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Design of Traffic Cone Collector Machine

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Abstract

The traffic cone collecting process may be time-consuming, labor-intensive, and dangerous to workers. Therefore, the "Design of Traffic Cone Collector Machine" project seeks to address the ongoing issues of efficiently managing and collecting traffic cones on roads. The objectives of this project are to investigate the existing traffic cone collecting and storage mechanism, to identify the most efficient traffic cone collecting and storage mechanism and to design a complete traffic cone collector machine. The scopes of the research are analyse the existing traffic cone collector machines, study the types and sizes of traffic cones commonly used in Malaysia, develop a detailed design for the traffic cone collector machine, design an automated traffic cone collecting mechanism, design an automated traffic cone storage mechanism and validate the traffic cone collecting and storage mechanism. The design of the machine is drawn and simulate using Solidwork software. The final design of the machine shows that it can collect the traffic cone at 10s per cone and have a storage capacity of 390 traffic cones.

1. Introduction

Road safety is a critical global concern, and the management of traffic control devices, such as traffic cones, is essential for ensuring the safety of drivers and pedestrians. Traffic cones are widely used on roads and highways to mark lanes, guide vehicles, and manage traffic during construction or maintenance activities. However, the manual process of deploying and collecting these cones is labor-intensive, time-consuming, and possesses significant safety risks to workers. Addressing these challenges, the "Design and Development of Traffic Cone Collector Machine" project aims to investigate the existing traffic cone collecting and storage mechanism, to identify the most efficient traffic cone collecting and storage mechanism and to design a complete traffic cone collector machine. This initiative intends to reduce human effort, eliminate safety concerns, and contribute to sustainable practices in road maintenance and traffic control. The proposed automated traffic cone collector machine will provide a safer, more efficient, and environmentally friendly approach to traffic cone management, benefiting construction sites, road maintenance operations, and event traffic control scenarios.

Based on JKR Malaysia, the traffic guiding cone must adhere to the requirements specified in the drawings or as authorised. Only red or orange colour options are available for traffic guiding cones, which must be made of LDPE material. As indicated in the design, the cone must weigh a minimum of 3.0 kg and have a rubber base of 500 mm x 500 mm and a height of 750 mm. Additionally, reflective strips made of white high-intensity prismatic retro reflective sheeting will be included. In order to keep the traffic guiding cone from being moved by high winds or surface runoff, it must be weighted down with a rubber base [2].

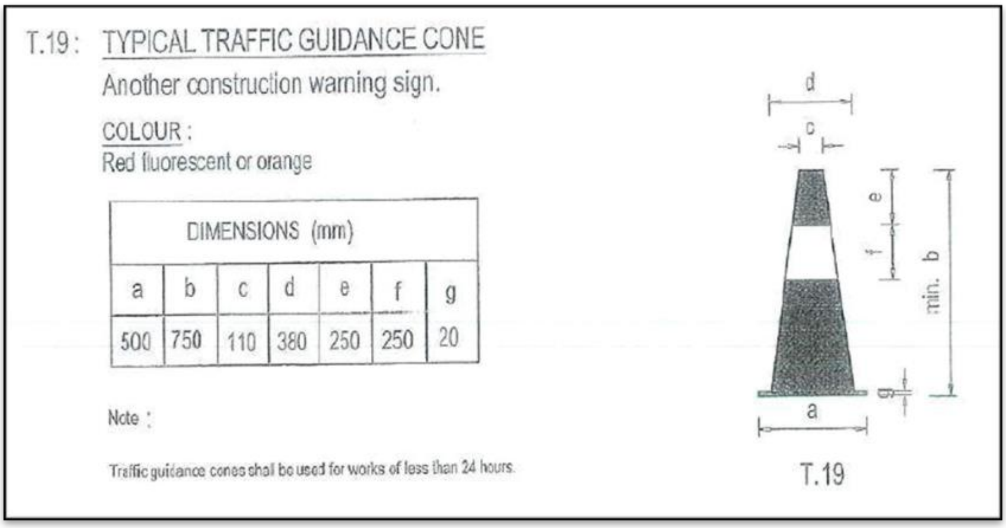


Figure 1.1: *Typical traffic cone sizing provided by JKR [2].*

This project had evaluated and compared eight patents focusing on traffic cone collection and storage mechanisms. Table 1.1 shows the patents that were selected when investigating the existing traffic cone collecting and storage mechanism.

Table 1.1: *Patents of the existing traffic cone collecting and storage mechanism.*

No.	Patent Number	Name
1	CN111719454B [3]	Automatic retracting device for traffic cones
2	CN113235485B [4]	Traffic cone winding and unwinding devices and vehicle
3	CN209836847U [5]	Automatic storage facilities that receive and releases of traffic awl and warning light
4	CN110644394B [6]	Automatic traffic cone winding and unwinding machine
5	CN111827162B [7]	Full-automatic storage vehicle and method for storing traffic cone barrels
6	CN107059687B [8]	Pulling type traffic cone collecting and releasing vehicle
7	CN111501612B [9]	Automatic traffic road cone collecting and releasing vehicle and collecting and releasing method
8	CN111441282A [10]	Traffic cone collecting and storing vehicle

2. Methodology

2.1 Project Flow

The development of a traffic cone collector machine follows a structured process flow. It begins with concept generation, where creative ideas are brainstormed. These ideas are developed into various design concepts. Each concept undergoes concept evaluation based on feasibility, cost, and safety. The best idea is chosen in the concept selection phase. Next, design sketching provides preliminary visualizations, which are refined into precise detail drawings. To visualize the operation, design animation is created. The process concludes with component analysis and selection, ensuring the best materials and parts are chosen for durability and efficiency. This methodical approach ensures a well-designed, functional traffic cone collector machine.

2.2 Concept Generation

Table 2.1 shows the devices used in traffic cone collector machine and their functions.

Table 2.1: *Devices used in traffic cone collector machine.*

Device	Input	Function	Output
Channel Moving Device	Meet traffic cone	Catch traffic cone and guide it to the grabbing device	Traffic cone is guided to grabbing device
Pre-Processing Device	Meet traffic cone	Prepare the traffic cone readily to grabbed	Traffic cone is prepared to be grabbed
Grabbing Device	Mechanical energy	Grab traffic cone	Traffic cone grabbed

Table 2.1 (Continued).

Device	Input	Function	Output
Lifting Device	Mechanical energy	Lift the grabbed traffic cone	Traffic cone is lifted
Staking Device	Traffic cone	Receive traffic cones from lifting device and stake them	Staked traffic cones
Traffic Cone to Storage Delivery Device	Mechanical energy	Deliver the fully staked traffic cones from staking device into the storage mechanism	Staked traffic cones is delivered into storage mechanism
Traffic Cone to Designated Storage Area Guidance Device	Mechanical energy	Receive staked traffic cones from staking device and guide them to vacant storage area	Staked traffic cones is guided to their storage area
Traffic Cone to Designated Storage Area Transportation Device	Mechanical energy	Transport staked traffic cones to their designated storage area	Staked traffic cones is transported to their storage area and stored
Motor	Electrical energy	Convert	Mechanical energy
Sensor	Traffic cone position	Sense traffic cone position	Position signal
	Number of traffic cone	Sense the number of traffic cone stacked	Number signal
	Storage vacancy	Sense the storage row that have vacancy area	Position signal
Power Generator	Chemical energy	Generate power	Electrical energy

Figure 2.1 shows the function structure of the traffic cone collector machine.

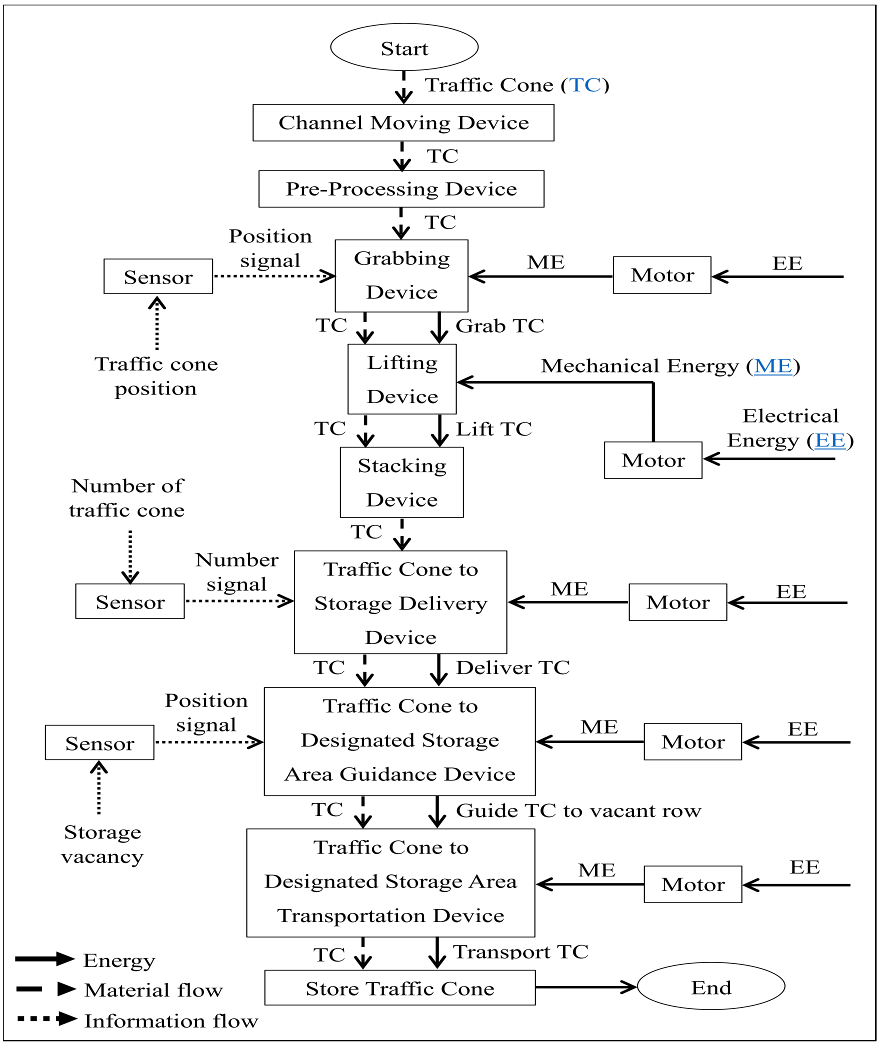


Figure 2.1: *Function structure of the traffic cone collector machine.*

2.3 Design Concept

Table 2.2 shows the components that are used in the traffic cone collector machine.

Table 2.2: *Design concept of traffic cone collector machine.*

Subfunctions	Concept
Channel Moving Device	Triangle Shape Guiding Plate
Pre-Processing Device	Push Down the Traffic Cone into Horizontal State
Grabbing Device	Scooping The Traffic Cone
Lifting Device	Ball Screw Rail Guide
Stacking Device	Servo Linear Actuator
Traffic Cone to Storage Delivery Device	Ball Screw Rail Guide
Traffic Cone to Designated Storage Area Guidance Device	Ball Screw Rail Guide
Traffic Cone to Designated Storage Area Transportation Device	Roller Conveyor
Motor	Electric Motor
Sensor	Laser Sensor
Power Supply	Diesel Engine

2.4 Component Analysis and Selection

Figure 2.2 shows the components tree diagram for the traffic cone collector machine collecting mechanism and storage mechanism. The analysis is conducted and the components that are suitable to use will be selected from the specific catalog.

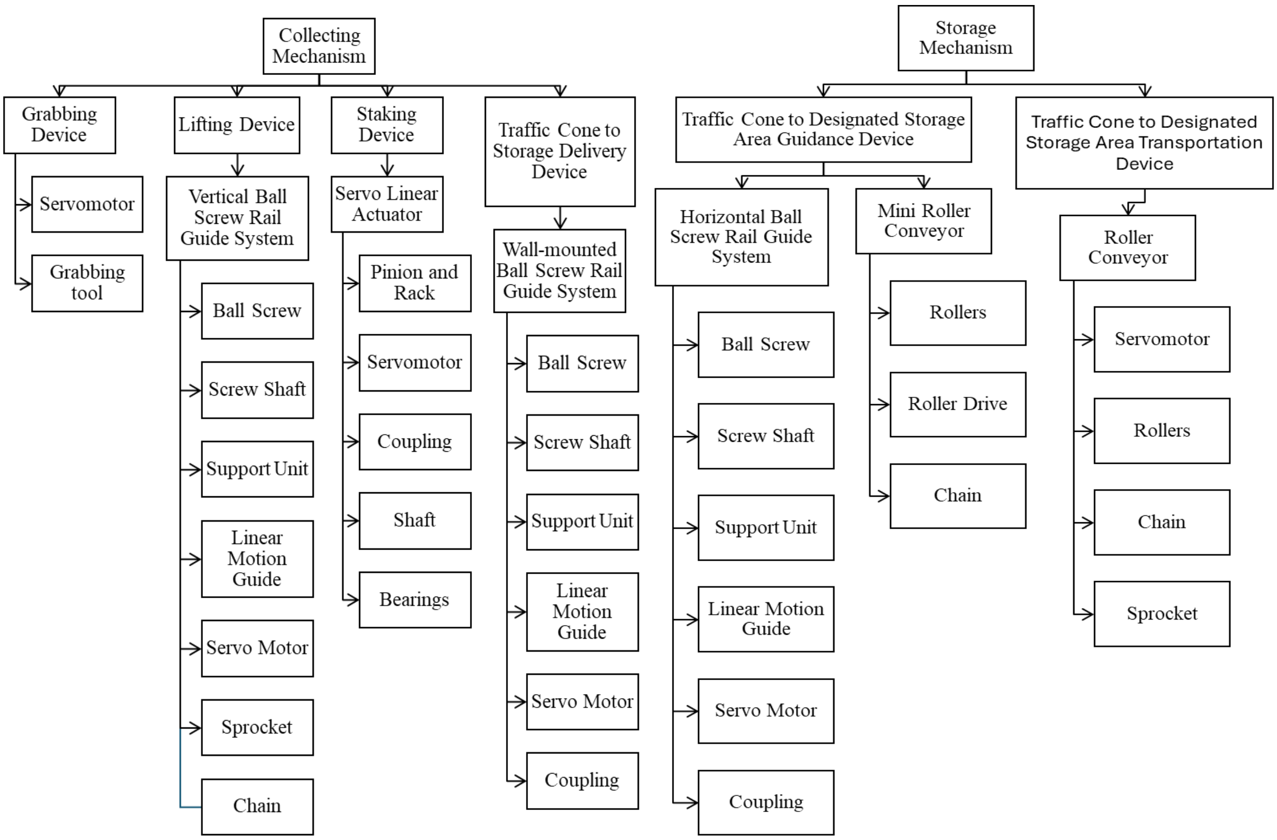
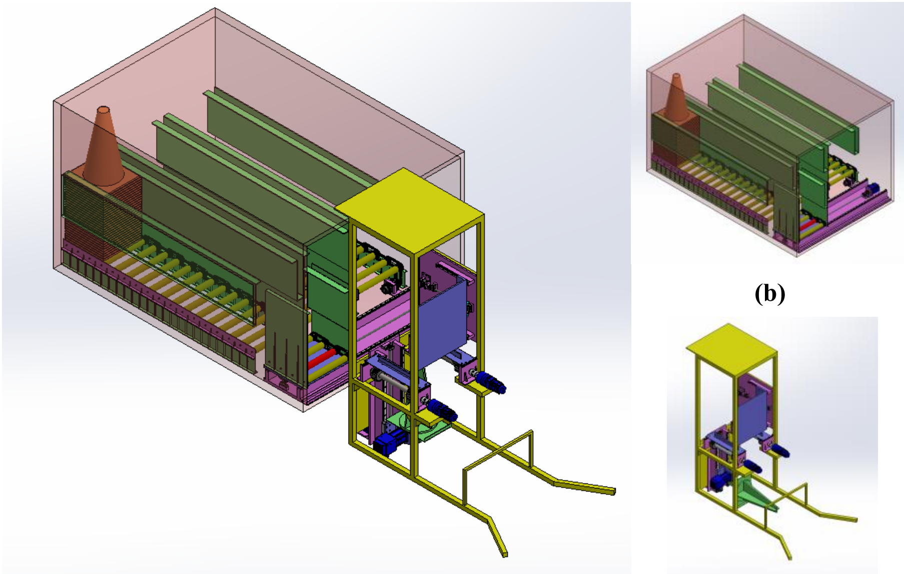


Figure 2.2: *Collecting mechanism and storage mechanism components tree diagram.*

3. Design of Traffic Cone Collector Machine

3.1 Overall Design



(a) (b) (c)

Figure 3.1: *(a) Overall design of traffic cone collector machine (b) Storage mechanism (b) Collecting mechanism.*

3.2 Collecting Mechanism Machine Process Flow

First, the lorry is driving backward and approaching the traffic cone on the road. Then the traffic cone is pushed into horizontal state and moves to the grabbing device.

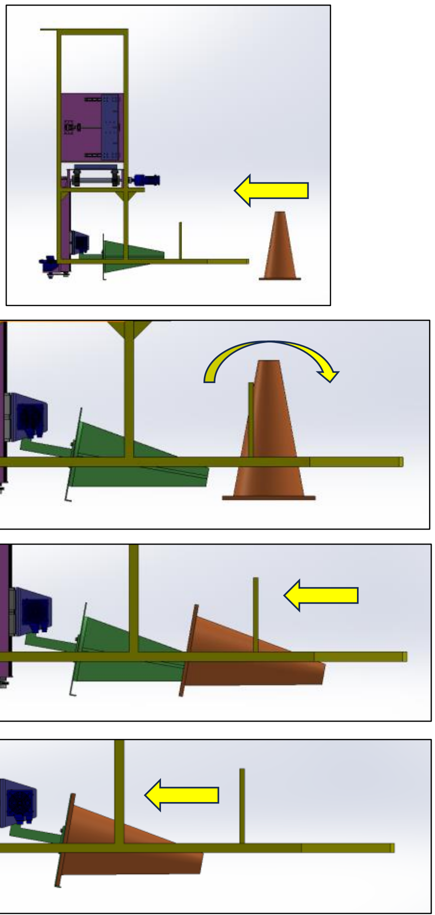


Figure 3.2: *Traffic cone movement.*

The second step is grabbing the traffic cone using grabbing device. The servo motor of the grabbing device started to rotate, the grabbing tool grab turned up and grabbed the traffic cone upward.

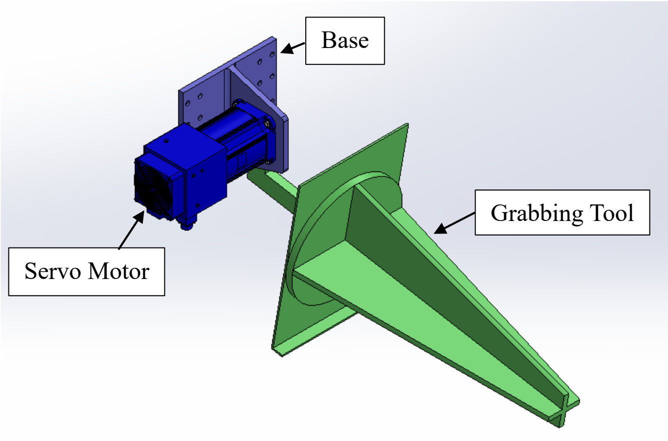


Figure 3.3: *Components of grabbing device.*

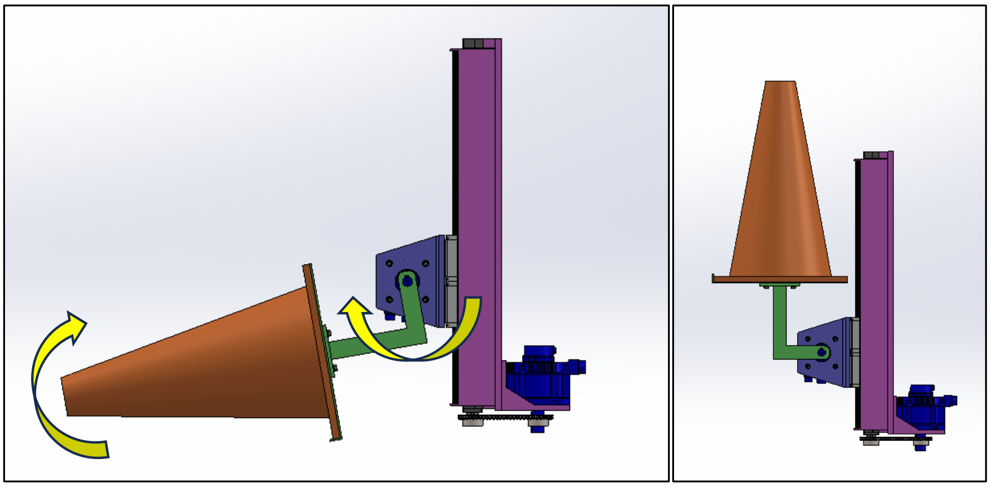


Figure 3.4: *The movement of the grabbing device.*

The third step is lifting the traffic cone up to the staking device using lifting device. The servo motor of the lifting device started to rotate the screw shaft, the rotation of the motor is transferred to the screw shaft through sprockets and chain as shown in figure 3.6. The ball screw moving upward due to the rotation of the screw shaft and the traffic cone is being lifted.

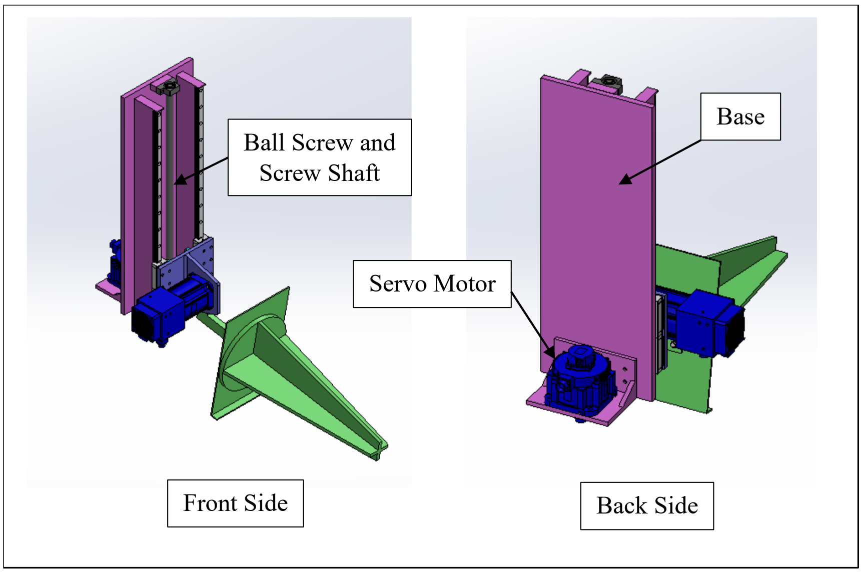


Figure 3.5: *Front view and back view of lifting device.*

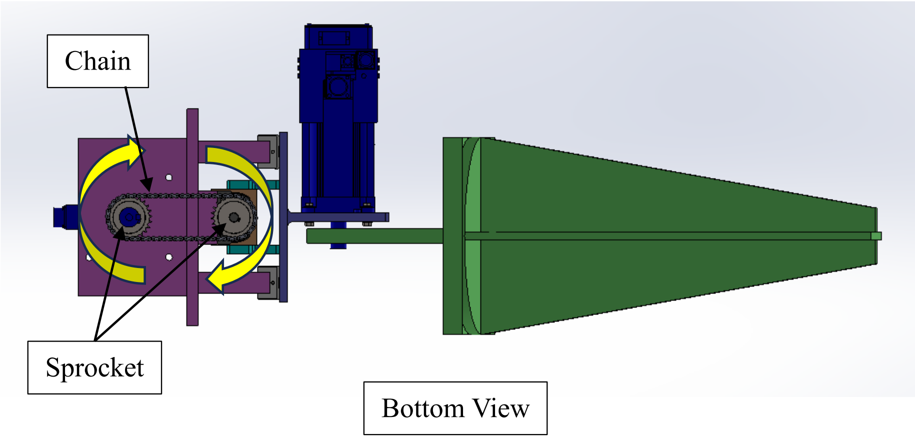


Figure 3.6: *Bottom view of lifting device.*

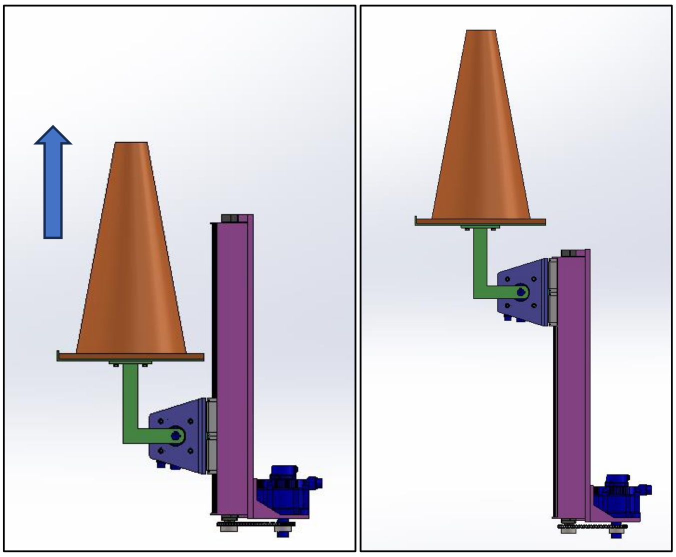


Figure 3.7: *The movement of the lifting device.*

The fourth step is staking the traffic cones using staking device. Both servo motors are rotating in the direction opposite to each other. The pinions are rotated and move the sliding plates in the direction opposite to each other. Now, the staking device is in opened condition. The lifting device moves the traffic cone upward and entering the staking device. After that, both servo motors rotate in the direction opposite to the initial direction and the staking device is in closed condition. The lifting device is moving downward and left the traffic cone stake on the staking device.

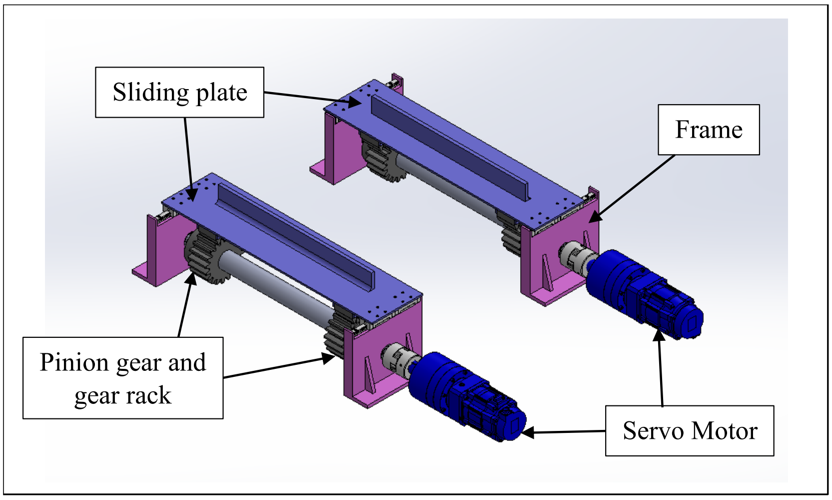


Figure 3.8: *Staking device isometric view.*

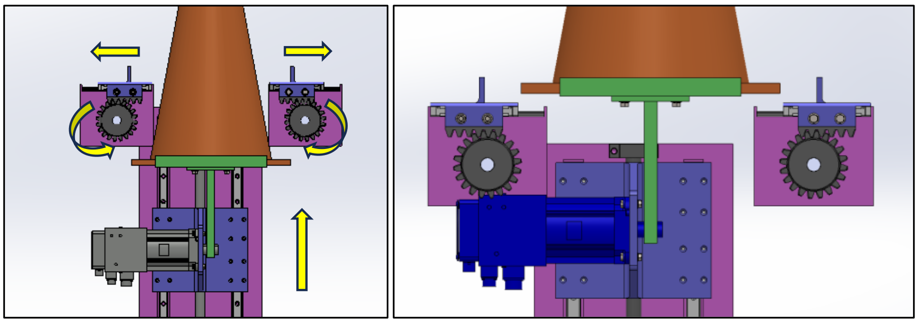


Figure 3.9: *Opened condition of the staking device.*

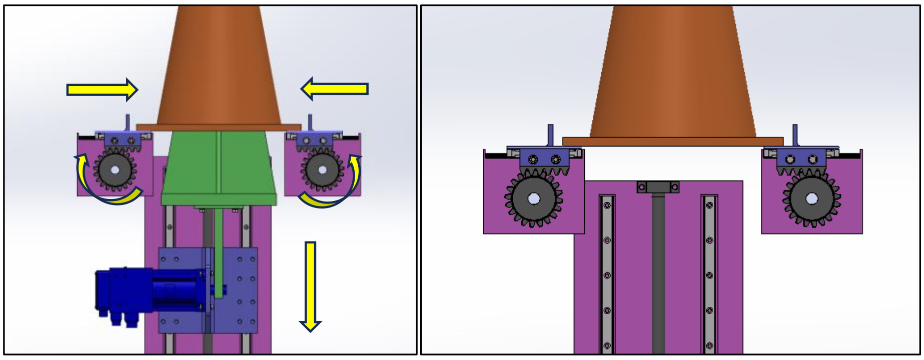


Figure 3.10: *Closed condition of the staking device.*

Lastly, the staked traffic cones will be sent into the storage mechanism when there are 26 traffic cones staked on the staking device using traffic cones to storage delivery device. The servo motor of the traffic cones to storage delivery device started to rotate the screw shaft. The ball screw moving forward due to the rotation of the screw shaft and the staked traffic cone is being pushed into the storage mechanism by sliding plate.

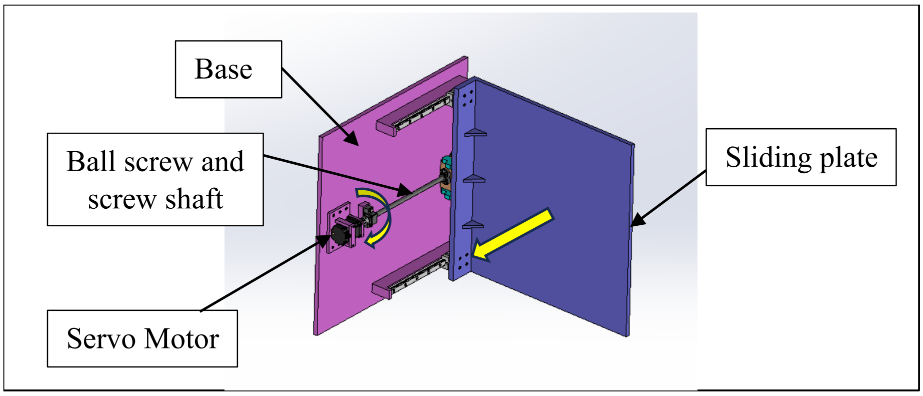


Figure 3.11: *Traffic cones to storage delivery device isometric view.*

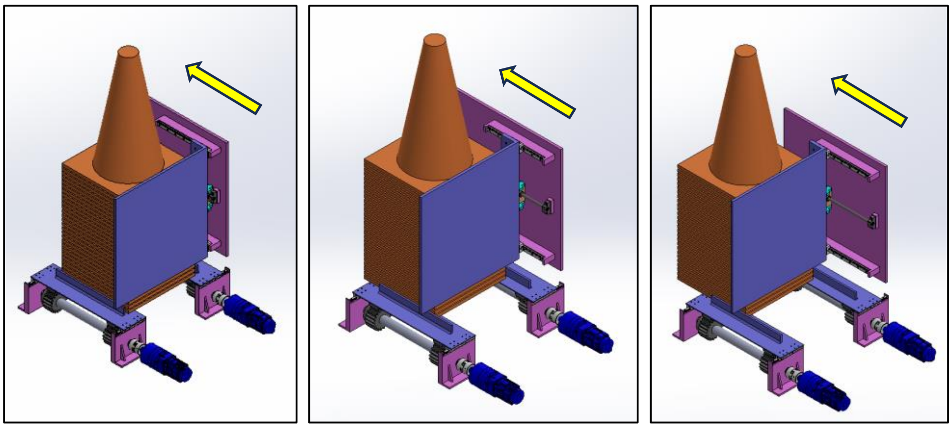


Figure 3.12: *The movement of the traffic cones to storage delivery device.*

3.3 Storage Mechanism Machine Process Flow

In designing the traffic cone storage mechanism, a lorry was chosen as the carrier for the traffic cones. Essentially, a lorry typically comes equipped with a metal box. The metal box is assumed to be designed with inner dimensions of 315cm in length, 200cm in width, and 180cm in height. The capacity of the storage mechanism is set as 390 traffic cones where each row of roller conveyor consists of 5 staked traffic cones. Each staked traffic cone has 26 traffic cones staked. First, traffic cone to designated storage area guidance device received the staked traffic cones from the collecting mechanism. Then, the servo motor of the traffic cone to designated storage area guidance device started to rotate the screw shaft. The ball screw moving left or right due to the rotation of the screw shaft and the staked traffic cone is being guided to the specific row of storage location.

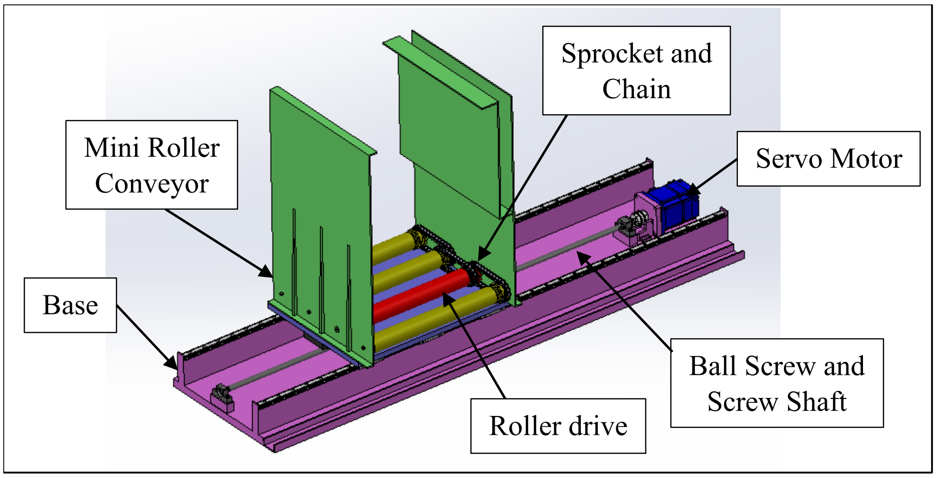


Figure 3.13: *Isometric view of traffic cone to designated storage area guidance device.*

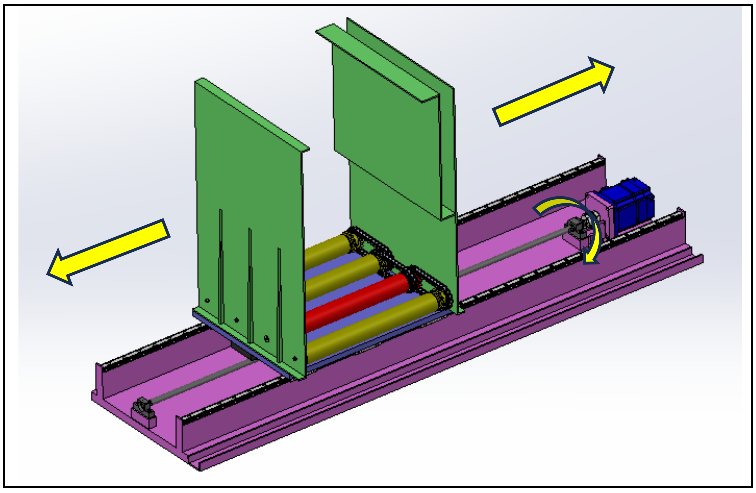


Figure 3.14: *The movement of traffic cone to designated storage area guidance device.*

After the stacked traffic cones are guided to the specific row of storage location, the roller drive starts to rotate. The rotation is transferred to other rollers through sprocket and chain. The rotation of the roller provides linear motion to the staked traffic cones and makes it move into the specific row of storage location.

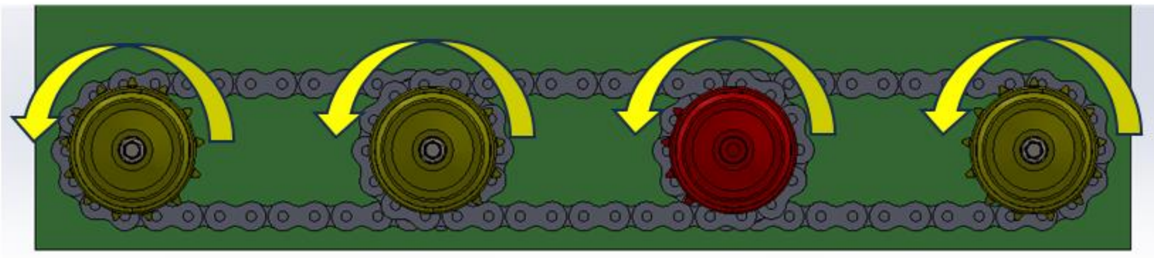


Figure 3.15: *The movement of roller drive in mini conveyor.*

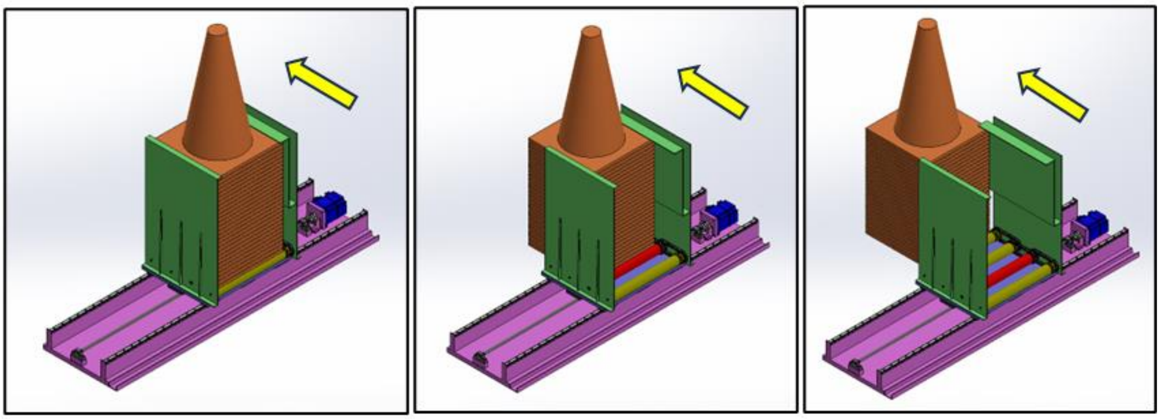


Figure 3.16: *The movement of staked traffic cones on mini conveyor.*

Finally, the roller conveyor inside the specific row of storage location received the staked traffic cones. The servo motor of the roller conveyor started to rotate and the rotation is transferred to other rollers using sprockets and chains. The rotation of the roller provides linear motion to the staked traffic cones and makes it move deeper into the specific row of storage location.

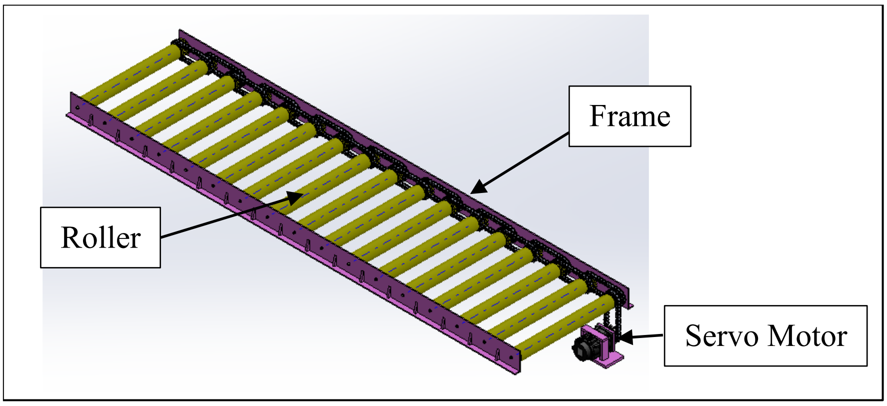


Figure 3.17: *Isometric view of roller conveyor.*

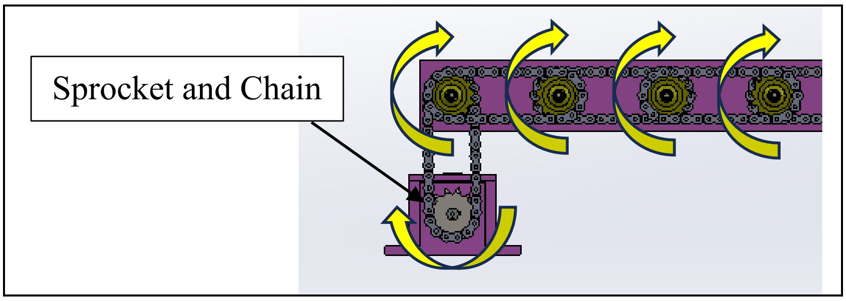


Figure 3.18: *The movement of sprocket and chain.*

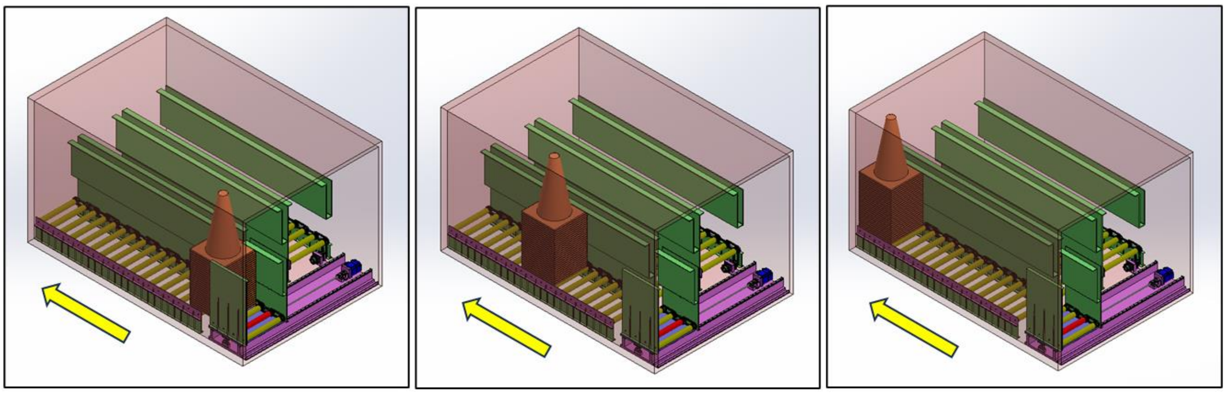


Figure 3.19: *The movement of staked traffic cones on roller conveyor.*

3.4 Component Analysis and Selection

Table 3.1: *The summary of components selected.*

<table>
<tr><th>No.</th><th>Component</th><th>Manufacturer</th><th>Description</th></tr>
<tr><td colspan="4">Traffic Cone to Storage Area Transportation Device</td></tr>
<tr><td colspan="4">Roller Conveyor</td></tr>
<tr><td>1.</td><td>Roller</td><td>Interroll</td><td>• Model name:
Series 3500 welded steel double sprocket head 5/8”, T13
• Reference length = 600 mm
• Static Safety factor: 10.5</td></tr>
<tr><td>2.</td><td>Servomotor</td><td>Yaskawa</td><td>• Model name: SGM7J-01AFA61
• Rated output: 100 W
• Rated torque: 0.318 Nm
• Instantaneous maximum torque: 1.11 Nm
• Rated speed: 3000 min^{-1}
• Motor moment of inertia:
$0.0695 \times 10^{-4}\ kg \cdot m^2$
• Allowable load moment of inertia: 35 times</td></tr>
<tr><td>3.</td><td>Sprocket</td><td rowspan="2">SKF</td><td>• Model name: PHS 10B-1B13
• Bore diameter: 16 mm</td></tr>
<tr><td>4.</td><td>Chain</td><td>• Model name: PHC 10B-1
• Chain length (Motor – Roller): 539.75 mm
• Chain length (Roller – Roller): 508 mm
• Service factor: 1.28</td></tr>
<tr><td colspan="4">Traffic Cone to Designated Storage Area Guidance Device</td></tr>
<tr><td colspan="4">Mini Roller Conveyor</td></tr>
<tr><td>1.</td><td>Roller</td><td rowspan="2">Interroll</td><td>• Model name:
Series 3500 welded steel double sprocket head 5/8”, T13
• Reference length = 600 mm
• Static Safety factor: 10.5</td></tr>
<tr><td>2.</td><td>Roller Drive</td><td>• Model name:
EC 5000 $Ø60\ mm$ welded steel double sprocket head
• Gear ratio: 49:1
• Power: 50 W
• Reference length = 600 mm
• Static safety factor: 10.5
• Minimum conveying speed: 0.03 m/s
• Maximum conveying speed: 0.44 m/s</td></tr>
<tr><td>3.</td><td>Chain</td><td>SKF</td><td>• Model name: PHC 10B-1
• Chain length (Roller – Roller): 508 mm
• Service factor: 1.28</td></tr>
<tr><td colspan="4">Horizontal Ball Screw Linear Guide System</td></tr>
<tr><td>1.</td><td>Ball Screw</td><td rowspan="2">THK</td><td>• Model name:
WTF 2040-2 ZZ +1770.5L C7 T H1K
• Static safety factor: 52.3
• Service life time: $4.2392 \times 10^6\ hr$
• Support unit: EK15, EF15</td></tr>
<tr><td>2.</td><td>Linear Motion Guide</td><td>• Model name: SSR25XW2SS+1990LY-II
• Static Safety Factor: 138.46
• Service life: $8.4567 \times 10^8\ hr$</td></tr>
</table>

Table 3.1 (continued).

No.	Component	Manufacturer	Description

Traffic Cone to Designated Storage Area Guidance Device			
Horizontal Ball Screw Linear Guide System			
3.	Servomotor	Yaskawa	• Model name: SGM7G-05AFA61 • Rated output: 0.45 kW • Rated torque: 2.86 Nm • Instantaneous maximum torque: 8.92 Nm • Rated speed: 1500 min^{-1} • Motor moment of inertia: $3.33 \times 10^{-4}\ kg \cdot m^2$ • Allowable load moment of inertia: 15 times
4.	Coupling	Tsubaki	• Model name: L050-S-12JX16J • Service factor: 1.52
Traffic Cone to Storage Delivery Device			
Wall Mounted Ball Screw Linear Guide System			
1.	Ball Screw	THK	• Model name: WTF 2040-2 ZZ +530.5L C7 T H1K • Static safety factor: 22.9 • Service life time: $1.4077 \times 10^5\ hr$ • Support unit: EK15, EF15
2.	Linear Motion Guide	THK	• Model name: HSR25R2QZSS+400L-II • Static Safety Factor: 90.9795 • Service life: $2.3494 \times 10^7\ hr$
3.	Servomotor	Yaskawa	• Model name: SGM7G-09AFA61 • Rated output: 0.85 kW • Rated torque: 5.39 Nm • Instantaneous maximum torque: 14.2 Nm • Rated speed: 1500 min^{-1} • Motor moment of inertia: $13.9 \times 10^{-4}\ kg \cdot m^2$ • Allowable load moment of inertia: 5 times
4.	Coupling	Tsubaki	• Model name: L075-S-12JX24JN • Service factor: 2.62
Staking Device			
1.	Servomotor	Yaskawa	Same as servomotor for wall mounted ball screw linear guide system
2.	Pinion	KHK gear	• Model name: SS6-20J25 • Safety factor for bending failure, S_F = 1.5 • Bending stress: $8.4088 \times 10^{-4}\ kgf/mm^2$ • Allowable bending stress at root: $12.6667\ kgf/mm^2$ • Safety Factor for Pitting, S_H: 1.5 • Hertz stress: $1.0735\ kgf/mm^2$ • Allowable hertz stress: $49\ kgf/mm^2$
3.	Rack	KHK gear	• Model name: SS6-110J • Safety factor for bending failure, S_F = 1.5 • Bending stress: $6.206 \times 10^{-4}\ kgf/mm^2$ • Allowable bending stress at root: $13.3333\ kgf/mm^2$ • Safety Factor for Pitting, S_H: 1.5 • Hertz stress: $1.0735\ kgf/mm^2$ • Allowable hertz stress: $52.5\ kgf/mm^2$
4.	Shaft	-	• Material: AISI 1030 quenched and tempered steel • Fatigue safety factor: 15.1942 • Yield safety factor: 28.433

Table 3.1 (continued).

No.	Component	Manufacturer	Description

Staking Device			
5.	Bearing	SKF	• Model name: 4302 ATN9 • Double row deep groove ball bearing
6.	Coupling	Tsubaki	• Model name: L095-S-15JX24JN • Service factor: 2.05
7.	Linear Motion Guide	THK	• Model name: SHS15V1QZSS+220L-II • Static Safety Factor: 251.6966 • Service life: 7.7563×10^8 hr
Lifting Device			
Vertical Ball Screw Linear Guide System			
1.	Ball Screw	THK	• Model name: • WTF 3060-2 ZZ +1093.1L C7 T H1K • Static safety factor: 25.0532 • Service life time: 4.9352×10^4 hr • Support unit: EK20, EF20
2.	Linear Motion Guide		• Model name: SHS30R1QZSS+1000L-II • Static Safety Factor: 54.5284 • Service life: 4.3117×10^6 hr
3.	Servomotor	Yaskawa	• Model name: SGM7G-13AFA61 • Rated output: 1.3 kW • Rated torque: 8.34 Nm • Instantaneous maximum torque: 23.3 Nm • Rated speed: 1500 min^{-1} • Motor moment of inertia: 19.9×10^{-4} $kg \cdot m^2$ • Allowable load moment of inertia: 5 times
4.	Sprocket	SKF	• Model name: PHS 06B-1B25 • Bore diameter sprocket 1: 17 mm • Bore diameter sprocket 2: 24 mm
5.	Chain		• Model name: PHC 06B-1 • Chain length: 609.6 mm • Service factor: 1.32
Grabbing Device			
1.	Servomotor	Yaskawa	• Model name: SGM7G-20AFA6C • Rated output: 1.8 kW • Rated torque: 11.5 Nm • Instantaneous maximum torque: 28.7 Nm • Rated speed: 1500 min^{-1} • Motor moment of inertia: 26.0×10^{-4} $kg \cdot m^2$ • Allowable load moment of inertia: 5 times
2.	Gearbox	Sesame	• Model name: PEE120-015 • Gear ratio: 1:15 • Safety factor: 1.5 • Nominal torque output: 283 Nm
Power Supply			
1.	Diesel Engine	Masato	• Model name: DG8250LE • Rated power: 6500 W • Maximum power: 7000 W • Fuel: Diesel

3.5 Cost Evaluation

Table 3.2: *Cost evaluation table.*

No.	Component	Quantity	Price (RM)	Cost (RM)
Traffic Cone to Storage Area Transportation Device				
Roller Conveyor				
1.	Roller	51	326.18	16635.18
2.	Servomotor	1	2343.10	2343.10
3.	Sprocket	1	24.00	24.00
4.	Chain	8667.75 mm	5.00/ 304.8 mm	142.19
Traffic Cone to Designated Storage Area Guidance Device				
Mini Roller Conveyor				
1.	Roller	3	326.18	978.54
2.	Roller Drive	1	1665.63	1665.63
3.	Chain	2032 mm	5.00/ 304.8 mm	33.33
Horizontal Ball Screw Linear Guide System				
1.	Ball Screw	1	2910.00	2910.00
2.	Servomotor	1	5876.20	5876.20
3.	Linear Motion Guide	2	3300.00	6600.00
4.	Coupling	1	122.00	122.00
Traffic Cone to Storage Delivery Device				
Wall Mounted Ball Screw Linear Guide System				
1.	Ball Screw	1	2400.00	2400.00
2.	Servomotor	1	5585.70	5585.70
3.	Linear Motion Guide	2	1710.00	3420.00
4.	Coupling	1	158.00	158.00
Staking Device				
1.	Servomotor	2	5585.70	11171.4
2.	Pinion	4	980.00	3920.00
3.	Rack	4	360.00	1440.00
4.	Shaft	2	362.29	724.58
5.	Bearing	4	126.00	504.00
6.	Coupling	2	1110.00	2220.00
7.	Linear Motion Guide	4	1100.00	4400.00
Lifting Device				
Vertical Ball Screw Linear Guide System				
1.	Ball Screw	1	4740.00	4740.00
2.	Servomotor	1	6179.50	6179.50
3.	Linear Motion Guide	2	2680.00	5360.00
4.	Sprocket	2	28.00	56.00
5.	Chain	609.6 mm	4.20/ 304.8 mm	8.40
Grabbing Device				
1.	Servomotor	1	10930.00	10930.00
2.	Gearbox	1	3800.00	3800.00
Power Supply				
1.	Diesel Engine	1	3899.00	3899.00
Total Cost				114,420.95

Assuming a group consists of two individuals: one person responsible for collecting traffic cones and another person responsible for storing them. Each person has a labor cost of RM1500 per month and works 8 hours per day. The total cost for the traffic cone collector machine is RM114,420.95, and it operates for 8 hours per day, matching the human labor schedule. The time needed for the traffic cone collector machine to breakeven its cost through labor savings is 3.2 years.

3.6 Final Product Specification

Table 3.3: Final product specification.

Product Specification	Description
Estimated Mass	253.35 kg
Dimension	5550 mm x 2100 mm x 2630 mm
Power	6450 W
Collecting time	10s/ cone
Capacity	390 cones
Total Cost	RM114,420.95

4. Conclusion

In conclusion, the design of the traffic cone collector machine has been successfully developed through a structured and methodical approach. The detailed design of a complete traffic cone collector machine was built. This was accomplished by initially sketching the machine, followed by creating detailed drawings and design animations using SolidWorks. Component analysis was also conducted to ensure the selection of appropriate and reliable components for the traffic cone collector machine. Through this rigorous process, the final design of the traffic cone collector machine was developed, meeting all the specified objectives and ensuring an efficient and practical solution for traffic cone collection and storage.

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