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Implementation of Hybrid Rail - Mounted Proto type for Pick & Pack Procedures in Storage Facility

Ms. Geetika.R[1], Ms. Arthi.R[2]

[1,2]Department of Shipping and Logistics, Remo International College

ABSTRACT

In modern warehouses, manual transportation between picking and packing areas reduces efficiency and increases labor dependency. This project will propose a rail-mounted automated transport system designed to optimize pick and pack operations. The system utilizes a rail track on which specially designed pallets, bins equipped with a metal chassis and DC motors and batteries that transport cartons or bins from the picking zone to the packing zone. The Relay switching is used to control movement, while ultrasonic sensors are used to identify bin locations and ensure precise stops at specified pick-and-pack locations. The buzzer emits audible alerts for operational events like the arrival of a bin, the identification of an obstacle or when it reaches its destination. After completing delivery to the packing area, the pallet autonomously returns to the picking area, ensuring continuous operation. By minimizing human intervention, the system enhances manpower productivity, reduces operational time, and lowers the chances of error during material handling. A prototype of this system can be developed using cost-effective components, demonstrating its feasibility as an alternative to labor-intensive methods. This rail-mounted approach provides a scalable and efficient solution for warehouse logistics automation.

Keywords: Mechanization, Mobility, Optimization, Productivity, Scalability

1. INTRODUCTION:

Hybrid Rail - Mounted System for pick and pack operations streamline warehouse efficiency by using overhead rails to transport robots or shuttles directly to inventory locations, minimizing human movement and errors.

2. Logistics Overview

Logistics is a core component of supply chain management, encompassing procurement, storage, transportation, inventory control, distribution, and packaging. Efficient logistics ensures that products move from producers to consumers in the right quantity, condition, and time. In today's competitive environment, warehouse operations—especially picking and packing—play a decisive role in customer satisfaction and cost control.

Efficiency Gains: These systems boost throughput by 2-4 times compared to manual picking, as rail shuttles retrieve items in seconds via optimized paths, reducing pick times from minutes to under 30

seconds per order. They enable 24/7 operations without fatigue, handling peak demands like e-commerce surges seamlessly.

Space and Cost Savings: Vertical rail designs maximize storage density up to 85%, freeing 50-70% of floor space for more inventory while cutting labour needs by 50-75% through automation. Long-term ROI emerges in 1-2 years via lower wages, reduced errors (99.9% accuracy), and energy-efficient motors.

Safety and Accuracy: Workers avoid ladders or heavy lifting, slashing injury rates by 80% and improving ergonomics in high-volume warehouses. Real-time inventory tracking via integrated software ensures FIFO/LIFO compliance, minimizing stock outs or expirations.

Implementation Impacts: Initial setup costs $500K-$2M but yields scalability for growing operations, with challenges like integration downtime offset by modular rail expansions. In shipping contexts like Chennai ports, they accelerate order fulfilment for international trade logistics.

3. Evolution of Logistics

✓ **Early and Ancient Logistics**

Logistics originated from basic survival needs such as food collection, storage, and distribution. Ancient civilizations like Egypt, Rome, China, and Mesopotamia developed organized logistics systems to support trade, construction, and military operations. Road networks, waterways, and storage facilities enabled efficient movement of goods and resources.

✓ **Medieval and Maritime Logistics**

During the medieval period, logistics expanded through maritime trade. Ports, warehouses, and merchant guilds facilitated long-distance exchange of commodities such as spices, textiles, and metals. Warehousing became central to international trade networks.

✓ **Industrial Revolution**

The Industrial Revolution marked a major transformation in logistics. Mechanized transportation, railways, steamships, and standardized packaging enabled mass production and large-scale distribution. Warehouses evolved into organized facilities supporting high-volume throughput and systematic inventory handling.

✓ **20th Century and Globalization**

Advances in containerization, road transport, air cargo, and communication systems reshaped logistics into a global operation. Warehousing and transportation became strategically integrated, supporting international trade and industrial growth.

✓ **Digital and Smart Logistics**

In the 21st century, logistics has become technology-driven. Automation, robotics, artificial intelligence, RFID, GPS tracking, and warehouse management systems have improved visibility, speed, and accuracy. Sustainability and green logistics have also gained importance.

Need for Efficient Logistics Systems: As production volumes and trade complexity increased, businesses required seamless material flow, efficient storage, and faster transportation. Rising costs, delivery delays, and inventory inefficiencies highlighted the need for advanced logistics solutions. Well-managed logistics systems enhance reliability, reduce waste, and improve customer satisfaction.

4. Role of Logistics

Logistics ensures efficient transportation, secure storage, effective inventory management, timely order fulfilment, real-time monitoring, customer satisfaction, and global connectivity. Each function contributes to overall supply chain performance and competitive advantage.

5. **Warehouse Layout and Design**

Warehouse layout determines operational efficiency. A well-designed layout minimizes material movement, reduces congestion, and improves workflow. Key functional areas include:

- Loading and Unloading Area
- Reception and Inspection Area
- Storage Area
- Order Picking Area
- Packing and Dispatch Area

6. PICK AND PACK OPERATIONS

Overview of Pick and Pack Process

Pick and pack is a core warehouse fulfilment activity where items are retrieved from storage and packaged for shipment. Accuracy and speed in this process directly affect delivery performance and customer satisfaction.

7. Stages of Pick and Pack Operations

✓ **Order Receipt and Processing:** Customer orders are received through the Warehouse Management System (WMS). The system verifies inventory availability, generates pick lists, and prioritizes orders based on urgency and handling requirements.

✓ **Pick Method Selection:** The WMS selects suitable picking methods based on order size, volume, and warehouse layout. Efficient selection reduces travel time and labour effort.

✓ **Picking and Verification:** Items are picked from assigned locations and verified using barcode or RFID scanning to ensure accuracy. Quality checks help identify errors before packing.

✓ **Packing:** Verified items are packed using appropriate materials to protect them during transit. Packaging is optimized based on item size, fragility, and shipping requirements.

✓ **Dispatch and Shipping:** Packed orders are sorted by destination and carrier, loaded onto vehicles, and dispatched. Final checks ensure correct order placement.

✓ **Return Handling:** Returned goods are inspected and either restocked, refurbished, or disposed of. Accurate inventory updates maintain system reliability.

PICKING AND PACKING METHODS

✓ **Piece Picking:** Each order is picked individually. This method is simple and accurate but inefficient for high-volume operations.

✓ **Batch Picking:** Multiple orders are picked simultaneously, reducing travel time and increasing productivity.

✓ **Zone Picking:** The warehouse is divided into zones, with pickers assigned to specific areas. This method improves efficiency in large warehouses with diverse SKUs.

✓ **Wave Picking:** Orders are grouped into waves and processed simultaneously based on schedules or priorities. Wave picking balances speed and labour utilization during peak demand.

8. RAIL-MOUNTED AUTOMATION IN WAREHOUSING

Concept of Rail-Mounted Systems

Rail-mounted systems use fixed tracks to guide automated pallets or bins between functional zones. Unlike free-moving AGVs, rail-guided systems offer predictable paths, reduced collision risk, and lower energy consumption.

Integration with Warehouse Operations

Rail-mounted transport connects picking and packing areas, ensuring continuous material flow. Sensors and control units enable precise stopping, obstacle detection, and synchronized movement with warehouse processes.

Advantages of Rail-Mounted Automation

- Reduced manual handling
- Improved speed and consistency
- Lower error rates
- Enhanced worker safety
- Scalable and cost-effective automation

9. PROPOSED SYSTEM DESIGN

System Overview: The proposed system consists of a rail track, motor-driven pallet, control unit, sensors, and alert mechanisms. It autonomously transports goods between picking and packing zones and returns to the starting point after delivery.

Flow of Operations

1. System activation
2. Detection of bin position
3. Controlled movement along rail
4. Accurate stopping at packing station
5. Audible alert
6. Return to picking area

10. COMPONENTS&COMPLETITON OF PROTOTYPE

Ultrasonic Sensors

Ultrasonic sensors detect obstacles and measure distance using sound waves, enabling safe and accurate movement of the rail-mounted cart. They provide real-time input to the ESP32 for precise positioning and collision avoidance during pick-and-pack operations.

ESP32 Microcontroller

The ESP32 acts as the central control unit, processing sensor inputs and controlling motor movement for smooth and accurate cart operation. It enables autonomous navigation, status indication, and reliable pick-and-pack execution with minimal human intervention.

DC Gear Motor

DC gear motors drive the wheels of the rail-mounted cart, providing controlled speed and high torque for smooth movement along the rails. They ensure precise stopping, stable handling of loads, and reliable motion during pick-and-pack operations.

L298N Motor Driver

The L298N motor driver interfaces between the ESP32 and DC motors, enabling bidirectional control of speed and direction through PWM signals. It ensures smooth, stable motor operation while protecting the microcontroller during automated pick-and-pack movement.

Battery mAH 12V

A 12V battery supplies the required electrical potential to operate the system, while the mAh rating indicates its energy capacity and operating duration. Higher mAh capacity enables longer continuous operation of the automated cart without frequent recharging.

BUZZER

A buzzer is an audio signalling device that converts electrical signals into sound to indicate alerts or system status. It provides clear audible notifications for warnings, errors, and operational conditions in automated systems.

Relay

A relay is an electrically operated switch that allows low-power control signals to safely operate high-power circuits. It provides electrical isolation and reliable switching for automation, motor control, and safety functions in the system.

Metal Chassis

The metal chassis provides a strong and stable structural base for the rail-mounted cart, offering high strength, rigidity, and load-bearing capacity. Its resistance to wear, vibration, and environmental conditions ensures durability, precise alignment, and reliable operation in warehouse automation systems.

FOAM BOARD

Foam board is a lightweight and rigid material used for structural support and prototyping in model construction. Its ease of cutting and assembly makes it suitable for creating enclosures and layouts in project demonstrations.

BLUETOOTH APP

The Bluetooth app enables wireless control of the automated cart by allowing the operator to send movement commands such as start, stop, forward, and reverse to the ESP32 microcontroller. This wireless interface enhances usability, safety, and operational flexibility while supporting smooth and reliable cart movement during warehouse operations.

11. BENEFITS AND APPLICATIONS

The rail-mounted automated pick and pack system enhances warehouse efficiency by reducing labour dependency, improving order accuracy, and enabling continuous operation. It is suitable for medium- to large-scale warehouses seeking cost-effective automation without complex navigation systems

12. CONCLUSION

This project demonstrates the practical application of a rail-mounted automated system for pick and pack operations in warehouses. By integrating guided transport, sensor-based control, and microcontroller-driven automation, the system addresses key challenges of manual material handling. The prototype confirms feasibility, scalability, and operational benefits, making it a viable solution for modern warehouse logistics. Future enhancements may include full WMS integration, data analytics, and advanced communication interfaces to further improve performance.

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