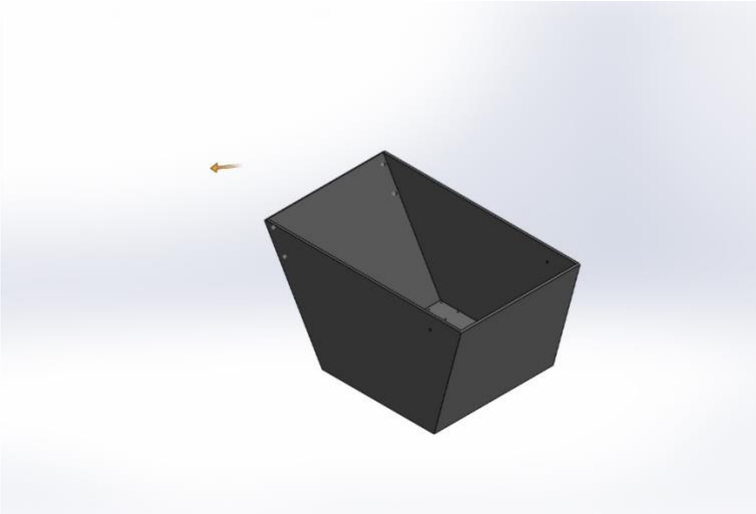


Figure 42: Basket - CAD

Figure 43: Handle- CAD

Name of Component	Feature
Soft padding	A thick layer of padding is attached to the bottom of the basket to prevent fruits from getting damaged.

Table 22: Soft padding – CAD

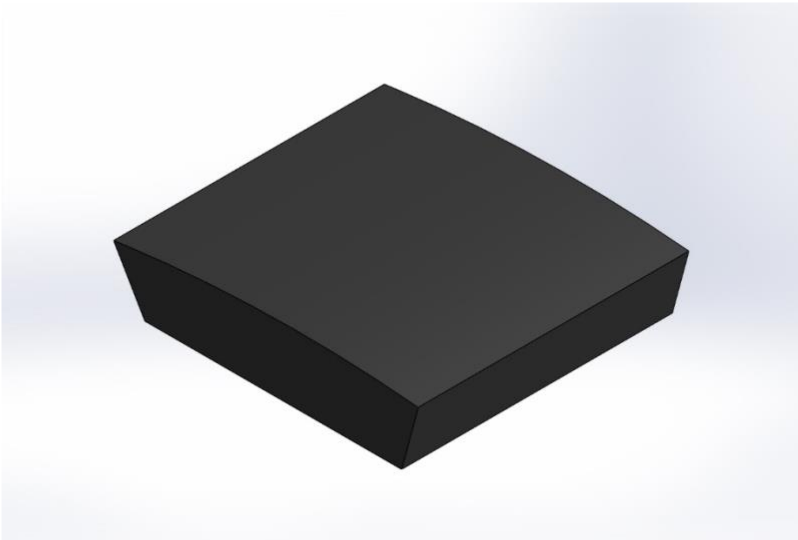


Figure 44: Soft padding – CAD

Name of Component	Feature
Castor wheels	To ensure smooth mobility of the cart

Table 23: Castor wheels

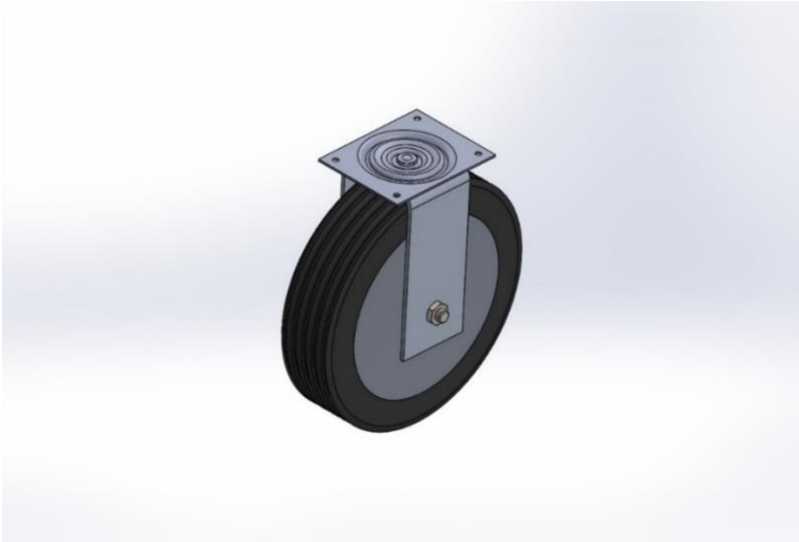


Figure 45: Castor wheels - CAD

Name of Component	Feature
Rods	Provide the framework for the net

Table 24: Rods - CAD

Name of Component	Feature
Net	Used to catch the fallen fruits from the tree.

Table 25: Net - CAD

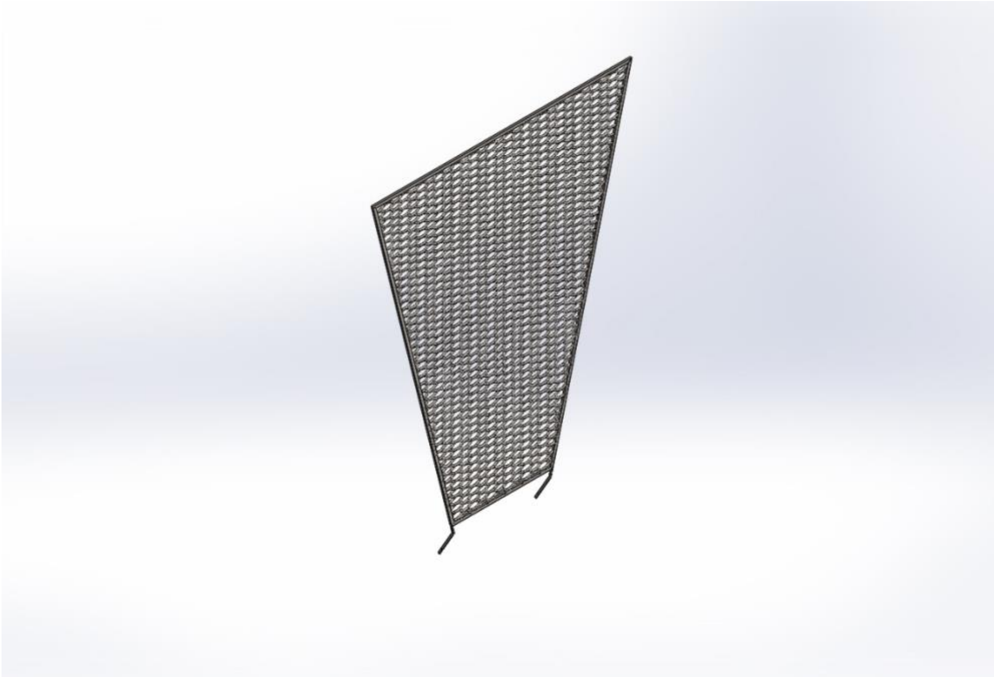


Figure 46: Net with rods-CAD

Load Calculation of Gripper

Gripping Force

The force required in a gripper application is majorly defined by the style of the jaw used. We are using the frictional grip. The next step in determining the gripper force is the weight of the apple that it experiences due to both gravity and acceleration. Although our application doesn't have linear acceleration, it still rotates along with the fruit to break it from the stem. So, acceleration is also considered.

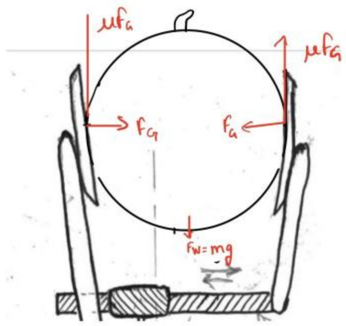


Figure 47: Forces on Gripper

The force due to the mass:

$$F_w\text{=mg} \qquad (1)$$

The friction is responsible to hold the apple:

$$F_f = \mu N F_g \qquad (2)$$

Where N is the number of fingers, F_g is the gripping force and F_f is the frictional force

A safety factor (F_s) is also included because of the uncertainty of circumstances.

$$F_g = F_s * F_w \qquad (3)$$

Equating equations (2) and (3):

$$F_g = {F_s * m(g+a)}/{\mu N}$$

For our Apple picker,

$F_s = 2$

An extra acceleration of 0.5g is taken for the rotation of the gripper.

Average mass of apple is 250gm. So, m (g + a) = 3.67N

As, we are using rubber pads and the coefficient of friction between apple and rubber is 0.5(approximately).

N=2, for two finger pads

$$F_g = 7.34\ N$$

Torque Calculation

Rack and pinion gear is used for closing and opening the claw. The average diameter of an apple is approximately 0.07m. So, the length of the rack we are choosing is 0.12m. According to our estimation, radius of pinion should be 0.01m.
The force required to move the rack along the one finger of the claw is also added in the total torque calculation. Approximate mass of the rack and finger would be 0.1kg. The friction between rack and pinion is also considered which is about 0.2.
So total force is:

$$F_T = 7.34 + 0.1 * 9.81 * 0.2$$
$$F_T = 7.53\ N$$

As the force required is not that large and the operation is constant and small, only the constant torque is considered.

$$\tau = F_T * radius * sin\theta$$
$$\tau = 7.53N * 0.01m$$
$$\tau = 0.0753Nm$$

Speed

The speed for the pinion would be 0.05m/sec. We chose this speed because the distance covered by finger of the claw is very small when it closes to hold the apple and if higher speed is chosen it may cause damage to the apple.
Rotational speed of rack:

$$n_p = V_{linear} * \frac{60}{\pi * diamter}$$

where:
n_p= rotational speed of pinion (rpm)
V_{linear}= linear speed on rack

$$n_p = 0.05 * \frac{60}{3.14 * 0.02}$$
$$n_p = 47.77\ \text{rpm}$$

Power
Power required:

$$P = \tau.\omega$$
$$P = 0.0753Nm * 5\ rad/s$$

$$P = 0.37W$$

Motor Selection

A geared DC motor is a perfect choice for our application. It has a gear ratio of 1:75 with output speed of 60 rpm which is very close to our required speed. The rated torque and current are 0.098Nm and 230mA respectively.
Our required torque is well within limits of rated torque. We can further reduce the speed using PWM. As we are already using motor drivers which has voltage drop of approximately 2V, the speed and power delivered would be reduced.

Figure 48: Geared Motor

Load Calculation for rotating the gripper

Twisting an apple instead of pulling it will save the spur branch from any damage. We are taking an approximate force to pluck the apple that is 3N. As it is a constant operation the moment of inertia of gripper is not considered.
Taking friction and safety factor into account, the force is approximately 5N.
Only a bearing is used because we are already using the geared motor and it meets the conditions required.
Inner radius of bearing is 0.02m

Torque Calculation

Torque required:

$$\tau = F_T * radius * sin\theta$$
$$\tau = 5.0N * 0.02m$$
$$\tau = 0.10Nm$$

The same motor is being used for both the operations.

Working of Electronics

We are using Arduino and L298N motor driver for our apple picker. As L298N has a voltage drop of 2V and our motors work on 6V, we are using a 9V battery.
The motor responsible for handling the closing and opening of the gripper has a duty cycle of 60%. This is done to limit the stall current. Our required torque is 19% of the maximum torque on rated voltage, which is within limits for a continuous operation, but the problem arises when the gripper holds the apple. Since the motor has a high stall torque of 0.39Nm, it could lead to the motor drawing the maximum stall current which produces a lot of heat in the motor. Such high torque can also damage the apple. So, by controlling the input voltage through PWM, we could limit the maximum current drawn.
By reducing the duty cycle, the speed of the motor is also reduced. So, we may get a speed lower than we expected. But as the distance covered is too small, it will not have a huge impact on the working.

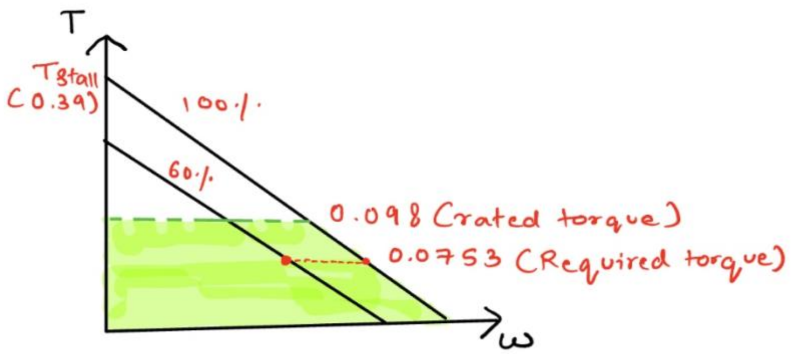


Figure 49: Torque (Nm) vs Speed (rad/s)

The motor responsible for rotating the gripper also works on 60% of the duty cycle (approx. 5.4V). The rotation speed should not be so high because it could disturb the grip of the apple. This is the reason we are reducing its speed using PWM.
The gripper is controlled using a push button. When the push button is pressed, it closes the gripper. For rotating the gripper another push button is used. When both the push buttons are pressed together, the apple is released, and the gripper goes back to its original position.

Circuit Diagram

The circuit diagram includes a schematic of L298N motor driver module, Arduino, and connections between them.
NOTE: Although we are using a driver module in apple picker the circuit diagram includes the inside circuitries of the module which include the voltage regulator, L298N IC and capacitors.

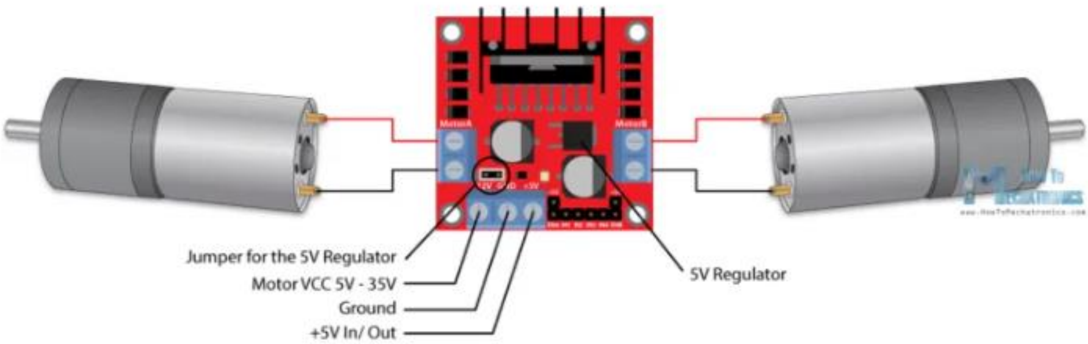


Figure 50: L298N motor driver module

Circuit Diagram Explanation

Jumper 4

It is connected to battery and the input of voltage regulator. When the supply voltage is within 12V, we can enable the jumper for 5V Regulator. The module uses 78M05 voltage regulator. Since, L298N only draws less than 100mA, the rest can be used as output for Arduino power supply, which we used because our supply voltage is only 9V.

Jumper 5

Jumper 5 as also shown in figure 47 has three connections: supply voltage (Vcc), ground (GND) and +5V which is either used as input or output depending on the supply voltage.
The battery is connected to J5. From J5, the battery is also connected to Vs through diodes and J4.
The +5V is connected to output of voltage regulator and Vss. When the J4 is enabled, this port acts as output, else it is used as input.

The diodes are used to dump excess power.

Pinouts of L298N IC

- ENA and ENB enables the PWM signal for motor A and B respectively.
- IN1, IN2 and IN3, IN4 are used to control the spinning direction of motor A and B respectively.
- OUT1, OUT2, OUT3 and OUT4 are output pins for motor A and motor B.
- Sens A and B are used for current sensing and since we are not using them, they are directly connected to the ground.
- Vss- logic supply voltage for IC
- Vs- drive voltage for motors

Pinout diagram of L298N module

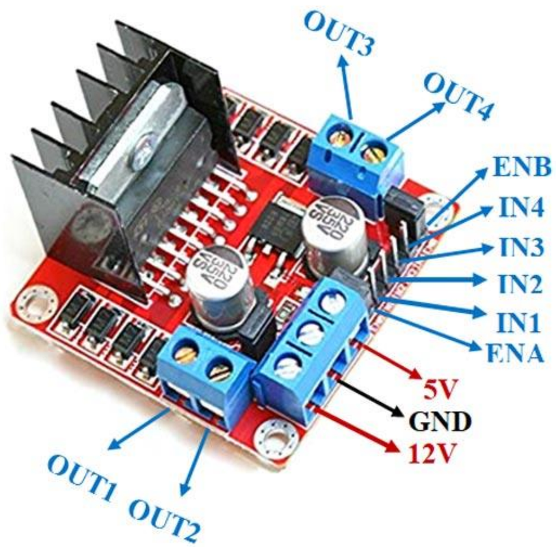


Figure 51:Pinouts of module

Make-or-Buy Decision on component basis

The following table is inclusive of all the components that have been used to manufacture PickIT Fruit picker and the decision to either make them or buy them or buy certain parts and modify them.

All quantities are mentioned based on the requirement to manufacture one fruit picker. However, certain components are only sold in bulk and hence is not quantifiable, so the quantity is not specified in the table.

Part No.	Part Name	Quantity	Decision	Reason
1	Power Supply	1	BUY	Easier world-wide adaptability, high safety standards required
2	Push Button	2	BUY	Low cost, easily available in the market
3	Switch	1	BUY	Low cost, easily available in the market
4	GM71,1 6V Gearmotor	2	BUY	High electrical expertise required, easily available in the market
5	Motor Driver	1	BUY	Low cost, easily available in the market
6	Arduino Nano	1	BUY	High electrical expertise required, easily available in the market
7	Wires	-	BUY	Low cost, easily available in the market
8	Handle of the Fruit picker	1	MAKE	Custom Design
9	Telescopic Rods	1	BUY/MAKE	Low cost, easily available in the market
10	Radial Ball Bearing	2	BUY	Low cost, easily available in the market
11	Housing of Rotation Mechanism	1	MAKE	Custom Design
12	Gripper	1	MAKE	Custom Design
13	Rubber Padding of gripper	2	BUY/MAKE	Low cost, easily available in the market
14	Nuts and Bolts	-	BUY	Low cost, easily available in the market
15	Wheels	4	BUY	Low cost, easily available in the market
16	Handle bar for the cart	1	MAKE	Low cost, easily available in the market
17	Basket for the cart	1	MAKE	Custom Design
18	Soft padding for the cart	1	BUY/MAKE	Low cost, easily available in the market
19	Net	1	BUY/MAKE	Low cost, easily available in the market
20	Stainless Steel Channels for the net	2	BUY/MAKE	Low cost, easily available in the market

Table 26: Make and Buy decision overview

Technology Selection for "make" parts

Mentioned below are the different technologies used to manufacture the make parts along with the materials used, the advantages and disadvantages and a stepwise description of the manufacturing process.

Housing for Rotation mechanism	**Technology**	**Advantages**	**Material**
	Injection Molding	Great precision, high repeatability combined with speed and low cost per piece	ABS
Process	**Step 1 - Preparation of the mold:** Three sperate molds of the housing and the molds for the Motor Shaft Sleeve & Motor Covering are made ready, considering 2 degrees as draft angle and assembled into the clamping unit of the Injection molding production line. One mold is in the shape of a cylinder without a lid and the other mold is of the lid.		
	Step 2 - Injection Molding: A single screw extruder is used to feed the molten polymer (ABS) into the nozzle that injects the material into the mould of the housing. The material in the mould is cooled and solidified. The mobile hydraulic cylinder of the clamping unit retracts, thus dropping the finished housing/other components onto a collection tray.		
	Step 3 - Attachment of Internal Components: A plane made of ABS polymer is placed inside this housing to which the battery holder is attached. The red shaft along with the bearings and circlips are fitted inside the second housing.		
	Step 4 - Finishing: The surface finish of the Basket is improved for aesthetic reasons by using wool wheels.		
	Step 5 - Threading: : Tapping and Drilling is used to create threaded holes in the parts of the housing where it will be attached to the telescopic rod and gripper, in places where the lid has to be attached and on the second housing to attach it to the first .		
	Step 6 - Attachment: The housing is fixed onto the telescopic rod using the threads present on either parts. The lid and the housing are attached together with the help of screws once the motor, motor shaft sleeve, motor covering, battery,circlips and bearings are assembled in the housing.		

Table 27: Manufacturing of the housing for rotation mechanism

<table>
<tr><th rowspan="2">Gripper</th><th>Technology</th><th>Advantages</th><th>Material</th></tr>
<tr><td>Injection Molding, Tapping and Drilling</td><td>Great precision, high repeatability combined with speed and low cost per piece</td><td>ABS</td></tr>
<tr><td rowspan="5">Process</td><td colspan="3">Step 1 - Preparation of the molds: Five seperate molds of different parts of the housing are made ready, considering 2 degrees as draft angle and assembled into the clamping unit of the Injection molding production line. The moulds for the rack and pinion are also made as seperate parts that have to be injection moulded.</td></tr>
<tr><td colspan="3">Step 2 - Injection Molding: A single screw extruder is used to feed the molten polymer (ABS) into the nozzle that injected the material into the molds. The material in the molds is cooled and solidified. The mobile hydraulic cylinder of the clamping unit retracts, thus dropping the finished parts of the gripper onto a collection tray.</td></tr>
<tr><td colspan="3">Step 3 - Attachment of Internal Components: The motor, motor housing and the Rack & Pinion gear are assembled inside the housing of the gripper and the components of the claw are attached with an adhesive.</td></tr>
<tr><td colspan="3">Step 3 - Finishing: The surface finish of the gripper is improved for aesthetic reasons by using wool wheels.</td></tr>
<tr><td colspan="3">Step 4 - Threading: Tapping and Drilling is used to create threaded holes in the part of the gripper's housing so that they can be attached to the by screws.</td></tr>
</table>

Table 28: Manufacturing of Gripper

Handle of the Fruit Picker	Technology	Advantages	Material
	Injection Molding	Great precision, high repeatability combined with speed and low cost per piece	Silicone Rubber
Process	**Step 1 - Preparation of the mold:** The mold of the handle is made ready, considering 2 degrees as draft angle and assembled into the clamping unit of the Injection molding production line.		
	Step 2 - Injection Molding: A single screw extruder is used to feed the molten polymer (Silicone Rubber) into the nozzle that injected the material into the mold of the handle. The material in the mold is cooled and solidified. The mobile hydraulic cylinder of the clamping unit retracts, thus dropping the finished handle onto a collection tray.		
	Step 3 - Polishing: The surface finish of the handle is improved for aesthetic reasons by using wool wheels.		
	Step 4 - Installation of the buttons: Buttons are installed in the holes that are provided on the handle. This Handle is attached to the telescopic rod through an interference fit.		

Table 29: Manufacturing of Handle of PickIT

Basket of the Cart	Technology	Advantages	Material
	Injection Molding	Great precision, high repeatability combined with speed and low cost per piece	HDPE
Process	**Step 1 - Preparation of the mold:** The mold of the basket is made ready, considering 2 degrees draft angle and assembled into the clamping unit of the Injection molding production line.		
	Step 2 - Injection Molding: A single screw extruder is used to feed the molten polymer (ABS) into the nozzle that injected the material into the mold of the basket. The material in the mold is cooled and solidified. The mobile hydraulic cylinder of the clamping unit retracts, thus dropping the finished basket onto a collection tray.		
	Step 3 - Polishing: The surface finish of the Basket is improved for aesthetic reasons by using wool wheels.		
	Step 4 - Threading: Tapping and Drilling is used to create threaded holes in the part of the basket where the net will be attached.		

Table 30: Manufacturing of Basket of the Cart

	Technology	Advantages	Material
Handle Bar of the Cart	Injection Molding	Great precision, high repeatability combined with speed and low cost per piece	HDPE
Process	**Step 1 - Preparation of the mold:** The mold of the handle is made ready, considering 2 degrees draft angle and assembled into the clamping unit of the Injection molding production line.		
	Step 2 - Injection Molding: A single screw extruder is used to feed the molten polymer (ABS) into the nozzle that injected the material into the mold of the handle bar. The material in the mold is cooled and solidified. The mobile hydraulic cylinder of the clamping unit retracts, thus dropping the finished handle bar onto a collection tray.		
	Step 3 - Polishing: The surface finish of the Basket is improved for aesthetic reasons by using wool wheels.		
	Step 4 - Threading: Tapping and Drilling is used to create threaded holes in the part of the handle where it will be attached to the basket .		

Table 31: Manufacturing of Handle of the cart

Make/Buy Parts: Parts that are bought from the manufacturer/wholesaler and then modified or machined on.

Part Name:	**Stainless Steel Rods**
BUY	https://www.alibaba.com/product-detail/China-factory-supply-cost-price-High_1600551778537.html?spm=a2700.galleryofferlist.topad_creative.d_title.73d045124sQ27m
MAKE	Cutting of the channels into lengths of 2000 mm with the help of a circular saw. These channels are then attached the main body of the cart with the help of screws and adhesive.

Table 32: Customization of Stainless-steel rods to which the net is attached

Part Name:	**Net**
BUY	https://www.alibaba.com/product-detail/100-polyester-3d-net-fabric-breathable_62177136547.html?spm=a2700.7803241.0.0.7e4f3e5f8zz405
MAKE	Cut the net into pieces of dimension 2000 x 1600 mm. Attach the net into the stainless-steel rods with the help of stitching.

Table 33: Custom Fitting of Net onto the rods

Part Name:	**Soft Padding of the Cart**
BUY	https://www.alibaba.com/product-detail/Cheap-Expandable-Polyethylene-EPE-Foam-Package_60795681817.html?spm=a2700.7803241.0.0.6f313e5fLkRUSo
MAKE	Cut the padding into pieces of dimension 660 x 580 x 140 mm. Attach the padding onto the base of the basket with the help of synthetic resin adhesive.

Table 34: Custom installation of soft padding of the cart

Part Name:	**Rubber Padding Of Gripper**
BUY	https://www.alibaba.com/product-detail/Rubber-extruded-seal-strip-foam-rubber_1600085375680.html?spm=a2700.7803241.0.0.a45d3e5fOsBPmB
MAKE	Cut the padding into pieces of dimension 71 x 5 mm. Attach the padding onto the claws of the gripper with the help of synthetic resin adhesive.

Table 35: Custom installation of anti-slip rubber padding onto claws of the gripper

Part Name:	**Telescopic Rods**
BUY	https://www.alibaba.com/product-detail/Multi-function-telescopic-pole-telescopic-rod_62051227668.html?spm=a2700.7803241.0.0.23503e5f4SCFnM
MAKE	Specifications given to Manufacturer: 35mm & 30mm OD rods with a thickness of 5mm and a flip lock mechanism attached. Front end to be threaded and left open to attach housing for rotation mechanism. Back end to be left open for attaching the handle.

Table 36: Specification given to manufacturer for telescopic rods

Requirement Manual for "buy" (CotS) parts

Requirements Manual (Buy)		
Serial No.	Part	Requirements
1	Wheel	**Type :** Castor Wheel **Diameter:** 8-10 inch
2	Power Supply	**Voltage:** 9V **Minimum current to be delivered**: 10mA
3	Nuts and Bolts	M1.6x16 M2x20 M5x25 + Hex Nut M5 M8x40 + Hex Nut M8 M10x70 + Hex Nut M10 M10x80 + Hex Nut M10 M5x25
4	Push Buttion	**Operating Voltage:** 6V - 12V
5	Switch	**Operating Voltage:** 6V - 12V
6	Motor	**Type:** Geared Motor **Nominal Voltage:** 6V **Output Speed:** 60rpm **Torque Requirement:** 0.10 Nm **Maximum Length:** 72mm
7	Microcontroller	**Model:** ATMEGA328P Modul **Minimum number of pins:** 11
8	Wires	**Material :** Copper **Insulation :** Silicone
9	Radial Ball Bearings	**Inner Diameter:** 21mm **Outer Diameter:** 42mm
10	Motor Driver	**Type:** L298N **Required number of pins:** 15

Table 37: Requirements manual

Technical Drawings: Main Assembly

See Appendix C

Program Flow Chart

See Appendix D

Bill of Material (Mechanical and Electrical)

See Appendix E

Power requirement for different Operations

While Closing the Gripper

When the gripper is being moved to close the gripper 0.37W of power is needed. This power was already calculated in the torque calculation.

While Holding the Apple

When the gripper is closed and holding the apple it reaches the stall torque and draws maximum current from the motor, but we are limiting the maximum current drawn through PWM which is reducing the stall torque.
New stall torque,

$$\tau_{stall\ new} = \tau_{stall} \times Duty\ cycle$$

As mentioned earlier, we are using the duty cycle of 60% which will deliver 5.4V to the battery.

$$\tau_{stall\ new} = 0.39Nm * 0.6$$
$$\tau_{stall\ new} = 0.234\ Nm$$

Now, for calculating the maximum current drawn for the new stall torque we need to know the resistance of the windings.
We know,

$$U_{terminal} = U_i - i_A R_A$$

When there is stall torque, back emf or voltage induced is zero. So,

$$U_{terminal} = i_A R_A$$

Rated voltage of motor =6V
Stall current=850mA

$$R_A = 6000/850$$
$$R_A = 7.05\ ohms$$

After implementing the PWM, the terminal voltage is 5.4V and resistance is 7.05 ohms. So, the maximum current drawn is: 0.76A
Although, in real scenario the current increases and decreases the with PWM and it depends on the pulse width of the PWM signal.

$$P_{in} = U_{terminal}(V) \times i_A \ (A)$$
$$P_{in} = 5.4 \times 0.76$$
$$P_{in} = 4.104 \ W$$

While Rotating the Gripper

The torque required for rotating the gripper was calculated to be 0.10Nm. The speed we decided for it was 5 rad/s or approximately 48 rpm. We may get bit less speed than expected because of PWM but it does not affect the operation as higher speeds are more dangerous (gripping of apple).

$$P = \tau \ (N.m) \times \omega \ (\frac{rad}{sec})$$
$$P = 0.10Nm * 5 \ rad/sec$$
$$P = 0.50 \ W$$

While opening the gripper back again

The power required to open back the gripper is same as the power while closing it.

$$P = 0.37 \ W$$

Average Energy Demand for 1 Apple

As mentioned in the torque calculation, the distance gripper will cover is approximately 0.05m and speed for the same is 0.05m/s. So, the total time for this operation is 1 second and the energy consumed by motor1 during this operation is:

$$E = Power \ \times time$$
$$E = 0.37 \ W \ \times 0.000277 \ h$$
$$E_{closing,1} = 10.2 * 10^{-5} \ Wh$$

We know the power requirement for motor 1 during this operation. Let's assume this operation is done for 10 seconds because the gripper also rotates to pluck the apple and it also depends on the user. The energy for motor1 is calculated differently for both closing and holding is because of different power requirement.

$$E = 4.104W \ \times 0.00277 \ h$$
$$E_{holding,1} = 0.011 \ Wh$$

Now, the energy requirement for motor 2 is while that of rotating the gripper. The time taken is approximately 8 seconds.

$$E = 0.5 \ W \times 0.0022 \ h$$
$$E_{rotating,2} = 0.00111 \ Wh$$

Energy required to open the gripper will be same as closing the gripper.

$$E_{opening,1} = 10.2 * 10^{-5} Wh$$

The total energy used for these operations is:

$$E_{total} = E_{closing,1} + E_{holding,1} + E_{rotating,2} + E_{opening,1}$$
$$E_{total} = 0.0123\ Wh$$

Total energy requirement

We have already calculated the energy required but we also have to consider various losses as well. For example, the user let the motors run for longer period than calculated or maybe the whole operation takes longer. So, we are also considering safety factor of 3. The energy required to operate Arduino is very less as compared to the motors, it can be neglected.

$$E_{total} = 0.0369\ Wh$$

We want at least pluck 150 apples. So, the total energy requirement would be approximately 5.53 Wh.

Battery

We are choosing a 9V-650mAh lithium-ion battery. There are various reasons for selecting a lithium-ion battery:

- It is light-weighted. This is very useful for our apple picker as battery contributes less in terms of weight.
- It has high energy density.
- Li batteries are known to have long shell life and high temperature operation.
- It has flat discharge characteristics

The battery we are using can be charged up to 500 times. We also kept in mind that the real full voltage of lithium-ion battery is 8.4V.
Converting mAh to Wh gives us 5.85Wh. This is perfect for our product because are using 0.0329Wh for 1 apple and we could easily pluck 158 apples.

Figure: 9V Li-ion battery

Battery Management System and Charger

The main purpose of the BMS is to monitor the battery and protect it from:

- Over-current
- Over-voltage
- Under-voltage
- Over-temperature
- Ground fault or leakage current detection

As our battery already include features such as:

- Short circuit protection
- Overload protection
- Overcurrent protection
- Over charge and discharge protection
- Battery PTC protection

Our battery already has a BMS. The battery can be charged via Micro-USB, which is already included with battery pack.

Production Planning

Production planning is an important step in any business or start up as it provides the required number of units to be produced in time, avoiding delays or missing components. It also helps in predicting any material shortage that could delay the throughput time. The productivity and efficiency of facility is primarily dependent on the depth of the Production planning as it helps lower the production cost and overtime of workers.

Production Planning Process

1. **Forecasting** – Important for product development
   i) Capacity Calculation
   ii) Throughput time
   iii) Takt time

2. **Process Planning** – Finding the most economical way to perform operation to have the product manufactured

3. **Routing** – It tells us the workflow in the production facility considering the flow of raw materials to main parts analogous to assembly of purchased parts.

4. **Material Control** – Flow of material without interruption of production process and production cost, inventory control, material planning, transportation and purchase procedure.

5. **Tool control** – Ensures that all the machinery required for manufacturing is in the correct position along with all the tools required.

6. **Loading and scheduling** – Determines the work that labor need to do for each machine.

Capacity Calculation

Forecasting

As presumed in the Planned Sales Volume, the direct sales were to be 3500 fruit pickers in the first year of operation. For the financial year of 2023, working days are expected to be 251 which translates to 7.5 hours of work shifts and 30 minutes of breaktime for 5 days a week. For the years after, as the demand increases, targeted number of products sold will also increase depending on sales data collected from 2022. The workshop set up would take three to four weeks until all paperwork, raw material, purchased material, machinery is set up along with hiring the work force.

Takt time

Takt time determines the rate at which a product has to be completed in order to meet customer demand. Upon reconsidering the market based on the current situation of war and energy crisis, we have decided that the goal for the first year would be 1250 fruit pickers.

$$Takt\ time = \frac{Number\ of\ units\ to\ be\ produced}{Available\ time}$$

Working hours available per year = 251 *days* * 8 *hours* = 2008 *hours*

$$Takt\ time = \frac{2008\ hours}{1250\ units} = \mathbf{1.61\ hours}$$

Production time approximation

Injection Molding

This manufacturing process consists of a 4 stages which are clamping, injection, cooling and ejection. The cooling process is the most time consuming and hence will increase the overall cycle time.

The molding time can be approximated with the formula given below:

$$t_c = \frac{h^2 max}{\alpha}$$

$$\alpha = \frac{\lambda}{\rho * c}$$

Name	Variable	Value for ABS
The maximum wall thickness of part [mm]	h_{max}	-
Thermal diffusion coefficient [m^2/s]	α	-
Density [kg/mm^3]	ρ	$1.07 * 10^{-6}$
Thermal conductivity [W/m*K]	λ	0.2618 W/m*K
Specific heat [J/kg*K]	c	1900 J/Kg*K
Injection time [s]	t_i	2

Table 38: Values for Injection molding

Plugging in the above values to find the thermal diffusion constant is:

$$\alpha = \frac{0.2618 \frac{J}{s * m * K} * \frac{m}{1000mm}}{1.07 * 10^{-6} \frac{kg}{mm^3} * 1900 \frac{J}{kg * K}} = 0.129 \frac{mm^2}{s}$$

Production time for injection molding:

$$t_{total} = t_c + t_i$$

Part Name	Wall Thickness [mm]	Production time per unit[min] = t_{total}	Setup time per unit[h]
Handle of Fruit Picker	2.5	0.85	0.02
Basket of Cart	10	12.95	0.05
Handle bar of Cart	50	16.67	0.02
Housing of Rotation Mechanism			
Housing	7	6.35	0.03
Holding plate	2	0.55	0.03
Motor housing 1	4	2.1	0.02
Housing plate	10	12.95	0.02
Gripper			
Body 2	10	12.95	0.03
Motor housing 1	4	2.1	0.02
Gripper housing	5.5	3.93	0.01
Claw holder	7.5	7.27	0.02
Rack spur	19	15.1	0.02
Spur gear	18	15.1	0.05
Pinion securement	1.5	0.8	0.05

Table 39: Table to calculate time taken per piece to be injection molded

Drilling and Tapping

This manufacturing process is mainly used for drilling and tapping holes in parts that are made from ABS by injection molding.

The machining time of drilling and tapping is calculated using the following formula:

$$Machining\ Time = \frac{Length\ of\ cut\ [mm]}{Feed[mm\ per\ rev] * Rotation\ speed\ \left[\frac{rev}{min}\right]}$$

For ABS, we use a rotation speed of 1200 rev/min and a feed of 0.01 mm/rev.
For Stainless Steel, we use a rotation speed of 1800 rev/min and a feed of 0.005 mm/rev

No.	Part Name	Material	Length of cut (thickness)	Number of holes	Machining Time [min] (Drilling per hole)	Machining Time [min] (Milling per hole)	Production time per unit [min]	Setup time per unit [h]
1	Handle of Fruit Picker	ABS	2.5	3	0.21	-	0.21	0.01
2	Basket of Cart	ABS	10	8	0.83	0.83	1.66	0.01
3	Handle bar of Cart	ABS	50	4	1.12	1.12	2.24	0.01
	Housing of Rotation Mechanism							
4	Housing	ABS	7	8	0.34	0.68	1.16	0.02
5	Housing Plate	ABS	10	4	0.34	0.68	1.66	0.01
	Gripper							
6	Body 2	ABS	10	4	0.83	0.83	1.66	0.01
7	Gripper housing	ABS	5.5	8	0.46	0.46	0.92	0.02
8	Claw holder	ABS	7.5	4	0.63	0.63	1.26	0.01
9	Channels to hold net	STAINLESS STEEL	6.5	4	0.75	0.75	1.35	0.005

Table 40: Time taken for drilling and tapping of each part

Diagrams of Subparts that undergo the production processes mentioned above :

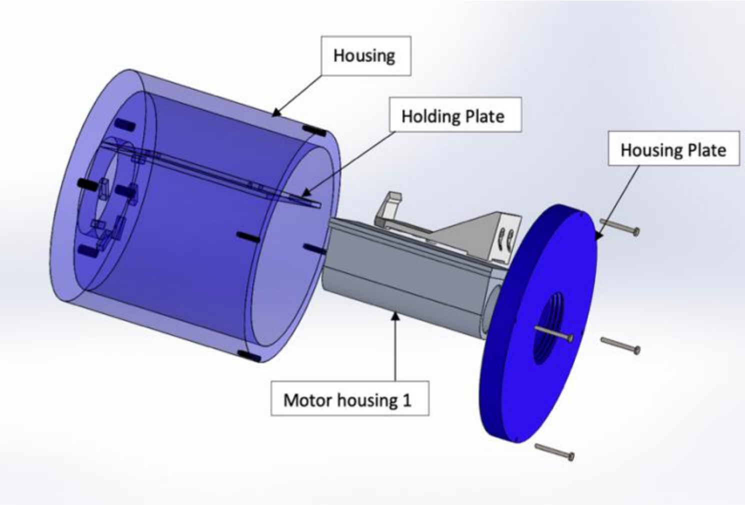


Figure 52: Housing of rotation mechanism

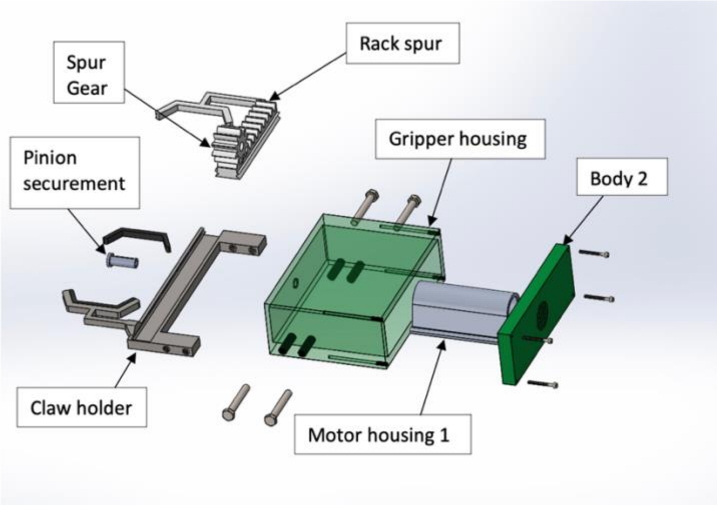


Figure 53: Gripper

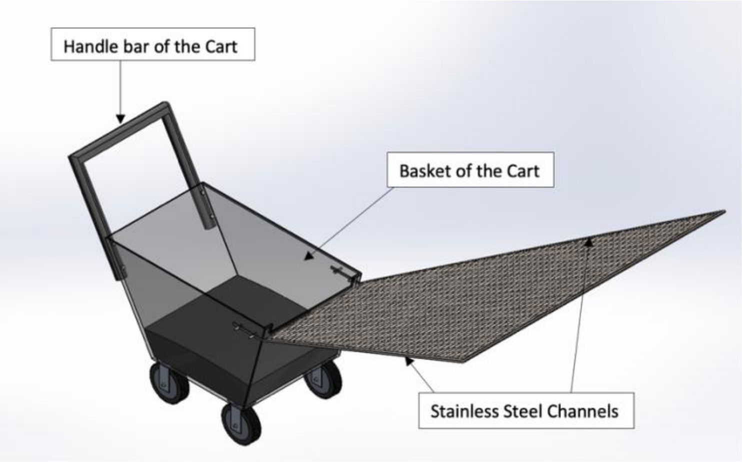


Figure 54: Cart

Figure 55: Handle of fruit-picker

Production Time of Parts

Part	Manufacturing Technology		Number of units per Apple picker	Time per unit [min]	Setup Time [h]	Operation time(minus setup time)[hours]	Machine capacity per production day [pieces]
Gripper	Injection Molding		1	28.5	0.2	7.3	15.37
	Drilling and Tapping			3.85	0.045	7.455	116.18
Housing of Rotation Mechanism	Injection Molding		1	17	0.1	7.4	26.12
	Drilling and Tapping			3.32	0.03	7.47	135.00
Handle of Fruit Picker	Injection Molding		1	0.85	0.02	7.48	528.00
	Drilling and Tapping			0.21	0.01	7.49	2140.00
Basket of the Cart	Injection Molding		1	5.5	0.05	7.45	81.27
	Drilling and Tapping			1.66	0.01	7.49	270.72
Handle bar of the Cart	Injection Molding		1	6.5	0.02	7.48	69.05
	Drilling and Tapping			2.24	0.01	7.49	200.63
Channels to hold net	COTS	Sawing	2	5	0.1	7.4	88.80
		Drilling and Tapping		5	0.1	7.4	88.80
Net of the Cart	COTS	Cutting	1	5	0.1	7.4	88.80
		Stitching		10	0.2	7.3	43.80
Soft Padding of the Cart	COTS	Cutting	1	5	0.1	7.4	88.80
		Gluing		4	0.08	7.42	111.30
Rubber Padding of the Gripper	COTS	Cutting	2	5	0.1	7.4	88.80
		Gluing		4	0.08	7.42	111.30

Table 41: Number of units of each part that can be manufactured in one day

Since only 15.37 gripper can be manufactured per day by injection molding, that is the bottle neck of the production process.

Bottle neck

Lot size

Lot size depicts the number of units manufactured per production run. To calculate this, we need to consider that a minimum of 1250 fruit pickers need to be produced in a year which mean:

$$Minimum\ number\ of\ units\ that\ need\ to\ be\ produced\ in\ 1\ day = \frac{1250\ units}{251\ days}$$

$$= 4.98\frac{units}{day} = \mathbf{5}\ units/day$$

From the above table, we can see that the manufacturing of the gripper is the process' bottleneck and manufacturing only 15.37 units a day. However this is alright as only 5 units need to be manufactured in a day.

Hence, the lot size is 5 units considering the production run of one day. The extra unit will be kept for the next day as well as for quality checks.

Overall Equipment Efficiency

OEE is calculated using three factors: availability, performance and quality.

$$OEE = Availability * Performance * Quality$$

Availability is a measure of how constant the running of the machines is, or in other words, how little downtime there is.

$$Availability = \frac{Run\ Time}{Planned\ Production\ Time}$$

Performance is a measure of the speed of production. It is the achieved completion time as a percentage of the best possible completion time.

$$Performance = \frac{Ideal\ Cycle\ Time * \ Lot\ Size}{Run\ Time}$$

Quality is simply put the ratio of good pieces produced to total pieces produced. This value gives an idea of how many pieces come out with a defect that required them to be discarded.

$$Quality = \frac{Good\ Count}{Total\ Count}$$

Since the goal is to manufacture 1250 fruit pickers and the lot size is 5 fruit pickers per day, the days of operation required =

$$\frac{1250\ fruitpickers}{5\ \frac{fruitpickers}{day}} = 250\ days$$

In the table below, the OEE is calculated by taking the above mentioned factors into account. The values were estimated by taking the complexity of the pieces produced, manufacturing technology and number of moving parts.

Part	Manufacturing Technology		Time per unit [min]	Setup Time [h]	Number of units per Apple picker	Lot Size	Run Time [hours]	Availability	Quality	Performance	OEE [%]
Gripper	Injection Molding		28.5	0.2	1	5	2.58	99.0%	93.0%	92.0%	84.7%
	Drilling and Tapping		3.85	0.045		5	0.37	94.5%	96.5%	94.5%	86.2%
Housing of Rotation Mechanism	Injection Molding		17	0.1	1	5	1.52	99.0%	93.0%	92.0%	84.7%
	Drilling and Tapping		3.32	0.03		5	0.31	94.5%	96.5%	94.5%	86.2%
Handle of Fruit Picker	Injection Molding		0.85	0.02	1	5	0.09	99.0%	93.0%	92.0%	84.7%
	Drilling and Tapping		0.21	0.01		5	0.03	94.5%	96.5%	94.5%	86.2%
Basket of the Cart	Injection Molding		5.5	0.05	1	5	0.51	99.0%	93.0%	92.0%	84.7%
	Drilling and Tapping		1.66	0.01		5	0.15	94.5%	96.5%	94.5%	86.2%
Handle bar of the Cart	Injection Molding		6.5	0.02	1	5	0.56	99.0%	93.0%	92.0%	84.7%
	Drilling and Tapping		8.34	0.01		5	0.71	94.5%	96.5%	94.5%	86.2%
Channels to hold net	COTS	Sawing	5	0.1	2	5	0.52	98.5%	88.5%	88.0%	76.7%
		Drilling and Tapping	5	0.1		5	0.52	94.5%	96.5%	94.5%	86.2%
Net of the Cart	COTS	Cutting	5	0.1	1	5	0.52	95.0%	85.0%	91.0%	73.5%
		Stitching	10	0.2		5	1.03	96.5%	88.0%	84.5%	71.8%
Soft Padding of the Cart	COTS	Cutting	5	0.1	1	5	0.52	95.0%	85.0%	91.0%	73.5%
		Gluing	4	0.08		5	0.41	97.0%	83.0%	80.0%	64.4%
Rubber Padding of the Gripper	COTS	Cutting	5	0.1	2	5	0.52	95.0%	85.0%	91.0%	73.5%
		Gluing	4	0.08		5	0.41	97.0%	83.0%	80.0%	64.4%
										Total	**79.9%**

Table 42: OEE

Machinery Requirements

Machine	Requirements
Injection Molding	Min Mold thickness: 1.5mm Max Mold thickness: 50mm Approximate size of machine: 6.5m x 1.5m x 2.5m
Drilling and Tapping	Tolerance: +/- 0.005 inch Type: CNC Milling machine Approximate size of machine: 0.8m x 0.6m x 1.9m
Sawing (Cutting) machine	Minimum cutting depth: Type: Circular Saw
Sewing/Stitching machine	Minimum sewing thickness: 1.5mm
Fabric cutting machine	Minimum cutting depth : 0.8mm

Table 43: Requirements of Machines

Machine type	**Total time of Machine use per day**	**No. of machines required**
Injection molding machine	6.8125	2
CNC Milling machine	3.03	1
Circular saw	0.52	1
Sewing machine	1.03	1
Rotary fabric cutter	1.56	1

Table 44: Number of Machines required

Manufacturing and Assembly Flow Chart

The entire assembly process is divided into four subassembly stages and two main assembly stage.

Sub-assembly 1 : Gripper		
Step	**Action**	**Time to complete [sec]**
1	Motor is placed in the motor housing which is glued onto the inner side of the gripper housing.	180
2	Pinion is attached onto the spindle of the motor from outside the gripper housing and locked in place with the help of pinion securement.	120
3	The lid of the gripper housing and screwed in place with the help of 4 screws	60
4	The pinion along with the claw are fixed onto the gripper housing with the help of epoxy based adhesive and screws.	80
5	Rubber padding is glued into the claw with the help of adhesive.	20
		460

Table 45: Sub-assembly 1: Gripper

Sub-assembly 2 : Housing of Rotation Mechanism		
Step	**Action**	**Time to complete[sec]**
1	Plate is attached in place with the help of adhesive	20
2	Motor is placed in the motor housing which is glued onto the plate the housing.	180
3	Battery holder is glued onto the plate in the housing	120
4	Lid is screwed onto the housing with the help of 4 screws	60
		380

Table 46: Sub-assembly 2: Housing of Rotation mechanism

Sub-assembly 3 : Main body of Fruit Picker		
Step	**Action**	**Time to complete[sec]**
1	The 2 pushbuttons and switches are installed in the handle of the fruit picker.	120
2	The wires from the handle are made to travel through the telescopic rods and the handle is attached to the telescopic rod with the help of interference fit.	80
		200

Table 47: Sub-assembly 3: Main body of fruit-picker

Assembly 1 : Complete assembly of the Basket		
Step	**Action**	**Time to complete [sec]**
1	The net that is supported by the channels is attached onto the basket of the cart by the help screws.	180
2	The handle bar is attached to the basket by the help of screws.	180
		360

Table 48: Assembly 1: Complete assembly of the Basket

Assembly 2 : Complete Assembly of the Fruitpicker		
Step	**Action**	**Time to complete [sec]**
1	The telescoping rods are attached to the Housing of the rotation mechanism.	20
2	The bearings are attached on the other side of the housing of the rotation mechanism and the circlips are put in place to secure the bearings.	180
3	The gripper is attached onto the rod coming out of the housing of the rotation mechanism.	60
		260

Table 49: Assembly 2: Complete assembly of the Fruit-picker

Packaging and shipping also need to be considered which will take approximately 200 seconds. Since sub-assembly 1 takes the longest time of 460 seconds, it is the bottleneck process

Since there are 2 bottle necks, one in production and one in assembly, it is important to verify that both processes together do not exceed the takt time that was initially calculated.

Since injection molding is the slowest process and since there are 2 injection molding machines, one for manufacturing the Gripper and the Housing of the rotation mechanism and the other machine for the handle of the fruit picker, basket of the cart and handle bar of the cart. Since these 2 machines run in parallel and parts produced on machine one take longer to be manufactured, the total of the setup time and production time is considered along with the time drilling and tapping for all the parts that are injection molded.

$$\begin{aligned} &Total\ time\ required\ for\ injection\ molding \\ &\quad = Total\ production\ time + Total\ Setup\ time \\ &\quad = (45.5 + 18)min \\ &\quad = \mathbf{63.5\ min} \end{aligned}$$

$$Total\ time\ required\ for\ drilling\ and\ tapping = \mathbf{17.58\ min}$$

Since the sub-assemblies happen in parallel, the one that takes the most time is taken into account for calculation. It's the same for the main-assemblies as well.

$$Total\ assembly\ time = (460 + 360)s = 820s = \mathbf{13.67min}$$

$$Time\ taken\ for\ shipping\ and\ packaging = 200s = \mathbf{3.33min}$$

Hence, the total time to complete 1 fruit-picker $= (63.5 + 17.58 + 13.67 + 3.33)min$
$$= \mathbf{94.75\ min} = \mathbf{1.58\ hours}$$

To successfully meet our demand, the time taken to complete one apple picker should be less than the takt time that was calculated initially.

$$\mathbf{1.58\ hours} < \mathbf{1.61\ hours}$$

Therefore, we will be able to successfully meet our goal of manufacturing 1250 fruit pickers in the upcoming year.

Value Chain

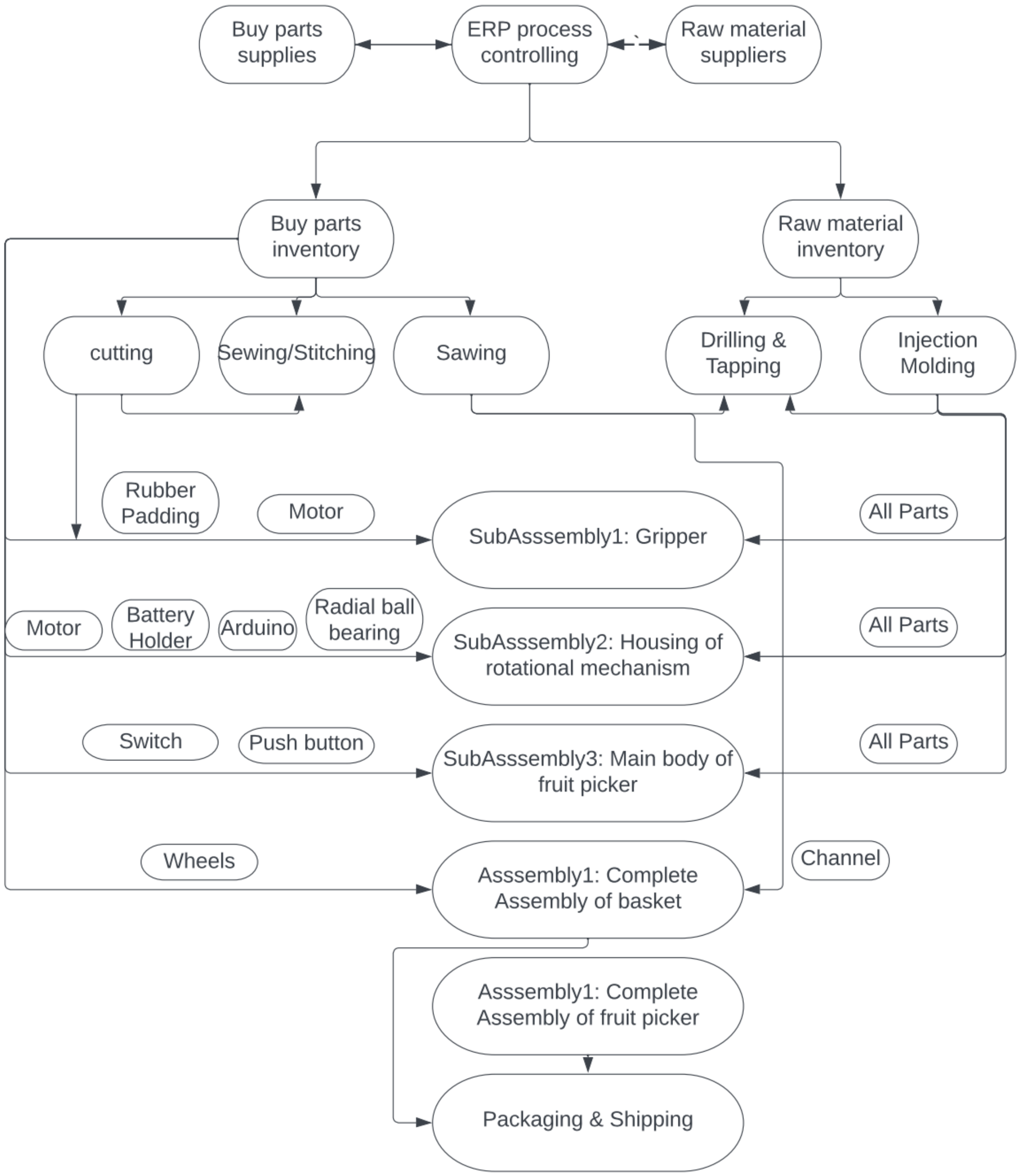


Figure 56: Manufacturing flowchart

Cost Calculation

Rental Cost

One of the main factors that have to be considered when renting a factory/warehouse is number and size of the machines in the production line. Another important factor is the number of employees per machine and amount of space required to store raw materials.

Having kept all these facts in mind, an approximation was derived. A total area of around $1000m^2$ would be required for smooth operation. The industrial rental prices vary from city to city but an average estimate of 15 €/m^2 [9] can be considered. Hourly cost can be calculated considering an average of 30 days in a month which adds up to 720 hours a month.

$$Total\ rental\ cost\ (monthly) = 15\frac{€}{m^2} * 1000m^2 = 15000€$$

$$Hourly\ rental\ cost = \frac{15000€}{720\ hours} = \mathbf{20.8€\ per\ hour}$$

Labor Cost

Approximately 13 workers need to be working in the factory to carry out smooth production, assembly and packaging. Since most of the operations are automated and the use of latest technology required us to use high skilled labor but the number of workers can be significantly reduced and hence, an hourly wage of 25€ will be paid to each worker.

$$Hourly\ cost = Operator\ hourly\ cost * \%of\ time\ of\ machine\ assistance$$

$$Hourly\ cost = 25€ * (45\%\ of\ time\ for\ machine\ assistance)$$

$$Hourly\ cost = 11.25€\ per\ hour\ per\ labor$$

$$Total\ Hourly\ cost = \mathbf{146.25€}$$

Electricity Cost

The total electricity cost can be calculated from the average machine power consumption per hour and the current price of energy is Germany which is 0.34€/kWh.

Machine	Electricity consumption
Injection Molding Machine	5.8 kWh
CNC Milling Machine	3.2 kWh
Circular Saw	1.8 kWh
Sewing Machine	0.9 kWh
Rotary Fabric cutter	0.5 kWh
Others	10 kWh
Total	**33.8 kWh**

Table 50: Estimated energy consumption

To calculate the total electricity cost, the number of each machine is also considered and is calculated as follows:

$$Electricity\ hourly\ cost = 33.8\ kWh * \frac{0.34€}{kWh} = \mathbf{10.14}\frac{\mathbf{€}}{\mathbf{hour}}$$

Machine Investment hourly Cost

Machine	Quantity	Cost
Injection Molding Machine	2	30,000 €
CNC Milling Machine	1	10,000 €
Circular Saw	1	100 €
Sewing Machine	1	150 €
Rotary Fabric cutter	1	75 €
Total	**7**	**70,325 €**

Table 51: Total investment on Machines

Description	Amount
Total Machine Investment	70,325 €
Total Depreciation cost (annual)	7,032.5 €
Total hourly depreciation cost	1.14 €/hour
Total hourly tool cost	0.5 €/hour
Total Machine addition costs (5% of machine investment)	0.4 €/hour
Total Machine overheads hourly cost	1 €/hour
Total	**3.04 €/hour**

Table 52: Machine Investment hourly cost

In these calculation, the depreciation is calculated assuming that the machines will lose all their value in 10 years and the additional costs include the cost for maintenance, repairs, lubrication etc. The tool cost is calculated as 1% of machine investment.

Hence the Machine investment hourly costs add up to a total of **3.04€/hour**.

Material Cost

Description	Amount
Mechanical Buy parts hourly cost	7.95 €/hour
Electrical buy parts hourly cost	13.19 €/hour
Raw material for make parts hourly cost	2.17 €/hour
Consumables hourly cost	4.5 €/hour
Total	**27.81 €/hour**

Table 53: Material hourly cost

The cost of consumables include cost of wear parts such as lubricants, cutting tools. This data has been approximated from historical data of similar machines and number of hours of operation.

Overhead Hourly Cost

The overhead hourly cost takes into account R&D costs, administration costs, sales and marketing cost.

$$Total\ Overhead\ hourly\ cost = 10\%\ of\ 208.04^{*}\ €$$
$$Total\ Overhead\ hourly\ cost = 20.80\ €/hour$$

*This value includes the labor, rental, machine investment, material and electricity costs that were calculated above.

Since there are still some unforeseen costs that might occur for example if the material does not arrive on time or if there are strikes causing delays in production, bank loan interests etc, an addition cost of 10€/hour is added onto the final cost such that the company can still stay afloat in bad market conditions.

Hence, the total cost of PickIt sums up to **228.84 €/hour**.

Product Pricing

Upon considering a profit margin of 30%,

Cost price of PickIt per hour = 228.84 €/hour
Profit on Pickit per hour = 30% of 228.84 €/hour = 68.65 €/hour
Selling price of PickIt per hour = 297.49 €/hour

Number of working hours in one year = 2008 hours

$$Total\ Running\ Cost = 597{,}359.92€$$
$$Total\ Revenue\ = Total\ running\ Cost + Profit\ Margin$$
$$= \ 597{,}359.92\ € + 30\% * 597{,}359.92\ €$$
$$= \mathbf{776{,}567.90}\ €$$

The projected revenue for the first financial year of sales is around **776,567.90 €** and the projected profit is **179,207.98 €**.

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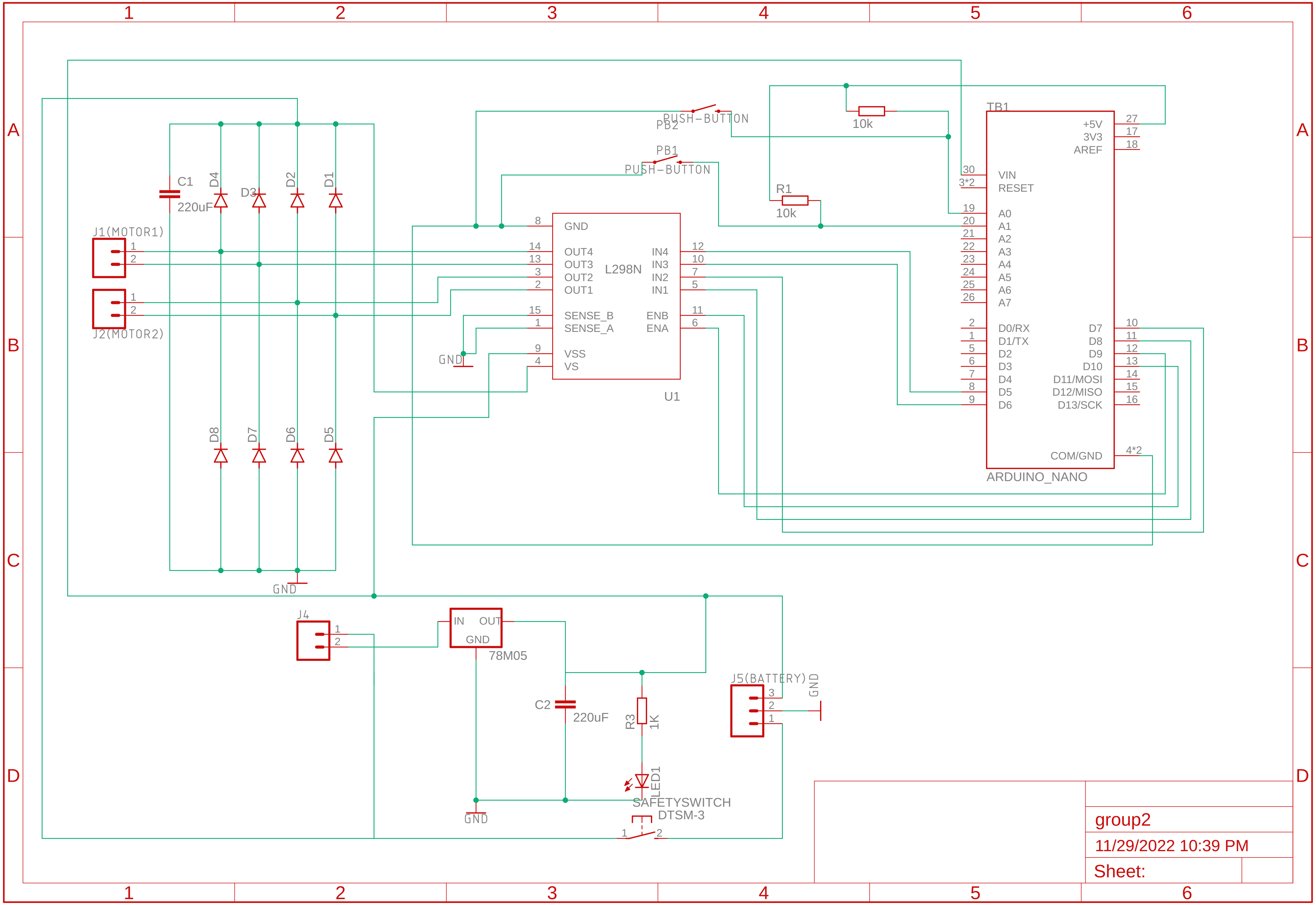
APPENDIX A

Group:	2
Team Members:	Anagh Premchand, Lovepreet Singh, Shreenithi Madhavan, Shreshth Khosla
Date (original)	17.10.2022
Date(revised):	23.10.2022

Component	Function	Failure mode	Cause for failure	Effect for failure	SEV	OCC	Detection	RPN	Action	Revised SEV	Revised OCC	Revised Detection	Revised RPN
Gripper	Holds onto the fruit firmly	does not activate the claw **(No function)**	Drained Battery	Fruit does not get grabbed	8	3	5	120	Design was adapted to make batteries easliy replaceable	8	4	5	160
		claw perfoms poorly **(Partial function)**	Motor/Gear failure		8	3	3	72	Choice of motor made after considering avergae motor lifespan	8	2	3	48
		Breakage of claw **(Partial function)**	Fruit > ⌀ ~90 mm		7	2	4	56	Better claws adapted to withstand higher forces	7	2	4	56
Antislip Rubber Pad	Used to provide friction to hold the fuit without it slipping away	Improper gripping/ slipping (P**artial function)**	wearing out of rubber	Fruit slips away and falls down	5	2	2	20	Design modified considering thicker pads	5	2	2	20
Motor	Expand and contract the gripper	claw perfoms poorly **(No function)**	Winding insulation breakdown and bearing wear	Gripper unable to expand/contract	9	4	6	216	Design adjusted to make maintainance feasible	9	4	6	216
Rack & Pinion Gear	Expand and contract the gripper	claw does not open/close **(Malfunction)**	Improper contact of gears	hinderance of claw movement	7	2	8	112	Design adapted to ease lubrication of gear	7	2	8	112
Housing for Rotational Mechanism	Provide a secure closure for motor and gear	Motor & gear not protected **(Under function)**	Improper installation, physical damage	motor&gear exposed to unsuitable conditions	4	1	2	8	Proepr sealing of housing	4	1	2	8
Stopper/Lever	Extract and retract the telescopic rod	Lever stuck & unable to extend/retract **(Under function)**	Build up of unwanted material	unable to change length of rod	7	3	3	63	User advised to clean regularly	7	3	3	63
Telescopic Rod	Support of gripper & housing of motors	Material degradation **(Under function)**	excessive exposure to UV radiation	Unable to handle heavy loading	8	2	2	32	Provide outer coating	8	2	2	32
		Breakgae of rod **(No function)**	Excess load on the rod		10	2	1	20	Design modified considering thicker cross section	10	2	1	20
Switch	Opening and closing the claw	No transmission of signal **(No function)**	shorting of wires	Gripper unable to expand/contract	9	3	5	135	Wires properly connected & insulated	9	3	5	135
Pushbutton	Sends voltage to Rotate the claw	Broken button **(Occassional function)**	loose connection	Gripper unable to rotate	9	3	4	108	Wires properly connected & insulated	9	3	4	108
Rope	Hanging the picker on a nail for storing & wrap around wrist for better stability	Breakage of rope **(Under function)**	Fatigue breaks, tear	falls of the wrist/waist	4	2	2	16	Stronger rope used while designing	4	2	2	16
Basket	Store plucked fruits	rusting **(Under function)**	exposure to	unable to store all fruits safely	3	5	1	15	Provide outer coating	3	5	1	15
Soft pad for basket(water resistant material)	Prevents the plucked furits from getting damaged	fruit spoilt **(Under function)**	tear	damages and darkens the fruits	9	4	2	72	Average lifespan of padding considered while designing	9	4	2	72
Stainless Steel Rod (Net)	Holds the net at the desired angle	Unable to hold net in place **(Under function)**	Fracture due to ageing	Net may fall off	7	5	2	70	User advised to clean/lubricate occassionaly	7	5	2	70
Net	Collects the falling friuts	not collecting fruits **(Under function)**	Tear	fruit falls through hitting the ground	8	3	4	96	Stronger material used while designing	8	3	4	96
Wheel	Easy mobility of the basket	uncoordinated mobility **(Under function)**	rusting /no lubrication in bearing	unable to move the basket conveniently	5	1	2	10	Average lifespan of padding considered while designing	5	1	2	10
Straight Bevel Gear	Rotates the claw	Grabber unable to rotate properly **(Malfunction)**	pitting/wear of gear	claw not rotating	7	2	8	112	Design of housing adjusted to make maintainance feasible	7	2	8	112
Motor	Providing torque to the gears and the claws to rotate	overheating **(Malfunction)**	Winding insulation breakdown and bearing wear	fruit unplucked from tree	9	4	6	216	Design adjusted to make maintainance feasible	9	4	6	216
Battery	Powering supply for gears and claws	no power in gripper **(No function)**	Drained Battery	gripper not functioning	9	2	4	72	Design adjusted to make maintainance feasible	9	2	4	72

APPENDIX B



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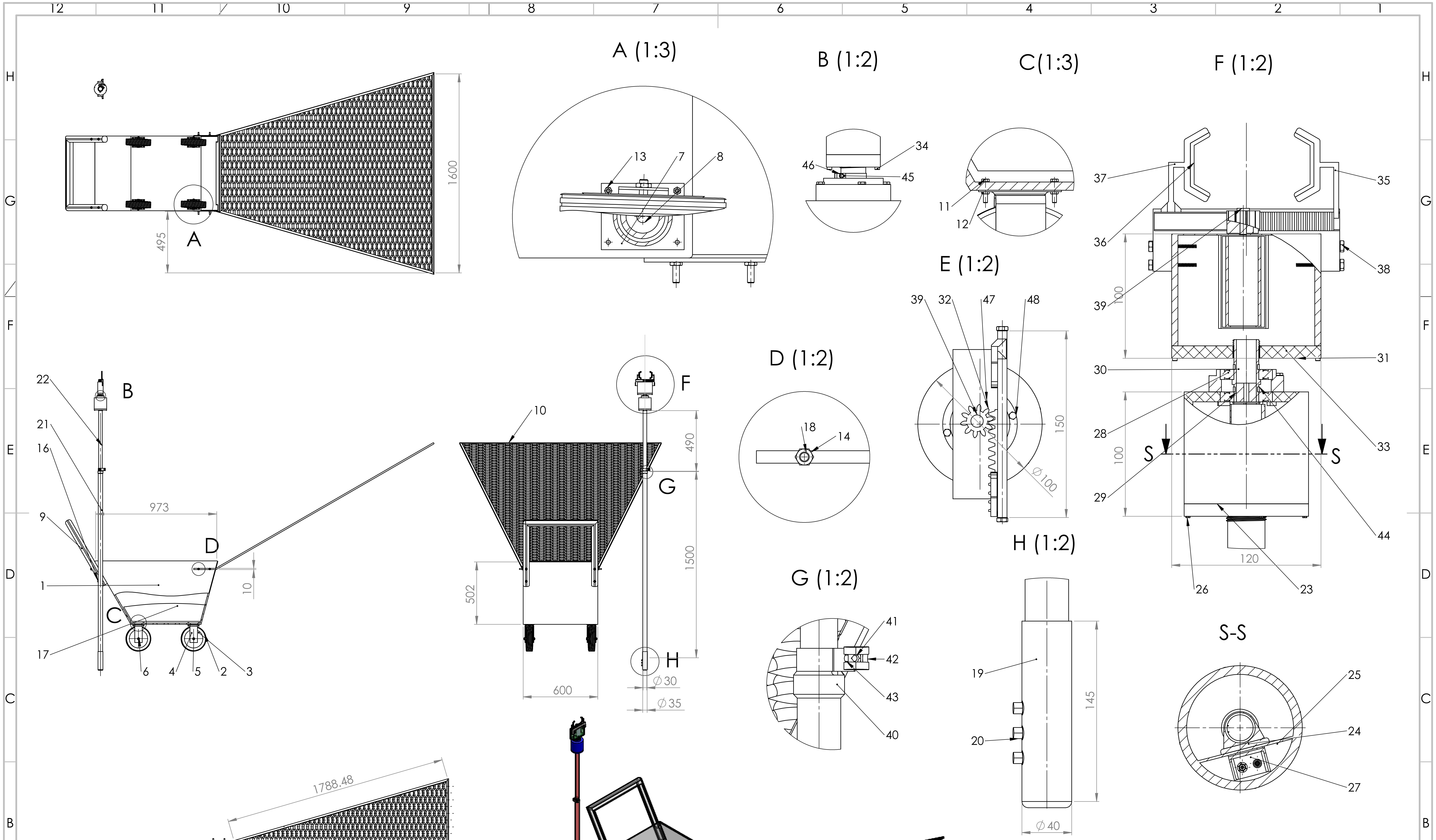
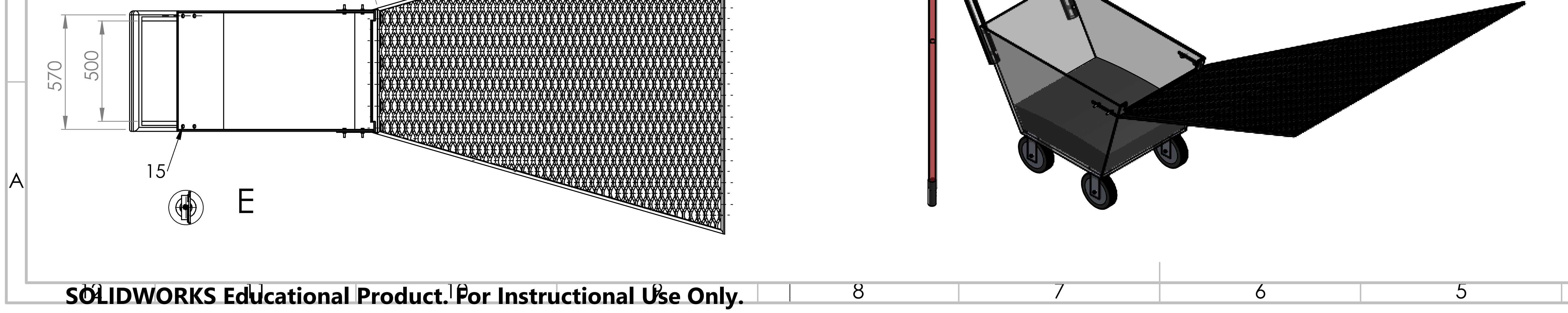
APPENDIX C





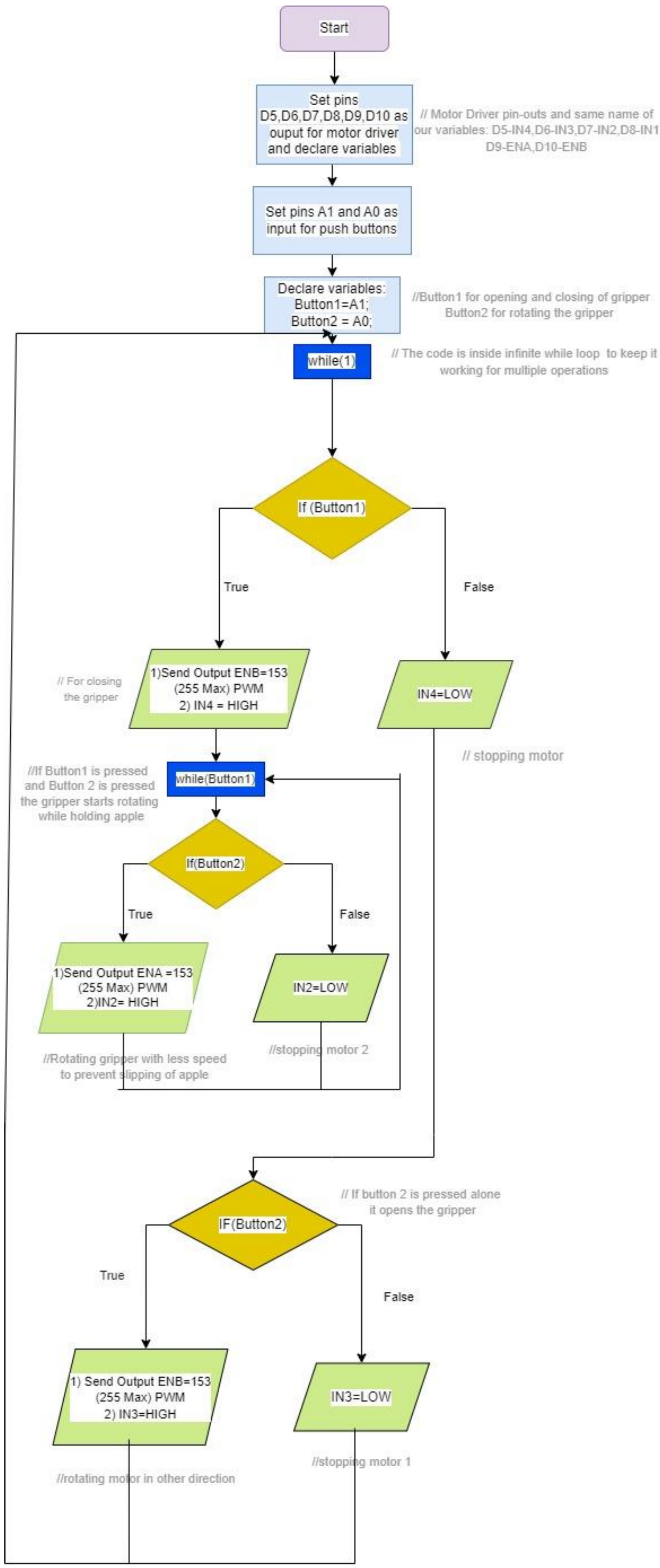
General Tolerances acc. to ISO 2768 - mK
Surface finish acc. to ISO 1302
Edge finish acc. to ISO 13715

Faculty or Department	Technical reference	Drawn by	Checked by	
Technology & Bionics	Group 02	Shreenithi	Shreshth	Page 1 of 1

HOCHSCHULE RHEIN-WAAL Rhine-Waal University of Applied Sciences	Document type: Assembly Drawing	Document status: Released
	Title, Additional title: PickIT	Drawing number: 28639-SE05.02-001.02
	Material: — Weight: 30157.23 grams	Scale: 1:20 Creation date: 09.01.2023 Proj.

48	4	Hexagon Bolt	DIN EN 24014 - M3 x 20 x 20-C	28639-01-048		201 Annealed Stainless Steel
47	1	Ball bearing holder		28639-01-047		ABS PC
46	2	Hexagon Thin Nut	ISO 4035 - M1.6 - C	28639-01-046		201 Annealed Stainless Steel
45	2	Hexagon Bolt	DIN EN 24014 - M1.6 x 12 x 9-C	28639-01-045		201 Annealed Stainless Steel
44	2	circlip		28639-01-044		1023 Carbon Steel Sheet
43	1	Knob		28639-01-043		201 Annealed Stainless Steel
42	1	Clamp lever		28639-01-042		Custom Plastic
41	1	Barrel		28639-01-041		201 Annealed Stainless Steel
40	1	Clamp body enclosed		28639-01-040		Custom Plastic
39	1	Pinion securement		28639-01-039		201 Annealed Stainless Steel
38	4	Hexagon Bolt	DIN EN 24014 - M5 x 35 x 35-C	28639-01-038		201 Annealed Stainless Steel
37	1	Claw holder		28639-01-037		Plain Carbon Steel
36	2	Rubber padding		28639-01-036		Rubber
35	1	Rack Gear	DIN - Rack-spur - rectangular 2.25M 20PA 19FW 10.881PH 82L---Sall	28639-01-035		ABS PC
34	4	Socket Head Cap Screw	EN ISO 4762 M2 x 20 - 16S	28639-01-034		201 Annealed Stainless Steel
33	1	Gripper housing lid		28639-01-033		ABS PC
32	1	Spur Gear	DIN - Spur gear 2.25M 10T 20PA 18FW ---S10A75H50L4N	28639-01-032		ABS PC
31	1	Gripper housing		28639-01-031		ABS PC
30	1	Motor shaft covering		28639-01-030		1060 Alloy
29	1	Motor shaft sleeve		28639-01-029		1060 Alloy
28	2	Radial Ball Bearing	DIN 625 - 16004 - 12,SI,NC,12_68	28639-01-028		201 Annealed Stainless Steel
27	1	9V-Battery holder		28639-01-027		ABS PC
26	4	Hexagon Bolt	DIN EN 24014 - M1.6 x 16 x 16-C	28639-01-026		201 Annealed Stainless Steel
25	1	Rotational housing lid		28639-01-025		ABS PC
24	2	Motor housing		28639-01-024		1060 Alloy
23	1	Rotational housing		28639-01-023		ABS PC
22	1	Part2^telescopic rod		28639-01-022		1060 Alloy
21	1	Part1^telescopic rod		28639-01-021		1060 Alloy
20	3	Pushbutton		28639-01-020		ABS PC
19	1	Handle of fruitpicker		28639-01-019		ABS PC
18	4	Hexagon Bolt	DIN EN 24014 - M8 x40 x 40-C	28639-01-018		201 Annealed Stainless Steel
17	1	Cart padding		28639-01-017		Silicon Rubber
16	4	Hexagon Thin Nut	ISO 4035 - M10 - C	28639-01-016		201 Annealed Stainless Steel
15	4	Hexagon Bolt	DIN EN 24014 - M10 x 70 x 26-C	28639-01-015		201 Annealed Stainless Steel
14	4	Hexagon Thin Nut	ISO 4035 - M8 - C	28639-01-014		201 Annealed Stainless Steel
13	1	Hexagon Thin Nut	ISO 4035 - M5 - C	28639-01-013		201 Annealed Stainless Steel
12	15	Hexagon Thin Nut	ISO 4035 - M5 - N	28639-01-012		201 Annealed Stainless Steel
11	16	Hexagon Bolt	DIN EN 24014 - M5 x 25 x 16-C	28639-01-011		201 Annealed Stainless Steel
10	1	Net		28639-01-010		Nylon 101
9	1	Cart handle		28639-01-009		ABS PC
8	4	Rivet		28639-01-008		201 Annealed Stainless Steel
7	4	Link		28639-01-007		201 Annealed Stainless Steel
6	4	Hexagon Nut	ISO 8675 - M10 x 1 - Cx 80 x 26-C	28639-01-006		201 Annealed Stainless Steel
5	4	Hexagon Bolt	DIN EN 24014 - M10 x 80 x 26-C	28639-01-005		201 Annealed Stainless Steel
4	4	Wheel cover		28639-01-004		1060 Alloy
3	4	Wheel inner		28639-01-003		Insulated Mold Casting
2	4	Wheel outer		28639-01-002		Neoprene
1	1	Cart chassis		28639-01-001		ABS PC
item	qty.	description	specification	drawing no.	rev.	material

APPENDIX D



Start
Set pins D5,D6,D7,D8,D9,D10 as ouput for motor driver and declare variables
// Motor Driver pin-outs and same name of our variables: D5-IN4,D6-IN3,D7-IN2,D8-IN1 D9-ENA,D10-ENB
Set pins A1 and A0 as input for push buttons
Declare variables: Button1=A1; Button2 = A0;
//Button1 for opening and closing of gripper Button2 for rotating the gripper
while(1)
// The code is inside infinite while loop to keep it working for multiple operations
If (Button1)
True
False
1)Send Output ENB=153 (255 Max) PWM 2) IN4 = HIGH
// For closing the gripper
IN4=LOW
// stopping motor
while(Button1)
//If Button1 is pressed and Button 2 is pressed the gripper starts rotating while holding apple
If(Button2)
True
False
1)Send Output ENA =153 (255 Max) PWM 2)IN2= HIGH
IN2=LOW
//Rotating gripper with less speed to prevent slipping of apple
//stopping motor 2
IF(Button2)
// If button 2 is pressed alone it opens the gripper
True
False
1) Send Output ENB=153 (255 Max) PWM 2) IN3=HIGH
IN3=LOW
//rotating motor in other direction
//stopping motor 1

APPENDIX E

Mechanical BOM

No.	Quantity	Manufacturer	Component Name	Material	Mass [g]	Price/kg [€]	Price/part [€]	Price [€]
1	1	Manufactured in house	Handle of fruit-picker	ABS	63.4	2.5	0.16	0.16
2	1	COTS	Telescopic Rods	1060 Alloy	1169.99	-	8.50	8.50
3	2	COTS	Radial Ball Bearing	not specified yet	15.48	-	0.20	0.40
4	2	COTS	Circlip	1023 Carbon steel sheet	3.33	-	0.30	0.60
5	1	Manufactured in house	Housing of Rotation Mechanism	ABS PC	248.29	2.8	0.70	0.70
6	1	Manufactured in house	Gripper	ABS	462.95	2.5	1.16	1.16
7	2	COTS + Machined in house	Rubber Padding of Gripper	Rubber	0.98	0.9	0.05	0.10
8	4	COTS	Wheels	Neoprene	979.2	-	3.50	14.00
9	1	Manufactured in house	Handle bar of Cart	ABS	5271.09	2.5	3.85	3.85
	1	COTS + Machined in house	Net	Nylon	147.53	0.4	0.25	0.25
10	1	COTS + Machined in house	Soft Padding of Cart	EPE (Expandanble Polyethylene)	208.93	-	0.30	0.30
11	1	Manufactured in house	Basket of Cart	ABS	22671.91	2.5	8.70	8.70
14	4	COTS	Bolt - M1.6x16	Galvanized stainless steel	0.03	-	0.10	0.40
15	4	COTS	Bolt - M3x20	Galvanized stainless steel	0.19	-	0.10	0.40
16	16	COTS	Bolt - M5x25	Galvanized stainless steel	0.68	-	0.10	1.60
17	2	COTS	Bolt - M8x40	Galvanized stainless steel	2.77	-	0.20	0.40
18	4	COTS	Bolt - M10x70	Galvanized stainless steel	6.89	-	0.20	0.80
19	4	COTS	Bolt - M10x80	Galvanized stainless steel	7.68	-	0.20	0.80
20	1	COTS	Bolt - M5x25	Galvanized stainless steel	0.68	-	0.20	0.20
21	16	COTS	Nut - M5	Galvanized stainless steel	0.68	-	0.89	14.24
22	2	COTS	Nut - M8	Galvanized stainless steel	2.77	-	1.10	2.20
23	4	COTS	Nut - M10	Galvanized stainless steel	6.89	-	1.30	5.20
24	4	COTS	Nut - M10	Galvanized stainless steel	7.68	-	1.50	6.00
						Total price per unit in Euros		70.95
						VAT (19%)		13.48
						Total cost after VAT		**84.43**

Electrical BOM

No.	Quantity	Manufacturer	Component	Description	Unit Price[€]	Reference
1	2	Ekulit	GM71,1 6V Gearmotor	6V DC geared motors	19.2	GM25-370-16250-57-12D8
2	1	Joy-it	L298N Motor Driver	Motor driver for 2 motors	7.34	JT-MD2-L298N
3	1	Enegon	650mAh Li-ion Battery	9V Battery	14.5	B07VKN5TP9
4	2	Itt Schadow	DT 6 RT Push button	Push buttons	0.81	9.90E+12
5	1	E-Switch	Switch	Safety Switch	1.77	RR812C1121
6	1	Adruino	Arduino Nano V3	Microcontoller	24.52	A000005
7	1	ZoZoMaiy	Wires	For connecting components	9.59	B08NXGGS54
				Total price per unit in [€]	77.73	
				VAT (19%)	14.7687	
				Total cost after VAT	**92.4987**	