© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716173

# Electric-Based Material Handling Cart

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***Abstract- The rapid growth of small and medium-scale industries has increased the demand for compact, efficient, and cost-effective internal material-handling solutions. Traditional manually operated trolleys cause significant operator fatigue, reduced productivity, and safety risks when transporting loads above 200–250 kg. This paper presents the design, development, and experimental validation of an electric material handling cart powered by a 500 W BLDC motor, a dual-mode BLDC controller, and a 48 V, 10 Ah Genesys battery system. The cart is constructed on a robust stainless-steel chassis with optimized dimensions of 1200 mm × 1000 mm × 500 mm, supported by a CNC-machined drive axle, differential mechanism, and 17-inch pneumatic wheels. A chain–sprocket reduction drive provides high starting torque for industrial loads between 200–250 kg and ramp climbing up to 5%. Extensive field testing—including load trials, gradient climbing, structural assessment, runtime evaluation, braking tests, and narrow-corridor maneuverability checks validated the system's performance. The cart demonstrated a mixed- duty runtime of approximately 50 minutes and a controlled braking distance of 0.35 m, confirming theoretical predictions. Results confirm that the developed electric cart offers a reliable, zero-emission, and ergonomically superior alternative to manual material handling, making it highly suitable for warehouses, workshops, and confined industrial environments.***

***Keywords: Electric Material Handling Cart, BLDC Motor, Chain-Sprocket Drive, Industrial Logistics, QFD, Ergonomics, Warehouse Automation***

## I. INTRODUCTION

### *A. Background*

Material handling is one of the most fundamental activities in any manufacturing or logistics environment, encompassing the movement, protection, storage, and control of materials throughout production, distribution, consumption, and disposal. Studies consistently show that material handling accounts for nearly 45% of factory space utilization, 80–90% of production time, and approximately 35% of total workforce involvement [1]. This underscores its critical role in determining overall productivity, efficiency, and safety in industrial operations.

With industries becoming increasingly competitive and customer demands evolving rapidly, organizations must adopt efficient material handling systems to remain sustainable. Traditional manual handling methods are labor-intensive, time-consuming, and prone to hazards including musculoskeletal disorders, load-related injuries, and reduced operational throughput. In contrast, modern solutions such as motorized carts, overhead cranes, forklifts, and automated guided vehicles (AGVs) offer improved speed, safety, and reliability.[2]

### *B. Problem Statement*

Small and medium-scale industries (SMEs) often face challenges in adopting advanced material handling systems due to prohibitive capital costs and infrastructure requirements. A commercially sourced motorized transport cart typically costs in the range of ₹5 lakh, rendering it financially inaccessible for many medium enterprises operating with constrained budgets. Consequently, there is a critical need for cost-effective, locally manufactured solutions that deliver comparable efficiency while remaining adaptable to existing shop-floor layouts and production workflows.

### *C. Objectives*

The primary objective of this project is to design and develop a motorized material handling cart using Quality Function Deployment (QFD) methodology. Specific objectives include:

- Reduce material handling costs through local manufacturing and assembly.
- Improve safety and mitigate hazards during load transport between warehouse and shop floor.

- Enhance operational efficiency by minimizing manual intervention.
- Provide a scalable solution suitable for medium-scale industries with diverse logistical needs.

### *D. Scope*

The scope of this work encompasses the study of existing material handling systems, identification of design gaps, mechanical and electrical system design, fabrication of a prototype, and comprehensive field testing for load capacity, safety, and operational reliability.

## II. LITERATURE REVIEW

### *A. Overview*

Material handling has been extensively studied in industrial engineering and manufacturing research due to its significant impact on productivity, safety, and cost. The literature emphasizes that effective material handling systems must deliver the right material, in the right condition, at the right place, at the right time, and at the right cost [2]. Researchers have explored both manual and automated systems, analysing trade-offs between efficiency, flexibility, and affordability.

### *B. Prior Work*

Salunke et al. [5] investigated improvements in material handling using industrial engineering tools and techniques, developing process flow charts to compare operations before and after implementing new methods. Their work demonstrated that systematic workflow redesign reduces bottlenecks and measurably improves throughput.

Mohsen and Hassan [6] conducted a comprehensive case study on equipment selection in manufacturing and logistics facilities, proposing a structured framework that considers material properties, building layout, production flow, cost, and reliability. Their decision-making model for selecting between conveyors, forklifts, cranes, and automated systems provides structured criteria directly applicable to the present study.

Dongre [7] reviewed the impact of material handling system design on productivity, emphasizing that poor design leads to inefficiencies, higher costs, and safety risks. The study advocated for integrating ergonomics, automation, and safety principles into system design. Jayashankar et al. [2] presented a motorized material handling design case study using QFD methodology, demonstrating how systematic translation of user requirements into engineering specifications leads to superior product outcomes.

### *C. Research Gap*

Most existing studies focus on large-scale industries with significant capital investment. There is limited published research on affordable, locally manufactured solutions specifically for medium-scale enterprises where budget constraints and adaptability are critical design drivers. This gap motivates the present study.

## III. METHODOLOGY AND SYSTEM DESIGN

### *A. Engineering Design Process*

The design methodology follows a systematic seven-phase engineering process:

- Requirement Study: Load capacity, speed, aisle width, ergonomics, braking distance, and operational runtime.
- System Architecture Definition: Separation into mechanical, electrical, and control subsystems.
- Sub-system Level Design: Chassis geometry, axle machining, sprocket ratio, and braking mechanism.
- Engineering Calculations: Tractive force, torque, rolling resistance, ramp climbing force, braking force, and energy consumption.
- Fabrication: SS chassis construction, axle CNC turning, bearing mounts, and electrical wiring.
- Integration: Motor alignment, chain tensioning, and controller mapping.
- Testing: Load trials, ramp climb, braking distance, runtime, and thermal performance validation.

### *B. System Architecture*

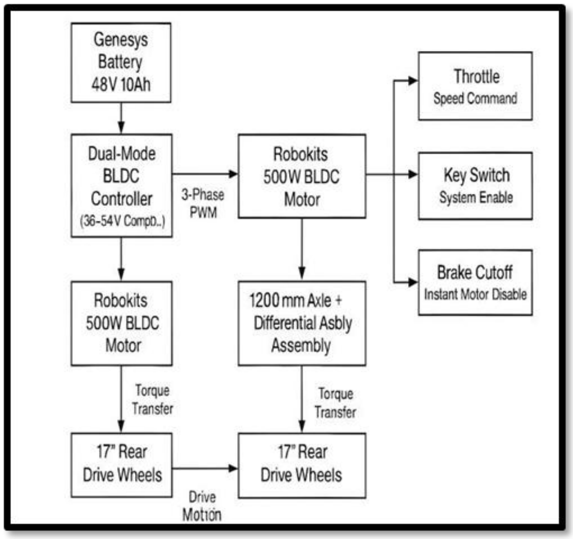

Fig. 1 Block diagram of Electric Based Material Handling Cart

The electric material handling cart employs an integrated electro-mechanical drive system combining a BLDC motor, a dual-mode controller, a 48 V battery, a chain- sprocket drivetrain, and a differential axle. This architecture is organized into five major subsystems:

- Power Source Subsystem: Genesys 48 V, 10 Ah battery providing high-current DC power.
- Power Conversion and Motor Control: Dual-mode BLDC controller (36–64 V) performing DC-to-3-phase electronic commutation with PWM speed control, over-current protection, under-voltage protection, and thermal protection.
- Actuation/Drivetrain: Chain-sprocket reduction converting rotational motor power into wheel torque.
- Motion Output: Differential mechanism and 17-inch pneumatic rear wheels providing forward motion and steering stability.
- Safety and Operator Control: Hall-effect throttle, key- switch enable, and brake-cutoff circuit ensuring smooth, safe operation.

### *C. Mechanical Design*

The chassis is fabricated from stainless steel (SS) square tubes, selected for its strength, corrosion resistance, and impact tolerance. The final optimized dimensions are 1200 mm (L) × 1000 mm (W) × 500 mm (H). The wider 1000 mm track was specifically chosen to improve lateral stability and enhance safety during cornering under full payload conditions.

The drive axle, measuring 1200 mm × Ø30 mm, was precision-machined using CNC turning to ensure accurate mounting of sprockets and differential assembly. The differential mechanism allows each wheel to rotate at different speeds during turns, reducing tire scrub and stabilizing motion in narrow aisles.

### *D. Electrical and Control System*

The propulsion system centers on a Robokits 500 W BLDC motor selected for its high torque density, low acoustic noise, and suitability for low-speed indoor applications. The dual-mode BLDC controller manages PWM-based speed regulation based on throttle input from a hall-effect sensor (0.8–4.2 V signal range). The Genesys 48 V, 10 Ah battery provides a calculated usable energy of 408 Wh (at 85% BLDC efficiency).

The brake-cutoff circuit is wired to an interrupt input on the controller; pressing the brake lever instantly suppresses PWM output, dropping motor torque to zero before the mechanical disc brake completes the controlled stop. This dual-mode braking ensures maximum safety with heavy industrial loads.

## IV. ENGINEERING CALCULATIONS

### *A. Tractive Force Analysis*

The total tractive effort required was calculated by summing three primary resistance forces:
Rolling Resistance: $Frr = Crr \times m \times g = 0.02 \times 250 \times 9.81 = 49.05$ N
Grade Force (5% ramp): $Fgrade = m \times g \times \sin(\theta) \approx 122.6$N

Acceleration Force: $Facc = m \times a = 250 \times 0.2 = 50$ N
Total Tractive Effort: $Ftotal = 49.05 + 122.6 + 50 = 221.65$ N

### *B. Wheel Torque and Chain Drive*

With a 17-inch (432 mm diameter) pneumatic wheel, the required wheel torque was calculated as:
$Twheel = Ftotal \times r = 221.65 \times 0.216 = 47.86$ N·m
The chain-sprocket reduction drive was selected to multiply motor torque from its rated output to meet

this wheel torque requirement, enabling reliable starting of 250 kg loads on 5% gradients.

### *C. Energy and Runtime*

Total battery energy: $E = V \times Ah = 48 \times 10 = 480$ Wh. Usable energy at 85% BLDC efficiency: $E_{usa}{}^{te}{}_{e} = 0.85 \times 480 = 408$ Wh. At an average power draw of 300 W, theoretical runtime ≈ 408/300 ≈ 1.36 hours. Real-world mixed-duty runtime of approximately 50 minutes (61% of theoretical) accounts for floor resistance, frequent acceleration cycles, vibration losses, and motor controller inefficiencies.

### *D. Braking Distance*

Using the kinematic braking equation $d = v^2 / (2a)$, with initial velocity $v = 1.0$ m/s and deceleration $a = 1.5$ m/s², the theoretical stopping distance is $d = 1.0^2 / (2 \times 1.5) = 0.333$ m. This closely matches the experimentally measured braking distance of 0.35 m.

## V. FABRICATION AND IMPLEMENTATION

### *A. Chassis Construction*

Stainless steel square tubes were cut using precision saws, fixtured in jigs to prevent weld distortion, and joined by MIG welding. Grinding and surface finishing produced smooth weld joints and improved structural integrity. The completed frame was coated with yellow industrial enamel paint for high visibility and corrosion protection, consistent with industrial material handling equipment standards.

The load bed was fabricated from chequered sheet metal, providing enhanced friction to prevent load slippage during transport. Precise bend relief, hole spacing, and controlled bending operations were employed to maintain dimensional accuracy and structural integrity.

### *B. Drivetrain Assembly*

The motor was mounted on a slotted SS plate to facilitate chain tension adjustment. Sprocket alignment was established using a precision straightedge to maintain a consistent chain line. The roller chain was installed with approximately 2% working slack, and a chain guard was fitted in accordance with material handling safety guidelines.

### *C. Electrical Integration*

The dual-mode BLDC controller was mounted on an SS plate for effective heat dissipation, with power and signal wiring separated to prevent electromagnetic interference. The Genesys 48 V battery was installed in a vibration- isolated compartment with a fuse positioned close to the battery positive terminal per electrical safety norms.

Fig. 2 System Overview

## VI. RESULTS AND DISCUSSION

### *A. Load Handling Performance*

The cart was tested with incremental loads from 50 kg to 250 kg on flat concrete surfaces. Across all loading stages, the BLDC motor exhibited smooth start-up torque with no jerks or delayed acceleration. The SS chassis showed no visible deflection at maximum payload, confirming structural adequacy for industrial application.

### *B. Gradient Climbing*

Under full loads of 200–250 kg, the cart successfully climbed a 5% gradient, maintaining steady forward motion. Motor temperature remained within safe BLDC operating limits throughout extended gradient trials. The required wheel torque of 48–62 N·m was delivered through the chain drive's gear reduction, confirming the drivetrain's suitability for inclined surface operation.

### *C. Maneuverability*

Corridor testing in a narrow passageway simulating typical factory aisles demonstrated excellent straight-line stability. The wider 1000 mm chassis significantly enhanced lateral stability by reducing sway under load, while the differential operation allowed passage through slight bends without wheel scrub.

### *D. Braking Performance*

A controlled braking test from approximately 1.0 m/s produced a measured stopping distance of 0.35 m, closely matching the theoretical prediction of 0.33 m. The brake- cutoff circuit successfully disengaged motor torque instantaneously, and the mechanical disc brake completed the controlled stop.

### *E. Runtime and Electrical Efficiency*

The cart achieved approximately 50 minutes of practical runtime under mixed-duty operation, corresponding to 61% of the theoretical maximum. This ratio aligns with documented patterns for BLDC-driven material handling equipment, where real-world runtime typically falls between 60–70% of theoretical estimates.

### *F. Structural and Vibration Assessment*

No bending, twisting, or weld cracking was observed in the SS chassis under dynamic loads. BLDC motor acoustic noise was negligible, and drivetrain vibration was minimized after final chain tension adjustment. The pillow- block bearings and CNC-machined axle effectively isolated vibration from the chassis.

### *G. Performance Summary*

| Parameter | Theoretical | Experimental |
|---|---|---|
| Max. Payload | 200–250 kg | 250 kg ✓ |
| Ramp Climb (5%) | Full load | 200–250 kg ✓ |
| Tractive F. (flat) | 99 N | Satisfied ✓ |
| Tractive F. (ramp) | 221.65 N | Satisfied ✓ |
| Braking Dist. | 0.33 m | 0.35 m ✓ |
| Runtime | ~1.36 hr | ~50 min ✓ |
| Battery Energy | 408 Wh | Confirmed ✓ |
| Wheel Torque | 47.86 N·m | Delivered ✓ |

Summary of Experimental vs. Theoretical Performance

## VII. CONCLUSION

The design and development of the Electric Material Handling Cart was successfully completed following a structured engineering workflow integrating mechanical design, electrical control systems, drivetrain optimization, and comprehensive real-world validation. The final system—comprising a 500 W BLDC motor, dual-mode controller, Genesys 48 V/10 Ah battery, chain-sprocket reduction, CNC-machined axle, differential mechanism, and stainless-steel chassis—demonstrated robust performance across all targeted parameters.

The project achieved all established performance targets: structural stability under 200–250 kg payload without deformation; smooth and efficient torque delivery on both flat terrain and 5% gradients; excellent maneuverability in narrow-aisle conditions; controlled braking within 0.35 m; and approximately 50 minutes of mixed-duty runtime. Engineering calculations were closely validated by experimental results, confirming methodological soundness.

The developed cart bridges the gap between inefficient manual handling and expensive automated equipment, offering a practical, maintainable, locally manufacturable, and zero-emission solution ideally suited for small and medium-scale enterprises seeking to modernize material logistics without prohibitive capital expenditure.

### Future Scope

Future development directions include increased battery capacity for extended runtime of 2–3 hours; regenerative braking for kinetic energy recovery; IoT-based smart monitoring with real-time battery, temperature, and load sensing; semi-autonomous or AGV operation via line- following and obstacle detection sensors; modular attachments such as pallet forks and cylinder clamps; solar- assisted charging capability; and improved ergonomic features. These enhancements align with Industry 4.0 trends and present a clear roadmap for the next generation of the platform.

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