Journal of Computer Science

Research Article

Design and Implementation of an IoT-Based Application for Export-Import (EXIM) Document Management

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Article history
Received: 12-06-2025
Revised: 10-08-2025
Accepted: 27-10-2025

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Abstract: International trade in the Export-Import (EXIM) sector is a key driver of global economic growth. However, EXIM document management still faces challenges such as data inconsistencies, input delays, and a lack of real-time visibility into document status. These issues result in shipping delays and increase operational costs. This research aims to develop an Internet of Things (IoT)-based EXIM application with an edge computing architecture optimized for local environments without reliance on cloud services. The development method used Rapid Application Development (RAD) through the stages of requirements analysis, interface design, module development, and iterative implementation involving user validation. This application integrates IoT devices such as scanners and thermal printers to automate document input and package tracking. Data is processed in real time by an Edge Gateway and synchronized to a local server, enabling document and logistics monitoring without an external internet connection. Implementation results show an increase in data input and reporting efficiency of up to 500 a 70% reduction in document errors, and an average processing time of 80% compared to manual systems. This approach provides a replicable solution for small to medium-sized logistics industries with limited infrastructure, while supporting digital transformation, operational reliability, and sustainable economic growth in the international trade sector.

Keywords: Internet of Things (IoT), Export-Import (EXIM), Rapid Application Development (RAD)

Introduction

International trade, especially in the Export-Import (EXIM) sector, plays a significant role in the global economy (Purwanto and Loisa, 2020; Jayaweera et al., 2024). This industry faces significant challenges in the management of unintegrated logistics documents (Andry and Loisa, 2019; Sivalingam and Mathi, 2024). One of the problems faced by the logistics industry is related to the imperfection of data in EXIM documents, which causes difficulties in monitoring document status in real time. The sender and recipient do not have the same information, leading to uncertainty in logistics management. This challenge highlights the need for Internet of Things (IoT) integration to improve document and shipment visibility across the export-import logistics planning process. Previous research by Abdulaziz et al. showed that IoT implementation in small and medium-sized industries improved internal communication, reduced errors, and improved product quality and safety by up to 50% (Abdulaziz et al., 2023).

Previous research by Qin and Wan showed that the average value of the number of items processed per hour was higher (1057.56 T/H) compared to the comparison system (691.47 T/H), so the proposed system was more efficient and effective (Qin and Wan, 2024). In terms of logistics planning, IoT automates the update process by capturing field data (Tannady et al., 2023). The development of an export-import system has a positive impact on the efficiency of document input time, input process accuracy, tracking speed, and daily document creation productivity (Baso, 2024; Baluyot, 2025). To address this digitalization need, particularly in areas with limited cloud connectivity, this study proposes the development of a local IoT-based EXIM application with an edge computing architecture to ensure reliable data processing without internet dependency. The system was developed using the Rapid Application Development (RAD) method that supports iterative prototyping and rapid adjustments to user needs in the logistics sector.

SCIENCE Publications

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Although RAD emphasizes development speed and modular design, this study also incorporates technical approaches, such as describing the IoT architecture and real-time data handling mechanisms.

The RAD approach starts from identifying EXIM problems to developing prototypes in stages. The novelty of this research lies in a new approach to digitalizing the export-import process through an edge computing-based IoT system optimized for local environments, without dependence on the cloud. The novelty of this research lies in the contextual application of the five-layer IoT architecture in the EXIM application. By integrating various operational modules into an edge-based IoT system, this research demonstrates a practical implementation model that can be replicated by small- to medium-scale logistics industries in areas with limited connectivity. This is a real contribution in bridging the gap between IoT technology and real needs in the export-import logistics sector. The main contributions of this research include:

(i) Designing a five-layer architecture of an IoT-based EXIM application
(ii) Modeling data flows between modules to visualize user interactions and communication between modules
(iii) Designing the application's interface and business processes

Literature Review

Table 1 shows that previous research on IoT architecture development was generally based solely on literature studies and comparative reviews. The results of these studies focused more on the development of descriptive IoT layer concepts and designs, without any direct implementation or testing in real-world applications. Therefore, there is no empirical evidence regarding the effectiveness of the proposed architecture when implemented in systems requiring real-time data processing. The current research aims to address this gap by designing and implementing a five-layer IoT architecture in an edge computing-based export-import (EXIM) application. In addition to developing the architectural design, this research will examine the level of user satisfaction in terms of document processing, among other aspects. Thus, this research not only provides a conceptual model but also offers practical implementation validation that can support the development of a scalable and replicable IoT-based EXIM system.

Table 1: Research article comparison

Title (Author)	Topic & Method	Result	Strength	Weakness	Current Research
Edge-Computing-Driven Internet of Things: A Survey (Kong et al., 2023)	IoT Integration with Edge Computing (ECDriven-IoT) using literature study and research review methods.	ECDriven-IoT is able to overcome the computing limitations of IoT devices by processing on edge servers, reducing cloud load, and lowering latency.	Response time is much shorter than cloud and real-time services.	The complexity of edge computing architecture	The development of IoT architecture is divided into five main layers, including a connection mechanism to the EXIM application.
Expediency of Symptomatic Diagnostics Application of Enterprise Export-Import Activity in the Conditions of World Economy Sustainable Development (Smerichevskyi et al., 2021)	Symptomatic diagnostics in the company's export-import activities using the literature analysis method.	Negative symptoms of export-import operations were found, and preventive managerial steps were proposed to increase efficiency.	Understand the root causes of operational problems, providing concrete management recommendations.	There is no quantitative data.	Using quantitative data to evaluate user satisfaction before and after application implementation.
Applications Of Internet of Things (IoT) And Sensors Technology to Increase Food Security and Agricultural Sustainability: Benefits and Challenges (Morchid et al., 2024)	Application of IoT and sensor technology in agriculture to improve food security and sustainability using IoT architecture study methods.	Four layers of IoT architecture for smart agriculture: perception or sensing and actuator layer, network layer, cloud layer, and application layer.	High efficiency, resource saving, fast response.	Challenges in technology adoption: cost, infrastructure.	The design of the EXIM application using IoT is based on the five layers used in previous research (application, support, network, access, perception).

Connection Between IoT and EXIM Application

The EXIM application is a system for managing export-import processes such as document tracking, logistics, and distribution. In the logistics sector, Internet of Things (IoT) technology is used for automation and real-time process visibility. IoT supports the integration of functions such as warehouse and order management and enables data analysis for operational efficiency. Architecturally, IoT utilizes edge computing for local data processing and consists of five layers: perception, access, network, support, and application (Tang, 2020).

Materials and Methods

This research uses the Rapid Application Development (RAD) methodology to develop an export-import document management (EXIM) application. IoT is implemented in real-time through sensors, edge servers, and an application platform that processes documents in real time. The development stages include requirements analysis, designing a five-layer IoT architecture, prototyping, implementation, and system evaluation by comparing conditions before and after application implementation.

Figure 1 is a RAD method that explains clearly and specifically how an IoT-based EXIM system is designed, developed, and tested as follows:

1. Requirement Analysis. At this stage, system requirements were gathered by involving key stakeholders through an iterative approach in accordance with the principles of the RAD method (Kristianto et al., 2022; Rembulan et al., 2024). Requirements validation was conducted continuously, involving stakeholders at each iteration of data collection. Key activities included:
   a) The research subjects included 100 logistics staff who handle documents and deliveries
   b) Data was collected through structured interviews, observations, and business process documentation
   c) The instruments used included interview guides, observation sheets, visual documentation, and copies of export-import documents
   d) IoT monitoring included the activity of scanners and location sensors connected to an edge server and synchronized with the company database
2. System Design. This stage outlines the overall solution design with an architecture (Christianto et al., 2024) of three main components: backend (MySQL integrated with an edge server), middleware (edge gateway), and IoT interaction (barcode scanner, local network). The design uses Figma for UI prototypes, which are tested directly by stakeholders, making it iterative and user-driven. The architecture diagram shows the five IoT layers (perception, access, network, support, application) and an input-output mapping that illustrates user and database interactions (Pramudito et al., 2024)
3. Development. This stage explains the data storage and connection mechanisms between devices (Puspitarini et al., 2024). The application was developed using Microsoft Visual Studio (C#) and integrated with a barcode scanner connected to a Raspberry Pi-based edge gateway. Data is processed and sent to a local server via MQTT (real-time) and synchronized to a central server using HTTP. The EXIM application prototype was visualized and tested iteratively, with user feedback gathered through live trials, interviews, and questionnaires for feature improvements and usability
4. Testing. This phase evaluated the efficiency, accuracy, and speed of the EXIM application (Moghiss and Sendi, 2024) through testing in a test environment with historical data, then implemented in production with 100 logistics staff. Effectiveness was measured by processing time, input errors, synchronization speed, and user satisfaction using a questionnaire. When staff scan barcodes through IoT scanners, data is sent to the edge gateway and local server to automatically update documents. Manifest forms and invoices are verified by the admin before being printed. Data is temporarily stored in local storage and synchronized to the central server after firewall verification, ensuring security and operational continuity even in unstable internet connections

Results

Requirement Analysis

In the initial RAD phase, system objectives and information needs were identified through interviews (Rosa and Abad, 2025). Current business processes are still manual: physical documents are verified, administrators create import-export documents, and hand them over to couriers without systematic tracking. Packages are sorted, handed over to port/airport authorities, and then delivered to recipients with manual confirmation. This conventional system does not yet support real-time automation and integration as outlined in Table 2.

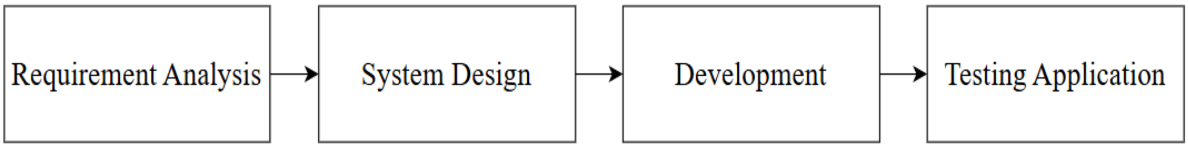

Fig. 1: Research Method (Riadi et al., 2024)

DOI: 10.3844/jcssp.2026.410.419

Table 2: Requirement analysis result

No	Business Process	Issues	Recommendation
1	Master Data	Sender/recipient data is inconsistent, no data format validation, and user access rights are not restricted.	Implementation of automatic validation, Role-Based Access Control, and synchronization with the local server.
2	Price List	Prices are not real-time, and there is no change history.	Automatically integrate modules and history.
3	Transaction	Shipment/stuffing plan worksheet data is not comprehensive, and there is a delayed feed.	Use IoT devices (scanners) to automatically capture real-time shipping data.
4	Finance	Invoice creation does not match the worksheet; cash flow is difficult to monitor daily.	Integration with shipping data and worksheets for automatic invoice creation.
5	Report	Reporting delays, no customization options, and historical data retention.	Automatic reporting feature along with report customization capabilities.

Table 3: Comparative Insights of Non-IoT and IoT Application (Glaroudis et al., 2020; Khezemi et al., 2025)

Aspect	Conventional (non-IoT)	Application (with IoT)
Data Input	Manual by admin using a form	Automatically via barcode scanning
Tool Integration	Separate; scanner and printer are not connected to the system	Integrated with edge gateways and desktop applications
Data Processing	Batch/periodic by users	Real-time via edge computing
Status Monitoring	The manual requires communication between departments	Automatically, status updates are directly sent to the local server
Storage	On each user's computer	Centralized on a local server with authentication controls
Security	Minimal protection, prone to data duplication	Local firewall, user authentication
Scalability	Limited, difficult to develop	Modular and scalable locally without internet

Table 2 lists the issues and recommendations provided for the five business processes. Each row describes the issues identified in each process, along with the proposed solutions or recommendations for the EXIM application. Therefore, a functional comparison analysis of conventional (non-IoT) systems and local IoT-based applications was carried out in Table 3 with several references from scientific journals.

Table 3 compares the conventional process with the IoT-based EXIM application. In the old system, users manually collected documents, filled out forms, and reprinted them if revisions were needed. This process was prone to input errors, slow approval times, and poorly documented. The IoT-based EXIM application overcomes these challenges: barcodes are scanned by an IoT scanner, data is automatically sent to the application via LAN, documents are automatically printed, and all activities are recorded in real time on a local server.

Structure Design

This stage is the design and refinement stage of user requirements by building an IoT architecture structure in the EXIM application (Leng et al., 2021), which is divided into two stages:

1. Overall Structure of Application. A depiction of the main framework of the system from an architectural perspective explains how the system is built from data collection to data storage (Siddiqui et al., 2022). Figure 2 displays the IoT-based EXIM Application layer, which consists of five parts. The Perception layer is a basic component in the IoT architecture for collecting information from the surface of objects through sensors and Radio Frequency Identification (RFID) (Narayana et al., 2024). Admins automatically scan barcodes on items using IoT Scanners. Thermal printers are used to print document labels/other outputs. Data from this layer is directly forwarded to Access, which is responsible for transferring the collected data to the transmission network by connecting physical devices to the edge gateway in real-time. The edge gateway not only functions as a device connector but also collects, filters, and processes data from IoT devices locally to reduce latency and increase efficiency. The Local Area Network (LAN) provides internal connections between devices via wires or wirelessly. The Network layer completes long-distance data transmission (Jahangeer et al., 2023), providing a secure and protected communication path between devices and local systems. Routers regulate data traffic between local networks. Firewalls provide protection against unauthorized access and maintain system integrity

The support layer functions as data processing through a local server that runs the main system, stores the database, and processes application logic (Raj and Shetty, 2022). Local storage physically stores data, documents, activity logs, and backups, while the authentication system ensures only authorized users (Administrators/Managers) can access the application through a credential verification process, strengthening overall system security. The application layer serves as the user interface for managing the import-export application across five main modules. Files/master data store important entity information such as document types, customers, and item data. Price lists are used during the quotation process to determine service prices. Transactions record all import-export activities, including document input and process tracking. Finance generates invoices and manages payment transactions. Reports provide real-time reports and analytical dashboards to support operational performance evaluation.

The current system architecture has limitations related to updates and backups, which must be performed at user request. However, all transaction data, documents, and user information do not leave the local network, thus avoiding the risk of hacking and ensuring operational processes continue even in the event of external network disruptions. To adapt to increasing demands or workloads in IoT-based EXIM applications, the architecture's scalability can be further enhanced by adding IoT devices and connecting them to an edge gateway/LAN. Network Attached Storage (NAS) or backup servers can be added to the local network to increase data and storage scalability.

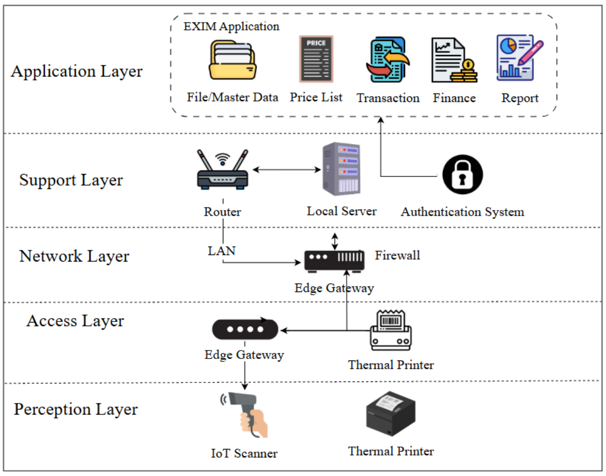

Fig. 2: Architecture of the IoT in EXIM Application

2. Functional/Application Structure. Focuses on the main functions of the application and describes the input and output when running business processes (Tormakangas, 2024). Table 4 shows an explanation of the data flow process between modules, including user and database interactions, to show intermodule communication

Table 4 displays the five main modules of the IoT-based EXIM application: file/master data, price list, transactions, finance, and reports, all of which support CRUD functions. The file module stores reference data for system validation, the price list manages the export-import pricing structure, transactions record key business activities, finance handles payments and integrated record-keeping, and reports present operational and managerial output in real time.

Development of IoT Technologies

This stage represents the implementation of the EXIM IoT application, describing computing, storage, and connectivity through the IoT's internal server structure and edge computing (Calderón et al., 2024). This section explains how data is stored and accessed, as well as the connections between devices in Fig. 3.

Figure 3 shows the data flow mechanism for users, applications, and IoT devices. Users access the application through an interface, which is then handled by the system service. The system service maps and manages connections with IoT devices such as scanners and thermal printers. CRUD requests or data exports from the file, price list, transaction, finance, and report modules are processed through middleware and forwarded to the EXIM Service system, which serves as the core of data processing. IoT devices are connected directly through a local network (LAN/WLAN) using an edge computing approach, where data from the device is sent and processed directly locally without having to pass through the internet. Figure 4 shows an example of visualizing the final results of system development by mapping components and features.

Table 4: Functional Structure of the Platform

No	Module	Input From	Output To	Functions
1	Master Data (File)	User	File Master Database	Container type, service type, stuffing location, loading/destination port, trucking company, shipping company, agent, warehouse, exporter/importer.
2	Price List	User	Price List Database	Export (selling price, agent incentives, rebates, surcharges, rate searches, offers to agents), import (mechanical costs, standard/special DO), and costs (feeder, agent, trucking, warehouse, operational).
3	Transaction	User, File, Price List	Transaction Database	Stuffing plans, job orders, billing requests, arrival notices, and job change approvals.
4	Finance	Transaction	Finance Database	Shipper invoices, credit notes, financial processes, refund/discount vouchers, cash disbursement receipts, and invoice recaps.
5	Report	Transaction, Finance	Report Database	Job sheets, shipper/sales data, approvals, and department records.

DOI: 10.3844/jcssp.2026.410.419

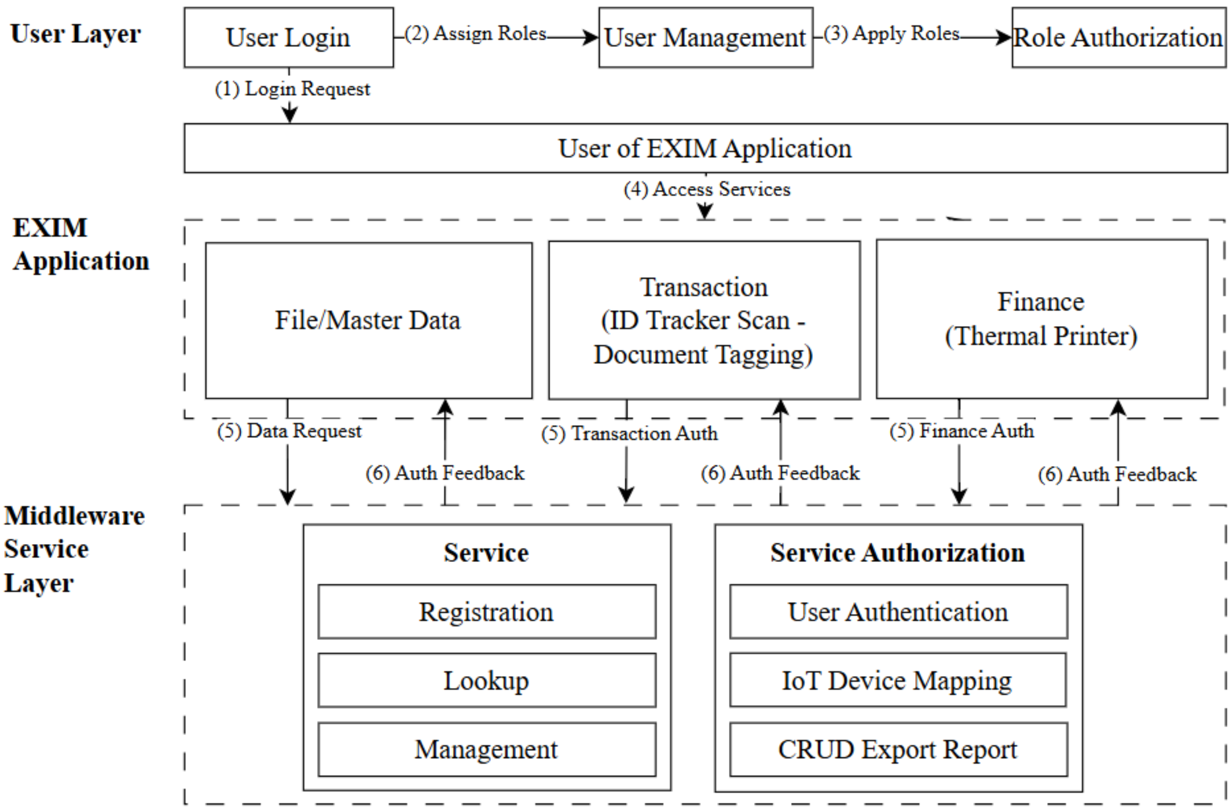

Fig. 3: Connection Mechanism of IoT

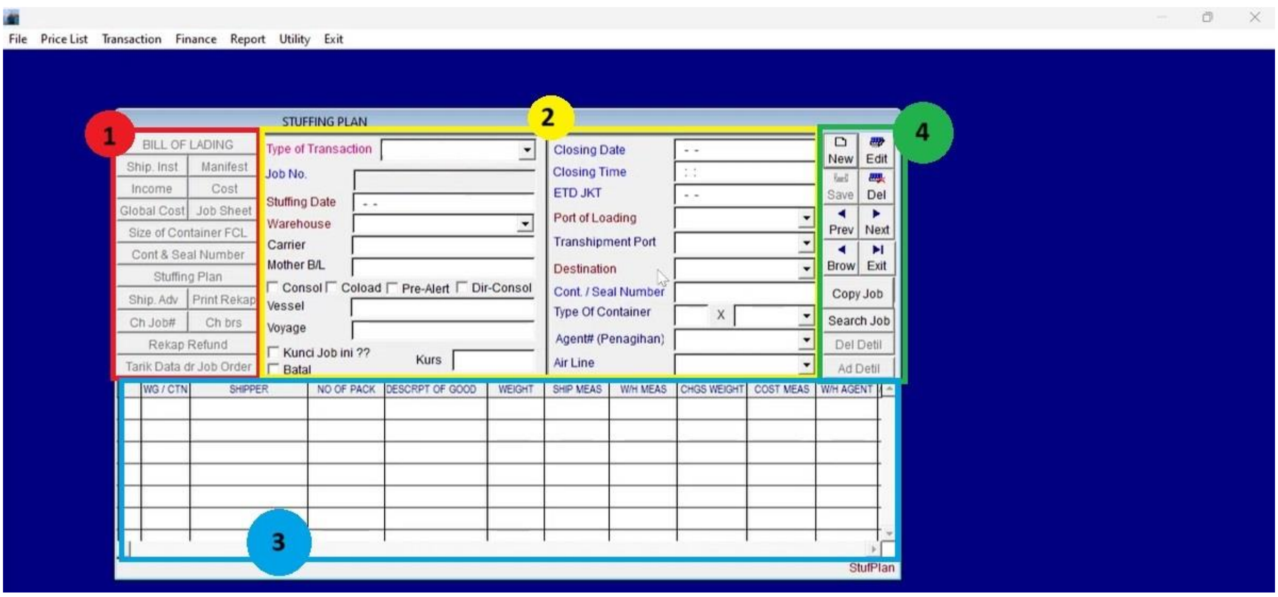

Fig. 4: Implementation of Stuffing Module in EXIM Application

Figure 4 displays the Stuffing Plan module interface in the IoT-based EXIM application for recording and processing container filling plans. This module consists of:

(1) Other Sub-Module for operational, financial, document, and tracking data
(2) General Data containing general transaction information
(3) Detail Table for details of shipment contents
(4) CRUD Button for data management

DOI: 10.3844/jcssp.2026.410.419

Testing Application

This stage analyzes the increase in efficiency, accuracy, and work speed after implementing the EXIM application, compared to the conventional system, based on a sample of 100 logistics and export-import staff. Table 5 shows the measurement results from using the conventional system and after implementing the EXIM IoT application.

Table 5 compares the conventional system with the IoT-based EXIM application based on process observations and user questionnaires. The results show that document input time was reduced by 57% with the help of automatic scanning and validation, to just 7–12 minutes per document set. Input errors decreased significantly, with 77% higher accuracy thanks to the system's autofill and validation features. Tracking time also increased in efficiency, 86% faster, because item position data was displayed in real time via sensors. The number of documents that could be processed per day increased by 57%, reaching 40–60 documents depending on complexity. Furthermore, user satisfaction scores increased by 52% due to the faster system and reduced repetitive work. Figure 5 shows the visual charts of improvements in time efficiency, accuracy, responsiveness, productivity, and user perception.

Table 5: Result of Change after Implementation EXIM IoT

No	Indicator	Goals	Before (Conventional)	After (EXIM IoT)	Formula	Interpretation
1	Average document input time	Time Efficiency	21 Minutes	9 Minutes	$\frac{21-9}{21} x\ 100\%$	Efficiency increased to 57%
2	Average input errors	Accuracy	13%	3%	$\frac{13-3}{13} x\ 100\%$	Accuracy Increased to 77%
3	Average tracking time	Responsiveness	42 Minutes	6 Minutes	$\frac{42-6}{42} x\ 100$	Faster Response to 86%
4	Documents per staff member per day	Productivity	28	44	$\frac{44-28}{28} x\ 100\%$	Productivity increased to 57%
5	Staff satisfaction	User Perception	2.9	4.4	$\frac{4.4-2.9}{2.9} x\ 100\%$	Satisfaction Increased to 52%

Fig. 5: Visual Chart Before and After Implementation of IoT

Discussion

This study examines the implementation of IoT architecture in an Export-Import (EXIM) application for the logistics industry to address operational issues such as data inconsistency. The RAD method is used to rapidly build an application prototype with a real-time dashboard based on legacy data and simulations. This desktop-based EXIM application adopts a local IoT system to improve accuracy, efficiency, and process speed. The system architecture consists of five layers: a scanner for reading barcodes, a thermal printer for printing documents, an edge gateway and LAN for connecting devices, and a firewall and router for data security. Scanned data is sent to a local server after verification, then stored and processed by the system. Users can automatically generate export documents based on the scanned data. The IoT-based EXIM implementation shows significant improvements in operational efficiency, tracking, and document management in a structured and automated manner. However, the system still has limitations such as reliance on a local network, limited scalability, and a lack of integration with cloud platforms. Further research will focus on developing cloud-IoT integration and conducting large-scale testing to ensure optimal performance across a wide range of operational conditions.

Conclusion

The development of an IoT-based Local EXIM Application system enables the automation of logistics flows through a structured system architecture, with layers of perception, access, network, support, and application. The main components of the system include File, Price List, Transaction, Finance, and Report modules, with data stored locally using internal servers and edge computing, enabling high access efficiency and security without dependence on the public cloud. After implementing the IoT-based EXIM application, it can provide a real impact on user operational efficiency because all activities, such as shipping data input, package tracking, document management, and reporting, are carried out digitally through a local server. New business processes allow each package and document to be tracked automatically through IoT devices, without relying on external internet or the cloud. Data is stored securely on a local server, and users can monitor all activities and generate reports at any time. The implications of this research contribute to the development of logistics management applications integrated with IoT, especially in the context of the use of local servers and edge computing. The results of the EXIM application design can be a reference for IoT-based logistics digitalization in other sectors, especially for organizations that require internal solutions without relying on the cloud. In addition, this system also supports increased productivity and work efficiency in the international trade sector.

Acknowledgment

All authors would like to thank the Bunda Mulia University, especially the P3M Department, which affiliates this research, and the Ministry of Education, Culture, Research and Technology, Indonesia, the logistics industry for their support, and the editorial team of the journal of computer science for reviewing and improving our paper, which can be well and smoothly.

Funding Information

The researchers would like to thank the Ministry of Education, Culture, Research, and Technology, Indonesia, for funding research on national competitive programs and assignments in BIMA KEMENRISTEKDIKTI, through the Regular Fundamental Research for fiscal year 2025, number: 0966/LL3/AL.04/2025.

Author's Contributions

Julia Loisa: Conducted an extensive literature review, carried out field research, and prepared the initial draft of the proposed model.

Johanes Fernandes Andry: Designed the research methodology, developed research instruments, and collected empirical data.

Devi Yurisca Bernanda: Performed data analysis and prepared the draft of the EXIM application model.

Lydia Liliana: Developed the EXIM application, integrated IoT components, and validated the predictive modeling framework.

Davina Valerian Cong: Compiled research documentation and contributed to the integration of IoT within the EXIM application.

Ethics

This article is original and unpublished. Corresponding authors confirm that all other authors have read and agree that the manuscript does not involve ethical issues.

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