BIS ENERGY AND ENGINEERING

Volume 3 2026 | DOI: 10.31603/biseeng.585
7th Borobudur International Symposium on Science and Technology (BIS-STE) 2025

UNIMMA PRESS
UNIVERSITAS MUHAMMADIYAH MAGELANG

Development of a digital green kanban system for the finished goods warehouse in the snack food industry

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Abstract

In the Industry 4.0 era, increasing the efficiency and speed of information flow is a crucial factor in maintaining the competitiveness of manufacturing companies, particularly in the snack food industry, which is characterized by large-scale, repetitive production and high volumes of finished goods. These characteristics pose significant challenges in maintaining the accuracy of shipped goods. One concept commonly applied to improve the efficiency and accuracy of the shipping process is the kanban system, as part of the lean manufacturing philosophy. However, the conventional kanban system still results in various inefficiencies, including data recording errors, excessive paper usage, and the misplacement of finished goods during shipping, which caused company losses amounting to IDR 357,508,500.00 between February and March 2025. This study employed a Research and Development (R&D) approach to design a Digital Green Kanban System framework integrated with an Enterprise Resource Planning (ERP) system. The research stages included needs analysis, mapping of material and information flows, and production flow design, resulting in a computer-network-based Digital Green Kanban System framework. Data were collected through observations of the production process, interviews with operators and logistics staff, and analysis of historical shipping data. The design results indicate that the proposed Digital Green Kanban System framework can support kanban lot-size control, production instruction scheduling, and direct data integration with the ERP system. The framework also improves information flow and traceability of finished goods, potentially reducing the risk of shipping errors. The main contribution of this research is the development of a Digital Green Kanban System framework specifically designed for internal production systems operating on a dedicated production line, serving as a strategic step toward process digitization and enhanced operational efficiency.

Published:
May 04, 2026

Selection and Peer-review under the responsibility of the 7th BIS-STE 2025 Committee

Keywords

Digital kanban, Green manufacturing, Lean production, Warehouse management

Introduction

The manufacturing sector plays a pivotal role in Indonesia's economic growth, with the food and beverage industry consistently demonstrating resilient and positive performance [1]. This sector is characterized by high product variety, strict quality requirements, and complex distribution processes, particularly for fast-moving consumer goods such as biscuits [2]. As production volumes increase and product variants expand, distribution accuracy at the finished goods stage becomes a critical operational concern [3]. Errors in outbound logistics such as product mix-ups and quantity discrepancies can undermine service levels, increase operational costs, and negatively affect customer trust [4]. Consequently, improving the reliability of finished goods delivery has become an important issue receiving growing attention from both practitioners and researchers ship [5]. Operational evidence of shipment inaccuracies observed in this study is summarized in Table 1 highlighting the persistence of delivery errors in high-volume distribution activities.

Table 1. Exchanged Product Data

Total Shipments (Cartons)	Exchanged Products	Percentage %	Total Shipments (Cars)	Exchanged Products	Percentage %
3.136.471	1473	0.05%	2.982	10	0.3%

Previous studies and industrial practices have sought to address distribution and warehouse errors through various approaches, including standard operating procedures, visual management tools, barcode systems, and conventional kanban implementations [6]. Among these approaches, kanban has long been recognized as an effective lean manufacturing tool for regulating material flow [7]. Kanban is also widely used to reduce waste and enhance process visibility across manufacturing and logistics operations [8]. In logistics and warehousing contexts, kanban-based systems and labeling mechanisms have been applied to support inventory control and improve picking accuracy [9]. These systems also facilitate better information flow between production and distribution units [10]. However, many existing implementations remain manual or semi-manual, relying heavily on paper-based documentation and operator experience, which can limit their effectiveness in high-variation and high-volume environments [11].

Despite these advancements, several gaps remain insufficiently explored in the existing literature [12]. Prior research has predominantly focused on kanban applications within production lines and inventory replenishment activities [13]. As a result, limited attention has been directed toward the role of kanban in outbound logistics for finished goods distribution [14]. Moreover, manual kanban systems and paper-based picking documents are prone to human error, document loss, and misinterpretation [15]. These issues become more critical in warehouses that handle visually similar products with different product codes [16]. Furthermore, the integration of digital identification and real-time information flow into kanban systems for finished goods shipping has not been comprehensively examined, particularly in make-to-stock environments with dense delivery schedules and multiple vehicle queues [17]. A preliminary identification of contributing factors based on a cause–effect perspective is illustrated in Figure 1.

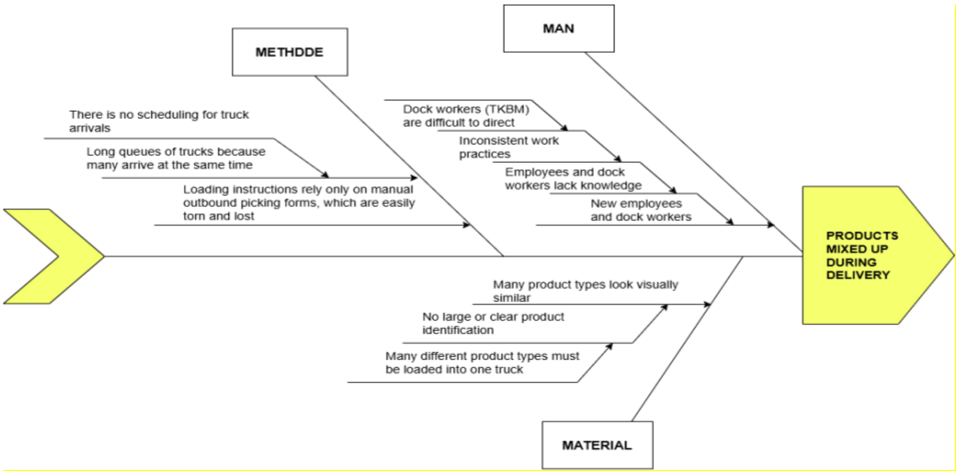

Figure 1. Fishbone Problem of Product Exchange in Shipping

To address these limitations, this study proposes the implementation of a digital kanban concept as a product identification and delivery support system in the finished goods warehouse of a large-scale biscuit manufacturing company. The proposed concept emphasizes clear digital labeling of product codes, improved visual differentiation, and structured support for outbound scheduling and loading activities. By embedding digital information into the kanban mechanism, the approach aims to strengthen process transparency, reduce dependency on manual documentation, and minimize the risk of product exchange during shipment.

Method

This research employs an engineering-oriented case study approach to design a Digital Green Kanban System for a finished goods warehouse in the snack food industry. The methodology is structured to systematically identify operational problems, analyze the existing system, and develop a digital kanban model that improves inventory control and supports sustainable warehouse operations. The research framework follows the sequential stages illustrated in Figure 2.

Research materials

The materials used in this research consist of operational and system-related data obtained from the finished goods warehouse. These include inventory records, material flow data, standard operating procedures (SOPs), warehouse layout information, and documentation related to current kanban practices. In addition, theoretical materials such as scientific articles, standards, and prior studies on kanban systems, digitalization, and green logistics are used to support the system design.

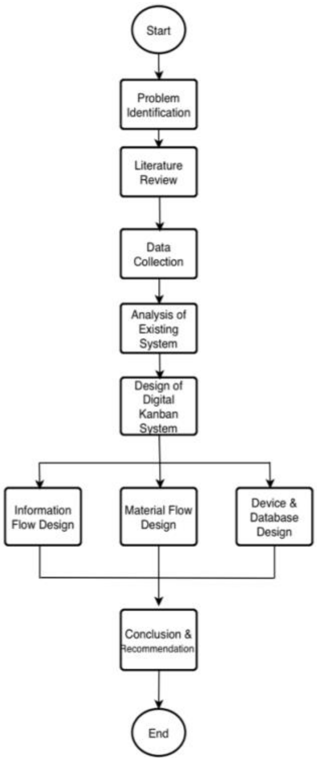

Figure 2. Research Methodology

Research procedures

The main procedures of the research are conducted in several structured stages. The research begins with problem identification through field observation to understand inefficiencies in the existing warehouse system. This is followed by a literature review to establish theoretical foundations and design criteria for a Digital Green Kanban System. Subsequently, data collection is performed to capture the current operational conditions. The collected data are then analyzed in the existing system analysis stage to identify bottlenecks, waste, and limitations in material and information flows. Based on this analysis, a Digital Green Kanban System is designed, including detailed designs of information flow, material flow, and supporting system architecture. The research concludes with system evaluation in a conceptual manner and the formulation of recommendations.

Data retrieval techniques

Data retrieval in this study is carried out using multiple techniques to ensure data validity and completeness. Direct observation is used to record actual material movement and warehouse activities. Semi-structured interviews are conducted with warehouse operators and supervisors to obtain insights into operational challenges and system requirements. Document analysis is applied to review inventory records, operational reports, and SOPs related to finished goods handling.

Analysis techniques

The analysis techniques focus on descriptive and process-based analysis. The existing warehouse system is analyzed by mapping current material and information flows to identify non-value-added activities and inefficiencies. Lean principles are applied to evaluate waste related to inventory, motion, and information delays. The findings from this analysis serve as the basis for designing the proposed Digital Green Kanban System.

System design and modelling

The core outcome of this research is the conceptual design and modeling of a Digital Green Kanban System. The system design encompasses information flow modeling to define real-time kanban signaling and interdepartmental data exchange, material flow modeling structured according to FIFO principles to ensure efficient movement of finished goods, and device and database modeling incorporating barcode or QR code technology supported by a centralized database to facilitate digital kanban operations.

Environmental considerations are embedded in the system design by minimizing paper usage and reducing unnecessary handling activities, aligning the system with green logistics principles.

Results

The existing warehouse system prior to the implementation of the Digital Green Kanban System was predominantly characterized by manual and paper-based kanban control. Monitoring data from January to February 2026 indicate that total paper consumption reached 165,956 sheets, with an average daily usage of 3,531 sheets. This substantial level of documentation reflects significant administrative waste within warehouse operations.

The reliance on traditional paper-based kanban cards also limits real-time information synchronization. Each change in material status must be manually recorded and physically transferred between departments. As a result, inventory data, production requests, and work-in-progress (WIP) updates are frequently delayed, isolated across functional units, or incomplete due to misplaced or late-submitted documents. This condition leads to fragmented information flow across the production network and increases the risk of delayed decision-making and operational inaccuracies.

Overview and analysis of existing system with traditional kanban system

Figure 3 illustrates the existing finished goods warehouse system prior to the implementation of the Digital Green Kanban System. The system operates using manual kanban cards, paper-based records, and fragmented information flow. Material movement, inventory control, and delivery preparation are largely dependent on operator experience and manual coordination, resulting in limited real-time visibility and higher operational waste. Finished products from production are transferred to the Final Work-in-Process (WIP) area and subsequently sent to the QC Process. Quality inspection is conducted manually, and inspection results are recorded on paper forms.

Products that fail inspection are separated as rejects and do not enter the packing process. However, the rejection status is not immediately reflected in the inventory records, creating delays in information updates. For products that pass QC, authorization to proceed is provided through physical kanban cards and verbal confirmation. The absence of a digital signal causes delays in communicating QC results to downstream processes.

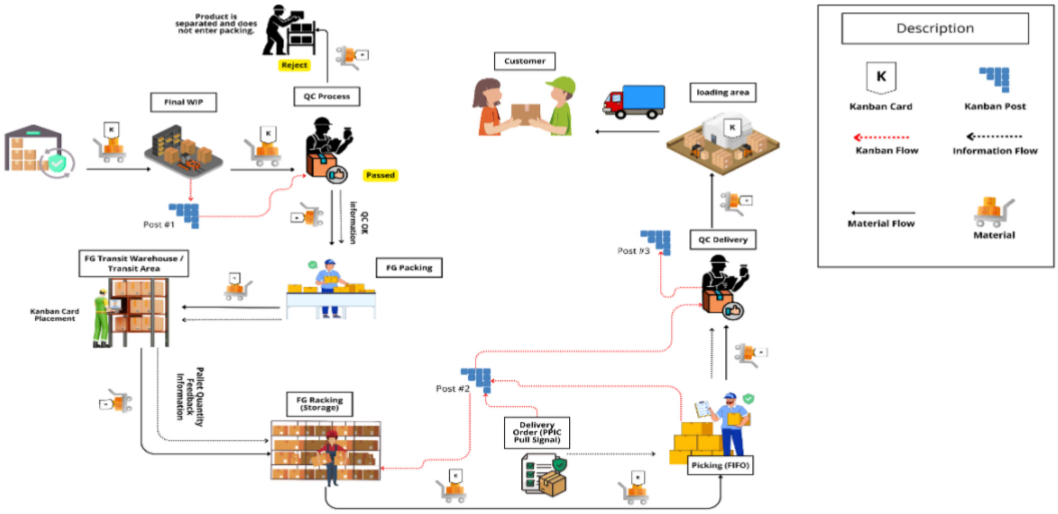

Figure 3. Material and information flow chart of existing system with traditional kanban

After QC approval, products are moved to the Finished Goods Transit Warehouse (Transit Area). Inventory status in this area is controlled using manual kanban card placement and kanban posts (Post #1). Pallet quantity and location information are recorded manually, increasing the risk of data inaccuracies and loss of traceability. The release of products to the FG Packing area depends on physical card availability and operator judgment. Information flow between the transit warehouse and packing is not synchronized in real time, which often leads to premature packing or temporary accumulation of inventory. Packed products are transferred to FG Racking (Storage). Inventory updates are conducted manually by recording pallet quantities on stock cards or log sheets. This manual recording process results in delayed inventory updates, limited visibility of stock levels, and a higher probability of discrepancies between physical and recorded inventory. The lack of integrated data makes it difficult to monitor inventory aging and enforce FIFO consistently across the storage area. When a Delivery Order (DO) is issued, picking activities are initiated based on printed documents and verbal instructions. Although the FIFO principle is intended, its execution depends heavily on operator awareness and experience rather than systematic control.

Kanban Post #2 functions only as a physical reference point, without the ability to generate real-time pull signals. This condition often results in inefficient picking routes, excessive handling, and the risk of picking incorrect or outdated stock. Picked products undergo Delivery QC, where quantity and packaging conditions are verified manually. Inspection results are documented on paper and communicated verbally to the loading area. At Kanban Post #3, shipment readiness is confirmed through manual checks, and loading activities are coordinated without integrated system support. This manual process increases the likelihood of delays, miscommunication, and loading errors. The results indicate that, in the existing condition, material flow and information flow are not fully synchronized. While material movement follows a defined sequence, information updates lag physical activities. The reliance on manual, paper-based kanban limits responsiveness, delays decision-making, and increases administrative waste, ultimately reducing operational transparency.

Overall, the existing warehouse system prior to the implementation of the digital kanban is characterized by manual and paper-based control mechanisms, delayed and fragmented information flow, limited real-time inventory visibility, inconsistent FIFO enforcement, and a higher risk of inventory inaccuracies and operational waste.

These findings highlight the necessity for a Digital Green Kanban System to improve synchronization, accuracy, and sustainability in finished goods warehouse operations. Figure 4 presents the existing finished goods kanban card.

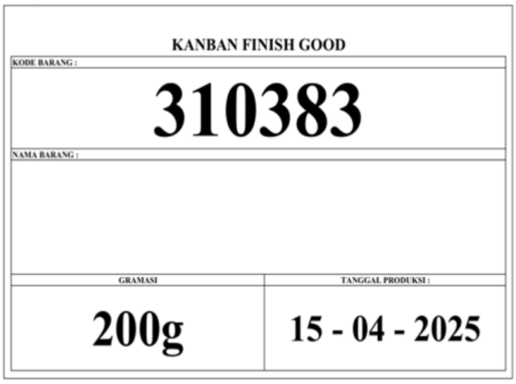

Figure 4. The existing kanban of finished goods (FG)

Overview of improvement system with digital green kanban system

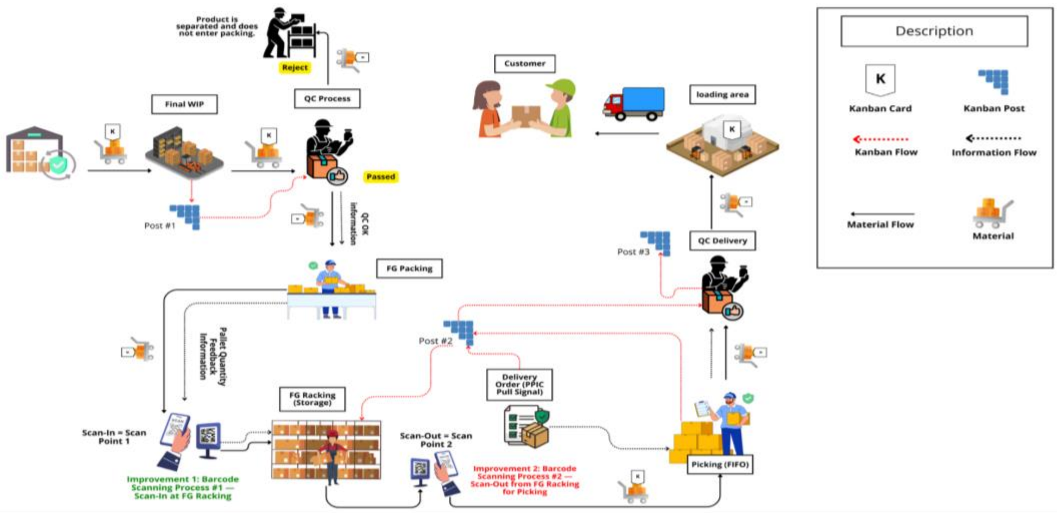

Figure 5. Material and information flow chart of improvement system with digital green kanban system

Figure 5 illustrates the material and information flow of the improved system using the Digital Green Kanban System. The operational process consists of the following stages:

1. *Production → Final WIP (output control)*
   After the implementation of the Digital Green Kanban System, finished products exiting the production line are immediately transferred to the Final WIP area under

digital control. Each pallet is equipped with an e-kanban ID, which is scanned at two control points: scan OUT (1) from production and scan IN (2) to Final WIP and QC. This mechanism enables real-time production recording and ensures that Final WIP inventory data remain continuously updated, thereby preventing overproduction by allowing downstream processes to be triggered only through validated digital kanban signals. In addition, the system provides precise tracking of goods movement and identifies the exact physical location of each pallet within the warehouse.

2. *Quality control (QC) → Packing of finished goods*
   Following quality inspection, products that pass QC are digitally authorized to proceed to the packing process. This authorization is executed through Digital Green Kanban System scan OUT (3) from the QC area and scan IN (4) to the packing process for FG racking preparation. The Digital Green Kanban System automatically updates the item status to "Qualified", ensuring that only approved products enter the packing process. Defective or non-conforming (NG) items are digitally blocked and physically separated, preventing them from entering downstream operations. The implementation introduces digital validation of QC approval, ensures clear segregation between qualified and non-conforming (NG) items, and eliminates errors associated with manual QC release processes.

3. *Packing → FG racking (inventory control without transit area)*
   In the improved system, finished goods are transferred directly from Packing to FG Racking, eliminating the need for a separate transit warehouse area. During this process, barcode scanning (scan IN at FG Racking) records pallet quantity, rack location, and time of entry into the storage system. Rack locations (slotting) are digitally determined and stored in the database, ensuring high inventory accuracy. The collected data also serve as the foundation for FIFO/FEFO logic in downstream picking activities. The improved system eliminates the transit area and redundant handling activities, introduces digitally controlled rack slotting, enhances inventory accuracy and transparency, and provides FIFO-ready data to support systematic picking operations.

4. *FIFO picking (demand pull system)*
   When a delivery requirement is generated, the system issues a pull signal from PPIC/logistics. Picking activities are performed directly from FG Racking using FIFO principles, enforced automatically by the system. During picking, e-kanban scan OUT (5) is conducted when goods are removed from the rack. This scan updates stock levels in real time and ensures that only authorized quantities are picked. The implementation strengthens demand-driven logistics by enabling automatic FIFO/FEFO enforcement, ensuring real-time stock updates, and reducing picking errors as well as unnecessary material handling activities.

5. *Shipping QC (error-proofing mechanism)*
   Before shipment, picked items undergo Shipping QC. At this stage, scan IN (5) is performed for final validation. The system cross-checks the scanned items against

the Delivery Order (DO) to verify item type, quantity, and shipment accuracy. This step acts as an error-proofing (poka-yoke) mechanism, effectively preventing incorrect shipments, quantity mismatches, or wrong product delivery. The implementation of automated Delivery Order (DO) verification functions as an error-proofing mechanism, leading to a substantial reduction in shipping errors and improved shipment reliability.

6. *Shipping area → Customer*

   Prior to loading goods onto the delivery vehicle, a final Digital Green Kanban System scan IN (6) is performed at the shipping area. This scan updates the item status to "Shipped", and once received by the customer, the status is updated to "Delivered". The digital record provides full traceability from production to customer delivery and supports performance monitoring and logistics reporting. By digitizing shipment confirmation processes, the system ensures accurate status recording, provides end-to-end traceability from warehouse to customer, and enhances delivery visibility for improved logistics performance.

7. *Overall System Performance*

   The proposed Digital Green Kanban System conceptually integrates material flow, information flow, and demand-pull signals into a unified digital platform. Based on system modeling and process redesign, the framework has the potential to enhance operational control, reduce reliance on manual documentation, and minimize administrative waste. The elimination of the transit area and the introduction of digital rack slotting are expected to reduce unnecessary handling activities and paper usage.

   Nevertheless, as the study focuses on system design and conceptual modeling, empirical post-implementation performance data such as reductions in shipping error rates, picking lead time, inventory discrepancies, and operational costs have not yet been measured. Therefore, the performance improvements described in this section represent projected operational benefits derived from process analysis rather than validated quantitative outcomes.

Discussion

This study focuses on the development of a Digital Green Kanban System as a strategic solution to address operational inefficiencies and shipment errors in the finished goods warehouse of a snack food manufacturing company. The initial system relied heavily on manual kanban cards and paper-based documentation, which resulted in delayed information flow, limited inventory visibility, and a high dependency on operator experience. These conditions posed significant risks in a high-volume, make-to-stock environment characterized by product variety and tight delivery schedules.

The analysis of the existing system revealed a clear imbalance between material flow and information flow. Although the physical movement of finished goods followed a defined operational sequence, information updates regarding quality status, inventory levels, and storage locations were not synchronized in real time. Consequently, decision-making related to picking, storage, and shipping was often reactive rather than proactive. Furthermore, the implementation of FIFO principles was inconsistent, as it relied primarily on manual judgment rather than systematic control, increasing the likelihood of picking errors, particularly for visually similar products.

Unlike the conventional system, the digital framework enables proactive decision-making by transforming kanban signals into real-time operational control mechanisms. This integration enables real-time recording and monitoring of product movement from production output through quality control, storage, and final shipment. As a result, synchronization between material and information flows is significantly improved, allowing warehouse operations to be managed based on accurate and up-to-date data.

One of the key improvements introduced by the proposed system is the elimination of the transit warehouse area. By enabling direct transfer of finished goods from the packing process to the finished goods racking area, non-value-added handling activities are reduced. This redesign aligns with lean manufacturing principles by minimizing waste related to motion, waiting, and unnecessary inventory buffering. In addition, digital rack slotting enhances storage accuracy and establishes a reliable foundation for the automated enforcement of FIFO/FEFO rules during picking operations.

The implementation of digital-based Shipping Quality Control (Shipping QC) represents another critical contribution of this system. Automated verification between scanned items and delivery orders functions as an effective error-proofing (poka-yoke) mechanism. This control point significantly reduces the risk of incorrect product types, quantity mismatches, and misdirected shipments before loading activities commence. The findings demonstrate that the Digital Green Kanban System can extend beyond production control to play a vital role in improving outbound logistics reliability.

From a sustainability perspective, the proposed system supports green logistics initiatives. The reduction of paper-based documents, elimination of physical kanban cards, and decrease in redundant material handling contribute to lower administrative waste and a smaller environmental footprint. Thus, the Digital Green Kanban System simultaneously enhances operational efficiency and environmental performance.

Overall, the results indicate that the digitalization of kanban systems in finished goods warehouses is an effective approach to improving operational control, shipment accuracy, and system sustainability, particularly in industries with high production volumes and complex distribution requirements.

Conclusion

This study successfully developed a Digital Green Kanban System designed to improve the operational performance of a finished goods warehouse in the snack food industry. The findings demonstrate that conventional, paper-based kanban systems lead to delayed information flow, limited inventory visibility, inconsistent FIFO implementation, and a higher risk of shipment errors.

The proposed system effectively synchronizes material and information flows through e-kanban identification, barcode/QR code scanning, and centralized data integration. The system enhances inventory accuracy, strengthens product traceability from production to customer delivery, and supports consistent FIFO/FEFO enforcement. In addition, the integration of digital Shipping QC serves as an effective error-prevention mechanism, significantly reducing the likelihood of delivery errors.

The elimination of the transit warehouse area and the digitalization of warehouse operations further support lean and green logistics principles by reducing non-value-added activities, paper consumption, and manual administrative workload. As a result, the proposed system not only improves efficiency and reliability but also contributes to more sustainable warehouse operations.

The main contribution of this research lies in the development of a Digital Green Kanban framework specifically tailored for internal production systems operating on dedicated production lines with high distribution volumes. This framework provides practical guidance for manufacturing companies seeking to implement digital transformation in finished goods warehouse management. Future research is recommended to evaluate post-implementation performance quantitatively, conduct cost–benefit analysis, and explore integration with advanced technologies such as the Internet of Things (IoT) and data analytics to further enhance decision-making capabilities.

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