A

Project Report

on

Automated Guide for Faster and Accurate Packaging of E- Commerce Orders

Submitted to

Sant Gadge Baba Amravati University, Amravati

Submitted in partial fulfilment of

the requirements for the Degree of

Bachelor of Engineering in

Computer Science and Engineering

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Session 2024-2025

SHRI SANT GAJANAN MAHARAJ COLLEGE OF ENGINEERING, SHEGAON – 444 203 (M.S.)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

This is to certify that **Ms. Tejal Vilas Raut, Ms. Khushbu Dipak Chavhan, Ms. Manisha Sanjay Nimbolkar and Ms. Dnyaneshwari Prashant Ugale** students of final year Bachelor of Engineering in the academic year 2024-25 of Computer Science and Engineering Department of this institute have completed the project work entitled "**Automated Guide for Faster and Accurate Packaging of E-commerce orders**" and submitted a satisfactory work in this report. Hence recommended for the partial fulfilment of degree of Bachelor of Engineering in Computer Science and Engineering.

C. M. Mankar
Project Guide

Dr. J. M. Patil
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Internal Examiner	**External Examiner**
(C.M. Mankar)	A. D. Shah
Name and Signature	**Name and Signature**
Date: 9/5/2025	**Date:** 9/5/25

Acknowledgement

It is our utmost duty and desire to express gratitude to various people who have rendered valuable guidance during our project work. We would have never succeeded in completing our task without the cooperation, encouragement and help provided to us by then. There are a number of people who deserve recognition for their unwavering support and guidance throughout this report.

We are highly indebted to our guide **C. M. Mankar** for his guidance and constant supervision as well as for providing necessary information from time to time. We would like to take this opportunity to express our sincere thanks, for his esteemed guidance and encouragement. His suggestions broaden our vision and guided us to succeed in this work.

We are sincerely thankful to **Dr. J. M. Patil**, and to **Dr. S.B. Somani** who always has been kind to extend their support and help whenever needed.

We would like to thank all teaching and non-teaching staff of the department for their cooperation and help. Our deepest thank to our parents and friends who have consistently assisted us towards successful completion of our work.

Tejal Vilas Raut (28)
Khushbu Dipak Chavhan (10)
Manisha Sanjay Nimbolkar (12)
Dnyaneshwari Prashant Ugale (05)

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Abstract

Completion of e-commerce operations depends on optimized logistic systems which optimize order dispatch and open new business opportunities. The integrated real-time inventory tracking together with automated retrieval system creates operational improvements through this warehouse management system. The system arranges storage facilities into racks and shelves and individual bins holding one product each to support real-time system update capabilities through interface systems. A USB barcode scanner together with IR sensors and LED-guided picking functions form essential components of akes. The automation system enables more rapid service delivery and higher workplace product this system which both improves worker performance by reducing expenses and misactivity which creates quick order processes alongside streamlined new employee adoption. A modern technology-based system enhances warehouse operations by lowering human engagement and supports environmentally responsible expansion in e-commerce delivery logistics.

Keywords: *Inventory management, Warehouse automation, E-commerce logistics, Barcode scanning, IR sensors, E-commerce logistics, LED-guided picking*.

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Sponsorship letter

SkaleIT

Date: 7th July 2024

To,

Dr. J.M. Patil

Dept of Computer Science Engineering

SSGMCE Shegaon

Dear Mr. Patil,

At SkaleIT Technologies, we are focused on delivering innovative, scalable, and intelligent technology products. As part of our commitment to nurturing future talent and encouraging practical learning, we are keen to sponsor selected final-year student projects from your esteemed department.

We believe that academic-industry collaboration is vital in shaping the future of technology, and we are excited about the opportunity to contribute by providing mentorship and technical support for the following project:

Project Name: Automated Guide for Faster and Accurate Packaging of E-Commerce Orders

Names of students in the group:

1. Khushbu Dipak Chavhan
2. Dnyaneshwari Prashant Ugale
3. Tejal Vilas Raut
4. Manisha Sanjay Nimbolkar

Thank you, and I look forward to our collaboration.

Warm regards,

Pankaj N

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Managing Partner

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CHAPTER 1

INTRODUCTION

INTRODUCTION

The adoption of automated systems in warehouses produces optimized e-commerce supply chains through live monitoring abilities together with order selection guidance and computerized inventory control processes. The research investigates modern technological solutions that enhance performance alongside cutting down human involvement.

1.1 PREFACE

The rapid e-commerce environment demands high-speed precise delivery service which smart warehouse automation makes possible. Business success depends on efficient logistics combined with warehouse management because these elements help businesses meet customer needs at optimized cost levels with no errors. This paper delivers an inventive automated warehouse management system which implements modern technology for maximum operational effectiveness.

An automated warehouse system inherits a layered architecture consisting of racks which support shelves which contain bins that keep individual products. Every storage container carries its own unique code to track real-time product information that includes product name as well as quantity and units. This system enhances warehouse operations through the inclusion of three advanced features that combine USB barcode scanners for inventory updates and IR sensors for securing product position tracking together with Arduino-based LED indicators for leading staff during product selection. Staff receive guidance from illuminated LEDs to pick items through the correct bin until the process is complete where the lights automatically shut off. This reduces the time needed for item location along with work requirements.

The logical automation system enables quick order processing and shipping operations

and assists new employees to learn without extensive training requirements. The system provides both economic value and expandability which enables warehouses to adjust their operations according to business expansion. Automated processes lower dependence on manual work which generates constant operational output and increases production efficiency.

Data analytics within this system integrates with present warehouse management software to generate additional insights which guarantee better business decisions. The adaptive automation model provides modern warehouses with sustainable success through rising e-commerce demands in the competitive logistics market.

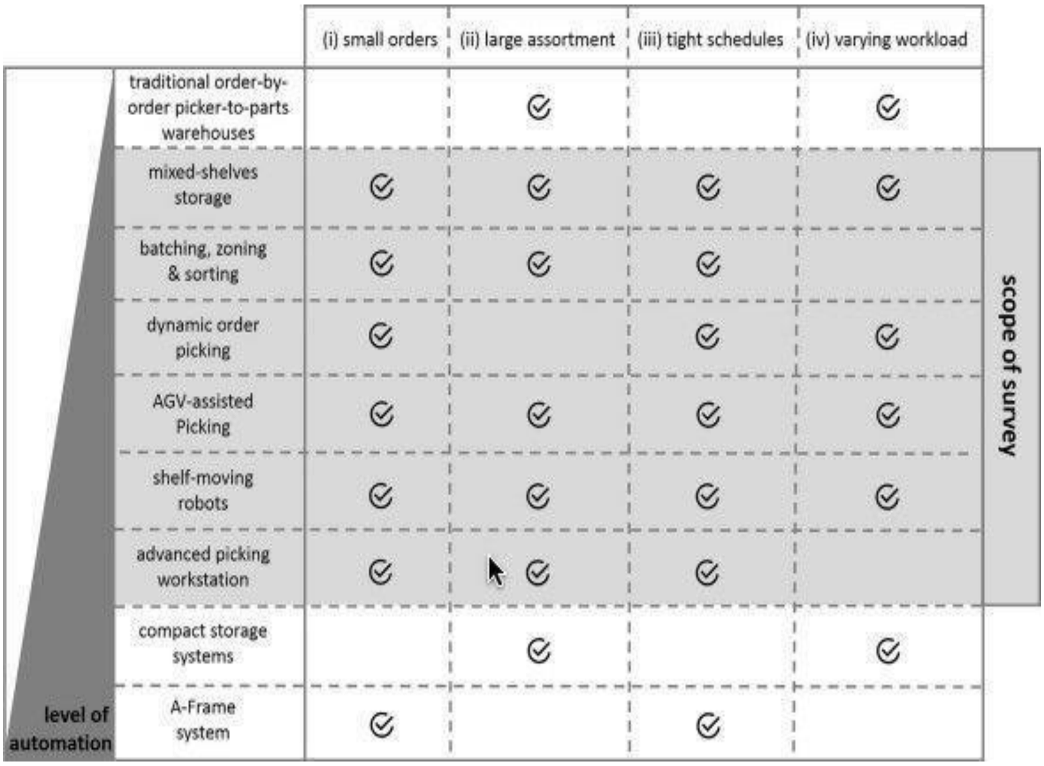

Figure 1.1 Overview of Warehouse system

Supply-chain operation relies on warehousing through its vital functions which comprise receiving storage order picking and shipping. The traditional picker-to-parts system utilizing human operators to pull items from racks is inefficient as it involves much walking patterns in addition to time consumption especially for small-sized orders. Contemporary warehouse technology that integrates automation attributes and design versatility aims to enhance efficiency and demand flexibility while accelerating order fulfillment thereby addressing e- commerce logistics requirements.

1.2 BACKGROUND

The world market has evolved with e-commerce now offering quicker convenient shopping that is available to all customers. With smooth operations there is a sophisticated set of logistics that is dependent on efficient warehouse management systems.

Operational excellence in warehouse centers ensures speedy and precise order processing to ensure customer satisfaction and business success in the market. Today's need for quicker delivery from the consumers compels contemporary warehouses to implement automated processes and real-time tracking and intelligent inventory management systems to maximize efficiency and reduce expenditure.

1.3 MOTIVATION

Warehouses are the backbone of supply chains, managing to get products moving smoothly from storage to customers. Yet, the rapid growth of e-commerce has introduced new challenges. Customers now anticipate fast, error-free deliveries of a broad range of products, in many cases in smaller order quantities. This forces warehouses to rethink old processes and implement smarter, more efficient techniques to compete.

One of the largest challenges is order picking—pulling product from storage to complete an order. This is not only a time-consuming step but also one of the most costly aspects of warehouse operations. Poor layouts and excessive travel distances between storage locations can slow down fulfillment, resulting in delays and higher costs. To counter this, contemporary warehouses are looking towards automation technologies such as Automated Storage and Retrieval Systems (AS/RS), mobile robots, and smart shelving systems. These technologies assist in streamlining order fulfillment, decreasing travel time, and enhancing efficiency.

Although there have been major developments, warehouse automation and order picking remain in a state of evolution. Researchers and business experts are constantly on the lookout for new methods to increase efficiency, enhance scalability, and minimize costs. This research seeks to study the current innovations and determine the best methods for developing smarter, more efficient warehouse systems. By streamlining operations, companies can match the high-speed e-commerce environment and provide customers with exceptional service.

The core warehousing supply chain process involves receipt of products and storage as well as order picking and shipping of packages to consumers. The shelf navigation method current in human pickers in picker-to-parts systems becomes ineffective due to walking wastage and the time taken for order completion particularly with small-order sizes. E-commerce growth necessitates new warehouse systems because of its rapid growth and its mix of small orders and vast variety and challenging delivery schedules and operation workload unpredictability.

E-commerce logistics is given solution by contemporary systems that employ automation and scalable designs to enhance operational velocity and manage market fluctuations and also complete orders in a timely manner to keep pace with e-commerce demands.

1.4 AIM OF RESEARCH AND STUDY

The objective of this research is to create a warehouse management system that improves inventory tracking via a cross-platform web application with real-time updates, barcode management, and LED-guided picking. It will also have a secure backend with Node.js and MySQL for handling data and user authentication.

1.5 OBJECTIVES AND SCOPE OF PROJECT

1. To develop a cross-platform web application using HTML, CSS, and JavaScript for managing racks, shelves, bins, and item movement efficiently.
2. To build a secure backend system using Node.js and MySQL for data storage, user authentication, and inventory transactions.
3. To ensure automatic inventory updates by dynamically displaying available stock whenever an item is added or picked.
4. To implement barcode-based item management for faster and more accurate item addition, tracking, and retrieval.
5. To allow picking of one or multiple items at a time and update inventory records in real time for better stock visibility.
6. To enable LED-guided item picking to assist workers in locating items quickly while minimizing errors in the picking process.

CHAPTER 2

LITERATURE

REVIEW

LITERATUR REVIEW

The literature survey covers a broad spectrum of topics related to automated packaging and smart warehouse management for e-commerce fulfillment. These include sensor-based systems for real-time item detection, integration of ESP32 microcontrollers for automation control, JavaScript-based web platforms for inventory and item movement management, MySQL- backed data storage for secure and structured information handling, and barcode-enabled item tracking for accuracy and speed. Studies also explore the implementation of LED-guided picking systems to enhance worker efficiency and reduce errors. Each study offers valuable insights into the challenges, innovations, and real-world applications within the domain of automated packaging and logistics, forming a strong foundation for the development of this system.

Reference 01:

Abu Tayab and Yanwen Li, "The contribution of the RPAtechnology in enhancing better business performance in warehouse management," *IEEE Access* , vol. 12, pp. 142–419, Sep. 2024, doi: 10.1109/ACCESS.2024.3470221.

Description:

This research undertakes a systematic review of literature and case studies to compare RPA's effect on warehouse management. It looks at automation in inventory tracking, order processing, and data entry to measure efficiency gains and error reduction. Productivity of the workforce is tested by evaluating task reallocation to value-added activities. The combination of RPA with AI and IoT is examined for its application in real-time data analysis, predictive maintenance, and demand forecasting. The insights are synthesized to evaluate the scalability, adaptability, and sustainability of RPA in contemporary logistics.

Reference 02:

H. Kalkha, A. Khiat, A. Bahnasse, and O. Hassan, "Enhancing warehouse efficiency with time series clustering: A hybrid storage location assignment strategy," *IEEE Access*, vol. 12,pp. 768–790, Jan. 2024, doi: 10.1109/ACCESS.2024.3386887.

Description:

E-commerce warehouses require efficient warehouse management systems since it guarantees quick delivery service with accuracy. Choosing the best locations for item storage is a significant challenge as it has a direct impact on picking efficiency as well as workflow operations. The research proposal introduces Intelligent Storage Location Assignment (ISLA) as an AI- driven clustering method committed to ordering best-selling ordered products together. ISLA makes use of actual warehouse data to provide improved order process movement control that reduces preparation time by as much as 69% from conventional warehouse methods. Market transition from AI within logistics is a yet to be researched area. The study completes the available gap in knowledge using examples of ways storage optimization by artificial intelligence constructs more intelligent and faster and better warehouse operations.

Reference 03:

N. Alherimi, A. Saihi, and M. Ben-Daya, “A systematic review of optimization approaches employed in digital warehousing transformation,” *IEEE Access*, vol. 12, pp. 145809–145831, Sep. 2024, doi: 10.1109/ACCESS.2024.3463531.

Description:

Digital technological advancements like robotics, artificial intelligence (AI), the Internet of Things (IoT), and blockchain technologies cause a critical shift in the warehouse industry. The new technologies have caused warehouse operations to translate to faster execution combined with improved performance and accuracy. Automated robotic systems with AI facilitates item picking processes to reduce by 10% as warehouse space utilization improves to 14.8% optimization and operational costs lower by nearly 10%. Companies apply digital twins made up of warehouse virtual copies to decide solutions prior to problems arising and blockchain increases supply chain security and information clarity. There is a lack of research in the most important areas since scientists require greater insight into the economic impacts that these technologies place on warehouses and how to enhance sustainability and human-robot collaborative operations. A study of digital optimization models scrutinizes their role in shaping warehousing development from 2010 until 2023 and particularly their search for untapped areas of research.

Reference 04:

Mahsa Tavasoli, E. Lee, Y. Mousavi, H. B. Pasandi, and A. Fekih, “WIPE: A novel web-based intelligent packaging evaluation via machine learning and association mining,” *IEEE Access*, vol. 12, pp. 45936–45947, Mar. 2024, doi: 10.1109/ACCESS.2024.3376478.

Description:

The suggested system manages stock operations in advanced warehouse configurations via techniques that maximize stock filling operations despite minimal maximum storage capacities and continuous customer orders. The process emphasizes how heuristic computation methods aid organizations in managing their between-warehouse and type-of-item inventory operations. Operational efficiency gets resolved through the introduction of sophisticated ICT technologies.

Reference 05:

Zhang Xiaoyi, Shen Changpeng, Liu Peng, Zhang Yigong, Lou Benjin, and Ma Wenkai, “Optimizing replenishment based on order structure in automated warehouse systems,” *IEEE Access*, vol. 11, 2023.

Description:

This is a delivery system that controls automatic packaging by use of IoT technology which works by demo website orders to trigger conveyor belts and piece dispensers. The system is run by way of IoT devices for real-time automation of procedures but has a scalability problem which is made viable through modular operation supported by parallel conveyor belts designed for larger systems. The article shows how automation makes it possible to manage warehouse operations such as inventory tracking and order processing and data logging functions. The application combines Automation Anywhere and UiPath with IoT and AI features to create improved predictive maintenance through real-time decision-making capabilities.

The approaches to improving warehouse operations include virtual warehouses along with process-picking systems and AI-driven decision support models. Joint scheduling coordinates the picking and delivering activities for workload allocation reasons and order splitting maximizes order format in order to accelerate processing. AS/RS and RMFS warehouse automation systems employ automated methods of order assignment with coordination functions. The study indicates that warehousing performance relies batching solutions and routing strategies and technological optimization methods which achieve shorter delivery times and enhanced service performance.

Reference 06:

H. Kalkha, A. Khiat, A. Bahnasse, and O. Hassan, "The rising trends of smart e-commerce logistics," *IEEE Access*, vol. 11, pp. 33840–33857, Jan. 2023, doi: 10.1109/ACCESS.2023.3252566.

Description:

This solution is a robust warehouse management system since it runs smoothly without errors and keeps scalability without making major infrastructure changes. This paper analyzes Smart Logistics (SL) in e-commerce distribution and illustrates how Information and Communication Technology (ICT) systems such as IoT, AI, Blockchain and 5G improve shipment tracking and route choice and supply chain management functionalities. Research calls for further study into Vehicle Routing Problems (VRP) implementations with computer vision and deep learning technology and assessments for checking product quality in e-commerce logistics operations.

Reference 07:

Y. Li, R. Zhang, and D. Jiang, "Order-picking efficiency in e-commerce warehouses: A literature review," *Journal of Theoretical and Applied Electronic Commerce Research*, vol. 17, no. 4, pp. 1812–1830, Dec. 2022, doi: 10.3390/jtaer17040091.

Description:

Warehouse operation strategies include virtual warehouses and process-picking systems and decision support models based on artificial intelligence. Joint scheduling coordinates picking and delivering processes for workload distribution and order splitting improves order format for speeding up processing. The automated warehouse systems RMFS and AS/RS employ automated methods to maximize order allocation in conjunction with coordination tasks. The study illustrates that the warehousing efficiency is based on routing solutions and batching techniques and technology optimization strategies which generate shorter time of delivery and improved service level performance.This system acts as a delivery system in charge of the automated packaging with the help of IoT technology, which works through demo website orders to trigger the conveyor belts and product dispensers. The system functions on IoT devices for real-time task automation but has scalability problems that become controllable through modular operations supported by parallel conveyor belts optimized for larger systems. The article illustrates how automation makes possible the control of warehouse activities such as inventory tracking and order processing and data recording work. The tool combines Automation Anywhere and UiPath with IoT and AI functionalities to generate improved predictive maintenance using real-time decision-making capabilities

Reference 08:

E. Khobotov and E. Averianova, "About one approach to inventory management in hierarchical warehouse systems with restrictions on warehouse capacity," in *Proc. 2022 19th Int. Conf. on Machine Learning and Data Science (MLSD),* Moscow, Russia, Sep. 26–28, 2022, pp. 6654– 6671, doi: 10.1109/MLSD55143.2022.99.

Description:

Contemporary studies in inventory management prioritize the optimization of stock control within hierarchical warehouse systems operating under capacity constraints. These studies aim to ensure efficient replenishment strategies amid perpetual demand scenarios. Various models address multi-product inventory management by incorporating critical factors such as storage costs, delivery expenses, and the risks associated with stock shortages. A significant research focus lies in leveraging convex optimization techniques to determine optimal replenishment timing and quantities while adhering to warehouse capacity and demand limitations. Furthermore, the integration of batch production methods with integer variable constraints has been shown to enhance decision-making efficiency in large-scale systems. Continued exploration of these models offers the potential to improve warehouse performance by achieving a balance between cost-efficiency, demand fulfillment, and storage space optimization within constrained environments.

Reference 09:

S. A. I. Shouborno, T. I. Mahmud, N. Ishraq, R. Ali, T. H. Joy, and S. A. Fattah, "Complete automation of an e-commerce system with Internet of Things," in *Proc. 2019 IEEE Region 10 Annual International Conference (IEEE R10-Asia)*, Dhaka, Bangladesh, Nov. 29–Dec. 1, 2019, pp. 789–802, doi: 10.1109/RAAICON48939.2019.39.

Description:

The IoT-based automated packaging system for small e-commerce startups integrates advanced technologies like robotics and artificial intelligence (AI) to streamline warehouse operations. The system utilizes conveyor belts equipped with sorting robots that work autonomously to reduce reliance on human labor and enhance operational efficiency. Through real-time order handling and product distribution, the system ensures swift and accurate processing. At the core of this automation is the Internet of Things (IoT), which enables seamless communication between devices, sensors, and systems, facilitating flawless execution of warehouse sorting tasks. Additionally, the system features an automated inventory update mechanism that provides immediate updates on stock levels, ensuring accurate and timely data. This not only improves inventory management but also optimizes logistics performance by minimizing errors and delays. By employing IoT and AI, this solution offers small e-commerce businesses an efficient and scalable way to manage their warehouses and fulfill orders with speed and precision.

Reference 10:

N. Boysen, R. B. M. De Koster, and F. Weidinger, “Warehousing in the e-commerce era: A survey,” *Eur. J. Oper. Res.*, vol. 277, no. 2, pp. 396–411, Aug. 2018, doi: 10.1016/j.ejor.2018.08.023.

Description:

Deep reinforcement learning (DRL) has emerged as one of the most effective techniques for optimizing order batching in warehouse management. By leveraging integer programming systems in conjunction with aggregate order decomposition, organizations can minimize the picking distance—a key factor in improving operational efficiency. Additionally, the classification of products into categories such as dry, fresh, and frozen enhances the batch picking process, as it allows for better organization and prioritization, reducing the overall expenses associated with order fulfillment. When integrated with optimal packaging techniques, order batching processes can further minimize waiting times, speeding up the entire workflow from picking to packaging.

Moreover, the use of heuristic algorithms significantly streamlines the picking operations and the order-truck distribution systems, optimizing both the speed of order fulfillment and the reduction of delays throughout the process. A dual-objective model is also employed to tackle both order batching and mixed- shelves storage challenges. This model ensures that orders are processed efficiently, even under complex storage conditions, by minimizing the distance required to pick items from various storage locations. In this context, batch picking proves particularly useful by enabling efficient item selection across different storage types, ensuring the system performs optimally even in diverse warehouse environments. genetic algorithms contribute to the process by optimizing the order processing and batch picking strategies, offering significant improvements in both speed and resource management. These algorithms evolve solutions over time, refining the order batching and picking processes to continually improve efficiency and reduce operational costs.

Reference 11:

F. Weidinger, N. Boysen, and M. Schneider, “Picker routing in the mixed-shelves warehouses of e-commerce retailers,” Eur. J. Oper. Res., vol. 274, no. 2, pp. 631–645, Oct. 2018, doi: 10.1016/j.ejor.2018.10.021.

Description:

The IoT automation supports the technique of Managing Multi-Product Stocks in Hierarchical Warehouse Systems by improving multi-storey warehouse replenishment operations. The warehouse system, when modeled using directed acyclic graph, achieves effective stock distribution and automated sorting robots improve inventory control alongside warehouse operations. Different optimization methods which the order-picking strategies use benefit warehouse operational efficiency. The initial system design enables knowledgeable order processing using extended and adjustable transportation windows which minimize picker travel distance and another system integrates order scheduling into processing to maximize delivery period efficiency.

CHAPTER 3

METHODOLOGY

METHODOLOGY

3.1 Methodology

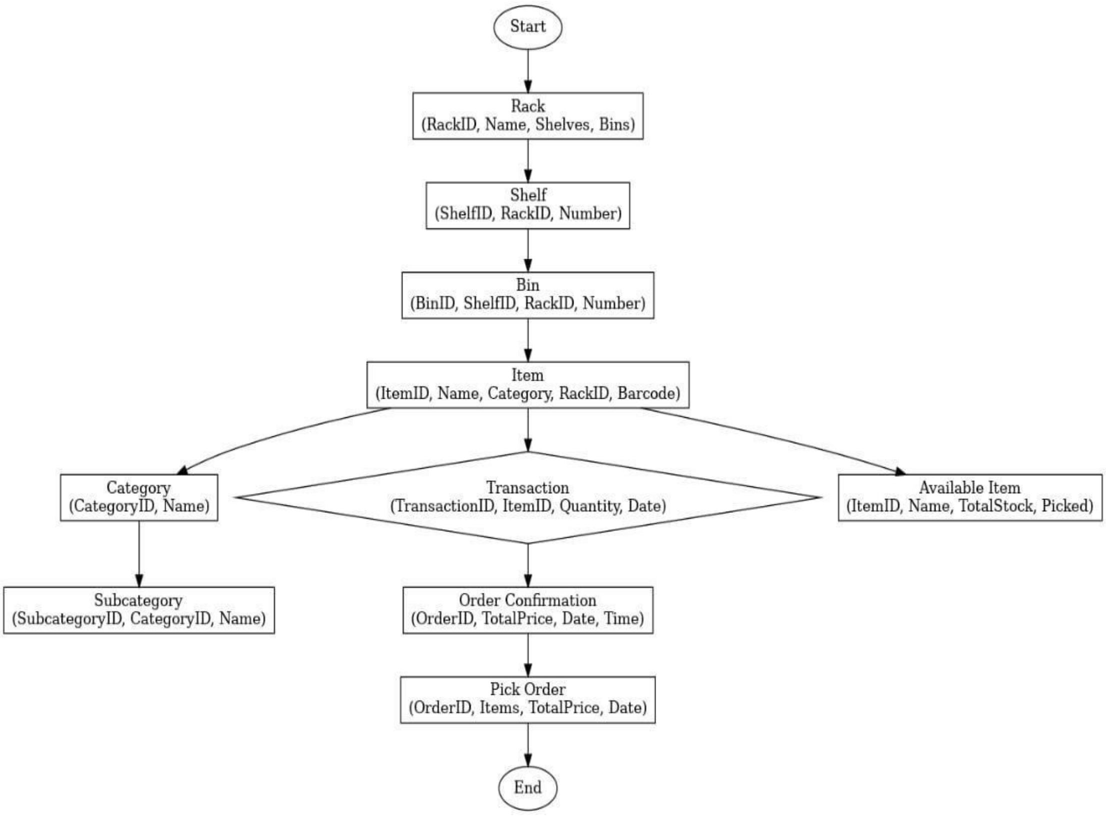

Figure 3.1 Warehouse Management Flowchart

3.1.1 Rack and Shelf Management

The system offers a systematic method of warehouse organization, enabling users to define and manage racks, shelves, and bins with ease. Users can create new racks, edit existing ones, and allocate shelves systematically, ensuring an organized storage environment. This functionality improves accessibility, reduces misplacement, and optimizes retrieval processes, resulting in quicker and more efficient warehouse operations.

3.1.2 Categorization and Item Management

To ensure order and efficiency, the system allows for accurate item categorization with multi-level categorizations, such as categories and subcategories. All items are given attributes like name, category, barcode, and storage point to enable easy tracking and retrieval. Users can enter items into specific racks and shelves, limiting confusion and guaranteeing orderly storage. The categorization process enhances searchability, inventory precision, and stock visibility, ultimately leading to enhanced warehouse management.

3.1.3 Barcode-Based Operations

The use of barcode technology greatly improves speed, accuracy, and operational efficiency. Users can input items into inventory by scanning barcodes, streamlining entry and avoiding manual errors. Barcode scanning makes item picking easy, enabling fast verification and product retrieval while assuring error-free transactions. This automation saves processing time, boosts productivity, and maximizes overall warehouse efficiency.

3.1.4 Item Availability and Monitoring

Real-time inventory monitoring guarantees accurate visibility of stocks and efficient warehouse operations. The system updates the availability of items automatically after every addition or picking process to avoid discrepancies. Users are able to obtain item information instantly via barcode scanning, allowing quick confirmation of stock status. This functionality maximizes inventory control, minimizes stockouts, and facilitates smooth supply chain movement.

3.1.5 Order Management

A secure and user-friendly order management system simplifies the buying process without compromising data security. Users are authenticated through OTP-based login/signup prior to accessing the system. The rich-featured interface enables users to add products to cart, move to checkout, and place orders with ease. A responsive add-to-cart mechanism improves the user experience, ensuring smooth order placement, real-time updates, and effective transaction handling.

3.1.6 LED-Based Item Picking

The system incorporates LED-guided item picking to optimize accuracy and efficiency in warehouse picking. When picking an item, an LED light on the related bin lights up, guiding the user for instant and error-free identification. IR sensors monitor movement objects to ensure accurate retrieval of items.The system accommodates single picking and bulk picking, with LEDs automatically being extinguished upon successful item selection. This aspect reduces search time, minimizes errors, and maximizes warehouse productivity.

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3.2 Warehouse Inventory

Table I: Warehouse Inventory Table

Sr. No	Attribute Used	Attribute Type	Attribute Description
1	rack_id	INT (Primary Key)	Unique identifier for each rack
2	rack_name	VARCHAR(50)	Name of the rack
3	num_shelves	INT	Number of shelves in the rack
4	num_bins	INT	Number of bins in the rack
5	shelf_id	VARCHAR(50) (Primary Key)	Unique identifier for each shelf
6	shelf_number	INT	Shelf number in the rack
7	bin_id	VARCHAR(50) (Primary Key)	Unique identifier for each bin
8	bin_number	INT	Bin number on the shelf
9	status	ENUM('used', 'unused')	Indicates if the bin is occupied (used) or empty (unused)
10	category_id	INT (Primary Key)	Unique identifier for each category
11	category_name	VARCHAR(100)	Name of the category
12	subcategory_id	VARCHAR(50) (Primary Key)	Unique identifier for each subcategory
13	subcategory_name	VARCHAR(255)	Name of the subcategory
14	item_id	INT (Primary Key)	Unique identifier for each item
15	item_name	VARCHAR(100)	Name of the item
16	quantity	INT	Quantity of the item available
17	quantity_unit	VARCHAR(50)	Measurement unit of the quantity (e.g., kg, pcs)
18	barcode_value	VARCHAR(255)	Unique barcode for scanning
19	transaction_id	INT (Primary Key)	Unique identifier for transactions
20	transaction_date	TIMESTAMP	Date and time of transaction
21	order_id	VARCHAR(20) (Primary Key)	Unique order identifier
22	price	DECIMAL(10,2)	Price of the ordered item
23	order_date	DATE	Date when the order was placed
24	order_time	TIME	Time when the order was placed
25	added_quantity	INT	Quantity of items added to inventory
26	picked_quantity	INT	Quantity of items picked from inventory
27	available_quantity	INT (Generated Column)	Available stock calculated as (added - picked)

Effective warehouse operations are built on organized structure, precise tracking, and real-time monitoring of the inventory. The warehouse inventory dataset given is a solid model for meeting these objectives. It has the necessary attributes for working with racks, shelves, bins, and items and incorporates advanced capabilities such as barcode scanning and dynamic updates of stock, facilitating smooth automation and enhanced accuracy.

The data set starts with fields like rack_id, rack_name, num_shelves, and num_bins to determine the physical warehouse layout. The fields provide systematic organization, whereas fields like bin_id, bin_number, and status facilitate bin monitoring in real time, maximizing space usage and storage efficiency.

Categorization is facilitated with multi-level classification by attributes such as category_id, category_name, subcategory_id, and subcategory_name. This allows for effective item grouping, minimizing search times and enhancing inventory retrieval. Each item is tagged with unique identifiers such as item_id, item_name, and barcode_value, facilitating error-free automation of item-picking operations through barcode scanning.

The data set facilitates dynamic stock tracking with columns such as added_quantity, picked_quantity, and available_quantity, all of which reflect current updates in stock levels. The derived column available_quantity gives exact stock visibility, enabling managers to estimate demand and avoid stock differences. Date-stamped columns such as transaction_date, order_date, and order_time facilitate traceability and generate a solid audit trail for every activity in the inventory.

By incorporating automation, structured storage, and real-time stock control, this dataset enables efficient warehouse management. It minimizes human effort, reduces errors, and streamlines operational workflows. Its comprehensive design forms the backbone of modern warehouse systems, making it an essential asset for organizations aiming to optimize logistics and operational efficiency.

3.3 Materials and methods

3.3.1 Hardware Components

3.3.1.1 Arduino Microcontroller:

This is the main controller for LED and sensor operations. It controls the communication between the system's hardware components and carries out predefined commands for item retrieval.

3.3.1.2 LED:

Light Emitting Diode is a widely used standard source of light in electrical equipment. Installed on each bin, LEDs act as a visual indicator to guide the warehouse staff to the right bin during the picking process.

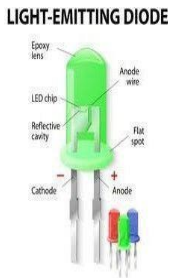

Figure 3.2 Light emitting diode

3.3.1.3 USB Barcode Scanner:

Capture critical details on items with regard to names, IDs, and quantities by the scanner in an automatic way and update database.

3.3.1.4 Database Server (for example, MySQL):

A database server is a form of server used to hold and manage databases. It grants the user the privilege of accessing information from a network and, in addition, keeps the information secure. This server keeps inventory data in storage and update and maintains up-to-date records in real-time as far as the stock level and item description is concerned.

3.3.1.5 Computer/Server:

This acts as the central interface for hosting the warehouse management software and coordinating communication between hardware components.

3.3.1.6 Power Supply Units:

These provide stable power to all hardware components, ensuring uninterrupted operation.

3.3.1.7 ESP-32:

ESP32 is a series of low-cost, low-power system-on-chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. It is a feature-rich SoC with integrated Wi-Fi and Bluetooth connectivity for a wide-range of IoT applications.

Figure 3.3 ESP-32

3.3.2 Software Modules

3.3.2.1 Arduino IDE:

This is Used for programming microcontrollers to control LEDs, IR sensors, and hardware interactions. It enables real-time automation and seamless communication between components.

3.3.2.2 Barcode Scanner API:

Processes barcode data from USB scanners and updates inventory in real-time. Ensures accurate tracking, quick updates, and seamless integration with the database.

3.3.2.3 Custom Warehouse Management Software:

Manages inventory, generates picking lists, and interfaces with hardware components. Provides centralized control for tracking, order processing, and automation.

3.3.2.4 Database Management System (DBMS):

Ensures real-time inventory synchronization across devices for accurate stock management. Provides secure, fast data access and transaction consistency.

3.3.2.5 Graphical User Interface (GUI):

Offers an intuitive platform for monitoring inventory, processing orders, and managing operations. Enhances user experience with easy navigation and real-time data.

3.3.2.6 Communication Protocols:

Enable interaction between hardware components and the database for accurate data exchange. Ensure real-time updates, reducing lag and improving system efficiency.

3.4 Data Analysis Methods

Warehouse operations rely heavily on precise and timely data to ensure that orders are fulfilled efficiently. With automation and advanced technologies like LED-guided picking systems, the Below are some key data analysis methods that help optimize the order picking process and inventory management.

3.4.1 Order Picking Time (OPT) Calculation

Order picking time (OPT) plays a critical role in warehouse efficiency. It helps determine how quickly an order can be fulfilled, which directly impacts customer satisfaction. The formula for calculating OPT is as follows:

$$OPT = Ts + (N \times Tp) + Tm$$

Where: Ts is the setup time before picking starts (such as preparing the order). N is the total number of items to be picked in the order. Tp is the time it takes to pick a single item.Tm is the time it takes to move between different locations in the warehouse.

By calculating OPT, the system can determine how long it will take to fulfill an order and optimize the entire picking process. The use of LED-guided navigation further streamlines this

process by guiding the workers to the right locations, reducing unnecessary movement and time wastage. A more efficient picking process means quicker order fulfillment, which in turn helps improve overall productivity in the warehouse.

3.4.2 Real-Time Inventory Update

Keeping track of inventory in real-time is crucial for ensuring the warehouse has the right stock levels. The system automatically updates the inventory whenever an item is picked or restocked. The formula used to calculate real-time inventory is:

$$S_t = S_{t-1} - O + I$$

Where: St is the updated stock level at time "t".St-1 is the stock level at the previous time.O is the number of items picked and removed from the warehouse.I is the number of items restocked or returned to the warehouse.

This formula ensures the inventory is always up-to-date by accounting for both outgoing and incoming items. With the help of barcode scanning, the system automatically updates the stock levels, which greatly reduces the chances of errors and ensures that the warehouse operates efficiently. Real-time updates allow warehouse managers to have a clear understanding of stock availability, making it easier to manage orders and prevent stockouts or overstocking.

3.4.3 Pick Accuracy Rate (PAR)

Pick accuracy is a critical factor in warehouse operations, as errors in picking can lead to delays and customer dissatisfaction. The Pick Accuracy Rate (PAR) measures how accurately the picking process is carried out by calculating the percentage of correct items picked. The formula for calculating PAR is:

$$PAR = (C / T) \times 100$$

Where: C is the number of correctly picked items.T is the total number of items picked.A higher PAR indicates fewer errors in the picking process, which leads to more accurate order fulfillment. The automation system's use of IR sensors and LED guidance helps ensure that workers pick the correct items, significantly improving the PAR. With fewer mistakes, the warehouse can fulfill more orders accurately, reducing the need for returns or corrections.

3.4.4 Efficiency Improvement (Time Savings Percentage, TSP)

One of the primary benefits of automation in warehouse operations is the time savings it brings.The Time Savings Percentage (TSP) measures the amount of time saved by automating tasks compared to the time taken before automation. The formula for calculating TSP is:

$$TSP = ((Tb - Ta) / Tb) \times 100$$

Where: Tb is the time it took to complete tasks before automation.Ta is the time it takes to complete the same tasks after automation.

By calculating TSP, we can determine how much time has been saved due to automation. A higher TSP indicates a significant reduction in time spent on tasks.

CHAPTER 4

IMPLEMENTATION

IMPLEMENTATION

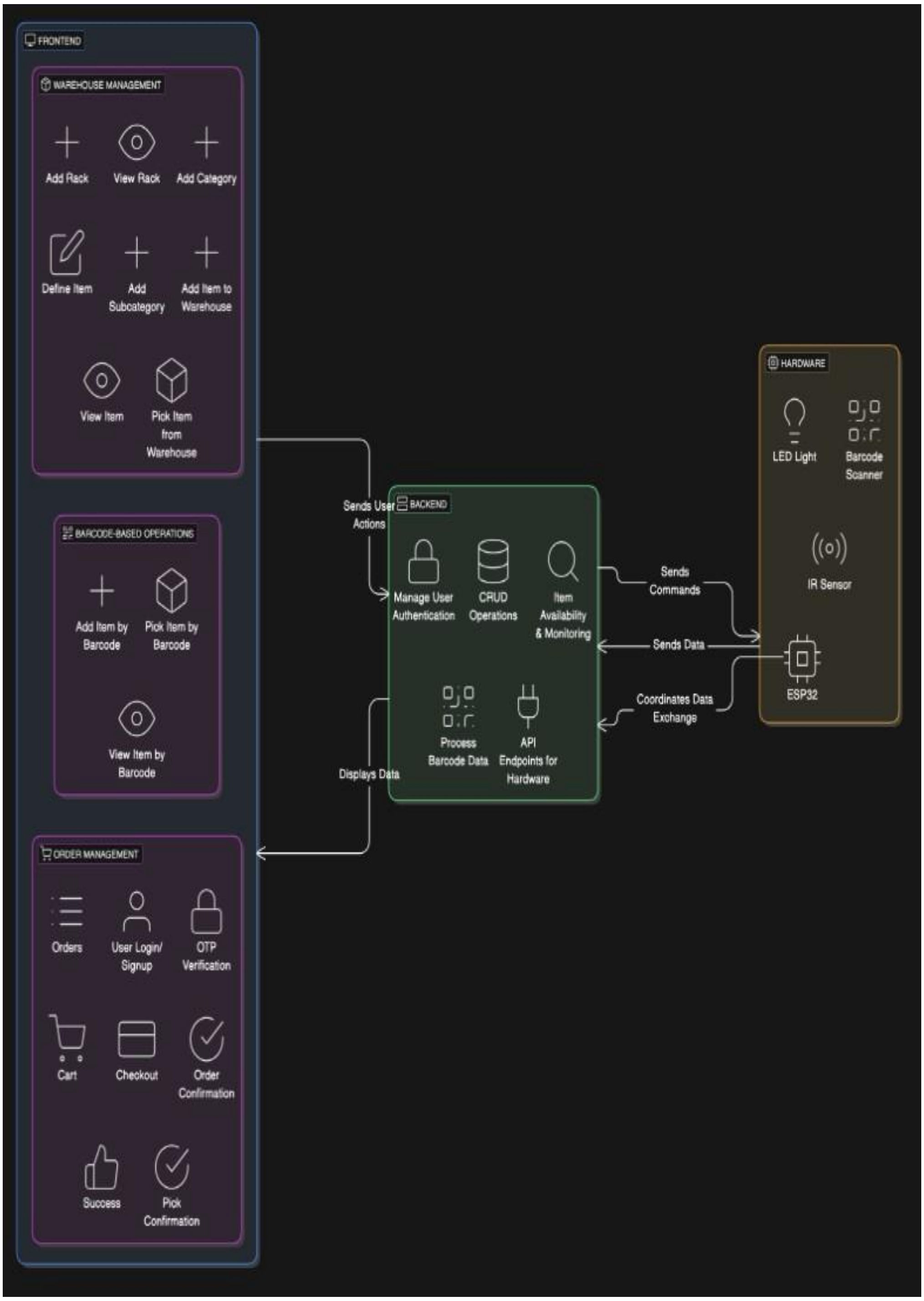

Figure 4.1 Warehouse Management Implementation diagram

Warehouse Management System Overview

A Warehouse Management System (WMS) combines contemporary technologies and techniques to maximize warehouse operations. It brings together software elements like frontend (UI), backend (Node.js + SQL), and hardware components like barcode scanners, LED indicators, and IR sensors to provide a smooth and efficient warehouse management experience. The system supports inventory, racks, items, and order management, enabling warehouse personnel to execute tasks more efficiently with real-time updates and precise tracking.

4.1 Frontend (UI) Functionality

The frontend is the user interface (UI) through which users at the warehouse communicate with the system. It is made user-friendly so that warehouse personnel find it easy to manage some of the warehouse activities. Some of the basic operations of the frontend include:

4.1.1 Warehouse Management

The frontend facilitates the warehouse team to add and view rack, shelf, category, and item details in an efficient manner. Items are located on racks and shelves for efficient organization and ease of retrieval when picking orders. Warehouse team is able to maintain and view racks, shelves, and categories efficiently, making item management an easier process.

4.1.2 Barcode-Based Operations

Barcode reading is incorporated within the frontend so that staff are able to easily and accurately read items while adding, picking, or viewing stock.This process minimizes manual errors, facilitates faster operations, and improves the accuracy of inventories by posting the system immediately with every scan.

4.1.3 Order Management

Users securely log in into the system from the frontend interface.An OTP verification process ensures user authentication for secure access into the system.Warehouse employees can process orders effectively using the frontend by checking order statuses, checking out products, and confirming order completion.The pick confirmation function verifies that the correct products are being picked, lowering the possibility of errors and ensuring customer satisfaction.

4.2 Backend (Node.js + SQL) Architecture

The backend of the WMS is the central system that handles data processing and operations management. It is developed with Node.js for server-side operations and SQL for data storage and management. The backend provides seamless interaction between the frontend and hardware, executing commands and ensuring system integrity. Some of the main features of the backend are:

4.2.1 User Authentication

The backend handles secure user authentication, enabling users to log in or sign up securely.OTP-based authentication prevents unauthorized access to the system, providing an additional layer of security.

4.2.2 Crud Operations

The backend is CRUD operation-capable (Create, Read, Update, Delete) to facilitate the management of different aspects of warehouse operations.These include rack, shelf, bin, and item operations to enable dynamic updating and correct categorization of inventory.Warehouse personnel can change item data, shelf information, and other related data whenever necessary so that the system will always be current and accurate.

4.2.3 Items Availability and Monitoring

The backend does real-time monitoring of item availability so that users can search for items using their barcodes.This capability will ensure that personnel can instantly verify the status and availability of products in the warehouse, making decision-making faster and minimizing delays.

4.2.4 Processing Barcode Data

The backend processes information from barcode scanners to efficiently add and pick items.When an item is scanned, the backend checks the item, updates the database, and makes sure correct data is being displayed in the system in real time.

4.2.5 Order Management

The backend processes cart management, checkout, and order processing to make sure customer orders are correctly processed and fulfilled.It handles all order transactions so that the system is kept current with the most recent order statuses.

4.2.6 API Communication

The backend also acts as a mediator between the frontend and hardware components, allowing seamless API communication.It issues commands to hardware items like barcode scanners, LEDs, and IR sensors so that there is seamless interaction between the hardware and software components.

4.3 Connection Between Frontend, Backend, and Hardware

Smooth functionality of Warehouse Management System hinges on frontend, backend, and hardware integration. This integrated system enables effective functioning of the warehouse from order ordering to picking merchandise and updating inventories.

4.3.1 Frontend to Backend

When the frontend is accessed by users, for example, to log in, to add products to a cart, or to handle inventory, these processes are handled by the backend. The frontend sends requests to the backend, and the backend refashions the system, for example, adding products to racks or changing the status of an order. The frontend then renders the refreshed data, making it possible for users to be constantly updated on the changes in real time.

4.3.2 Backend to Hardware

The backend talks directly to hardware elements such as barcode readers, LED displays, and IR sensors. For instance, during the scanning of a barcode, the backend confirms the item and instructs the LED displays to indicate the correct picking location. The backend controls the usage of IR sensors that monitor whether an item has been picked or not, ensuring the system is constantly updated with up-to-date information.

4.3.3 Hardware to Backend

Barcode scanners report to the backend, such as the details of the item scanned, so that the system can accurately track movement of inventory. IR sensors are used to sense the picking and report back to the backend to enable verification of item retrieval. LED indicators direct warehouse personnel to pick from the correct location by turning lights on based on instruction from the backend to optimize the process. Also, the LED lights are powered by the ESP-32 microcontroller to have the right lights shine at the appropriate places in order to pick items efficiently.

Overall,The combination of frontend, backend, and hardware elements provides a robust and efficient Warehouse Management System that makes warehouse operations seamless. With the ease of use of a frontend interface, a strong backend design developed with Node.js and SQL, and advanced hardware elements like barcode scanners, LED indicators, and IR sensors, the WMS maximizes each operation of warehouse management. The system supports real-time update, correct inventory monitoring, and accelerated order fulfillment, resulting in enhanced warehouse efficiency and productivity.

CHAPTER 5

RESULT AND DISCUSSION

RESULT AND DISCUSSION

5.1 Cross-Platform Web Application for Warehouse Management

The developed warehouse management system (WMS) implements a web application that features an easy-to-use interface to control racks shelves bins along with item transfer operations. The system delivers improved inventory monitoring while using automated work methods that eliminate manual mistakes.

5.2 Real-Time Inventory Updates

Table II: Real-Time Inventory Updation

Item ID	Item Name	Added Quantity	Picked Quantity	Available Quantity	Transaction Date
6	Dining Table	3	2	1	2025-01-10 10:30:20
7	Lakme Lipstik	10	3	7	2025-01-19 18:31:43
8	Vaseline	6	4	2	2025-02-09 09:51:21
12	LG	4	1	3	2025-01-12 14:52:23
16	Remote Control Car	4	2	2	2025-01-12 20:17:29
17	Vatika	19	6	13	2025-01-12 21:10:52

The available quantity column updates in real-time based on the difference between added_quantityand picked_quantityas per the data shown in above Table. The inventory record shows "Vatika" stores thirteen units of product that demonstrates light product usage whereas the "Dining Table" item contains only one unit thus requiring immediate ordering. The analysis reveals how monitoring stock movements should happen on a regular basis because transaction dates create varying movement patterns. A MySQL trigger enables automatic update functions by calculating available_quantity whenever an item receives efficient stock management.

A Heatmap analysis displays the data from the table for easier comprehension.

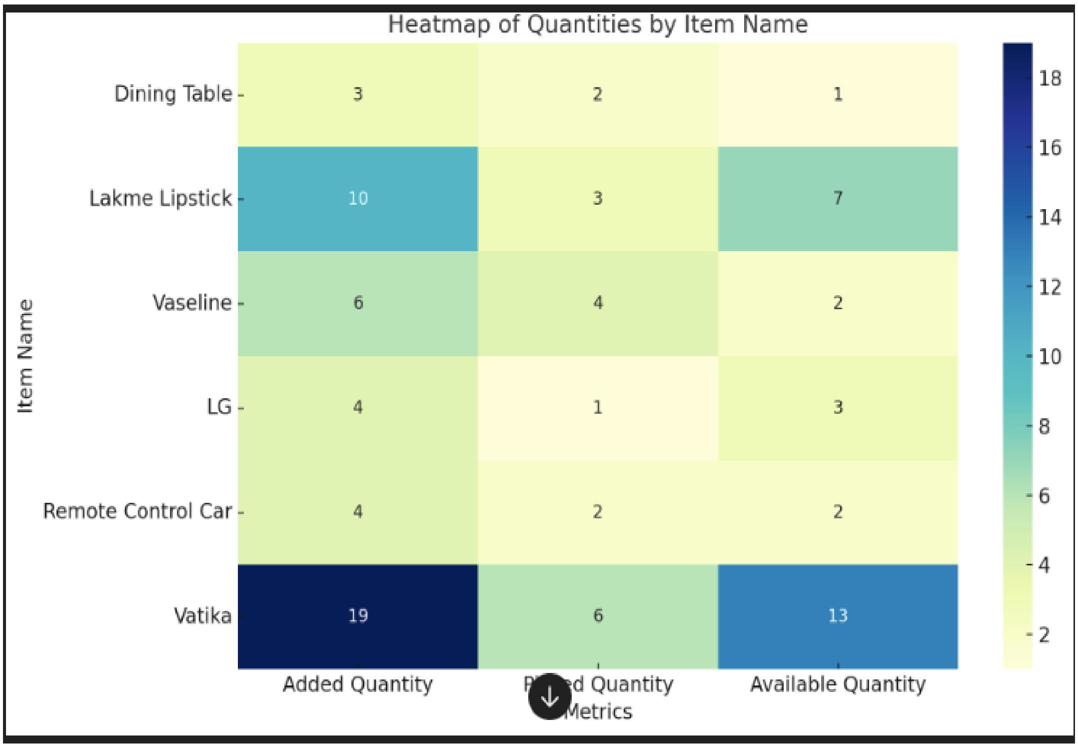

Figure 5.1 Heatmap of Quantities by Item Name

5.3 Efficient Barcode-Based Item Management

Figure 5.2 Reduction in Inventory Management

The line graph illustrates rapid time cuts in inventory management after barcode implementations because new item entries decreased from five minutes to one minute while picking time trimmed down to thirty seconds per piece. The system's upgraded performance emerges from decreased operational times which both speed up order processing and raise total efficiency along with inventory turnover capability.

5.4 Multi-Item Picking with Real-Time Updates

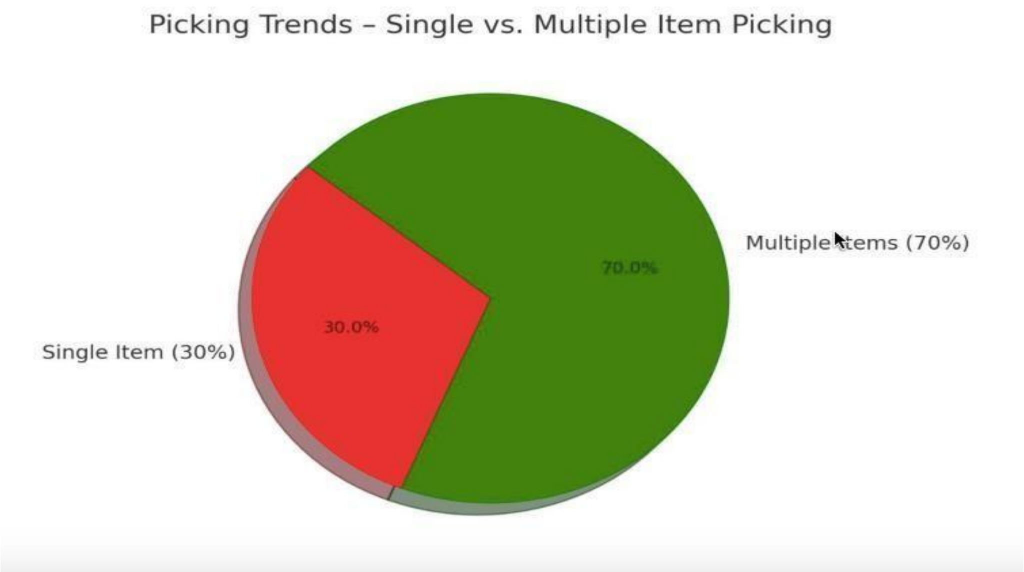

Figure 5.3 Picking Trends

The Picking Trends chart reveals workers choose to pick multiple items at once since 70% of employees prefer this method. Fifty percent shorter total picking duration results from this selected strategy which improves productivity alongside order delivery speed. The system proves more efficient because of its multi-item option which enhances inventory management operations.

The Picking Trends chart demonstrates that majority staff members (70%) choose to handle several items during each picking task instead of picking them one by one. Using multiple- item picking methods shortens the total picking process by 50% to enhance operational performance. This method delivers faster orders and improved operational workflow as its main advantages.

5.5 LED-Guided Picking for Improved Accuracy

Figure 5.4 Reduction in Picking time with LED Assistance

The data in the LED-Assisted Picking Bar chart establishes that letting employees use LED guides shortens search sessions and improves item finding precision. The system decreases errors during item selection as a result of which it enhances both operational speed of picking and overall efficiency rates. Through its design the system enables faster order completion which leads to increased operational performance in the warehouse.

The system shortens the time needed for item search from the regular average of 2 minutes per item to only 45 seconds per item when it illuminates their precise locations. The warehouse management system significantly reduces order fulfillment time by 65% which creates more efficient order delivery while minimizing item-based delivery mistakes. Modern eCommerce logistics applications find the system suitable because it combines real-time updates with barcode scanning and LED guidance to optimize warehouse operations.

The combined set of enhancements functions towards operational cost reduction as well as efficiency improvement and accurate inventory maintenance.

CHAPTER 6
CONCLUSION

CONCLUSION

6.1 CONCLUSION

This builds the intelligent warehouse automation system, which enhances e-commerce logistics through functionalities like inventory tracking in real time, LED-guided picking, barcode reading, and IR sensors. It reduces the duration order processing takes, reduces errors, and maximizes operational efficiency at lower cost. For the cost-effectiveness functionality, utilizing less expensive hardware like Arduino and USB barcode reader enables small- and medium-scale enterprises. It is precise and rapid in order fulfillment through the adoption of effective picking tactics and hybrid storage systems. The system supports ongoing optimization with its flexibility and incorporation with AI and machine learning. Emerging technologies like IoT and AI-powered automation will also enhance decision-making as well as lower costs. The solution maintains long-term efficiency and business expansion by incorporating easily into current warehouse management systems.

6.2 CONTRIBUTIONS

This project contributes significantly to the field of warehouse management by offering an automated, intelligent, and efficient system for inventory control and logistics operations. It enhances the tracking and management of inventory through the integration of IoT devices such as ESP32 and IR sensors, enabling real-time monitoring of item movement within the warehouse. The system streamlines operations using barcode-based item identification, incorporating key information like expiry and market dates to ensure precise tracking and timely stock updates. A user-friendly web interface developed using HTML, CSS, and JavaScript allows seamless access to inventory data, facilitating quick decision-making. The backend, powered by Java and MySQL, ensures smooth data management and robust storage of inventory records. Additionally, the project incorporates basic AI algorithms for forecasting inventory demands based on historical trends, helping maintain optimal stock levels and reduce wastage. By enabling remote monitoring through potential cloud integration, and improving accuracy through automation, this system drives data-driven decisions, reduces operational costs, and improves the overall efficiency of warehouse operations.

6.3 SCOPE FOR FUTURE WORK

Warehouse management is evolving to become smarter, faster, and more efficient with the integration of advanced technologies like IoT and AI. One of the key developments is the use of IoT devices for continuous real-time tracking of inventory, enabling automatic stock- level updates as goods move through the warehouse. This ensures accurate, timely data that supports better decision-making and helps maintain optimal stock levels while preventing overstocking or stockouts. Artificial Intelligence is also playing a vital role in demand forecasting and inventory management by analyzing historical data, market trends, and customer behavior. With AI-driven insights, warehouses can maintain balanced stock levels, reduce shortages or surpluses, and lower operational costs. Additionally, there is an increasing adoption of robots for tasks such as picking, placing, and sorting. These robots work alongside human workers to speed up operations, reduce errors, and handle large volumes of orders efficiently. Cloud-based warehouse management systems are also gaining prominence, offering centralized control that allows managers to monitor and operate warehouses remotely. These systems provide scalability, flexibility, and quick access to critical data, enhancing dynamic inventory management. Furthermore, the continuous integration of technologies like AI, IoT, robotics, and augmented reality (AR) is transforming warehouse operations, paving the way for a more streamlined and responsive logistics environment.

CHAPTER 7

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Dissemination of Work

Intelligent Automation for E-Commerce Smarter Packaging and Management of Smart Warehouses

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Abstract

Completion of e-commerce operations depends on optimized logistic systems which optimize order dispatch and open new business opportunities. The integrated real-time inventory tracking together with automated retrieval system creates operational improvements through this warehouse management system. The system arranges storage facilities into racks and shelves and individual bins holding one product each to support real-time system update capabilities through interface systems. A USB barcode scanner together with IR sensors and LED-guided picking functions form essential components of akes. The automation system enables more rapid service delivery and higher workplace producthis system which both improves worker performance by reducing expenses and misttivity which creates quick order processes alongside streamlined new employee adoption. A modern technology-based system enhances warehouse operations by lowering human engagement and supports environmentally responsible expansion in e-commerce delivery logistics.

Keywords: *Inventory management, Warehouse automation, E-commerce logistics, Barcode scanning, IR sensors, E-commerce logistics, LED-guided picking*.

1. Introduction:

The global marketplace has reshaped its operations by leveraging e-commerce but customers require solutions which combine improved performance with reduced costs alongside better service delivery. The e-commerce supply chain relies on warehouse management as a vital component because it determines both speed and accuracy of processed order handling and operational performance levels [2]. Fast warehouse operations maintain peak performance during Black Friday and Christmas by processing significant volumes of small and diverse packages for increasing customer orders [4].

Real-time monitoring elements and automated order selection capabilities along with intuitive control methods make up the designed smart warehouse automation solution which addresses warehouse challenges in e-commerce operations [6]. Warehouses maintain essential supply chain operations through product receipt and storage functions and order selection and shipping procedures which decrease negative effects of price variations and unpredictable market changes. The evolution of market trends toward bigger smaller orders and wider variety of products with faster delivery requirements forces warehouse operations to change their approach [9].

Order picking stands as the most expensive warehouse operation since layout design determines both operational efficiency and travel path length. The implementation of contemporary automation systems such as AS/RS combined with mixed-shelving organsizes operations for scale and diminishes journey lengths. A review examines novel order-picking techniques which enhance warehouse efficiency within e-commerce networks [7].

Supply chain operations depend heavily on warehouses since they produce various functions beginning with inventory reception up to order packing. Standard shelf-based order selection processes do not work well with small order quantities as it causes time delays [8]. Modern automated warehouse installations improve operational speed while they respond to market changes and they quicken the handling of orders for electronic commerce platforms.

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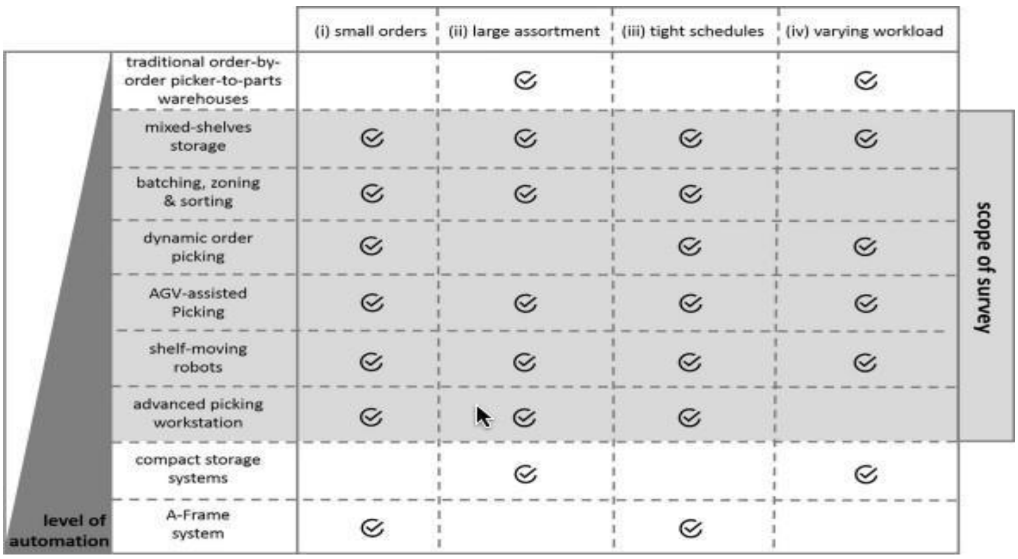


[10] Fig 1. Overview of warehousing system suited for e-commerce

Warehousing is an integral part of the supply chain that includes receiving, storing, picking, and shipping merchandise. With online shopping, traditional warehouse systems have been riddled with inefficiencies, most notably in the management of small orders [10].To meet the demands of online shopping better, newer systems with automation and organizational improvements have been set up. These systems help reduce the complexity of order fulfillment and improve efficiency.

2.Literature Survey:

This study conducts a systematic review of literature and case studies to analyze RPA's impact on warehouse management. It examines automation in inventory tracking, order processing, and data entry to assess efficiency gains and error reduction. Workforce productivity is evaluated by exploring task reallocation to value-added activities. The integration of RPAwith AI and IoT is analyzed for its role in real-time data analysis, predictive maintenance, and demand forecasting. Insights are synthesized to assess RPA's scalability, adaptability, and sustainability in modern logistics [1].

Fast accurate delivery services are enabled when warehouse management practices use best-in-class product placement strategies to optimize picking processes. The implementation of ISLAallows AI to manage storage cluster assignments and delivers products quickly and shortens preparation times by between 69% and 74%. The application of AI for warehouse storage management leads to enhanced efficient warehouse management systems according to research-based findings [2].

Warehouse operations have received substantial speedup and efficiency improvements from the implementation of AI together with IoT and robotics and blockchain technologies while precision has increased. AI automation speeds up warehouse procedures by 10 percent and simultaneously decreases operation requirements by 14.8 percent while saving 10 percent of overall expenses. Both decision processes and supply chain safety receive benefits from implementing blockchain systems. Additional research needs to be conducted to clarify both economic performance and sustainability effectiveness and automation methods in warehouse infrastructure development [3].

IoT-Based Automated Packaging System for Small E-commerce Startups. The system combines robotics with artificial intelligence to operate through a conveyor belt system which uses sorting robots for warehouses to reduce human involvement. The real-time order handling and product distribution along with warehouse sorting processes within IoT relies on its fundamental operations for achieving seamless automation. The warehouse hierarchy maintains an instant inventory update system that leads to efficient accurate logistics management [4].

The strategies for enhancing warehouse operations encompass virtual warehouses as well as process-picking systems and AI-based decision support models. Joint scheduling synchronizes the picking and delivering processes for workload distribution purposes and order splitting optimizes order format to increase processing speed. The warehouse automation systems AS/RS and RMFS use automated approaches to optimize order assignment together with coordination functions. The analysis shows that warehousing effectiveness depends on batching methods and routing solutions and technological optimization approaches which create shorter delivery times and better service performance [5].

While allowing scalability for extensive warehouse management features the system does not require infrastructure changes and provides error reduction functions. Smart Logistics utilizes IoT together with AI, Blockchain and 5G and IoT to manage their supply chains and track shipments as well as optimize delivery routes. A combination of deep learning technology and computer vision implements quality evaluations for VRP although heuristic computations optimize inventory processes and stock placement under restricted storage areas [6].

The system operates as a delivery platform to manage automatic packaging through IoT technology that services demo website orders to trigger conveyor belts and dispenser compartments. This system functions using IoT devices to perform real- time task automation although it needs modular operation and parallel conveyor belt addition to handle scalability problems in bigger systems. The article presents examples showing how automated warehouse management allows inventory tracking and order processing together with data documentation. The application produces enhanced predictive maintenance by combining Automation Anywhere and UiPath technology with IoT and AI capabilities in order to provide real-time decision capabilities [7].

The research examines optimal inventory management within hierarchical distribution facilities that handle inventory replenishment under capacity restrictions when demand remains consistent [8]. The demand fulfillment process in large-scale systems requires balancing costs through convex functions with integer constraints among storage efficiency and demand fulfillment [9].

Technology automation optimizes warehouse replenishment through directed acyclic graphs that enhance stock distribution efficiency and also uses automated sorting robots to control inventory. Strategies for order picking implement optimization techniques which combine constant time-windows, delivery planning and deep reinforcement learning for enhancing order batch efficiency. The implementation of integer programming (MIP) shortens picking routes but heuristic and genetic algorithms help optimize batch processes and cut down waiting times between shipments and trucks. The batch processing becomes more cost-efficient through product classification methods that separate foods into dry, fresh, frozen divisions [10].

The use of IoT automation enhances warehouse operation by rearranging inventory locations better and allowing robots to handle inventory management and smartly arrange order pickup routes to minimize movement distances. Multi- storey warehouses benefit from delivery optimization through these implemented methods [11].

2. Methodology

2.1 Praposed methodology Workflow :

A basic illustration of methodology working appears as follows:

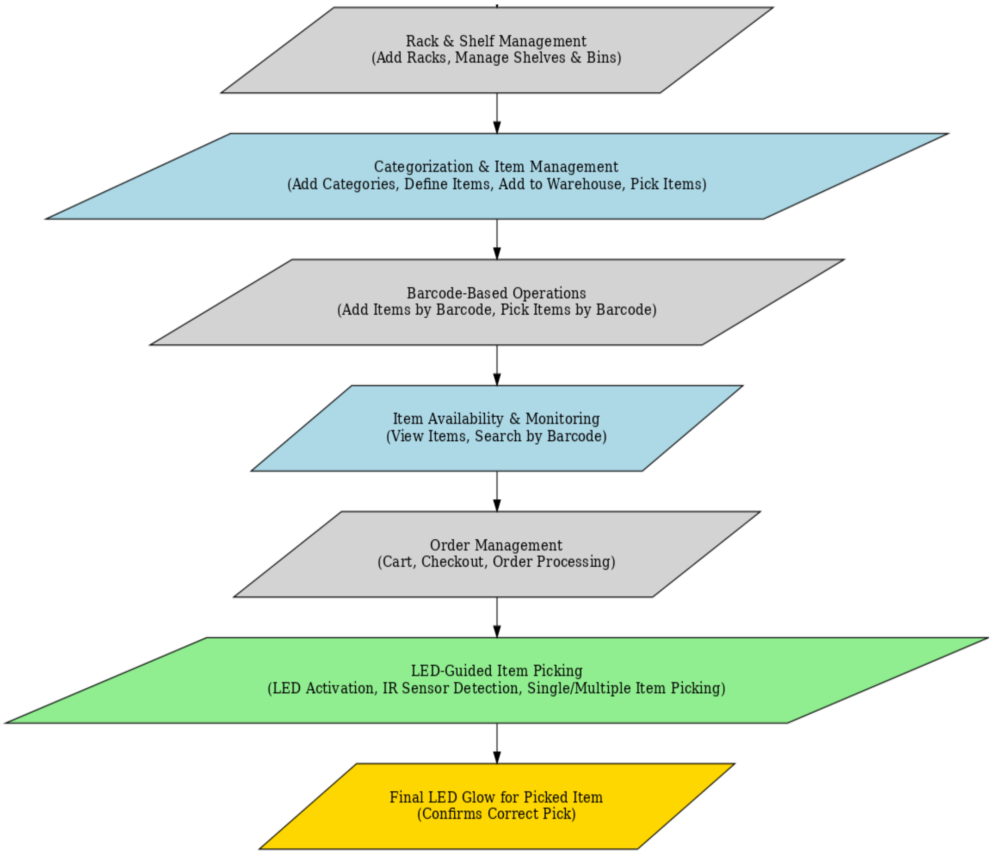


Fig 3.1. Warehouse Management Methodology Workflow

2.1.1 Rack and Shelf Management

The rack and shelf management tool allows users to define rack structure then arrange and control racks located in warehouse areas. This functionality allows users to add new racks as well as check rack availability and organize shelves and bins to create proper item arrangement.

2.1.2 Grouping and Item Management

Grouping capability exists because users can create categories along with subcategories for better effective item management. Items require identification attributes that include their name together with category details and barcodes and storage location. Users who access this system can insert items onto their designated racks and shelves to check the status of item retrieval.

2.1.3 Barcode-Based Operations

Barcode scanning serves to enhance scanning precision along with operational speed. The barcode scanner enables item entry into the warehouse and automated item selection functions through barcode scanning thus lowering human involvement and mistakes.

2.1.4 Item Availability and Monitoring

Users have access to warehouse items through viewing functionality following the addition phase and product selection operations. Real-time inventory tracking benefits from barcode scanning because the system enables users to view items through this method.

2.1.5 Order Management

Users can perform safe authentication through OTP verification when they log in or sign up for the order management system. Users can add products to their cart followed by proceeding to checkout before finishing their order confirmation. Order processing functions correctly and the system includes a responsive add-to-cart button which enhances user experience.

2.1.6 LED-Based Item Picking

Users can easily access items due to the LED-based item picking functionality in the system. When an item needs immediate picking the system highlights the corresponding LED light on a specific bin. Because of its IR sensors the system detects moving objects which results in precise item selection. The system operates under two picking modes that optimize efficiency during item retrieval to shorten the time needed for retrieval operations.

2.2 Warehouse Inventory Dataset

A warehouse requires both an efficient operational method and an efficient tracking system which handles inventory arrangement. This data collection offers complete information about warehouse item placement systems and retrieval protocols in any storage facility. The data set contains essential information about racks and shelves and it includes all necessary details for bins along with inventories and their categories and their quantitative values and barcode identification attributes. The analytical combination of status indicators used/unused with automatic stock availability calculation along with time-stamped transactions will establish both accuracy and operational efficiency. The data collection serves as the foundation for automated warehouse management together with best practices of inventory oversight.

Table 3.2.Warehouse Inventory Dataset

Sr. No	Attribute Used	Attribute Type	Attribute Description
1	rack_id	INT (Primary Key)	Unique identifier for each rack
2	rack_name	VARCHAR(50)	Name of the rack
3	num_shelves	INT	Number of shelves in the rack
4	num_bins	INT	Number of bins in the rack
5	shelf_id	VARCHAR(50) (Primary Key)	Unique identifier for each shelf
6	shelf_number	INT	Shelf number in the rack
7	bin_id	VARCHAR(50) (Primary Key)	Unique identifier for each bin
8	bin_number	INT	Bin number on the shelf
9	status	ENUM('used', 'unused')	Indicates if the bin is occupied (used) or empty (unused)
10	category_id	INT (Primary Key)	Unique identifier for each category
11	category_name	VARCHAR(100)	Name of the category
12	subcategory_id	VARCHAR(50) (Primary Key)	Unique identifier for each subcategory
13	subcategory_name	VARCHAR(255)	Name of the subcategory
14	item_id	INT (Primary Key)	Unique identifier for each item
15	item_name	VARCHAR(100)	Name of the item
16	quantity	INT	Quantity of the item available
17	quantity_unit	VARCHAR(50)	Measurement unit of the quantity (e.g., kg, pcs)
18	barcode_value	VARCHAR(255)	Unique barcode for scanning
19	transaction_id	INT (Primary Key)	Unique identifier for transactions
20	transaction_date	TIMESTAMP	Date and time of transaction
21	order_id	VARCHAR(20) (Primary Key)	Unique order identifier
22	price	DECIMAL(10,2)	Price of the ordered item
23	order_date	DATE	Date when the order was placed
24	order_time	TIME	Time when the order was placed
25	added_quantity	INT	Quantity of items added to inventory
26	picked_quantity	INT	Quantity of items picked from inventory
27	available_quantity	INT (Generated Column)	Available stock calculated as (added - picked)

3.3. Materials and Equipment

3.3.1. Hardware Components

We employed Arduino IDE to regulate both LEDs and sensors. Item retrieval in the warehouse depended on LEDs attached to bins coupled with infrared sensors which updated product inventory information. The USB barcode scanner operated through the database to receive item details and update information. The ESP32 module served as the wireless communication solution that worked alongside the MySQL database which ran on the MySQL server.

3.3.2. Software Modules

Programming of microcontrollers happened through the Arduino IDE interface. The API of the barcode scanner collected data before adding it to the existing database content.

The custom warehouse management software operated as the control system for inventory management and picking activities. Real-time data synchronization occurred through the use of the DBMS. Through its graphic user interface the staff gained access to all operations while communication protocols were also available.

3.4 Data Analysis Methods :

3.4.1Order Picking Time (OPT) Calculation

The duration it takes to fulfill orders represents a determining component for warehouse operations since it determines order delivery speed. The algorithm to find order picking time for the automated system works through this calculation:

$$\mathbf{OPT=Ts+(N\times Tp)+Tm}$$

Where:

The setup time Ts marks the beginning of order picking operational start time. The parameter Tp stands for the duration required for selecting one single item.
The period Tm represents the time required for workers to travel from one location to another in the warehouse area.
The formula enables workforce optimization together with LED-guided navigation to reduce order fulfilment duration.

3.4.2 Real-Time Inventory Update

Real-time inventory tracking requires accurate monitoring of warehouse stock levels which the system maintains in an instant fashion. This mathematical equation preserves consistently accurate warehouse inventories.

$$\mathbf{St=St-1-O+I}$$

Where:

The current stock quantity designated as St exists at time t.
The existing inventory quantity before time t can be represented by St−1. The number of warehouse items which will leave counts alongside I as O.
The variable I indicates the quantity of items that return for both restocking and incoming restock.
The system monitors inventory levels because it uses barcode scanning for automatic updates to track items during pick and restock operations leading to better warehouse stock management.

3.4.3Pick Accuracy Rate (PAR)

The automated picking system accuracy evaluation relied on the Pick Accuracy Rate (PAR) to determine correct item selection statistics. The calculation method to determine these results uses this specific equation.

$$\mathbf{PAR=(CT)\times100}$$

Where:

The formula determines the total number of accurate items with C as a variable among T items picked.
The total items loaded under the variable T determine the value of predicted accuracy rates.
The system’s combination of IR sensors with LED guidance leads to a better PAR rating that indicates less error during picking operations. The accuracy of orders and the frequency of errors during picking both improve because of these system features.

3.4.4 Efficiency Improvement (Time Savings Percentage, TSP)

Time Savings Percentage (TSP) serves as the tool to determine the duration reduction from warehouse automation. The automated system reveals the length of time required before and after its installation.

$$\mathbf{TSP=(Tb-TaTb)\times10}$$

Where:

The variable Tb represents the prior tasks' completion duration and Ta represents the duration following automation implementation.
The time duration used to perform identical functions when automation launches becomes Ta.
The formula delivers insights about time savings from automated technologies therefore showing improved warehouse system productivity and efficiency.

3 Implementation diagram :

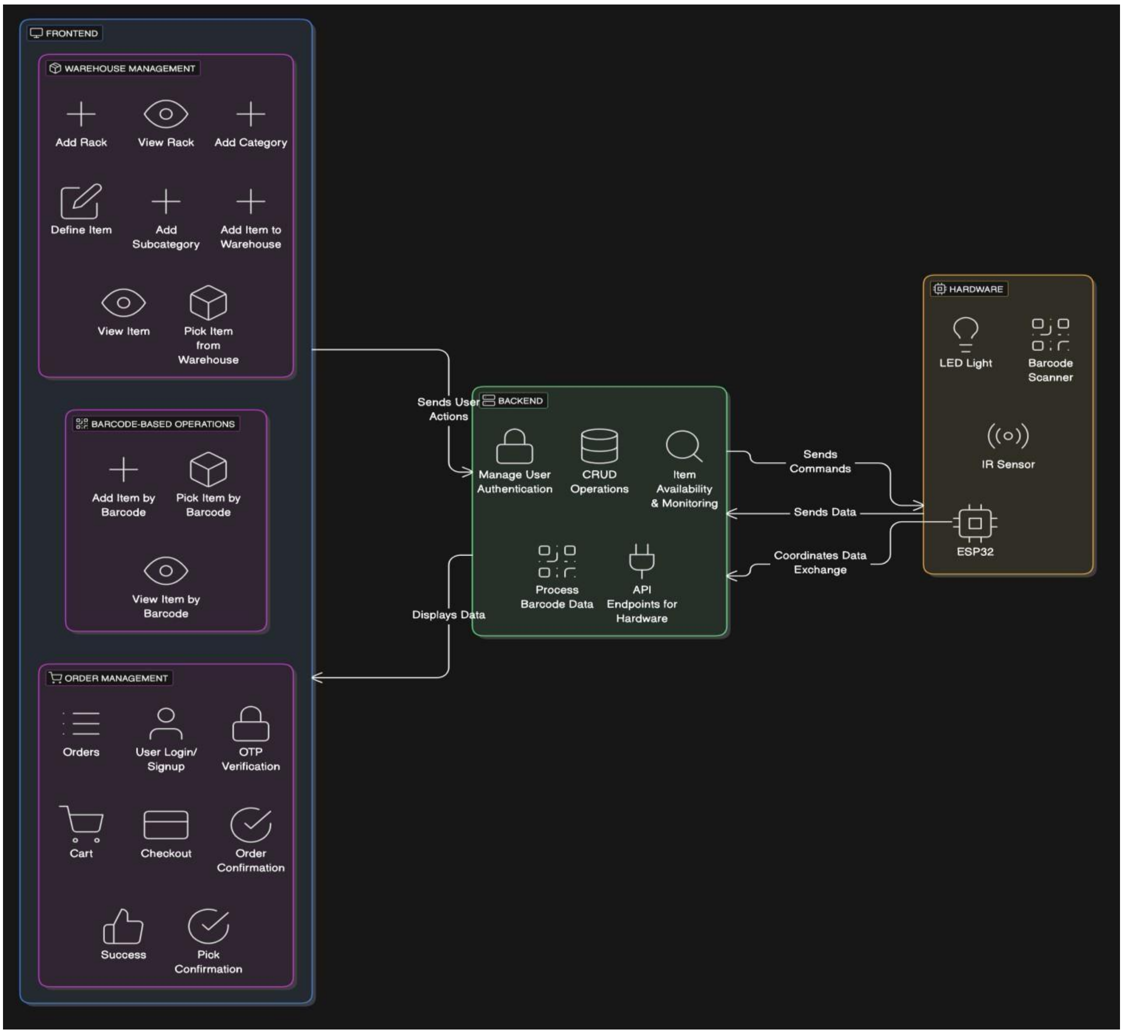


Fig.4.1 Warehouse Management System implementation

Warehouse Management System Overview

A single WMS integrates elements from frontend (UI) and backend (Node.js + SQL) and hardware elements (barcode scanners and LEDs and IR sensors) to enhance warehouse optimization. Through its user-friendly interface users can handle racks shelves items and orders in an optimized manner.

4.1 Frontend (UI) Functionality

The system interface provides easy access to warehouse employees who need to manage rack systems and shelves and assign item categories. The use of barcodes improves overall accuracy in both adding items and selecting them for picking and recording their locations. Users authenticate through OTP while they monitor orders and check selected items using the system.

4.1 Backend (Node.js + SQL) Architecture

The Node.js system operates as the server component while SQL functions as the storing database system. The authentication system uses OTP verification to maintain user security. The rack system benefits from CRUD functions that ensure quick and effective management operations for racks shelves and items. Things are handled in the backend which processes barcode details, oversees order handling and establishes API connections for hardware devices.

4.2 Connection Between Frontend, Backend, and Hardware

User-initiated actions which include login authentication and cart modifications along with object handling are processed by the backend system. The system connects to barcode readers and IR sensors and LEDs which serve for item verification and guided picking operations. The ESP-32 system regulates LED communication to deliver both accurate tracking and instant warehouse monitoring.

4 Result and Discussion:

5.1Real-Time Inventory Updates

Database triggers monitor stock management by automatically updating the available_quantity column through the subtraction method between added_quantity and picked_quantity values. The inventory analysis reveals that "Vatika" maintains 13 units in stock but "Dining Table" features only one unit therefore requiring urgent replacement.
Monitoring stock movement remains essential because transactions take place at different dates. The inventory data appears in a heatmap visualization for easier understanding.

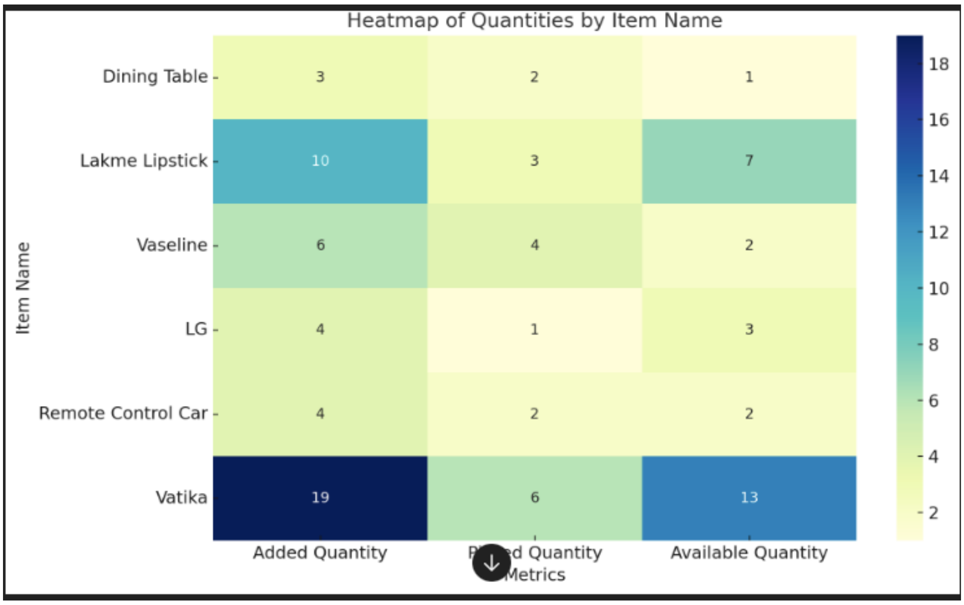


Fig.5.1 Heatmap of Quantities by Item Name

4.1.Efficient Barcode-Based Item Management

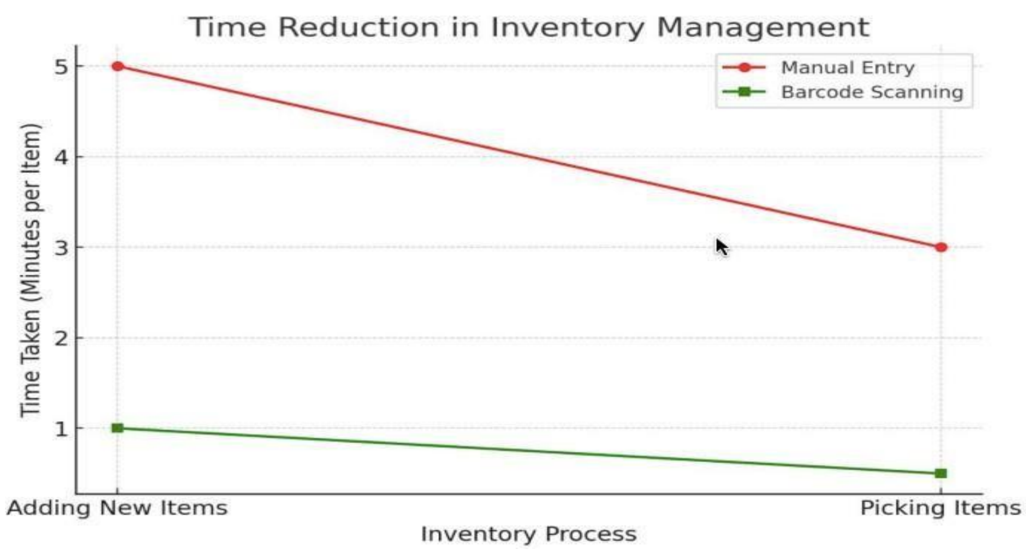
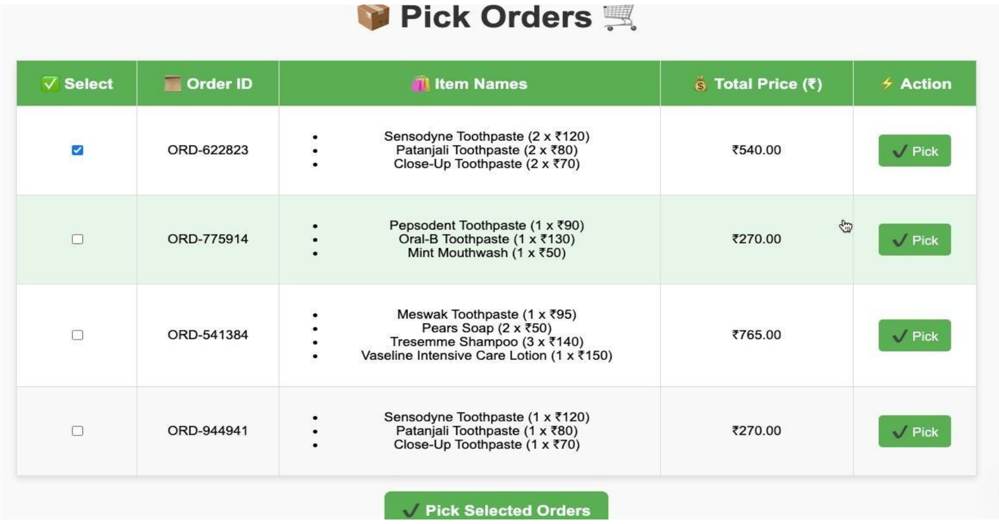


Fig 5.2 Reduction in Inventory Management

The line graph illustrates rapid time cuts in inventory management after barcode implementations because new item entries decreased from five minutes to one minute while picking time trimmed down to thirty seconds per piece. The system's upgraded performance emerges from decreased operational times which both speed up order processing and raise total efficiency along with inventory turnover capability.

4.2.Multi-Item Picking with Real-Time Updates



Pick Orders

Select	Order ID	Item Names	Total Price (₹)	Action
☑	ORD-622823	• Sensodyne Toothpaste (2 x ₹120) • Patanjali Toothpaste (2 x ₹80) • Close-Up Toothpaste (2 x ₹70)	₹540.00	✓ Pick
☐	ORD-775914	• Pepsodent Toothpaste (1 x ₹90) • Oral-B Toothpaste (1 x ₹130) • Mint Mouthwash (1 x ₹50)	₹270.00	✓ Pick
☐	ORD-541384	• Meswak Toothpaste (1 x ₹95) • Pears Soap (2 x ₹50) • Tresemme Shampoo (3 x ₹140) • Vaseline Intensive Care Lotion (1 x ₹150)	₹765.00	✓ Pick
☐	ORD-944941	• Sensodyne Toothpaste (1 x ₹120) • Patanjali Toothpaste (1 x ₹80) • Close-Up Toothpaste (1 x ₹70)	₹270.00	✓ Pick

✓ Pick Selected Orders

Fig 5.3 Multi-item picking webpage

The Pick Orders interface streamlines order processing by allowing users to select single or multiple orders, displaying details like Order ID, item quantities, and total price. Clicking the "Pick selected Orders" button activates LEDs at storage locations, ensuring accurate and faster item selection. This system enhances efficiency, minimizes search time, and reduces order fulfillment errors.

4.3. LED-Guided Picking for Improved Accuracy

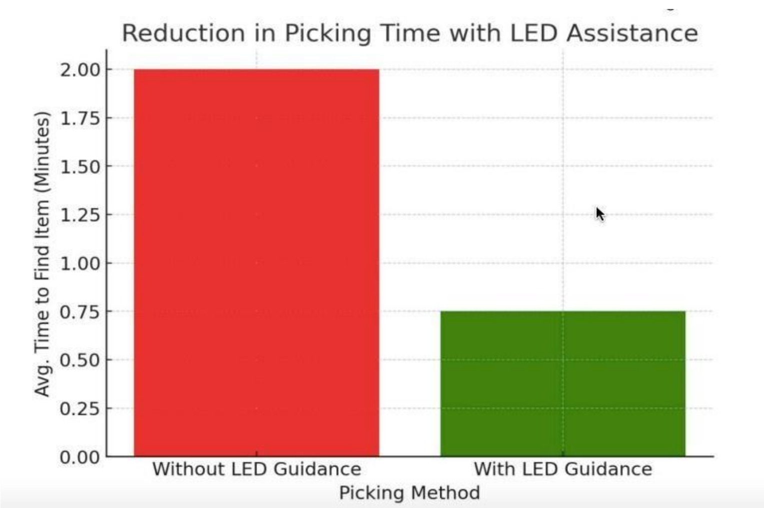


Fig 5.4 Reduction in Picking time with LED assistace

The LED-Assisted Picking system enhances item retrieval both in speed and precision thus improving warehouse operational efficiency by reducing mistakes. The item search duration decreases to 45 seconds from 2 minutes while order fulfillment times drop by 65%. The system enables real-time data management with barcode readers and LED indicators for improved eCommerce logistics control which leads to lower operational expenses.

5 Future Scope

Warehouse management will eventually develop highly efficient smart systems that execute rapidly with improved operations. Integration between AI and IoT enables firms to monitor inventory in real time operations while creating accurate demand projections to avoid stockouts or overstockage problems. The procedure of facility management becomes simpler because the cloud-based system allows access to perform processes from every location. AR allows picking workers to perform tasks at superior levels that yield exceptional performance results. Other products together with energy-saving lights help decrease power consumption levels. Multifunctional power monitoring systems help decrease warehouse power usage through self-generated power systems that boost warehouse sustainability capabilities. The efficient and economic structure of the smart warehouse design remains in place.

6 Conclusion

A well-organized supply chain system leads to improved order handling processes while accelerating business expansion in e-commerce operations. The system utilizes current inventory monitoring while automation executes retrieval procedures and LED-steered product picking which grants faster speeds and more precise results through barcode scanners and infrared sensors. The implementation of structured storage provides instant system updates that reduces operational mistakes while cutting down costs. The automation system improves customer service by boosting team performance and making it simpler to hire new employees. The system achieves efficiency and scalability alongside sustainability because it promotes minimal human involvement.

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