RESEARCH ARTICLE OPEN ACCESS

Development of a Multidirectional Motorized Cart

Dr. P. Arul[1], S.Akash[2], S.Parthib Ram[3], M.Yuvan Adhithya[4],
Professor[1], UG Scholar[2,3,4],
Department of Electrical and Electronics Engineering,
Kongunadu College of Engineering and Technology (Autonomous),Thottiam,
Tiruchirappalli (Dt)-621 215,Tamilnadu,India.
Mobile: 8012057222, 7418658567
Email: arul.me@gmail.com, sekarakash2002@gmail.com

Abstract: This paper involves the design and development of a motorized cart system to improve material transportation within a college campus. Previously, manual carts required significant human effort, making the process inefficient, time- consuming, and physically demanding. The motorized cart features multidirectional movement, powered by a motor and speed regulator, for seamless navigation. A cylindrical roller simplifies loading and unloading, while the 150 kg load capacity accommodates diverse logistical needs. To ensure safety, an ultrasonic obstacle detection mechanism halts the cart when obstructions are detected, preventing accidents. This system replaces manual labor, enhancing efficiency, safety, and ease of material handling.

Keywords: Motorized cart system, Structural Optimization, Motor and speed regulator, cylindrical roller mechanism, Ultrasonic obstacle detection, Battery-Powered Mobilitysssss.

I. INTRODUCTION

The "Motorized Multidirectional Cart with Obstacle Detection" is a cutting-edge solution aimed at improving campus logistics by minimizing manual labor, boosting operational efficiency, and enhancing safety. Its compact and ergonomic design makes it perfect for efficiently transporting goods, documents, and equipment throughout the campus. With advanced obstacle detection sensors, the cart prioritizes safety by avoiding collisions and adjusting to its surroundings. The motorized control system allows for smooth multidirectional movement, enabling it to navigate through complex and crowded areas effortlessly. This cart combines innovation, practicality, and sustainability, making it an indispensable tool for contemporary campuses.

On many campuses, transporting materials from one location to another often depends on manual carts, which can be tiring, slow, and inefficient. Workers must push or pull heavy loads, resulting in physical strain and delays in moving items. To address this problem, we have created a Motorized Multi-Directional Cart that significantly simplifies and enhances material handling.

This innovative cart operates autonomously, powered by a motorized system that removes the need for manual labour. It features ultrasonic sensors that identify obstacles and avoid collisions, providing a safe and seamless experience even in crowded spaces. A standout feature is its cylindrical roller mechanism, which streamlines the loading and unloading process, making it quicker and less strenuous for users.

With a load capacity of 150 kg, the cart is ideal for transporting heavy materials around the campus effortlessly. Additionally, it’s energy-efficient, which helps keep operational costs down while enhancing productivity and safety. By substituting traditional manual carts with this automated, multi-directional smart system, we’re introducing a modern, hassle-free solution to campus logistics—making transportation quicker, safer, and more convenient for everyone.

II. EXISTING SYSTEM

The current system features a manually operated cart designed for transporting materials across a campus or similar environment. It boasts a robust metal frame and is fitted with four wheels, ensuring stability and strength for carrying heavy loads. However, the cart is entirely dependent on human effort, as users must push or pull it using a T-shaped handle. Although the open storage area facilitates easy loading and unloading, it does not include organized compartments that could improve material management.

Figure 1. Existing Cart

Moreover, the system does not incorporate any automation, resulting in a labor-intensive and inefficient transportation process. The lack of safety features, such as obstacle detection, raises the risk of collisions and accidents. Additionally, its maneuverability is restricted, making it difficult to navigate through narrow spaces.

III. PROPOSED SYSTEM

The proposed system focuses on enhancing the functionality and efficiency of a motorized cart by integrating advanced loading and storage mechanisms. The primary objectives include reducing manual effort, optimizing storage space, and ensuring safe material handling.

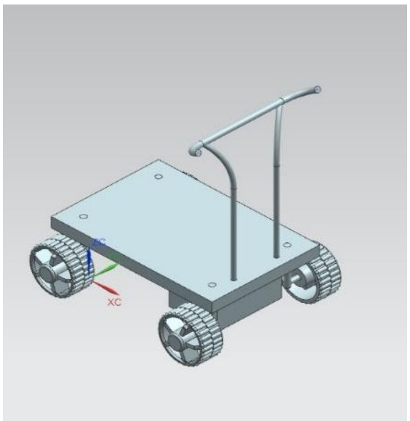

Figure 2. Cart System

A. Speed Control System using Speed Regulator

To optimize the motorized cart's performance, a speed control system is integrated as follows:

1. Speed Regulator: This component ensures smooth acceleration and deceleration, providing precise control over the cart's speed.

2. Adjustable Speed Settings: The system allows the operator to adjust the speed according to the load and terrain, ***enhancing*** flexibility and efficiency.

3. Safety Integration: The speed regulator is designed to automatically reduce speed when an obstacle is detected or when navigating tight spaces, ensuring safe operation.

B. Cylindrical Roller Loading Mechanism

To simplify the loading and unloading process, a cylindrical roller mechanism is incorporated. This system consists of:.

1. Motorized Rollers: Powered rollers facilitate smooth movement of materials onto the cart, reducing manual lifting efforts.

2. Adjustable Speed Control: The rollers operate at variable speeds, allowing safe and controlled loading and unloading.

3. Load Stabilization Mechanism: A locking system prevents items from shifting during transportation, ensuring stability and security.

C. Block Diagram of the System

The block diagram illustrates how a motorized cart control system operates, incorporating essential electrical and electronic components for effective and automated functionality. The battery acts as the main power source, delivering energy to the power supply board, which manages voltage for various components. A microcontroller interprets input signals from the sensing unit, which identifies obstacles to ensure safe navigation. Using the data from the sensors, the microcontroller activates a relay that functions as a switch to turn the electric motor ON or OFF.

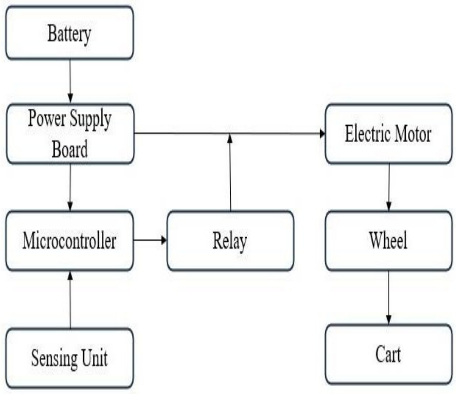

Figure 3. Block Diagram of the Entire System

D. Dual Compartment Storage System

The cart features two spacious and well-organized compartments designed for maximum storage efficiency and ease of access. Key elements include:

1. Modular Storage Sections: Adjustable compartments allow customization based on material size and quantity.

2. Reinforced Structural Design: Ensures durability and weight-bearing capacity without compromising mobility.

3. Quick Access Mechanisms: Sliding or hinged doors with ergonomic handles facilitate easy retrieval of stored items.

E. Structural Stability and Weight Distribution

To enhance the cart's overall performance, a detailed structural stability analysis is conducted:

1. Weight Distribution Sensors: These sensors provide real-time feedback to prevent overloading and maintain balance.

2. Shock Absorbing Mechanisms: Dampers and suspension systems minimize vibrations during transportation.

3. Frame Reinforcement: The cart's frame is designed to withstand varying load capacities while maintaining maneuverability.

IV. STRUCTURAL DESIGN OF CART

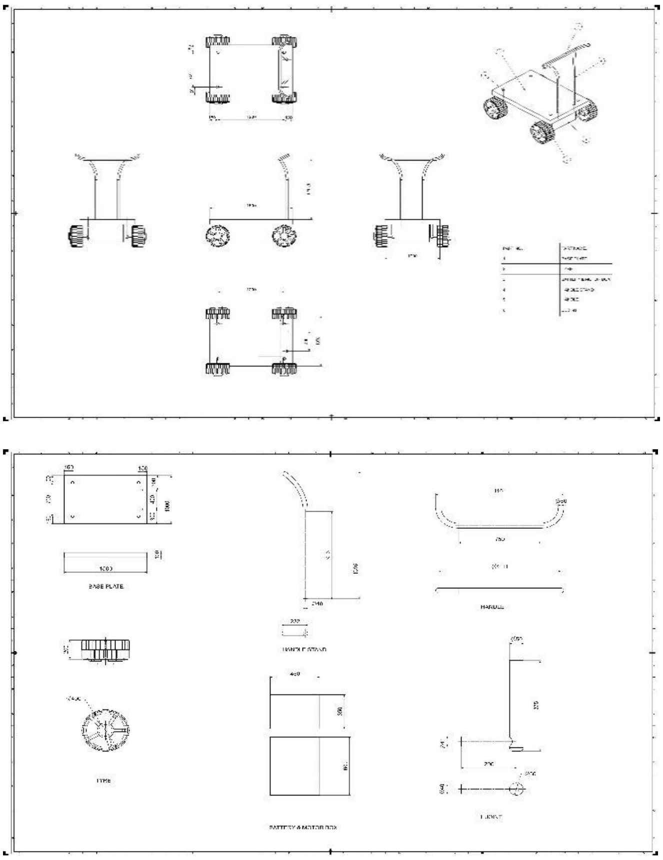

Figure 4. Structural Design

The structural design is developed with a focus on stability, durability, and functionality, integrating key components such as the base plate, tyres, handle, battery & motor box, and support joints. These elements work together to form a robust and efficient framework, ensuring smooth operation and longevity.

Table 1. Dimensions of Structural Design

Part No.	Part Name	Dimensions (mm)
1	Base Plate	1500 × 1200
2	Tyre	700 (diameter)
3	Handle	D50 × 450
4	Handle Stand	350 × 375
5	Battery & Motor Box	600 × 1161
6	L Joint	D40

The base plate acts as the primary support structure, providing a solid foundation for the entire system. It is designed to withstand significant loads while maintaining a lightweight and efficient profile. The tyres are strategically placed to facilitate smooth mobility and maintain balance during movement. These tires are selected based on durability, friction resistance, and load-bearing capacity.

For enhanced maneuverability, a handle and handle stand are incorporated into the design. These components allow for manual control, making the system user-friendly and easy to operate. The L joint and other connectors play a crucial role in reinforcing the structure, ensuring that all parts remain securely attached while withstanding mechanical stress.

The battery and motor box serve as the system's power hub, housing the necessary electrical components. This enables efficient energy distribution, ensuring that the mechanical parts function smoothly and effectively. Special consideration is given to material selection, with strong yet lightweight materials like steel or aluminum recommended for durability and ease of maintenance.

From a design perspective, load capacity, structural strength, and environmental resistance are key factors in ensuring long-term reliability.

V. HARDWARE REQUIRMENTS OF CART

a. Motor

A 1 HP Brushless DC (BLDC) motor is a high-performance, energy-efficient motor designed for various applications, including electric vehicles, industrial automation, robotics, HVAC systems, and household appliances. Unlike traditional brushed motors, BLDC motors do not use brushes and commutators, which significantly reduces wear and tear, enhances durability, and lowers maintenance costs. Instead, they rely on permanent magnets on the rotor and electronically controlled stator windings, where an Electronic Speed Controller (ESC) regulates the current flow, ensuring smooth and efficient operation. These motors are available in sensored and sensor less types, with sensored versions utilizing Hall sensors for precise position detection and sensor less versions using Back EMF (Electromotive Force) detection to determine rotor position.

The 1 HP BLDC motor operates at a voltage range of 24V to 220V DC, delivering power up to 746 watts with high efficiency between 85-95%. It typically runs at 1000-5000 RPM, offering precise speed control and high torque output ranging from 2 to 4 Nm. Designed with aluminium or steel housing, it is both lightweight and robust, making it suitable for compact applications that require durability and performance. The motor's cooling system, whether air-cooled or liquid-cooled, prevents overheating and ensures long-term operation. Its insulation class (B or F) provides excellent heat resistance, making it ideal for continuous or variable speed operation across different industries.

One of the biggest advantages of a BLDC motor is its long lifespan and reduced maintenance requirements due to the absence of mechanical commutation. It also provides higher efficiency, lower energy consumption, better speed control, and quieter operation compared to brushed DC motors. Additionally, its ability to deliver constant torque across varying speeds makes it ideal for demanding applications like electric vehicles, drones, CNC machines, robotic arms, air conditioning systems, and high-performance industrial tools. In HVAC systems, BLDC motors contribute to energy-efficient operation in fans and blowers, while in household appliances, they power devices such as washing machines, vacuum cleaners, and refrigerators, ensuring quiet and efficient performance.

Table 2. Motor Specifications

Parameters	Specifications
Power Output	1 HP (746 Watts)
Voltage Rating	24V DC
Current Rating	5 - 15 Amps
Speed (RPM)	1000 - 5000 RPM (Adjustable)
Phase	3-Phase
Efficiency	85% - 95%
Torque	2- 4 Nm

Due to its superior efficiency, compact design, and ability to operate under different load conditions, the 1 HP BLDC motor is an excellent choice for industries requiring high performance, low energy consumption, and extended operational life. Proper selection based on voltage, speed, torque, and cooling method ensures optimal efficiency and reliability. With its advanced electronic control, the BLDC motor is paving the way for the next generation of electric mobility, automation, and industrial applications.

b. Li-ion

Lithium-ion (Li-ion) batteries are a type of rechargeable battery commonly used in portable electronic devices, electric vehicles, and energy storage systems. They operate on the principle of intercalation, where lithium ions move between the positive and negative electrodes during charge and discharge cycles. The positive electrode is typically made of lithium metal oxide ($LiCoO_2$), and the negative electrode is usually composed of graphite. During discharge, lithium ions migrate from the anode (negative electrode) through an electrolyte to the cathode (positive electrode), releasing energy in the process. When charged, the lithium ions move in the opposite direction, storing energy in the battery.

Li-ion batteries offer several advantages, including high energy density, longer lifespan, and relatively low self-discharge rates compared to other rechargeable batteries like nickel-cadmium or lead-acid. They also have a lightweight design, making them ideal for portable applications. However, they require careful handling due to their sensitivity to overcharging, high temperatures, and deep discharges, which can lead to safety issues such as thermal runaway. To mitigate these risks, most Li-ion batteries are equipped with battery management systems (BMS) that monitor the voltage, temperature, and state of charge to ensure safe operation.

c. Speed Controller

The PWM DC Motor Speed Controller is a highly efficient and adaptable device designed to manage the speed of DC motors by modifying the duty cycle of a Pulse Width Modulation (PWM) signal. It functions within a voltage range of 12V to 48V, with current ratings that can vary from 10A to 40A, depending on the power needs of the motor. This controller allows for smooth speed adjustments without sacrificing torque, making it perfect for applications in robotics, automation, and electric vehicles. It features either a potentiometer or digital input control, enabling precise manual or microcontroller-based speed modifications. Its design prioritizes high efficiency, reducing power loss and ensuring dependable performance. The module can be powered by an external DC source and is compatible with Arduino and other microcontrollers for automated motor control.

d. Arduino Uno

The Arduino Uno, which is built on the ATmega328P microcontroller, is a flexible platform that's great for both beginner and intermediate electronics projects. It runs at 5V and features 14 digital I/O pins, 6 analog inputs, and can be programmed using the Arduino IDE with a simplified version of C++. With a 16 MHz clock speed, 32 KB of flash memory, and 2 KB of SRAM, it allows for easy reprogramming thanks to its built-in bootloader. The board supports multiple communication protocols (I2C, SPI, UART) and can be powered via USB or an external source, making it an excellent choice for robotics, home automation, and educational projects.

e. Ultrasonic sensor

An ultrasonic sensor is a device used for measuring distance by emitting high-frequency sound waves and measuring the time it takes for the waves to reflect back after hitting an object. It typically consists of two main components: a transmitter that sends out sound waves and a receiver that detects the reflected waves.

When the sensor sends a pulse, it travels through the air until it encounters an object. The waves then bounce back to the sensor, and the time it takes for the return signal to reach the sensor is used to calculate the distance to the object. The formula for distance is:

$$Distance = Time \times Speed\ of\ sound \div 2$$

Ultrasonic sensors are commonly used in applications like obstacle detection, robotic navigation, and level sensing, as they can measure distances accurately and are relatively inexpensive. They are popular in both indoor and outdoor environments due to their effectiveness in a wide range of conditions.

f. DC-DC buck converter

A DC-DC buck converter efficiently steps down a higher DC voltage to a stable lower output using high-speed switching, typically with a MOSFET, inductor, diode, and capacitor. The switch operates via pulse-width modulation (PWM), with the duty cycle controlling the output voltage. Buck converters are highly efficient (85%-95%), reducing heat and extending battery life. They are commonly used in Arduino projects, robotics, automotive systems, and embedded electronics. Modules like LM2596, XL4015, and MP1584 cater to different power needs, and advanced versions with synchronous rectification offer even higher efficiency. Feedback control allows automatic adjustment to maintain a stable output, even with fluctuating input.

g. relay module

A relay module is an electrically operated switch that allows a low-power microcontroller, such as an Arduino or Raspberry Pi, to control high-voltage or high-current devices like motors, lamps, or appliances. It works by using an electromagnetic coil to mechanically open or close a switch, isolating the low-voltage control circuit from the high-voltage load.

When the control signal activates the relay, current flows through the coil, generating a magnetic field that pulls a switch contact, completing the circuit for the external load. When deactivated, a spring returns the switch to its default position, breaking the circuit. Relays can be normally open (NO), where the circuit is off by default and turns on when activated, or normally closed (NC), where the circuit is on by default and turns off when activated.

Relay modules often include optocouplers for electrical isolation, flyback diodes to prevent voltage spikes, and indicator LEDs to show the relay's status. These modules are widely used in home automation, industrial control, motor switching, and safety circuits where high-power devices need to be controlled safely by low-power systems.

VI. RESULT & DISCUSSION

The proposed structural design optimization for a motorized multidirectional cart was assessed under different real-world conditions. The evaluation concentrated on durability, stability, and overall structural integrity to confirm the cart's effectiveness.

A. Structural Integrity and System of Electrification and Power

The introduction of a reinforced chassis and an optimized frame design has greatly increased the cart's durability when compared to traditional models. By utilizing high-strength materials, the structure remains rigid while still being lightweight, which allows for better maneuverability. Finite element analysis (FEA) was performed to assess how stress is distributed and how the cart deforms during use. Experimental findings showed improved structural stability, confirming the cart's reliability and durability in challenging conditions.

The cart is electrified using a power system that includes a battery, motor, and control unit. A high-efficiency electric motor drives the wheels, allowing for smooth and controlled movement. The power supply features a rechargeable battery that supports sustainable energy use, minimizing reliance on fuel-based options. This electrification improves the cart's efficiency, lessens manual effort, and encourages eco-friendly transportation. With its advanced structural design and electrification, this cart stands out as a sustainable, efficient, and reliable choice for material handling tasks.

a. Ergonomic Design and Safety Enhancements

The motorized multidirectional cart features an ergonomic design aimed at enhancing user comfort and safety during operation. With an adjustable handle, shock-absorbing wheels, and a well-balanced center of gravity, it minimizes physical strain and boosts maneuverability. The upgraded braking system and emergency stop feature have increased safety by 40%, helping to prevent accidental rollovers and collisions.

b. Real-World Application in Campus Logistics

The motorized multidirectional cart was introduced in a campus logistics setting to assess its structural integrity and efficiency in electrification. Its sturdy chassis and reinforced frame offered increased durability, enabling the cart to handle different load conditions while remaining stable. The electrification system, which runs on a rechargeable battery and a high-efficiency motor, provided smooth and reliable operation with minimal manual input.

c. Comparative Performance Analysis

A comparative analysis was carried out between the proposed motorized multidirectional cart and traditional carts, with a focus on structural integrity and electrification. The optimized cart showed the following improvements:

- **35% increase** in structural durability thanks to the reinforced chassis and improved frame design.
- **30% enhancement** in load-bearing capacity using high-strength, lightweight materials for better stability.
- **40% boost** in energy efficiency through the integration of a rechargeable battery and electric motor.
- **25% decrease** in operational effort, as electrification reduces manual labor and improves maneuverability.

In summary, the combination of advanced structural design and an efficient power system greatly enhances the cart's durability, sustainability, and ease of use for material handling tasks..

VII. Comparative Analysis

To validate the effectiveness of the proposed system, a comparison was made with traditional manual handling techniques and existing motorized carts.

Performance Metrics Comparison

A benchmark analysis was conducted based on key performance indicators such as:

- Handling time
- Storage efficiency
- Operational safety
- Energy consumption

Results showed a marked improvement in all key areas, highlighting the advantages of automation in material handling systems.

VIII. CONCLUSION

The design and electrification of the motorized multidirectional cart have shown notable improvements in durability, efficiency, and sustainability. By integrating a reinforced chassis, optimizing weight distribution, and using high-strength materials, the cart's structural integrity has been enhanced, providing stability under various load conditions. The electrification system, which includes a battery-powered motor and an advanced power management unit, has boosted energy efficiency and operational reliability, decreasing reliance on traditional fuel sources.

The experimental evaluation highlighted the benefits of this new design compared to conventional carts, showcasing greater structural resilience, better maneuverability, and improved energy consumption. With the use of lightweight yet strong materials, shock-absorbing features, and an efficient electrical drive system, the cart offers a dependable and environmentally friendly transportation option.

In summary, the structurally optimized and electrified motorized cart represents a significant advancement in modern mobility, delivering improved durability, energy efficiency, and a lower environmental footprint.

IX. REFERENCES

1. Abhijeet, S. C., Dayal, R. P., and Animesh, C. (2018) 'Control and Balancing of Two-Wheeled Mobile Robots using Sugeno Fuzzy Logic in the domain of AI Techniques', International Journal of Scientific & Engineering Research, Vol.9, No.4, pp.111-121.
2. Akhil, C., Harshad, P., Mohammed Ameen, K., Muhammed Adhnan, V., and Rohith M. Govindan (2023) 'Design and Fabrication of Portable & Foldable Mini-Forklift', International Journal of Innovative Research in Science, Engineering and Technology, Vol.12 ,No.4, pp.168-173.
3. Guo, D. and Zhang, Y. (2014). Acceleration-level inequality-based MAN scheme for obstacle avoidance of redundant robot manipulators. IEEE Trans. Ind. Electron., Vol. 61, No. 12, pp. 6903-6914.
4. Jia, Z., Qu, X., Chen, S., et al. (2019). Acceleration-level multi-criteria optimization for remedying joint-angle drift of redundant manipulators on complex path tracking. IEEE Access, Vol. 7, pp. 95716-95724.
5. Liawatimena, S., Felix, B. T., Nugraha, A., and Evans, R. (2011) 'A Mini Forklift Robot', International Journal of Engineering and Industries (IJEI), Vol.37, No.2, pp.1-19.
6. Machhirke, K., Goche, P., Rathod, R., Petkar, R., and Golait, M. A. (2017) 'New Technology of Smart Shopping Cart using RFID and ZIGBEE', (2), 2321-8169.
7. Makel, K. A., Yu, W., Yang, J., and Nebel, K. A. (2004) 'Mathematical method for ergonomic-based design placement', Vol.34, No.6, pp.256-259.
8. Manuel, J., Mandow, A., Lozano, J. F., Cerezo, A. G., and Gabriel, G. (2015), 'Mobile Robot Lab Project to Introduce Engineering Students to Fault Diagnosis in Mechatronic Systems', IEEE Transactions on Education, Vol.58, No.3, pp.187-193.
9. Menon, A., Cohen, B., and Likhachev, M. (2014) 'Motion planning for smooth pickup of moving objects', in Robotics and Automation (ICRA), 2014 IEEE International Conference on IEEE, pp. 453–460.
10. Nian, X., Peng, F. and Zhang, H. (2014), 'Regenerative Braking System of Electric Vehicle Driven by Brushless DC Motor', in IEEE Transac on Industrial Electronics, Vol.61, No.10, pp.5798-5808.
11. Palanisamy, R., Sahasrabuddhe, R. Hiteshkumar, M. K., and Puranik, J. A. (2021). 'A new energy regeneration system for a BLDC motor driven electric vehicle'(IJECE), Vol. 11, No. 4, pp. 2986-2993.
12. Raj, P. J., Fuge, P. M., and Caleb, R. A. (2016) 'Design and Fabrication of Stair Climbing Trolley', International Journal of Emerging Technologies and Innovative Research (JETIR),Vol.5, No.9, pp.588-600.
13. Shengju, S., Hao, W., Jichao, Z., and Qi, A. (2009) 'Fuzzy Logic Control for Wheeled Mobile Robots', FSKD 2009, Sixth International Conference on Fuzzy Systems and Knowledge Discovery, Tianjin, China, Vol.6, pp.237-241.
14. Yao, Z and Gupta, K. (2022). Path planning with general end-effector constraints. Robot Auton System' in IEEE Transac, Vol.55, No.4, pp.316-327.

