

# Electric Stairs Climbing Trolley

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*Abstract- The Electric Stairs Climbing Trolley is an innovative material handling solution designed to overcome the physical limitations of traditional hand trucks when navigating vertical obstacles. Manual transportation of heavy loads across multi-level structures often poses significant ergonomic risks and operational inefficiencies. This project presents the design and fabrication of a motorized trolley utilizing a Tri-Star wheel mechanism to automate the ascent and descent of staircases, thereby enhancing safety and productivity in logistical tasks. The system is built upon a robust mild steel chassis constructed from 40x40x5mm angle sections, ensuring structural integrity under load. The core locomotion is provided by two planetary wheel assemblies, each featuring three 175mm diameter wheels mounted on a custom-fabricated 4mm steel star bracket. Propulsion is delivered by dual 36V, 60 RPM worm gear motors, which provide the high torque necessary for climbing. The power transmission system employs a chain-drive reduction, linking an 18-tooth freewheel sprocket on the motor shaft to a 44-tooth sprocket on the main 20mm drive rod.*

## I. INTRODUCTION

In daily life and industrial environments, transporting heavy loads from one floor to another is a common but challenging task. In places where elevators or lifts are not available, workers must carry materials manually on stairs. This process requires significant physical effort, takes more time, and increases the risk of injuries such as back pain or accidents.

Traditional trolleys are designed to move only on flat surfaces and cannot be used on stairs. To overcome this limitation, the electric stair-climbing trolley has been developed. It is a motorized device equipped with a special wheel mechanism that allows it to move smoothly over stairs while carrying heavy loads.

## II. PROBLEM STATEMENT

The primary challenge in traditional material handling is the "staircase bottleneck," where the efficiency of transport is halted by vertical steps. Manual hand

trucks require the operator to bear a significant portion of the load's weight while simultaneously pulling it upward, a motion that is inherently unstable and physically exhausting. This often leads to chronic back injuries, fatigue, and a high risk of accidents where the load may slip and fall back down the stairs, causing property damage or severe injury.

## III. LITERATURE REVIEW

Design and Development of a Staircase Climbing Robot Author: S. G. Tzafestas Year: 2018 Findings: The research identifies that a planetary wheel system significantly reduces the impact force felt when a wheel strikes a riser. It emphasizes the need for a high gear reduction ratio to ensure stability

Conclusion: The study concludes that an autonomous or semi-autonomous tri-wheel mechanism is the most stable configuration for varied stair heights, provided the motor torque is sufficient to overcome the peak load at the point of rotation.

Mechanical Analysis of a Tri-Star Wheel Mechanism for Load Carrying Author: Rajesh Kumar and Amit Pal Year: 2019 Findings: This paper focuses on the stress distribution within the "star" bracket. It finds that using 4mm to 5mm thick steel plates prevents deformation of the central axis during heavy lifting.

Conclusion: The researchers conclude that the radius of the star assembly must be at least 1.5 times the riser height to ensure a smooth "walking" motion without the trolley bottoming out.

Efficiency of Chain Drive vs. Gear Drive in Stair Climbing Applications Author:

M. Naveen and J. Suresh Year: 2020 Findings: The study compares power transmission methods and finds that chain drives offer better shock absorption than direct gear drives when the wheels impact a step.

### Summary

The comprehensive review of the aforementioned literature underscores a critical consensus: the Tri-Star wheel mechanism is the most viable and efficient mechanical solution for navigating staircases. A recurring theme in the research is the delicate balance between torque, wheel geometry, and structural rigidity. Scholars like Tzafestas and Zhang emphasize that the success of a stair-climbing trolley is less about speed and more about controlled torque, which is best achieved through high-reduction worm gearboxes and robust chain drive systems. The literature confirms that a planetary wheel arrangement effectively "re-centers" the load with every step, a feature that manual trolleys lack.

### IV. MECHANICAL METHODOLOGY

- The development of the Electric Stairs Climbing Trolley followed a structured engineering design process, transitioning from conceptualization to a fully functional prototype. The methodology was divided into five distinct phases: Design & Modeling, Material Selection, Component Procurement, Fabrication & Assembly, and Electrical Integration. Each phase was guided by the need for high torque, structural stability, and ergonomic safety.
- A significant portion of the methodology focused on Tri-Star wheel kinematics. Standard staircases typically have a riser height of 150mm to 180mm. For the trolley to climb successfully, the radius of the star assembly had to be calculated such that the rotating wheel could reach the next step before the central shaft made contact with the stair edge. This led to the selection of 175mm wheels and a 280mm star-to-star width.
- Basic Frame: The mild steel angles of material of mild steel are selected for the frame. The mild steel angles are cut into required size by cutting machine. The end of the mild steel angles cut into 90 degrees(angle) to form rectangular frame. After cutting, the end of the mild steel angles is grinded so that it becomes smooth and convenient for welding. The mild steel angles are welded together to form a rectangular basic frame.



Figure 1 Square pipe

### Battery:

The battery is an electrochemical converting chemical energy into electrical energy. The main purpose of the battery is to provide a supply of current for operating the cranking motor and other electrical units.

Specification, Voltage 12v Current 7.2Ah

- An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smart phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode, and its negative terminal is the anode. Wheel size should match stair height.



Figure 2 Lead acid battery

### Tri-Star Wheel Assembly Fabrication

This is the most critical mechanical part of the project.

1. Marking: An equilateral triangle with a side length of 280mm was marked on the 4mm MS sheet.
2. Profile Cutting: The "Star" shape was cut using a gas cutter or high-definition plasma cutter. A central hole of 20mm was drilled for the main shaft, and three holes of 12mm were drilled at the tips for the individual wheel axles.

3. Assembly: Three 175mm wheels were bolted to each star plate using high-tensile fasteners. Two star plates were used per side (sandwiching the wheels) to provide lateral stability.
4. Shaft Preparation: The 20mm MS bright rod was cut to a width of 820mm. Keyways were machined at the ends to lock the star assemblies and the 44-teeth sprockets.
5. Motor Mounting: Two motor mounting plates were welded to the vertical frame. The 36V motors were bolted here, ensuring the 18-teeth motor sprocket aligned perfectly with the 44-teeth shaft sprocket.

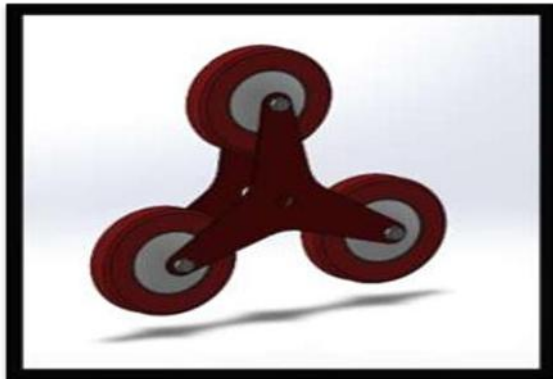


Figure 3 Tri-Star Wheel Assembly

#### PMDC Gear Motor

This motor is PMDC worm gearbox motor. The standard voltage requirement for the gear motor is 36 volts DC. The electrical system in a running automobile usually puts out between 24 and 36 volts, so it's safe to say the motor can handle up to 36 volts with no problem. The minimum required current for the motor is 4 amps at 60 rpm. Direct-current motors transform electrical energy into mechanical energy. They drive devices such as hoists, fans, pumps, punch-presses, and cars. These devices may have a definite torque-speed characteristic or a highly variable one. The torque-speed characteristic of the motor must be adapted to the type of the load it has to drive. The reason is that the torque-speed characteristics of dc motors can be varied over a wide range while retaining high efficiency.

It takes a lot of force to accelerate the wiper blades back and forth across the windshield so quickly. In order to generate this type of force, a worm gear is used on the output of a small electric motor. The worm gear reduction can multiply the torque of the motor by

about 50 times, while slowing the output speed of the electric motor by 50 times as well. The output of the gear reduction operates a linkage that moves the wipers back and forth. This motor is 100 watts and 60 rpm at 36V.

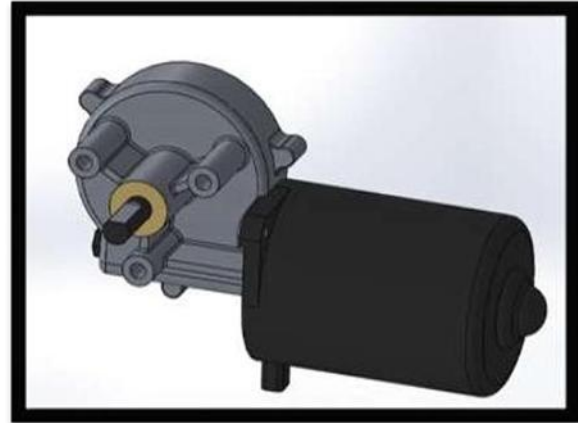


Figure 4 Wiper motor

Cutting: -

Cutting is the separation or opening of a physical object, into two or more portions, through the application of an acutely directed force.

Implements commonly used for cutting are the knife and saw, or in medicine and science the scalpel and microtome. However, any sufficiently sharp object is capable of cutting if it has a hardness sufficiently larger than the object being cut, and if it is applied with sufficient force. Even liquids can be used to cut things when applied with sufficient force (see water jet cutter).



Figure 5 Cutting Operation

**CAD MODEL**

Figure- Cad model of the assembled project is designed on Solid works 2024 software

**SOLID MODELING**

The entire model has been designed with the help of designing software solid works.

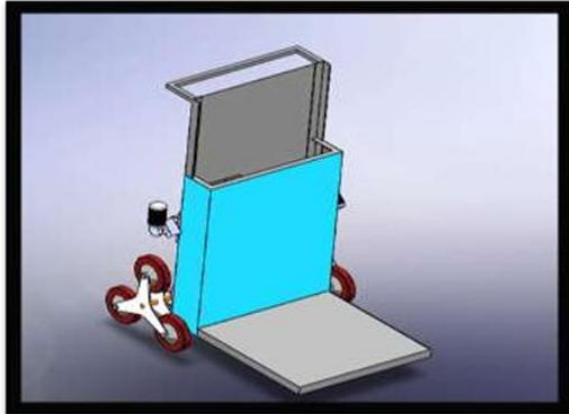


Figure 6 Isometric view1

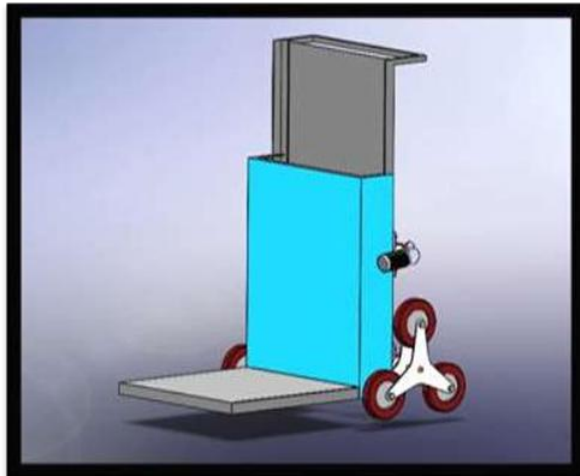


Figure 7 Isometric view 2

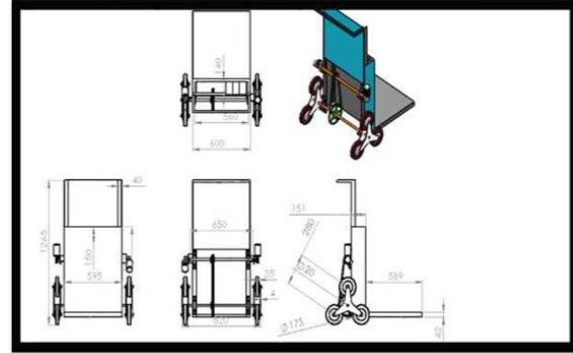


Figure 8 Drafting

**Calculations**

**Design Parameters**

The following constraints are used for all calculations based on the fabricated prototype:

- Total Weight (Load + Trolley):  $W = 60 \text{ kg}$  (Approximately 588.6 Newtons)
- Wheel Diameter (D): 175 mm (Radius  $r = 0.0875$  meters)
- Stair Riser Height (h): 150 mm (0.15 meters)
- Motor Speed (N1): 60 RPM
- Sprocket Teeth (Motor/Driver):  $T1 = 18$  Teeth
- Sprocket Teeth (Shaft/Driven):  $T2 = 44$  Teeth

**Velocity and Transmission Ratio**

The transmission system uses a chain drive to multiply torque from the motor to the main drive shaft.

1. Transmission Ratio (G):  $G = T2 / T1$   $G = 44 / 18$   
 $G = 2.44$
2. Final Shaft Speed (N2):  $N2 = N1 / G$   $N2 = 60 / 2.44$   
 $N2 = 24.6 \text{ RPM}$  (Approx)

**Torque Calculation**

To successfully climb a step, the motor must provide enough torque to lift the center of gravity over the pivot point of the Tri-Star assembly.

1. Required Torque (T-req): Maximum torque is required when the trolley is mid-pivot.

Using the moment equilibrium:  $T\text{-req} = \text{Load (Newtons)} \times \text{Distance (meters)}$   
 $T\text{-req} = 588.6 \text{ N} \times 0.12 \text{ m}$   
 $T\text{-req} = 70.6 \text{ Nm}$

2. Available Torque (T-avail): Assuming the 36V 60RPM motor provides 15 Nm at its gearbox output:  $T\text{-total} = (\text{Motor Torque} \times \text{Transmission Ratio}) \times \text{Number of Motors}$   
 $T\text{-total} = (15 \text{ Nm} \times 2.44) \times 2$   
 $T\text{-total} = 73.2 \text{ Nm}$

Verification: Since the Available Torque (73.2Nm) is greater than the Required Torque (70.6Nm), the system is capable of lifting the load.

#### Shaft Design (Torsional Strength)

The main drive shaft is 20mm in diameter and made of Mild Steel (MS).

1. Polar Modulus ( $Z_p$ ):  $Z_p = (3.141 \times \text{Diameter}^3) / 16$   
 $Z_p = (3.141 \times 20 \times 20 \times 20) / 16$   
 $Z_p = 1570 \text{ mm}^3$  (Approx)
2. Induced Shear Stress ( $\tau$ ):  $\text{Stress} = \text{Total Torque} / \text{Polar Modulus}$   
 $\text{Stress} = 73,200 \text{ N-mm} / 1570 \text{ mm}^3$   
 $\text{Stress} = 46.6 \text{ N/mm}^2$

Safety Check: The allowable shear stress for Mild Steel is  $80 \text{ N/mm}^2$ . Since our induced stress (46.6) is much lower than 80, the 20mm shaft is safe.

#### Battery Endurance

The system uses three 12V 7Ah lead-acid batteries in series (Total 36V, 7Ah).

1. Total Energy Capacity:  $\text{Energy} = \text{Voltage} \times \text{Amp-hours}$   
 $\text{Energy} = 36\text{V} \times 7\text{Ah} = 252 \text{ Watt-hours}$
2. Estimated Runtime: If the two motors draw approximately 4 Amps under full load:  $\text{Runtime} = \text{Battery Capacity} / \text{Current Draw}$   
 $\text{Runtime} = 7\text{Ah} / 4\text{A} = 1.75 \text{ Hours}$  (Actual practical runtime on stairs is estimated at 45–60 minutes).

#### Summary of Design Safety

- Torque: Sufficient for 60 kg total weight.
- Shaft Strength: Factor of Safety (FoS) is approximately 1.7.
- Transmission: 2.44 reduction successfully provides the necessary climbing force.

#### Working:

The electric stair-climbing trolley works by converting electrical energy into mechanical motion to move loads on both flat surfaces and stairs. It uses a battery, motor, and a special wheel mechanism (tri-wheel arrangement) for smooth operation.

When the trolley is switched ON, the battery supplies power to the DC motor. The motor rotates and transfers motion to the wheels through a shaft or gear system. On a flat surface, the trolley moves like a normal trolley.

When the trolley reaches a staircase, the special tri-wheel mechanism comes into action. As the front wheel touches the step, the wheel assembly rotates, lifting the trolley upward. One wheel takes support on the lower step while the next wheel moves onto the upper step. This process repeats step by step, allowing the trolley to climb the stairs smoothly.

The gear system helps in increasing torque, which is necessary to lift heavy loads. The load placed on the trolley is supported by a strong frame and should be evenly distributed to maintain balance.

Thus, the trolley moves efficiently on stairs with less human effort, making it safe and easy to transport heavy materials.

#### Result:

The electric stair-climbing trolley was successfully designed, fabricated, and tested under different working conditions. The performance of the system was evaluated based on load capacity, stair-climbing ability, stability, and ease of operation.

During testing on flat surfaces, the trolley moved smoothly with proper control and required very little human effort. When tested on stairs, the tri-wheel mechanism worked effectively by lifting the trolley step by step without jerks. The motor provided sufficient torque to carry loads in the range of approximately 50–100 kg, depending on the design and motor capacity. The trolley was able to climb standard stairs (height 150–180 mm) without slipping. The grip of the wheels was satisfactory, and the structure remained stable during operation. Proper load distribution was found to be important for maintaining balance and preventing tilting.

#### CONCLUSION

The electric stair-climbing trolley is a practical and efficient solution for transporting heavy loads over stairs. The system was successfully designed, fabricated, and tested, and it performed well under different working conditions. The use of a motorized mechanism along with a tri-wheel arrangement helped in smooth and safe stair climbing.

The project achieved its main objectives of reducing

human effort, improving safety, and increasing efficiency in material handling. Compared to manual carrying methods, the trolley significantly reduced physical strain and the risk of injuries. It also saved time and made the transportation process easier.

The results showed that the trolley can carry moderate loads and climb standard stairs without slipping or losing balance. The design is simple, cost-effective, and suitable for small-scale as well as practical applications such as warehouses, hospitals, and residential buildings.

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