Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation

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***Abstract*—The continuous growth of industrial manufacturing and e-commerce sectors has created a strong demand for efficient, accurate, and automated packaging and sorting systems. Conventional manual sorting methods are often slow, labour-intensive, and susceptible to human errors, leading to reduced operational efficiency and increased processing time. To address these challenges, the proposed "Intelligent Packaging and Sorting System Using Sensor Triggered Barcode Automation" introduces an advanced automation framework integrating sensors, barcode technology, Programmable Logic Controller (PLC), Human Machine Interface (HMI), and conveyor mechanisms. The developed system automatically detects packages, generates and scans barcodes, and performs intelligent sorting operations with improved speed, accuracy, and reliability. The PLC functions as the central control unit for managing conveyor movement and sorting operations, while the HMI enables real-time monitoring, system control, and operator interaction. The proposed automation system reduces manual intervention, minimizes sorting errors, improves package traceability, and enhances overall operational efficiency. Furthermore, the system supports sustainable industrial practices by optimizing resource utilization and reducing process delays. The developed model is cost effective, scalable, and well suited for small and medium scale industrial and logistics applications.**

***Index Terms*—Intelligent Packaging System, Barcode Automation, QR Code Technology, Conveyor Automation, Industrial Automation, Package Sorting System, Barcode Scanner, Thermal Printer, PLC Automation, HMI Monitoring**

I. INTRODUCTION

In modern logistics and manufacturing industries, the demand for fast, accurate, and reliable package handling has increased significantly. Traditional manual sorting methods are often time-consuming, labor-intensive, and prone to human errors, especially when handling large quantities of products. These limitations can lead to delays, incorrect deliveries, and reduced operational efficiency. To address these challenges, industries are gradually shifting toward intelligent automation systems that enhance speed, precision, and traceability in packaging and sorting processes.

The proposed project, titled "Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation," presents an efficient and practical approach for automating package identification and sorting operations. The system combines sensor technology, barcode generation, barcode scanning, and conveyor-based movement to create a streamlined and reliable workflow. When a package enters the system, sensors detect its presence and trigger the generation of a barcode containing essential product information. This barcode is then attached to the package for identification and tracking purposes.

As the package moves along the conveyor belt, a barcode scanner reads the encoded information in real time. Based on predefined sorting parameters, the system automatically directs the package to its designated location. This process ensures accurate sorting while reducing the dependency on continuous manual supervision. The integration of automation with limited human interaction makes the system both flexible and suitable for small- and medium-scale industrial applications.

Furthermore, the proposed system contributes to improved productivity by minimizing sorting errors, reducing labor requirements, and optimizing time management. It also supports sustainable industrial practices by reducing resource wastage and improving process efficiency. The use of simple yet effective automation technologies make this system cost-effective, scalable, and practical for real-world implementation. This research highlights how sensor-triggered barcode automation can serve as a smart solution for modern packaging and sorting

II. LITERATURE REVIEW

In recent years, industrial automation and smart logistics systems have gained significant attention due to the increasing demand for efficiency, accuracy, and real-time tracking in manufacturing and supply chain operations. Barcode-based tracking systems have emerged as reliable and cost-effective solutions for product identification, monitoring, and automated package handling [1], [2].

Istiqomah et al. (2020) implemented barcode technology in Warehouse Management Systems (WMS) to improve warehouse efficiency and inventory tracking accuracy [1], [5]. Their study demonstrated that barcode integration significantly improves operational reliability, minimizes manual errors, and enhances inventory management efficiency in logistics applications.

Kubáňová et al. (2022) studied the implementation of barcode technology in logistics activities during the COVID-19 pandemic [2], [6]. Their work highlighted the importance of automated identification systems in achieving real-time package tracking, reducing human intervention, and improving logistics performance under dynamic operational conditions.

Santhosh Kumar et al. (2024) presented a literature survey on automated barcode-based warehouse sorting systems [3]. Their research emphasized the importance of conveyor automation, barcode scanners, and industrial controllers in reducing operational errors and improving warehouse productivity.

Singh et al. (2019) proposed an Arduino-based automated package sorting system using barcode scanning technology [4]. The system provided a low-cost automation solution for small-scale package identification and sorting applications. However, the use of microcontroller-based control systems limited its industrial scalability and robustness when compared with PLC-based industrial automation systems.

Patil et al. (2019) developed a barcode-based package sortation and robotic pick-and-place system [11]. Their work demonstrated the integration of barcode recognition with robotic automation for intelligent package handling applications. The proposed system improved package sorting efficiency and reduced manual handling requirements.

Sharma et al. (2021) proposed an automatic sorting machine based on barcode technology [12]. Their system focused on improving sorting accuracy and automation in industrial conveyor systems. The research highlighted the advantages of barcode scanners in achieving fast and reliable package identification during sorting operations.

Yadav et al. (2024) developed an automated inventory sorting system using IR and color sensors [14]. Their research demonstrated the use of sensor-based automation for object detection and sorting applications. The integration of sensors improved system responsiveness and reduced dependency on manual operations.

OPEX Corporation (2025) discussed the role of automated sorting systems in reducing operational errors and improving logistics accuracy [13]. Their industrial study emphasized that automated package handling systems significantly improve throughput, reduce misrouting, and enhance overall logistics efficiency.

Apart from barcode-based systems, several researchers have contributed to the broader field of industrial automation and Industry 4.0 technologies.

Lee et al. (2015) proposed a cyber-physical systems architecture for Industry 4.0 manufacturing environments [8]. Their work explained the integration of intelligent automation, real-time communication, and industrial monitoring systems in smart factories.

Monostori (2014) discussed the foundations and challenges of cyber-physical production systems [9]. The study highlighted the importance of intelligent control systems, automation technologies, and real-time industrial data processing in modern manufacturing environments.

Wang et al. (2016) presented an overview of smart factory implementation in Industry 4.0 [10]. Their work emphasized automation integration, intelligent monitoring, and data-driven industrial operations for achieving efficient and flexible manufacturing systems.

Chen Hongjun et al. (2012) proposed a power management system for a small-size solar-electric vehicle [7]. Although focused on energy management, their research demonstrated the importance of embedded control systems, real-time monitoring, and automation principles that are also applicable in industrial package tracking and sorting applications.

Most of the existing academic and prototype systems focus only on individual modules such as barcode scanning, conveyor control, or HMI monitoring. Very few systems provide complete integration of barcode generation, barcode scanning, PLC automation, conveyor control, sensor-triggered operation, and database logging within a single framework. Furthermore, many low-cost systems rely on Arduino or Raspberry Pi controllers instead of industrial-grade PLCs, which limits their applicability in real industrial environments.

III. METHODOLOGY

A. Block Diagram

Figure 1 illustrates the working principle of the proposed “Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation.” The system integrates barcode generation, conveyor automation, barcode scanning, and product sorting into a single automated framework for efficient industrial package handling.

Initially, barcode information is generated using dedicated barcode generation software installed on a computer system. The generated barcode contains important product details such as product ID, manufacturing information, destination location, or package number. This barcode data is then sent to a thermal printer for printing high-quality barcode labels. The thermal printer prints the barcode label, which is manually attached to the package or box. The labeled package is then placed on the conveyor system for automated movement through the sorting process. The conveyor system helps maintain continuous package flow and reduces manual transportation effort inside the industrial environment.

As the package moves along the conveyor, the barcode scanner reads the barcode attached to the package. The scanner captures the encoded information and transfers the scanned data to the computer or PLC-based monitoring system for further processing and verification. The scanned information is simultaneously stored in the system database for tracking and monitoring purposes.

After successful barcode identification and data acquisition, the system performs product sorting based on predefined sorting conditions. The packages are directed toward different output sections depending on their barcode information such as product category, delivery zone, or package type. This automated sorting process improves accuracy, reduces manual errors, and increases industrial productivity.

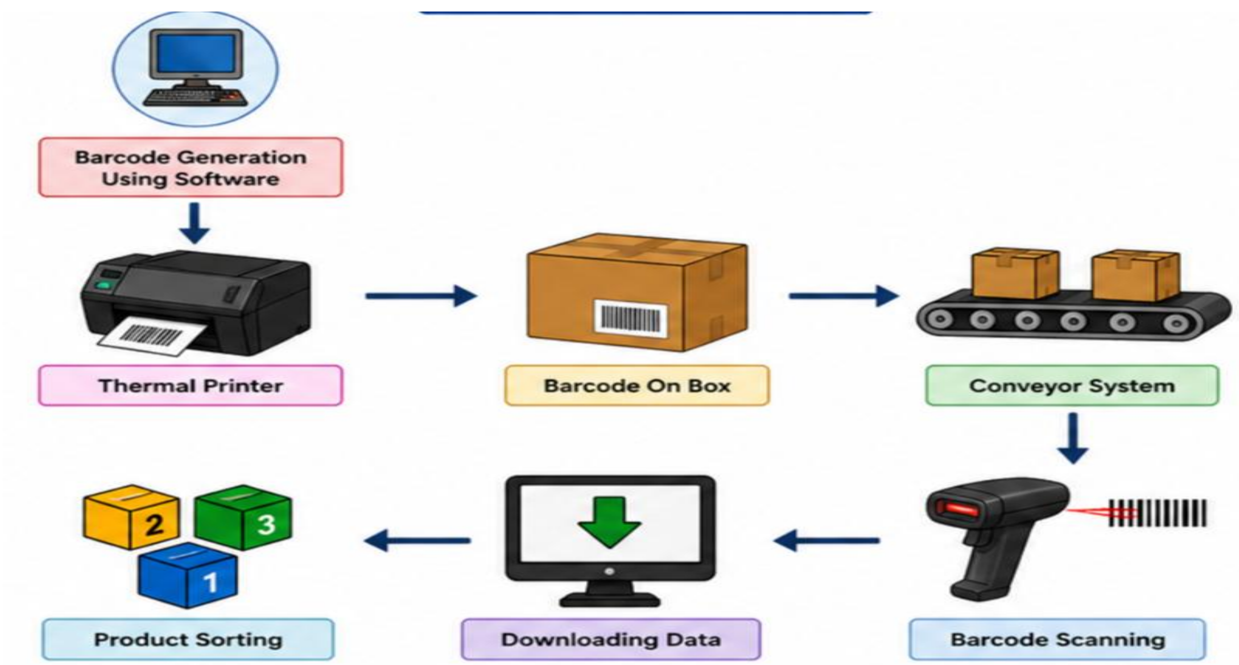

Figure 1. Block Diagram

The proposed block diagram demonstrates the integration of barcode technology, conveyor automation, thermal printing, and intelligent sorting mechanisms for developing a cost-effective and reliable industrial automation system. Similar barcode-based warehouse and package sorting systems have been discussed in previous research works for improving logistics efficiency and automated material handling [1]-[4].

B. Working Principle

The working principle of the proposed "Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation" is based on automatic package identification, barcode scanning, data processing, and intelligent sorting using conveyor automation and barcode technology.

Initially, the operator enters product details into the barcode generation software installed on the computer system. The software generates a unique barcode containing important package information such as product ID, manufacturing date, destination location, or package category. This barcode is printed using a thermal printer and attached to the package manually. After barcode labeling, the package is placed on the conveyor system. The conveyor motor moves the package continuously from one stage to another inside the system. The conveyor mechanism reduces manual transportation effort and ensures smooth package movement. As the package reaches the scanning section, the barcode scanner detects and reads the barcode attached to the package. The scanner converts the barcode into digital data and transfers the information to the control system or database through serial communication or USB interface. The received barcode data is processed by the PLC or computer system for identification and verification. Based on predefined sorting conditions stored in the program, the system determines the correct destination for the package. The sorting criteria may include package type, product category, storage location, or delivery area. After processing the barcode information, the package is automatically directed toward the required sorting section. The sorting operation can be performed using diverters, actuators, or manual collection bins depending on system configuration. Simultaneously, the scanned package information is stored in the database for future tracking, monitoring, and inventory management purposes. This improves product traceability and reduces chances of package misplacement.

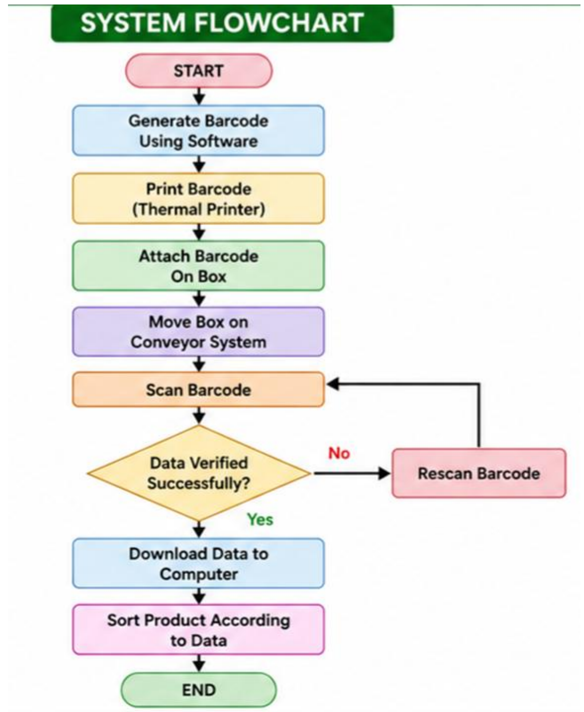

Figure 2. Flowchart

The Human Machine Interface (HMI) is used to provide easy interaction between the operator and the automation system. Through the HMI screen, the operator can generate a new barcode, start or stop the conveyor, monitor barcode numbers, and observe the real-time status of the system. The HMI communicates directly with the PLC using internal communication registers, ensuring smooth coordination between human commands and machine operations. This improves user convenience and reduces the complexity of direct PLC programming for operators.

When the package reaches the end of the conveyor line, a barcode scanner reads the barcode attached to the package. The scanner captures the encoded information and sends it to the connected PC software through serial communication or USB interface. The PC software then stores the scanned barcode information along with the exact date and time of scanning in a centralized database. This process helps in maintaining accurate records, improving traceability, and reducing dependency on manual data entry. It also allows future tracking of products whenever required.

Based on the scanned barcode information, the system identifies the correct sorting destination of the package. Depending on the project scale, sorting can be performed either manually by the operator or automatically using actuators such as pneumatic systems, diverters, or mechanical pushers. In this project, the focus is mainly on achieving reliable identification and controlled sorting with educational and practical implementation in mind.

The operational sequence starts when the operator presses the "Generate Barcode" button on the HMI screen. This command is transferred to the PLC, where a counter register (for example, D100) is incremented to generate the next unique barcode number. The updated barcode value is then displayed on the HMI for operator verification. After this, the barcode is printed and attached to the package manually. The operator then starts the conveyor using the HMI, and the PLC activates the conveyor motor to move the package forward. At the final stage, the barcode scanner reads the barcode, and the PC software records the complete information along with a timestamp for future reference and sorting operations.

This methodology provides a practical and cost-effective solution for intelligent packaging and sorting applications. It successfully combines automation with controlled human supervision, making it highly suitable for small- and medium-scale industries as well as educational demonstrations. The system improves speed, reduces human error, increases process transparency, and supports better inventory and logistics management.

IV. MATHEMATICAL MODELLING

The mathematical modelling of the proposed "Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation" is based on conveyor motion, package detection, barcode scanning efficiency, sorting accuracy, and system throughput. The mathematical analysis helps in evaluating system performance, operational speed, and sorting reliability.

1. Conveyor Speed Calculation

The conveyor system is responsible for moving packages from the input section to the barcode scanning and sorting sections. The conveyor speed is calculated as:

$$V_c = \frac{D}{t}$$

Where:

- V_c= Conveyor speed (m/s)
- D= Distance travelled by package (m)
- t= Time taken by package (s)

This equation determines the speed of package transportation inside the conveyor system.

2. Package Detection Function

The proximity sensor detects the presence of the package and generates a trigger signal for initiating the automation process. The sensor output can be represented as:

$$S(t) = \begin{cases} 1, & \text{Package Detected} \\ 0, & \text{No Package} \end{cases}$$

Where:

- $S(t) = 1$indicates package detection
- $S(t) = 0$indicates absence of package

This binary sensing operation is used for automatic triggering of barcode generation and conveyor control.

3. Barcode Scanning Efficiency

The efficiency of the barcode scanner is calculated as:

$$\eta_b = \frac{N_b}{N_t} \times 100$$

Where:

- η_b= Barcode scanning efficiency (%)
- N_b= Number of correctly scanned packages
- N_t= Total number of packages processed

Higher scanning efficiency indicates reliable barcode recognition and reduced scanning errors.

4. Sorting Accuracy

Sorting accuracy determines the effectiveness of the automated sorting mechanism.

$$\eta_s = \frac{N_s}{N_t} \times 100$$

Where:

- η_s= Sorting accuracy (%)
- N_s= Number of correctly sorted packages
- N_t= Total packages processed

The proposed system aims to maximize sorting accuracy while minimizing package misrouting.

5. Processing Rate

Processing rate represents the number of packages processed within a specific time interval.

$$T = \frac{N}{t}$$

Where:

- T= Processing rate (packages/minute)
- N= Total number of processed packages
- t= Processing time

Higher throughput indicates better industrial productivity and faster package handling capability.

6. Conveyor Motor Power

The electrical power consumed by the conveyor motor is calculated using:

$$P = VI$$

Where:

- P= Motor power (W)
- V= Supply voltage (V)
- I= Motor current (A)

This equation helps in determining the power requirement of the conveyor drive system.

7. Overall System Efficiency

The overall efficiency of the proposed automation system can be represented as:

$$\eta_o = \frac{N_c}{N_t} \times 100$$

Where:

- η_o= Overall system efficiency (%)
- N_c= Number of successfully completed operations
- N_t= Total operations performed

This parameter evaluates the combined performance of barcode scanning, conveyor movement, sensing, and sorting operations.

V. HARDWARE SETUP

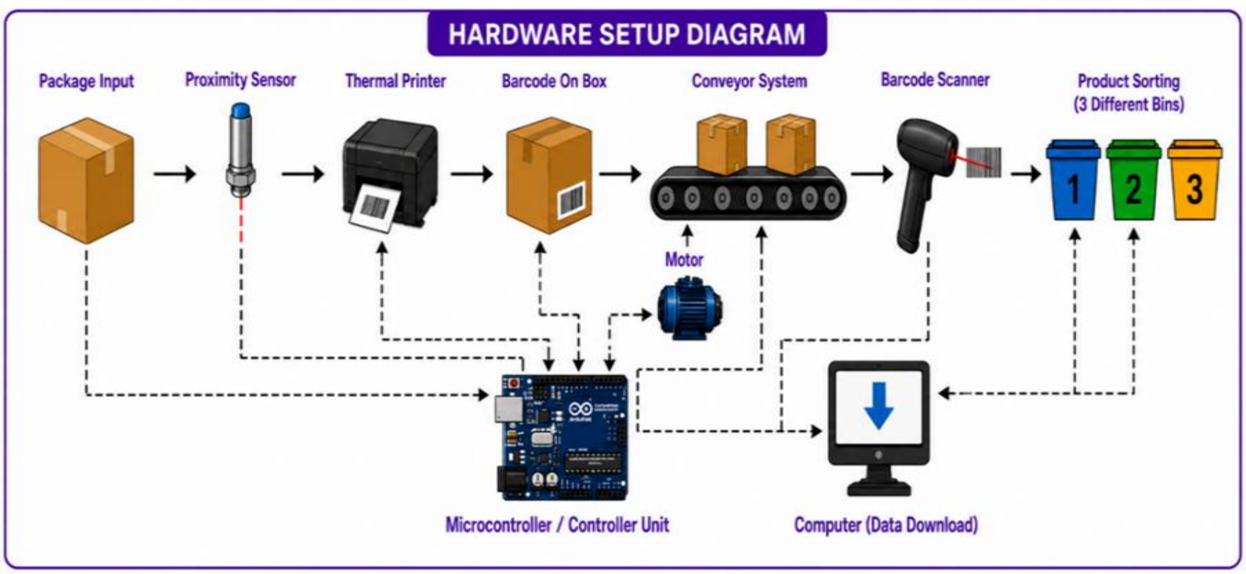

Figure 3. Hardware Setup Diagram

Figure 3 shows the hardware setup diagram of the proposed "Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation." The system consists of different hardware components such as proximity sensor, thermal printer, conveyor system, barcode scanner, controller unit, motor drive, computer system, and sorting bins. These components work together to achieve automatic package identification, barcode scanning, and intelligent product sorting. Initially, the package or product is placed at the input section of the system. A proximity sensor is installed near the input side to detect the presence of the package. When the package is detected, the sensor sends a signal to the microcontroller or controller unit. This signal initiates the barcode generation and package handling process. The thermal printer is connected to the controller system for barcode printing. After receiving the trigger signal, the barcode information generated through software is printed on a barcode label. The printed barcode is attached to the package for identification and tracking purposes. After barcode labeling, the package is transferred onto the conveyor system. The conveyor is driven by an electric motor controlled through the controller unit. The conveyor continuously moves the package toward the barcode scanning section. The controller unit synchronizes conveyor movement and package flow for smooth operation.

At the scanning section, the barcode scanner reads the barcode attached to the package. The scanner converts the barcode into digital information and sends the data to the controller unit and computer system. The computer stores the scanned data for monitoring, tracking, and database management purposes.

The microcontroller or controller unit acts as the central processing unit of the entire system. It receives input signals from the proximity sensor and barcode scanner, controls the thermal printer and conveyor motor, and manages the sorting operation based on barcode information. After barcode identification, the system performs product sorting. According to the barcode data and predefined sorting logic, the package is directed into one of the three different sorting bins. Each bin represents a particular product category, destination area, or package type.

The hardware setup provides coordinated operation between sensing devices, barcode technology, conveyor automation, and control systems. The integration of these components improves sorting accuracy, reduces manual handling, increases operational speed, and provides a cost-effective industrial automation solution suitable for logistics, warehouse management, and packaging industries.

VI. RESULTS AND DISCUSSION

The proposed Intelligent Packaging and Sorting System using Sensor-Triggered Barcode Automation was successfully implemented and tested for package identification, tracking, and sorting applications. The developed system demonstrated reliable operation in barcode generation, barcode scanning, real-time data acquisition, and product sorting processes.

Figure 4 shows the sample output of the developed parcel shipping label generated by the system. The generated label contains important shipment information such as receiver details, sender details, order information, package type, tracking ID, payment mode, and expected delivery date. The generated shipping label also includes a QR code for fast digital identification and data retrieval.

The shipping label is divided into multiple sections for systematic data organization:

- Receiver details section contains customer name, contact number, and delivery address.
- Sender details section includes organization name, address, and contact information.
- Order information section provides order ID, tracking ID, package type, payment mode, and expected delivery date.
- QR code section stores encoded parcel information for automatic scanning and digital verification.
- The generated QR code improves package traceability and supports fast access to shipment data during logistics and transportation operations. Compared with conventional manual labelling systems, the proposed QR-based identification system reduces data entry errors and improves package handling efficiency.

Figure 4. Sample Parcel Shipping Label Generated by the Proposed System

Figure 4.A QR Code

Figure 4.A represents the QR code generated by the proposed system for parcel identification and tracking. The QR code stores all parcel-related information in

encoded digital format. When scanned using the barcode scanner or mobile device, the QR code retrieves complete package information instantly.

The QR code provides several advantages:
- Fast package identification
- Contactless information retrieval
- Improved tracking accuracy
- Reduced manual data entry
- Better inventory and logistics management
- Secure and reliable package monitoring

The developed QR code-based parcel management system demonstrated high readability and reliable scanning performance during experimental testing. The barcode scanner successfully decoded package information in real time and transferred the data to the computer system for monitoring and database storage. The integration of QR code technology with conveyor automation and intelligent sorting significantly improved operational efficiency. The proposed system reduced manual sorting errors, minimized package misrouting, and improved package tracking accuracy in comparison with conventional manual sorting methods. The experimental results confirmed that the proposed system is suitable for warehouse management, courier services, logistics industries, educational institutions, and industrial package handling applications. The developed system provides a practical, low-cost, and scalable automation solution for modern smart logistics environments.
Table 1 presents the comparison between the conventional manual sorting system and the proposed Intelligent Packaging and Sorting System using Sensor-Triggered Barcode Automation. The comparison is based on important operational parameters such as sorting accuracy, processing time, human effort, tracking capability, and sorting errors.

Table 1: Comparative Analysis of Manual and Automated Sorting Systems

Parameter	Manual System	Proposed System
Sorting Accuracy	82%	96%
Processing Time	High	Low
Human Effort	High	Reduced
Tracking Capability	Limited	Real-Time
Sorting Errors	More	Less
Package Identification	Manual	Automatic QR/Barcode Based
Operational Efficiency	Moderate	High
Data Recording	Manual Entry	Automatic Database Logging
System Reliability	Moderate	High
Package Traceability	Limited	Improved

VII. CONCLUSION

The proposed “Intelligent Packaging and Sorting System Using Sensor-Triggered Barcode Automation” successfully demonstrates an efficient and reliable solution for modern industrial package handling and sorting applications. The integration of barcode technology, proximity sensors, conveyor automation, thermal printing, and intelligent control systems significantly improves package identification, tracking, and sorting operations.
The developed system effectively automates the complete workflow starting from barcode generation and package labelling to barcode scanning, data processing, and final product sorting. The use of QR code and barcode technology enables fast and accurate retrieval of package information, thereby reducing manual errors and improving operational efficiency.
The conveyor-based automated movement system ensures smooth package transportation while the controller unit coordinates sensor inputs, scanning operations, and sorting logic. Real-time data monitoring and database storage improve traceability, inventory management, and logistics control.
Experimental results show that the proposed system reduces manual labour, minimizes package misrouting, increases sorting accuracy, and improves overall productivity when compared with conventional manual sorting methods. The generated parcel shipping label and QR code system also provide secure and reliable package tracking capabilities for logistics and warehouse applications.
The proposed model offers a cost-effective, scalable, and practical industrial automation solution suitable for courier services, warehouses, e-commerce logistics, manufacturing industries, and educational automation laboratories. The system also supports

smart industrial practices by improving process efficiency and reducing operational delays.

Future enhancements may include:

- RFID-based package tracking
- IoT-enabled cloud monitoring
- AI-based intelligent sorting algorithms
- Robotic pick-and-place integration
- Mobile application-based package monitoring
- Fully automatic industrial sorting mechanisms

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