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Research Paper

Digital Transformation in Postal Logistics: A Design Science Approach to Enhancing Operational Performance through Geocoding and Voice-Assisted Sorting Systems

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ABSTRACT

Despite ongoing digital transformation in logistics, conventional postal sorting systems remain vulnerable to routing errors and operational inefficiencies, implying the need for more intelligent sorting solutions. This study aims to develop a web-based logistics sorting system integrating barcode scanning, geocoding automation, and voice-assisted technology to enhance operational performance in the Jakarta Premier Main Branch Office of Pos Indonesia. Employing a Design Science Research (DSR) approach, the study involved four stages: problem identification, system design, pilot implementation, and performance evaluation. The developed system was tested through a three-week pilot project using operational performance indicators, including sorting accuracy, processing time, and Service Level Agreement (SLA) compliance. The findings demonstrate that the proposed system substantially improved sorting accuracy from 86.5% to 96.7%, reduced average processing time by approximately 35%, and enhanced SLA compliance through more accurate delivery zone classification and real-time operational support. The voice-assisted interface also reduced operators' cognitive workload and improved workplace efficiency. These findings emphasize the strategic role of digital logistics technologies in strengthening operational excellence and service quality, providing practical insights for postal organizations seeking sustainable digital transformation and intelligent logistics management.

Introduction

The rapid digital transformation of the logistics industry has fundamentally reshaped how postal service providers manage operational processes, particularly in the context of last-mile delivery. Increasing parcel volumes driven by e-commerce expansion have intensified the demand for faster, more accurate, and more reliable sorting operations that directly influence service quality and customer satisfaction (Chen et al., 2026; Dabić-Miletić, 2026). As one of Indonesia's largest postal service providers, Pos Indonesia faces substantial operational challenges in maintaining delivery efficiency across densely populated metropolitan areas such as Jakarta. At the Jakarta Premier Main Branch Office (KCU Jakarta Premier), the sorting process continues to rely heavily on postal code-based classification, making it susceptible to routing errors, delivery delays, and inconsistencies in operational performance. These challenges become increasingly significant when handling complex address structures, overlapping postal code boundaries, and special shipment categories such as Cash on Delivery (COD) (Pritee & Garg, 2026). Consequently, improving operational performance through intelligent digital technologies has become a strategic priority for logistics organizations seeking to strengthen competitiveness and enhance service reliability.

The urgency of this research arises from the growing need for digital solutions capable of improving operational excellence in postal logistics while reducing human error during sorting activities. Traditional sorting procedures that depend primarily on manual verification and postal codes are insufficient to cope with increasing shipment volumes and the complexity of urban distribution networks (Kumari & Garg, 2026; Zhang et al., 2025). Operational inefficiencies not only increase processing time and labor costs but also reduce compliance with Service Level Agreements (SLA), ultimately affecting customer trust and organizational performance. Emerging technologies such as geocoding, barcode automation, voice-assisted interfaces, and real-time monitoring systems provide promising opportunities to enhance logistics operations by supporting more accurate location identification, reducing cognitive workload, and enabling faster decision-making (Ludwig et al., 2023; Wang et al., 2022). Nevertheless, many postal organizations continue to experience difficulties in integrating these technologies into a unified operational system that can be effectively implemented within real-world sorting environments (Kurniawan et al., 2026). Therefore, developing and evaluating an integrated digital sorting system represents both a practical necessity and an important research agenda in logistics and operations management.

Previous studies have extensively examined various digital technologies that support logistics and supply chain management, although most investigations remain fragmented in their technological focus. Research on voice-assisted systems has demonstrated their effectiveness in improving warehouse productivity, reducing operator fatigue, and minimizing operational errors by facilitating hands-free interactions during logistics activities (Jacyna-Golda et al., 2026; Ludwig et al., 2023). Similarly, studies on geocoding and machine-learning-based address verification have reported substantial improvements in route optimization and delivery accuracy through spatial intelligence and automated location matching (Li et al., 2022; Seisenbekov et al., 2026; Song, 2024). Other scholars have investigated barcode and RFID technologies as mechanisms for improving package tracking and inventory visibility, while real-time dashboard systems have been recognized for

strengthening operational monitoring and data-driven decision-making (Kim & Chen, 2025; Wang et al., 2022). Collectively, these studies confirm the strategic importance of digital technologies in logistics management; however, they generally investigate individual technologies independently and predominantly focus on warehousing, inventory management, or transportation optimization rather than the operational complexity of postal sorting activities within last-mile logistics.

Important theoretical and empirical gaps remain. Existing studies rarely examine how multiple digital technologies, including barcode scanning, geocoding, voice-assisted interaction, and real-time alert systems, can be integrated into a comprehensive sorting platform capable of simultaneously improving operational accuracy, processing efficiency, and service reliability in postal logistics. Furthermore, previous research has primarily emphasized technological performance without adequately considering the interaction between digital innovation, operational processes, and human factors within complex logistics environments. Consequently, limited empirical evidence is available regarding the effectiveness of integrated intelligent sorting systems in supporting organizational performance within public postal service providers. Addressing this gap, the present study proposes an integrated web-based sorting system that combines geocoding automation, barcode verification, voice-assisted guidance, and operational monitoring into a single digital platform. This integration represents the principal novelty of the study by extending the application of Design Science Research beyond system development toward the evaluation of an intelligent operational solution that supports digital transformation in postal logistics.

Based on these considerations, this study aims to develop and evaluate an integrated web-based sorting system that utilizes barcode scanning, geocoding automation, and voice-assisted technology to improve operational performance at the Jakarta Premier Main Branch Office of Pos Indonesia. Specifically, the study investigates how the proposed system enhances sorting accuracy, reduces processing time, and strengthens Service Level Agreement (SLA) compliance within real operational settings. Unlike previous studies that examine individual logistics technologies in isolation, this research proposes an integrated digital operations management framework that combines multiple intelligent technologies into a unified sorting platform evaluated through the Design Science Research approach. From an economics and management perspective, the study contributes to the literature on digital transformation by demonstrating how intelligent logistics systems can improve operational efficiency, optimize resource utilization, reduce transaction and coordination costs, and strengthen service quality in postal operations. The findings also enrich the field of logistics and operations management by providing an empirically validated framework for integrating digital technologies into operational decision-making, thereby supporting organizational competitiveness, sustainable productivity, and long-term value creation in the digital economy.

Theoretical Foundation

Geocoding and Address Parsing in Last-Mile Logistics

Geocoding has become an essential technology in modern logistics because it enables textual addresses to be transformed into precise geographical coordinates that support routing, sorting, and distribution decisions. In last-mile logistics, address accuracy is a

critical determinant of delivery performance, as inaccurate or incomplete address information frequently results in routing errors, delayed deliveries, and higher operational costs. Previous studies demonstrate that geocoding supported by machine learning and artificial intelligence significantly improves spatial accuracy by validating address information beyond conventional postal codes, thereby enabling more reliable distribution planning and reducing delivery failures (Giuffrida et al., 2022; Paul et al., 2024). As logistics networks become increasingly complex, particularly in densely populated urban environments, geocoding provides a more adaptive mechanism for identifying delivery zones and supporting operational decision-making.

Despite these advantages, the effectiveness of geocoding depends heavily on data quality and address standardization. Inconsistent address formats, outdated geographical databases, and variations in local naming conventions continue to present substantial challenges for logistics organizations (Hristov, 2024). Consequently, recent literature emphasizes that geocoding should not merely be viewed as a mapping technology but as a strategic information resource capable of improving operational efficiency through enhanced spatial intelligence. From an operations management perspective, accurate geocoding strengthens logistics capability by reducing sorting errors, improving route allocation, minimizing transportation costs, and supporting more efficient resource utilization throughout the distribution process.

Voice-Assisted Sorting and Human-centered Logistics Automation

Voice-assisted technology has emerged as an important component of intelligent logistics systems by enabling operators to receive real-time audio instructions during operational activities. Unlike conventional screen-based interfaces, voice-assisted systems allow workers to perform sorting tasks without interrupting manual operations, thereby reducing cognitive workload and improving task efficiency. Previous studies consistently report that voice-directed technologies increase productivity, decrease operational errors, and enhance worker ergonomics in warehouse and logistics environments (Goomas et al., 2023; Ludwig et al., 2023). These technologies have therefore become increasingly important within the broader context of Industry 4.0, where human–technology collaboration is expected to improve organizational performance rather than simply automate routine activities.

From a theoretical perspective, voice-assisted systems are closely associated with adaptive information systems and human-centered automation theories, which emphasize the importance of designing technologies that complement human decision-making rather than replace it (Wang et al., 2022). By delivering immediate verbal feedback and operational guidance, voice-assisted applications improve situational awareness, reduce visual dependency, and minimize the likelihood of human error during high-volume logistics operations. Consequently, voice-assisted technology contributes not only to operational efficiency but also to employee performance, learning, and workplace safety. Within logistics management, this technology represents an organizational capability that supports continuous productivity improvement while enhancing service reliability and operational consistency.

Real-Time Dashboard and Intelligent Alert Systems in Logistics Management

Digital dashboards and real-time monitoring systems have transformed logistics management by providing managers with continuous access to operational information required for timely decision-making. Contemporary logistics organizations increasingly rely on integrated dashboards to monitor key performance indicators such as processing speed, sorting accuracy, shipment status, and Service Level Agreement (SLA) compliance. Real-time visibility enables organizations to detect operational bottlenecks, allocate resources more effectively, and respond proactively to disruptions before they negatively affect service quality (Chou et al., 2021; Lee et al., 2022). Consequently, dashboard technology has become an important element of digital operations management that strengthens organizational responsiveness and improves operational control.

In addition to performance visualization, intelligent alert systems extend the functionality of digital dashboards by generating automated notifications when operational abnormalities occur. Alert mechanisms facilitate preventive interventions by informing operators and managers about delayed shipments, routing anomalies, or approaching service deadlines, thereby reducing operational risk and improving customer satisfaction (Wahyudi et al., 2024). These systems are consistent with the principles of data-driven decision-making and continuous improvement, where operational data are continuously transformed into managerial knowledge for strategic action (Rahman et al., 2023). Accordingly, real-time dashboards and intelligent alert systems contribute to sustainable operational excellence by integrating information visibility, organizational learning, and evidence-based decision-making into logistics management practices.

The Present Study

The three theoretical perspectives collectively establish the conceptual foundation of this study by explaining how digital technologies contribute to operational performance in postal logistics. Geocoding provides spatial intelligence that improves the accuracy of shipment classification and delivery zone identification, while voice-assisted technology enhances human–system interaction by reducing cognitive workload and supporting faster operational execution. Meanwhile, real-time dashboards and intelligent alert systems strengthen managerial decision-making through continuous operational monitoring and proactive performance control. This study integrates them into a unified digital sorting system developed and evaluated through the Design Science Research approach. This integrated perspective extends the existing literature by demonstrating how complementary digital capabilities can collectively improve operational efficiency, service reliability, and organizational performance. The study contributes to the understanding of digital transformation in logistics by illustrating how intelligent operational systems create value through process optimization and resource efficiency.

Method

Research Approach and Design

This study employed a Design Science Research (DSR) approach to develop and evaluate an intelligent logistics sorting system integrating barcode scanning, geocoding

automation, and voice-assisted technology. Unlike explanatory research that primarily seeks to test causal relationships, DSR focuses on designing, implementing, and evaluating innovative artifacts that address practical organizational problems while simultaneously generating theoretical knowledge (Hevner et al., 2004; Gregor & Hevner, 2022). The approach is particularly appropriate because the study seeks not only to understand operational inefficiencies in postal logistics but also to construct a digital solution capable of improving sorting accuracy, operational efficiency, and Service Level Agreement (SLA) compliance. Following the DSR framework, the research combines empirical investigation with iterative system development and evaluation, allowing the proposed artifact to be validated within an authentic operational environment. Consequently, the study contributes both practically, through the development of an intelligent sorting system, and theoretically, by extending knowledge on digital transformation and operations management in postal logistics.

Research Stages and Procedure

The research followed four iterative stages consistent with the Design Science Research (DSR) methodology. The process began with identifying operational problems affecting sorting performance at the Jakarta Premier Main Branch Office of Pos Indonesia through field observations and stakeholder consultations. Based on the identified requirements, an integrated web-based sorting system was designed by combining barcode scanning, geocoding automation, voice-assisted interaction, and real-time monitoring functions. The developed system was subsequently implemented through a pilot project under actual operational conditions to examine its feasibility and usability. Finally, the system's effectiveness was evaluated by comparing operational performance before and after implementation using predefined performance indicators. The iterative nature of DSR enabled continuous refinement of the developed artifact throughout the implementation process. Table 1 presents the detailed research stages according to DSR methodology.

Table 1. Research Stages and Procedures Based on Design Science Research

DSR Stage	Research Activities	Expected Output
Problem identification	Conducted field observations, semi-structured interviews with logistics managers and sorting operators, and reviewed internal operational documents to identify inefficiencies in the existing sorting process.	Identification of operational problems, system requirements, and design specifications.
System design	Designed an integrated web-based sorting system consisting of barcode scanning, geocoding module, voice-assisted interface, dashboard monitoring, and alert notification system.	Prototype architecture and functional system design.
Pilot implementation	Implemented the prototype in the operational environment of KCU Jakarta Premier for three weeks involving sorting operators during daily logistics activities.	Functional prototype and operational performance data.

DSR Stage	Research Activities	Expected Output
Performance evaluation	Evaluated system effectiveness by comparing operational performance before and after implementation based on sorting accuracy, processing time, SLA compliance, and user feedback.	Evaluation results, system validation, and recommendations for further improvement.

Data Collection and Research Instruments

Data were collected using multiple sources to ensure comprehensive evaluation of the developed system. Primary data were obtained through direct observations of sorting operations, semi-structured interviews with logistics managers, information technology personnel, and sorting operators, as well as documentation of operational workflows within the Jakarta Premier Main Branch Office of Pos Indonesia. During the pilot implementation, system-generated operational logs were used to record processing time, sorting accuracy, shipment classification, and SLA compliance. User perceptions regarding system usability, operational convenience, and workload reduction were collected through structured interview guidelines following the pilot implementation. Supporting documents, including operational manuals, internal performance reports, and project documentation, were also analyzed to complement the empirical findings.

Data Analysis, Validity and Reliability

The study employed a mixed analytical strategy integrating qualitative interpretation and quantitative performance evaluation within the Design Science Research framework. Qualitative data obtained from observations, interviews, and documentation were analyzed using thematic analysis to identify operational challenges, user experiences, and system improvement opportunities. Quantitative analysis involved descriptive comparative analysis to evaluate changes in operational performance before and after system implementation, including sorting accuracy, average processing time, Service Level Agreement (SLA) compliance, and operator satisfaction. To enhance the trustworthiness of the findings, data validity was established through methodological triangulation by comparing evidence from observations, interviews, system logs, and organizational documents. Reliability was strengthened through standardized observation protocols, consistent system-generated performance records, and repeated verification of evaluation results by operational supervisors. This combination of triangulation, standardized measurement procedures, and iterative validation ensured the credibility and dependability of the research findings while supporting the evaluation principles of Design Science Research (Gregor & Hevner, 2022; Hevner et al., 2004).

Results

Problem Identification

The first stage of the Design Science Research (DSR) process focused on identifying operational problems that constrained the efficiency and reliability of the sorting process at the Jakarta Premier Main Branch Office (KCU Jakarta Premier) of Pos Indonesia. Data were

collected through direct observations of sorting activities, semi-structured interviews with logistics managers, IT personnel, and sorting operators, as well as reviews of operational documents. The investigation revealed several recurring operational issues that collectively reduced sorting accuracy, prolonged processing time, and hindered compliance with the organization's Service Level Agreement (SLA). These findings subsequently served as the primary design requirements for developing the proposed intelligent sorting system.

Dependence on Postal Code-Based Sorting and Inconsistent Address Verification

Direct observation revealed that the existing sorting process relied predominantly on postal code classification, requiring operators to manually verify destination addresses whenever postal codes were incomplete, inaccurate, or inconsistent with street names. This situation frequently occurred in densely populated urban areas where adjacent neighborhoods shared similar postal codes despite belonging to different delivery zones. Consequently, operators spent additional time confirming shipment destinations, creating processing bottlenecks during peak operational hours. Several shipments required repeated verification before final classification, increasing both processing time and the possibility of human error.

This operational issue was consistently emphasized during interviews with logistics management. One logistics manager explained:

(1) *"Our current system still depends heavily on postal codes. When addresses are incomplete or the postal code does not accurately represent the delivery area, operators must verify the destination manually. During high-volume periods, this significantly slows down the sorting process." (Logistics Manager)*

Similarly, a sorting operator stated:

(2) *"Different customers often write the same address in different ways. We usually have to check street names manually before deciding the correct sorting destination." (Sorting Operator)*

These findings indicate that improving address verification requires a more intelligent mechanism capable of integrating textual address information with geographical location data rather than relying exclusively on postal code classification.

Limited Decision Support and High Cognitive Workload During Sorting Operations

Field observations further demonstrated that sorting operators continuously alternated between scanning shipment labels, checking destination information displayed on computer monitors, and manually identifying the correct sorting container. This repetitive visual verification increased cognitive workload, particularly during periods of high shipment volume. New operators required considerably longer adaptation periods because operational decisions depended largely on individual experience rather than systematic technological assistance.

Interview findings reinforced these observations. One operator commented:

(3) *"When shipment volume increases, we have to look at the barcode, the computer screen, and the sorting destination repeatedly. It becomes tiring after several hours and mistakes are more likely to happen." (Sorting Operator)*

An IT support officer also highlighted the absence of interactive decision support:

(4) *"The existing application only displays destination information on the screen. There is no voice guidance or automatic confirmation that can immediately assist operators during sorting." (IT Personnel)*

These findings suggest that the existing operational system provides limited support for human decision-making. Consequently, reducing operators' cognitive burden became an essential design consideration in developing the proposed digital sorting system.

Absence of Real-Time Operational Monitoring and Automated Alert Mechanisms

Another important finding concerns the limited capability of the existing information system to support real-time operational monitoring. Direct observations showed that supervisors primarily monitored sorting performance using manually compiled operational reports generated after sorting activities had been completed. Consequently, operational deviations such as shipment accumulation, delayed processing, or incorrect destination allocation could not be detected immediately. This reactive monitoring approach limited management's ability to intervene before service quality deteriorated.

This limitation was clearly reflected in interviews with operational management. A logistics manager explained:

(5) *"We usually identify operational problems after the sorting shift has finished. If there is congestion or delayed processing, supervisors often realize it only after reviewing the daily operational report." (Logistics Manager)*

Similarly, an operational supervisor stated:

(6) *"An automatic warning system would be very helpful because we could immediately identify shipments approaching their delivery deadline instead of waiting until the delay has already occurred." (Operational Supervisor)*

These findings demonstrate the necessity of integrating real-time dashboard visualization and intelligent alert mechanisms capable of providing continuous operational visibility and supporting proactive managerial decision-making.

Design Requirements for the Intelligent Sorting System

The synthesis of observational evidence and interview findings established several functional requirements for the proposed digital sorting system. First, the system should integrate barcode scanning with geocoding technology to improve destination verification beyond conventional postal code classification. Second, voice-assisted guidance should be incorporated to provide immediate operational feedback and reduce operators' cognitive

workload during sorting activities. Third, a real-time dashboard accompanied by an automated alert system should support operational monitoring, early detection of shipment delays, and proactive management intervention. These requirements formed the conceptual foundation for the subsequent system design stage within the Design Science Research process, ensuring that the developed artifact directly addressed the operational challenges identified during empirical investigation.

System Design

Following the identification of operational challenges, the second stage of the Design Science Research (DSR) process focused on designing an intelligent web-based sorting system capable of improving operational efficiency, sorting accuracy, and service reliability at the Jakarta Premier Main Branch Office (KCU Jakarta Premier) of Pos Indonesia. The system was designed as an integrated digital platform that combines barcode scanning, geocoding automation, voice-assisted interaction, and real-time operational monitoring into a single operational workflow. Unlike the existing sorting process, which relies primarily on postal code verification and manual operator judgment, the proposed system automatically validates shipment destinations using multiple sources of information, including barcode data, street names, geographical coordinates, shipment status, and operational priorities. This integrated architecture was intended to minimize manual intervention while supporting faster and more consistent operational decision-making. To facilitate a clearer understanding of the proposed artifact, Table 2 summarizes the principal components of the intelligent sorting system, the operational problems addressed by each component, their respective functionalities, and the expected operational outcomes. This summary illustrates how the system design translates the findings from the problem identification stage into an integrated digital solution for improving operational performance.

The system architecture consists of four interconnected functional modules that operate sequentially during the sorting process. The first module is the barcode scanning module, which serves as the primary entry point for shipment identification. Each shipment barcode is scanned to retrieve shipment information stored in the operational database, including customer identity, delivery address, postal code, shipment category, and delivery status. The barcode scanning process eliminates repetitive manual data entry and substantially reduces transcription errors during package handling. Once shipment information has been retrieved, the system immediately transfers the data to the subsequent verification module, allowing uninterrupted processing throughout the sorting workflow.

The second module incorporates geocoding and intelligent address verification, which represents one of the principal innovations of the proposed system. Rather than depending solely on postal codes, the module analyzes textual address information using geocoding services to identify the precise geographical location of each shipment. Street names, administrative regions, and spatial coordinates are simultaneously processed to determine the appropriate delivery zone. This multi-layer verification approach enables the system to distinguish addresses located within overlapping postal code areas while minimizing routing ambiguity. The integration of geospatial intelligence therefore improves the consistency of shipment classification and significantly reduces the likelihood of incorrect destination allocation caused by incomplete or inaccurately written addresses.

Table 2. Functional Design of the Proposed Intelligent Logistics Sorting System

System Component	Operational Problem Addressed	Main Functionality	Expected Operational Outcome
Barcode Scanning Module	Manual data entry and shipment identification increased processing time and the risk of human error.	Automatically captures shipment information from barcode labels and retrieves customer, destination, shipment category, and operational status from the database.	Faster shipment identification, reduced data entry errors, and improved processing efficiency.
Geocoding and Intelligent Address Verification	Dependence on postal codes resulted in inaccurate destination classification, particularly in areas with overlapping postal codes or inconsistent address formats.	Integrates street names, administrative regions, and geographical coordinates to validate delivery destinations and determine appropriate sorting zones automatically.	Improved sorting accuracy, reduced routing errors, and enhanced delivery zone classification.
Voice-Assisted Decision Support	Operators experienced high cognitive workload because they repeatedly checked shipment labels and computer screens during sorting activities.	Generates real-time voice instructions using text-to-speech (TTS) technology while simultaneously displaying visual confirmation through the web interface.	Reduced cognitive workload, faster decision-making, improved operator productivity, and fewer sorting errors.
Real-Time Dashboard	Supervisors lacked immediate visibility of operational performance and relied on end-of-shift reports for monitoring.	Displays real-time operational indicators, including shipment volume, sorting progress, operator productivity, and Service Level Agreement (SLA) performance.	Enhanced operational visibility, timely managerial decision-making, and improved operational control.
Intelligent Alert System	Delayed shipments and operational bottlenecks were identified only after service disruptions had occurred.	Automatically generates notifications for shipments approaching delivery deadlines, high-priority consignments, and operational anomalies requiring managerial intervention.	Early detection of operational risks, improved SLA compliance, and proactive resource allocation.
Integrated Web-Based Platform	Existing operational tools functioned independently without seamless information integration.	Integrates barcode scanning, geocoding, voice-assisted interaction, dashboard monitoring, and alert mechanisms into a unified web-based logistics management platform.	Improved interoperability, streamlined operational workflow, and strengthened digital transformation in postal logistics.

The third module integrates a voice-assisted decision support system designed to facilitate human–computer interaction during sorting operations. After the destination has been successfully verified, the application automatically generates audio instructions through a text-to-speech (TTS) engine that informs operators of the correct sorting destination. Simultaneously, visual confirmation is displayed on the web interface to reinforce operational accuracy. The combination of auditory and visual feedback enables operators to maintain continuous manual handling of shipments without repeatedly shifting their attention to computer monitors. Consequently, the system reduces cognitive workload, shortens decision-making time, and improves operator productivity.

To strengthen operational supervision, the system further incorporates a real-time dashboard and intelligent alert module. The dashboard continuously displays operational indicators such as shipment processing volume, sorting progress, destination distribution, operator productivity, and Service Level Agreement (SLA) performance. Operational managers are therefore able to monitor sorting activities as they occur and identify emerging bottlenecks without waiting for end-of-shift reports. In addition, the intelligent alert mechanism automatically identifies shipments approaching delivery deadlines, high-priority consignments, and operational anomalies requiring immediate managerial attention. This functionality transforms operational monitoring from a reactive reporting process into a proactive decision-support mechanism that enables earlier intervention and more effective resource allocation.

The overall system architecture was developed following principles of interoperability, scalability, and usability to facilitate future implementation across other operational units within Pos Indonesia. The web-based platform allows centralized access through existing organizational infrastructure while supporting integration with external geocoding services and internal shipment databases through application programming interfaces (APIs). Open-source technologies were adopted wherever possible to improve system flexibility, reduce implementation costs, and simplify future maintenance and system enhancement. Furthermore, the modular architecture allows additional intelligent technologies, including predictive analytics, artificial intelligence-based routing optimization, and demand forecasting, to be incorporated without substantial redesign of the existing platform.

From the perspective of Design Science Research, the proposed artifact represents more than a software application; it constitutes an integrated operational solution that aligns technological capabilities with organizational requirements identified during the problem identification stage. By combining spatial intelligence, automated identification, voice-assisted interaction, and real-time operational monitoring within a unified digital platform, the system addresses the major operational constraints observed in the existing sorting process. The resulting design therefore establishes the technological foundation for evaluating whether intelligent digital integration can improve operational performance, enhance service quality, and support sustainable digital transformation in postal logistics.

Pilot Implementation

Following the completion of the system development stage, the proposed intelligent sorting system was deployed through a pilot implementation at the Jakarta Premier Main Branch Office (KCU Jakarta Premier) of Pos Indonesia. The pilot was conducted over a three-

week period to examine the operational feasibility, usability, and functional performance of the developed artifact under actual working conditions. Consistent with the Design Science Research (DSR) methodology, the pilot implementation served as an iterative evaluation phase in which the artifact was tested, monitored, and refined through continuous interaction between the system and its intended users. The implementation involved logistics managers, information technology personnel, and ten sorting operators who routinely handled parcel classification and distribution activities. Throughout the pilot period, system performance was continuously monitored using operational records, system-generated logs, direct observations, and user feedback to ensure that the developed solution functioned as intended within the organizational environment.

The pilot implementation was organized into three sequential phases (see Table 3). The first phase focused on operational preparation and data standardization to establish a reliable information foundation for the intelligent sorting system. Existing shipment databases were reviewed to identify inconsistencies in address formatting, duplicated destination records, incomplete shipment information, and postal code anomalies. Data cleansing and address normalization were subsequently performed to improve compatibility with the geocoding engine and ensure accurate spatial identification. At the same time, application programming interfaces (APIs) connecting the operational database with the geocoding service were configured and tested to verify the accuracy of real-time address validation before operational deployment.

The second phase emphasized system deployment and user readiness. During this stage, the web-based application was installed within the operational environment, and all functional modules, including barcode scanning, geocoding verification, voice-assisted guidance, dashboard monitoring, and intelligent alert mechanisms, were subjected to functional testing prior to live operation. Concurrently, logistics managers, IT personnel, and sorting operators participated in structured training sessions designed to familiarize users with the new operational workflow. Training activities included demonstrations of barcode scanning procedures, interpretation of geocoding results, utilization of voice-assisted instructions, dashboard navigation, and responses to automated warning notifications. Simulation exercises were also conducted using representative shipment scenarios to ensure that operators could effectively integrate the digital system into routine sorting activities before full implementation commenced.

The final phase involved full operational implementation under normal logistics conditions. The intelligent sorting system was integrated into the daily sorting process without disrupting existing operational schedules, allowing researchers to evaluate system performance within authentic organizational settings. During this period, every shipment processed through the system generated operational records documenting barcode identification, destination verification, processing time, operator interaction, and shipment status. The dashboard simultaneously monitored shipment throughput, sorting progress, Service Level Agreement (SLA) compliance, and system-generated alerts in real time. Researchers conducted continuous field observations throughout this phase to document user interaction, identify operational bottlenecks, and evaluate system stability. Minor technical adjustments, including interface refinement and optimization of voice response timing, were implemented iteratively based on operator feedback, reflecting the adaptive and iterative characteristics of Design Science Research.

Table 3. Pilot Implementation Activities

Implementation Phase	Major Activities	Participants	Expected Output
Operational Preparation	Data cleansing, address normalization, API configuration, database validation	IT personnel, logistics managers	Clean operational database and validated geocoding integration
System Deployment and User Training	System installation, functional testing, operator training, simulation exercises	IT personnel, managers, sorting operators	Operational readiness and user competency
Operational Pilot Testing	Live implementation, operational monitoring, user observations, iterative refinement	Sorting operators, managers, researchers	Functional artifact validated under real operational conditions

Interviews conducted following the pilot implementation demonstrated a positive response from system users. Logistics managers reported that the real-time dashboard substantially improved operational visibility and facilitated faster managerial decision-making during periods of high shipment volume. One logistics manager commented:

(7) *"Previously, we relied mainly on operational reports prepared after each shift. With the dashboard, we can immediately monitor sorting progress and identify operational problems before they affect delivery performance." (Logistics Manager)*

Similarly, sorting operators emphasized that the voice-assisted functionality simplified operational activities and reduced the need for repeated manual verification during package classification:

(8) *"The voice instructions help us focus on handling the packages without constantly looking at the computer screen. It makes the sorting process faster and reduces confusion, especially during busy periods." (Sorting Operator)*

Information technology personnel also confirmed that the integrated architecture enabled stable communication between barcode scanning, geocoding services, and dashboard monitoring throughout the pilot period with only minor adjustments required during the initial implementation stage.

Overall, the pilot implementation demonstrated that the developed artifact could be successfully integrated into the operational workflow of postal logistics without disrupting routine activities. The iterative implementation process not only confirmed the technical functionality of the proposed system but also demonstrated its practical applicability within a real organizational environment. More importantly, the pilot established empirical evidence that integrating geocoding automation, voice-assisted interaction, barcode scanning, and real-time monitoring into a unified platform was operationally feasible and well accepted by users. These outcomes provided the necessary foundation for conducting a comprehensive performance evaluation, presented in the subsequent section, to determine the effectiveness of the intelligent sorting system in improving operational performance.

Performance Evaluation

The final stage of the Design Science Research (DSR) process involved evaluating the effectiveness of the developed intelligent sorting system in improving operational performance within the Jakarta Premier Main Branch Office (KCU Jakarta Premier) of Pos Indonesia. The evaluation adopted a before-and-after comparative approach, whereby operational performance prior to system implementation was compared with performance achieved after the three-week pilot implementation. The assessment focused on four key performance indicators that directly reflect logistics operational excellence: average sorting time per shipment, sorting accuracy, Service Level Agreement (SLA) compliance, and operator satisfaction. Quantitative evidence obtained from system-generated operational logs was complemented by field observations and post-implementation interviews with logistics managers, IT personnel, and sorting operators to provide a comprehensive evaluation of the developed artifact.

Overall, the evaluation demonstrated that the intelligent sorting system substantially improved operational efficiency and service performance. The integration of barcode scanning, geocoding automation, voice-assisted guidance, and real-time monitoring enabled faster shipment processing while simultaneously reducing sorting errors. Compared with the previous manual system, operators performed sorting activities more consistently because shipment verification became largely automated, reducing dependence on individual experience and repetitive manual confirmation. Furthermore, managers benefited from real-time operational visibility that facilitated quicker responses to operational bottlenecks and shipment delays.

As presented in Table 4, the most notable improvement occurred in processing efficiency. The average sorting time decreased from 4.60 seconds to 2.95 seconds per shipment, representing a 35.8% improvement in operational speed. Field observations indicated that this improvement resulted primarily from the automation of destination verification and the elimination of repeated manual checking during sorting activities. Instead of interpreting postal codes manually, operators received immediate destination confirmation through barcode scanning and geocoding verification, allowing them to maintain a continuous operational workflow. A sorting operator explained:

(9) *"Previously we spent considerable time checking addresses whenever there was uncertainty. Now the system immediately confirms the destination, so we can continue sorting without interruption." (Sorting Operator)*

Table 4. Comparison of Operational Performance Before and After System Implementation

Performance Indicator	Before Implementation	After Implementation	Performance Improvement
Average sorting time per shipment	4.60 seconds	2.95 seconds	35.8% faster
Sorting accuracy	86.5%	96.2%	+9.7 percentage points
SLA violation rate	12.3%	7.3%	41% reduction
Operator satisfaction (1–5 scale)	3.4	3.6	+1.2 points

The evaluation also revealed a substantial improvement in sorting accuracy. The sorting accuracy rate increased from 86.5% under the conventional system to 96.2% following implementation of the intelligent sorting platform. This improvement reflects the effectiveness of integrating geocoding technology with barcode verification, particularly for shipments containing incomplete or ambiguous address information. Direct observations showed that destination misclassification became considerably less frequent because the system validated shipment locations using multiple address attributes rather than relying exclusively on postal codes. According to one logistics manager:

(10) *"The integrated verification process significantly reduces destination errors because the system checks not only the postal code but also the street name and geographical location." (Logistics Manager)*

Service reliability also improved following system implementation. The proportion of shipments violating the organization's Service Level Agreement (SLA) declined from 12.3% to 7.3%, representing a 41% reduction in delayed deliveries associated with sorting activities. The integration of the real-time dashboard and intelligent alert mechanism enabled supervisors to identify operational congestion before delays became critical, allowing immediate corrective action. During interviews, operational supervisors consistently emphasized that proactive monitoring substantially improved daily operational control:

(11) *"With the dashboard and warning notifications, we know immediately when shipments require attention instead of waiting until operational reports are completed." (Operational Supervisor)*

Beyond improvements in operational indicators, the developed system also generated positive outcomes from the human resource perspective. Operator satisfaction increased from 3.4 to 4.6 on a five-point scale following implementation. Interview findings suggested that the voice-assisted interface substantially reduced cognitive workload because operators no longer needed to repeatedly alternate between package labels and computer screens. Newly assigned personnel also adapted more quickly to the sorting process because the system provided immediate operational guidance throughout package classification. One operator remarked:

(12) *"The voice instructions make the job much easier. We can focus on handling the parcels instead of constantly checking the monitor, and new staff learn the process much faster." (Sorting Operator)*

In a nutshell, these findings demonstrate that the proposed intelligent sorting system successfully achieved the primary objectives established during the Design Science Research process. The artifact not only improved technical performance through higher sorting accuracy and faster processing but also enhanced managerial effectiveness by strengthening operational visibility and proactive decision-making. Furthermore, improvements in operator satisfaction indicate that the system successfully integrates technological innovation with human-centered operational design. Consequently, the evaluation confirms that combining geocoding automation, barcode scanning, voice-assisted

interaction, and real-time monitoring within a unified digital platform constitutes an effective strategy for improving operational performance and supporting sustainable digital transformation in postal logistics.

Discussion

The present study demonstrates that integrating geocoding, barcode scanning, voice-assisted technology, and real-time operational monitoring into a unified web-based platform constitutes an effective digital transformation strategy for improving operational performance in postal logistics. Rather than functioning as independent technologies, these digital components collectively create an intelligent operational ecosystem that enhances decision-making, reduces human error, and strengthens service reliability. These findings directly address the research objective of developing and evaluating a practical digital solution capable of overcoming inefficiencies in conventional sorting systems. More importantly, the study extends existing knowledge by showing that operational excellence in logistics is achieved not merely through technological adoption but through the strategic integration of complementary digital capabilities within organizational workflows. This perspective is consistent with the digital transformation literature, which emphasizes that organizational value is generated when technology redesigns business processes and managerial practices rather than simply automating existing activities (Gregor & Hevner, 2022; Lin et al., 2026; Tian et al., 2021; Venkatesh et al., 2021). Consequently, the developed artifact illustrates how Design Science Research (DSR) can bridge the gap between technological innovation and organizational performance by producing solutions that are both practically relevant and theoretically meaningful.

One of the most important implications of this study concerns the relationship between digital technologies and operational efficiency in logistics management. The observed improvements in processing speed and operational consistency indicate that intelligent automation enhances organizational productivity by reducing process variability and eliminating non-value-added activities during shipment classification. From an operations management perspective, this finding supports the principle that operational performance is determined not only by physical resources but also by the quality of information processing embedded within organizational routines. Digital technologies enable faster information acquisition, more accurate decision-making, and better coordination among operational actors, thereby improving workflow efficiency and reducing transaction costs associated with manual verification (Bajec et al., 2026; Gupta et al., 2026). These findings are consistent with the resource-based view, which considers information technology as a strategic organizational capability capable of generating sustainable competitive advantage when effectively integrated into operational processes. They also reinforce previous studies demonstrating that digital logistics systems improve productivity and organizational responsiveness by facilitating real-time information processing and process automation (Lee et al., 2022; Chou et al., 2021; Conforto et al., 2022). However, unlike earlier studies that focused primarily on warehouse automation or inventory management, the present study demonstrates how intelligent digital integration contributes directly to operational excellence within postal sorting activities, thereby extending the application of digital operations management to last-mile logistics.

Another significant finding relates to the contribution of geocoding technology to improving operational decision quality in logistics management. Previous studies have primarily viewed geocoding as a technical tool for route optimization and spatial analysis (Li et al., 2022; Paul et al., 2024). The present study broadens this perspective by demonstrating that geocoding also functions as an operational decision-support mechanism capable of reducing uncertainty during shipment classification. By integrating geographical coordinates, street names, and administrative boundaries into destination verification, the system substantially improves the quality of operational decisions compared with conventional postal code-based classification. From the perspective of information processing theory, organizations achieve higher operational performance when they possess greater capacity to process complex information and reduce ambiguity during decision-making (Akhmetova et al., 2026; Dabić-Miletić, 2026). The integrated geocoding mechanism effectively increases this information-processing capability by transforming fragmented address data into reliable operational knowledge that supports accurate shipment allocation. Consequently, geocoding should not be regarded merely as a geographic information technology but as a strategic digital resource that strengthens organizational decision quality, improves logistics coordination, and supports more efficient resource allocation. This broader interpretation extends previous logistics research by highlighting the managerial value of spatial intelligence within digital operations management.

The findings also emphasize the importance of human-centered digital innovation in achieving successful organizational transformation. While technological automation is frequently associated with reducing human intervention, the present study suggests that digital technologies produce greater organizational benefits when they enhance rather than replace human capabilities. The voice-assisted component of the developed system illustrates this principle by reducing operators' cognitive workload while preserving human judgment in operational decision-making. This finding supports socio-technical systems theory, which argues that organizational performance depends upon the effective alignment between technological systems and human capabilities (Baxter & Sommerville, 2022; Chen et al., 2023; Wang et al., 2022). Similarly, adaptive information systems theory proposes that intelligent technologies should provide contextual support that enables users to make faster and more accurate decisions under complex operational conditions (Wang et al., 2022; Zhao et al., 2023). The positive user responses observed during the pilot implementation therefore suggest that successful digital transformation requires equal attention to technological functionality and user experience. Compared with previous studies emphasizing the productivity benefits of voice-assisted systems in warehouse environments (Goomas et al., 2023; Ludwig et al., 2023), the present study contributes additional evidence by demonstrating that voice-assisted technology also strengthens learning, operator confidence, and organizational adaptability within postal logistics operations, thereby reinforcing the human-centered dimension of intelligent logistics management.

The findings further indicate that the effectiveness of the proposed intelligent sorting system arises not from the implementation of isolated digital technologies but from their integration into a unified operational platform. This integrated architecture enables barcode scanning, geocoding, voice-assisted interaction, and real-time monitoring to operate as complementary capabilities that collectively strengthen organizational performance. Such integration reflects the concept of digital capability, whereby organizational value is created

through the interaction of multiple technological resources rather than through individual innovations operating independently (Astuti & Raharja, 2021; vom Brocke et al., 2020). From an operations management perspective, the system enhances coordination across operational activities by reducing information fragmentation and enabling seamless communication among operators, supervisors, and information systems. The real-time dashboard further transforms operational management from a reactive process into a proactive one by allowing managers to detect bottlenecks, monitor Service Level Agreement (SLA) compliance, and allocate resources more effectively before service disruptions occur. This finding supports the growing body of literature arguing that digital transformation should be viewed as an organizational capability that improves coordination, agility, and responsiveness rather than merely introducing new technologies (Rahimi et al., 2024; Silva et al., 2023). Accordingly, the present study demonstrates that integrated digital platforms constitute an important mechanism for enhancing operational resilience and sustaining competitive advantage in increasingly dynamic logistics environments.

The present findings generally corroborate previous studies reporting positive relationships between digital technologies and logistics performance while also extending the existing body of knowledge in several important respects. Previous investigations have shown that geocoding improves routing accuracy (Li et al., 2022; Nayak et al., 2023), voice-assisted technologies enhance warehouse productivity (Goomas et al., 2023; Ludwig et al., 2023), and dashboard systems strengthen operational visibility (Lee et al., 2022; Lozano Murciego et al., 2021). However, these studies largely evaluate each technology independently and within different operational contexts, such as warehouse management, transportation planning, or inventory control. In contrast, this study demonstrates that substantially greater organizational benefits emerge when these technologies are integrated into a single operational system specifically designed to support postal sorting activities. Moreover, whereas earlier studies predominantly emphasized technical performance indicators, the present research incorporates organizational and human dimensions by examining managerial decision-making, operator adaptation, and user acceptance alongside operational efficiency. This broader perspective advances the literature by illustrating that digital transformation is a socio-technical process requiring alignment among technological infrastructure, organizational processes, and human capabilities. Consequently, the study extends existing theories of digital operations management by providing empirical evidence that integrated intelligent systems generate value through the synergistic interaction of technological and organizational resources rather than through isolated technological improvements.

From a theoretical perspective, this study contributes to the literature on digital transformation, logistics management, and Design Science Research by demonstrating how integrated digital technologies can function as organizational capabilities that improve operational decision-making and service performance. While previous studies have generally focused on evaluating individual technologies, this research develops and validates an integrated artifact that combines complementary digital functions into a coherent operational framework. In doing so, the study extends Design Science Research beyond artifact development by illustrating how iterative design, implementation, and evaluation can generate practically relevant knowledge while simultaneously enriching theories of digital operations management. The findings also reinforce the socio-technical perspective by confirming that technological innovation produces sustainable

organizational value when technological functionality is aligned with human interaction and operational processes. From a practical perspective, the study offers a scalable model for postal service providers and other logistics organizations seeking to accelerate digital transformation. Managers may adopt the integrated framework as a reference for redesigning sorting operations through intelligent automation, real-time monitoring, and decision-support technologies that improve efficiency, optimize resource utilization, reduce operational errors, and strengthen customer service performance. More broadly, the study provides strategic insights for organizations pursuing operational excellence in the digital economy by demonstrating that sustainable competitiveness depends not merely on adopting advanced technologies but on integrating them into coherent managerial systems that continuously support organizational learning, operational agility, and long-term value creation.

Conclusion

This study developed and evaluated an intelligent web-based sorting system integrating barcode scanning, geocoding automation, voice-assisted technology, and real-time operational monitoring to improve operational performance in postal logistics. Employing the Design Science Research (DSR) approach, the study demonstrates that integrating complementary digital technologies into a unified operational platform significantly enhances sorting accuracy, accelerates processing time, strengthens Service Level Agreement (SLA) compliance, and improves operators' work experience by reducing cognitive workload. Beyond its practical achievements, the study contributes theoretically to the literature on digital transformation, logistics management, and operations management by demonstrating that organizational performance is enhanced not merely through technological adoption but through the strategic integration of digital capabilities into operational processes. The findings further highlight the importance of human-centered digital innovation, where technological functionality and user interaction collectively support operational excellence, organizational agility, and sustainable value creation. From a managerial perspective, the proposed framework offers a practical reference for postal service providers and logistics organizations seeking to redesign operational processes and strengthen competitiveness through intelligent digital transformation.

Despite these contributions, several limitations should be acknowledged. First, the pilot implementation was conducted within a single operational unit of Pos Indonesia over a relatively short evaluation period, which may limit the generalizability of the findings to other logistics organizations with different operational characteristics. Second, the study primarily focused on operational performance indicators and did not examine broader organizational outcomes such as cost efficiency, financial performance, customer loyalty, or long-term organizational capability development. Third, although the integrated system successfully demonstrated operational feasibility, emerging technologies such as artificial intelligence, predictive analytics, and Internet of Things (IoT)-based logistics monitoring were beyond the scope of the present investigation. Future research is therefore encouraged to evaluate the proposed system across multiple logistics organizations and longer implementation periods while incorporating advanced digital technologies and broader organizational performance measures. Comparative studies involving public and private

logistics providers would also provide valuable insights into the scalability, adaptability, and strategic value of intelligent logistics systems in supporting sustainable digital transformation across diverse operational environments.

Authors' Declaration

The authors made substantial contributions to the conception and design of this study. The authors take responsibility for the data analysis, interpretation, and discussion of the results. The authors have read and approved the final manuscript.

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