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Designing a Finished Goods Warehouse Management System to Reduce Paper Waste Using the Framework for the Application of System Thinking: A Case Study at PT XYZ

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ABSTRACT: Digital transformation in Indonesia's manufacturing sector has accelerated the adoption of warehouse management systems, with the automated warehouse market projected to grow from USD 25.6 billion in 2025 to USD 54.3 billion in 2031. Traditional paper-based warehouse operations created inefficiencies, environmental degradation, and operational challenges, including poor traceability, coordination gaps, and significant paper waste. This research aimed to design a comprehensive Finished Goods Warehouse Management System integrated with Outgoing Quality Control (OQC) functionality to address operational challenges at PT. XYZ, including limited human resources, inconsistent inspection duration, inadequate location tracking, and excessive paper consumption of approximately 200 sheets per month. The study employed a qualitative case study approach using the Framework for the Application of System Thinking (FAST) methodology, encompassing Scope Definition, Problem Analysis, Requirements Analysis, and Logical Design phases. The PIECES framework was used to evaluate system feasibility across Performance, Information, Economics, Control, Efficiency, and Service dimensions. Data collection involved observation, semi-structured interviews with warehouse administrators, quality control staff, OQC personnel, and production planning and inventory control (PPIC) staff, along with document review. The research produced comprehensive system models, including use case diagrams, activity diagrams, sequence diagrams, Entity Relationship Diagrams, Data Flow Diagrams, and user interface prototypes. The designed system integrated real-time status updates, automatic blocking mechanisms, barcode scanning technology, digital inspection forms with AQL-based auto-calculation, and complete traceability throughout the supply chain.The integrated WMS design provided practical solutions for improving operational efficiency, eliminating paper waste, ensuring product quality through mandatory quality control integration, and supporting sustainable manufacturing practices in the plastic injection molding industry.

KEYWORDS: Warehouse management system; quality control integration; FAST methodology; digital transformation; paper waste reduction; manufacturing industry

1. Introduction

Digital transformation became a strategic necessity for the manufacturing industry in Indonesia, driving the adoption of digital technologies to improve company operations. Manufacturing companies increasingly integrated web-based systems and advanced technologies such as barcode scanners to optimize warehouse management and production processes. The use of web-based warehouse management systems and barcode scanner technology in the manufacturing industry continued to increase, with the manufacturing sector identified as the primary user of these web-based solutions [1].

The automated warehouse market in Indonesia was expected to grow from USD 25.6 billion in 2025 to USD 54.3 billion in 2031, with a compound annual growth rate (CAGR) of 13.2%. In Indonesia, the rapid growth of e-commerce and third-party logistics (3PL) providers drove investment in automation. Advanced technologies such as automated guided vehicles (AGVs), robotic arms, and warehouse management systems (WMS) became increasingly common. In the manufacturing and industrial warehousing sectors, automated storage and material handling systems were essential for optimizing factory workflows. Demand in Indonesia increased in line with the development of industrial automation [2].

The growth of this market reflected the urgency of implementing computerized systems to address the complexity of modern warehouse management. Complex warehouse management activities became highly complicated when performed manually. Manual recording increased the risk of poor-quality information, which led to biased inventory assessments [3]. Technological advances provided solutions to facilitate access to and control of warehousing activities. Through the design of this web-based warehouse application, data were managed accurately and processed into valuable information to support decision-making. Consequently, many companies recognized the need for effective information systems [4].

Beyond operational efficiency concerns, the environmental impact of paper-based warehouse management systems became increasingly critical. Traditional warehouse operations relied heavily on paper documentation for receiving records, picking lists, quality control reports, and delivery order documents. This paper-intensive approach created inefficiencies and contributed significantly to environmental degradation and operational costs. The increase in the global economy and population, particularly due to rapid industrialization and urbanization in developing countries, was expected to sustain growth in worldwide paper consumption, which in turn led to higher energy usage, greater carbon emissions, and increased pollution [5]. The transition from paper-based to digital warehouse management systems therefore represented both an operational improvement and an environmental responsibility for modern manufacturing companies.

This research was conducted at PT XYZ, a manufacturing company facing challenges in finished goods warehouse management, particularly significant paper waste issues. PT XYZ operated in the plastic injection molding sector. The finished goods warehouse stored products ready for shipment, products that had not undergone OQC, and products awaiting assembly with other parts prior to shipment.

The flow of goods at PT XYZ began with the receipt of raw materials, which underwent incoming quality control (IQC), were stored in the raw material warehouse, and were distributed to production for the injection molding process. Production outputs underwent sorting or inline quality control, packaging, and were placed in the finished goods warehouse. Before shipment, a final inspection through OQC was conducted to ensure that only products meeting quality standards were shipped. Products that passed OQC were shipped to customers, while those that failed inspection were labeled as Not Good (NG) and returned to Quality Control for re-inspection.

The focus of this thesis was to analyze and design a Warehouse Management System (WMS) for the finished goods warehouse, incorporating an OQC feature so that quality control status was recorded in real time. This integration prevented the allocation of problematic stock, improved batch traceability, and significantly reduced paper waste throughout warehouse operations.

The first problem identified was limited human resources, which significantly affected the performance of the OQC process. Of the 45 personnel in the Quality Control Department, only one person handled OQC activities. This limitation caused distribution flow obstacles, prolonged inspection duration, and increased the risk of repeated or missed inspections. Due to the workload handled by a single individual, the OQC process required a long time, thereby hindering shipping activities and interdepartmental coordination. Each OQC inspection required multiple paper forms, including inspection checklists and defect documentation sheets, which multiplied paper consumption during each inspection cycle.

These human resource limitations also exacerbated coordination issues between OQC and the warehouse because no reliable mechanism existed to report inspection status in real time. As a result, warehouse staff often lacked information on whether OQC for a shipment had been completed or was still ongoing, leading to scheduling miscommunication. The uncertainty in OQC duration was observed from data collected over five working days, which showed inconsistencies in inspection time, as illustrated in Figure 1. The observation data indicated no consistent correlation between the number of inspected boxes or products and the time required to complete the OQC process. This uncertainty resulted in inaccurate scheduling of goods collection and increased the risk of delivery delays.

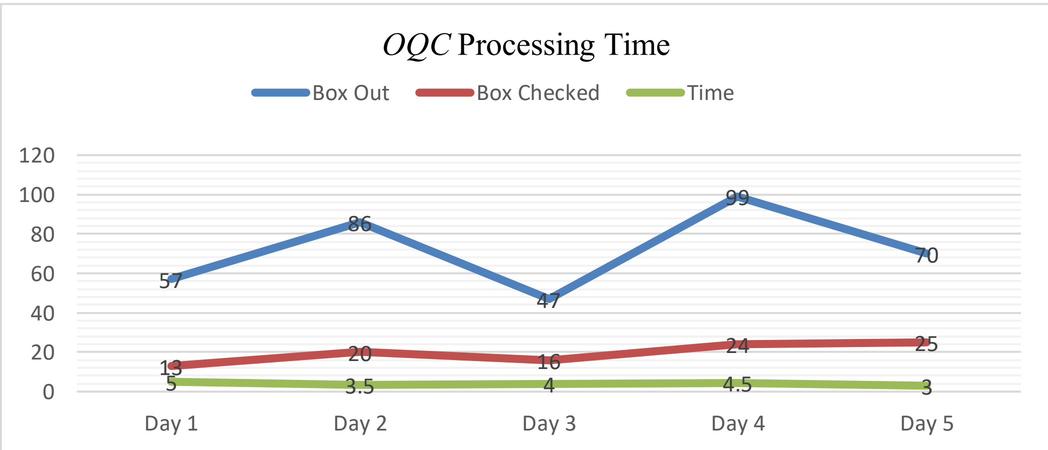

Figure 1. OQC process time.

Another issue identified was the irregularity of the finished goods warehouse location system. Product locations were not recorded in detail; only their presence in the warehouse was known without specific area or zone information. Storage areas were labeled using physical name tags, while company standards only described pallet arrangement patterns without detailed location mapping. This condition caused the goods retrieval process to take an average of 38 minutes or more, as warehouse staff performed manual checks to confirm stock availability and location. If stock was insufficient, the warehouse requested additional items from the packing department, and if unavailable, the request was forwarded to PPIC for re-production planning.

Another problem was found in the discrepancy between physical information name tags and product names printed on carton boxes. Due to time and resource constraints, existing name tags with similar specifications but different colors were reused. Visual documentation showed mismatches between tag information and actual products. This discrepancy caused retrieval activities to overlap with rearrangement processes, resulting in average retrieval times of 38 minutes or more.

Based on these findings, four interrelated problems were identified as affecting finished goods warehouse operations and quality control performance. First, limited human resources in the Quality Control Department. Second, inconsistent OQC inspection duration, which created scheduling difficulties and delivery delay risks. Third, irregular warehouse location management, which extended goods retrieval time. Fourth, mismatches between physical name tags and actual products, which increased the likelihood of retrieval errors.

From previous studies, the novelty of this research was identified as the development of an integrated warehouse management system that mandated quality control as part of the outgoing finished goods process. Unlike earlier studies, which did not accommodate integrated quality control checks within the WMS prior to shipping, this research embedded quality control as a compulsory workflow component [6, 7, 8, 9, 10, 11]. This integration included digital inspection records, workflow approval mechanisms, and an automatic blocking system for non-conforming products.

2. Materials and Methods

This study employed a qualitative case study approach to design a Warehouse Management System (WMS) for finished goods warehouse operations at PT XYZ. The case study method was selected for its ability to provide an in-depth examination of complex organizational phenomena within real-world contexts, thereby enabling a comprehensive analysis of warehouse management processes and the systematic application of design methodologies [12]. The research was conducted at PT XYZ’s facility, which operated in the plastic injection molding sector, with particular emphasis on the finished goods storage area, where integration challenges between warehouse operations and quality control processes were most evident.

2.1. Research participants and data collections.

Research participants comprised key personnel directly involved in warehouse operations, including warehouse administrators, quality control administrators, OQC staff, and PPIC staff. Data collection followed established qualitative research protocols and utilized three primary methods: observation, interviews, and documentation [13]. Observation focused on critical warehouse activities, including receiving, storage, picking, and OQC procedures, allowing researchers to identify operational bottlenecks and workflow inefficiencies in natural settings. Semi-structured interviews employed flexible questioning protocols to explore existing procedures, operational challenges, and system requirements while maintaining consistency across participant categories. Documentation analysis encompassed internal organizational materials, including standard operating procedures, work instructions, inventory reports, and warehouse layout diagrams, as well as external literature sources such as academic publications on warehouse management systems and relevant industry regulations.

2.2. Data analysis framework.

Data analysis was the process by which researchers analyzed information collected prior to, during, and after the data gathering phase of the study [14]. Raw data from multiple sources were systematically compiled and organized to identify information relevant to warehouse management system design requirements and OQC integration challenges. The data reduction process involved categorizing information according to emergent themes and analyzing warehouse operations using the PIECES framework to systematically identify improvement opportunities. Data display employed the FAST methodology, which provided a structured approach for translating analytical findings into system design specifications through visual modeling techniques, including use case diagrams, activity diagrams, sequence diagrams, entity relationship diagrams, and data flow diagrams. These analytical outputs were synthesized to develop system requirements aligned with PT XYZ's operational context, with particular emphasis on paper waste reduction and quality control integration.

2.6 FAST methodology framework.

The system design followed the FAST methodology, which consisted of four key phases implemented sequentially. The scope definition phase utilized the PIECES framework to assess system feasibility and define project boundaries, with data collection focused on identifying problems, opportunities, and directives in existing warehouse operations [15]. The problem analysis phase involved the systematic identification and documentation of business problems through root cause analysis, examining systemic issues and interconnections among organizational problems that were not immediately apparent. The requirements analysis phase identified, analyzed, and documented functional and non-functional system requirements based on the problem analysis, ensuring alignment with user expectations and business objectives. The logical design phase developed logical system models representing data structures, business processes, data flows, and user interfaces without consideration of physical implementation details. These models included use case diagrams, activity diagrams, sequence diagrams, entity relationship diagrams, and data flow diagrams, and were complemented by user interface design visualizations.

3. Results and Discussion

This study designed a finished goods warehouse management system using the FAST methodology, with the system analysis phase consisting of scope definition, problem analysis, requirements analysis, and logical design.

3.1. Scope definition.

The first phase of the project was the scope definition phase. Based on an initial understanding of problems, opportunities, directions, limitations, and organizational vision, the initial project scope was formulated. Consequently, an initial scope statement became one of the key outputs of this phase [15]. Data were collected to assess system feasibility and determine project boundaries using the PIECES (performance, information, economics, control, efficiency, and service) framework [16].

3.1.1. PIECES framework (performance, information, economic, control, efficiency, service).

The PIECES framework was originally introduced by James Wetherbe as a tool for assessing and improving existing systems within organizations [8]. The PIECES method was applied as an analytical approach to categorize problems, opportunities, and development directions in a structured manner. The results of this analysis provided evaluations that served as the basis for the system development process. The analysis of the finished goods warehouse management system at PT XYZ was summarized using the PIECES framework, as presented in Table 1.

Table 1. PIECES framework analysis of the finished goods warehouse management system at PT XYZ.

Factor	Current System Issue	Proposed System Solutions
Performance	OQC process time is inconsistent (180-300 minutes for similar volumes). Average picking time is 38 minutes. OQC personnel are limited to only one person.	Integrated WMS system with an OQC module can predict and optimize processing time. Real-time dashboard for monitoring throughput. System provides real-time notifications of OQC status. Digital inspection form speeds up data input.
Information	Manual recording using paper or Excel. Lot data was not previously available for OQC. Stock information is not real-time. Location tracking absent, Manual report.	A system with barcode scanning for automatic data input. Real-time stock visibility per location/lot/status. integrated database with complete traceability. automated report generation
Economic	High costs for Overtime. Reworking of undetected NG products. Paper-based documentation (≈200 sheets monthly)	Process optimization to reduce overtime. Detect NG products earlier through systematic OQC. Paperless digital documentation.
Control	No automatic blocking mechanism for uninspected goods, manual coordination via verbal communication, discontinued FIFO recording, limited audit trail	Status-based inventory control (Available, Blocked-Pending OQC, Blocked-NG, QC Pass); system-enforced FIFO, complete digital audit trail with timestamps
Efficiency	Time-consuming manual processes; double handling during picking; inconsistent OQC duration; repetitive data entry	Location optimization with route guidance; automated data population through barcode scanning; digital forms eliminating redundant entry; instant report generation
Service	Process inconsistency, single-person dependency creating bottlenecks, delayed manual reporting.	Standardized processes through system enforcement, multi-user accessibility reducing single points of failure, real-time reporting capability.

3.2. Problem analysis.

Problems with the current system were examined based on the findings obtained during the preliminary inquiry stage. These findings were critical in identifying system weaknesses and improvement opportunities. This phase aimed to enhance system performance in order to support the company's operational activities. One of the key outputs of this phase was a report outlining the identified problems, their root causes, impacts, and the expected benefits of the proposed solutions [16]. A summary of the problem analysis, covering the identified gaps (problems), causes, impacts, and ideal conditions, was presented in Table 2.

Table 2. Problem analysis.

GAP	Cause	Impact	Ideal
Limitations of OQC Staff	Only 1 OQC personnel handles the entire final inspection process	Distribution bottlenecks, inconsistent inspection duration (180-300 min), risk of missed or repeated inspections.	Digital system enabling efficient single-person operation through automated

			calculations and digital forms
Inconsistency in OQC process time	Absence of prior lot information, manual lot recording per box, manual AQL calculations.	Unpredictable processing time, scheduling uncertainty, potential delivery delays.	Real-time lot information provision, automated AQL-based sample calculation, digital inspection forms.
Warehouse-OQC coordination is not real-time	No real-time status reporting mechanism; reliance on verbal/messaging communication	Warehouse unaware of OQC completion status; scheduling miscommunication; shipping delays	Automated status updates and notifications; real-time dashboard monitoring
Item locations are not recorded specifically	Physical name tags only, no digital location recording, informal arrangement standards	The goods picking process takes an average of 38 minutes (ranging from 25 to 45 minutes). manual product location verification	Digital location management with zone/are, system-guided picking with exact location direction.
No blocking mechanism for goods that have not undergone OQC	Manual system cannot auto-block. Depends on communication and physical separation. No status-based inventory control	Risk of items that have not passed or failed OQC being shipped to customers.	WMS system with automatic blocking: Inventory status (Available, Blocked-Pending OQC, Blocked-NG, OQC Pass).
Poor traceability	Lot data is not linked to location, OQC results, and delivery. Manual records are difficult to trace.	Difficult to trace product history from receiving-OQC-shipping. time-consuming lot searches, problematic recall capability	Comprehensive digital traceability linking all transaction stages; visual timeline tracking

3.3. Requirement analysis.

Requirements analysis followed the problem analysis phase. The requirements analysis step of the FAST methodology was critical because it ensured that the proposed solution met system requirements and facilitated an understanding of user needs and expectations. This stage produced specifications for a new information system that were continuously evaluated, particularly in terms of how effectively they satisfied identified requirements [17].

3.3.1 Functional requirements overview.

The warehouse administrator required capabilities to manage finished goods receiving, coordinate picking operations, monitor real-time OQC progress, and generate comprehensive inventory reports. Essential functions included barcode-based location management and multidimensional stock reporting by location, lot, and status. The OQC role required an inspection queue dashboard, automated AQL-based sample calculations, digital inspection forms with defect documentation features, and automated status notification mechanisms. The quality control administrator required label generation with barcode printing, monitoring of OQC progress across production batches, and access to consolidated inspection reports. The PPIC role required real-time inventory visibility, stock analysis functions including turnover rate calculation and identification of slow-moving items, and comprehensive quality monitoring reports.

System requirements encompassed input, process, and output specifications across all user roles. Authentication mechanisms were defined to ensure role-based access control and system security. Input requirements included finished goods receiving data, storage location information, picking requests, and inspection queue data. Process requirements covered user authentication, barcode scanning workflows, automated picking list generation, real-time status updates, and notification mechanisms. Output requirements specified reports such as receiving documentation, picking lists, inventory summaries, inspection results, and traceability records. Previous studies indicated that comprehensive requirement specification during the analysis phase significantly reduced implementation risks and improved system acceptance.

3.4. Logical design.

The logical design phase was conducted to translate business requirements into system models that described data structures, business processes, data flows, and user interfaces. This phase included activities related to the preparation of business requirements documentation using structured modeling techniques. Diagrams such as unified modeling language diagrams, flowcharts, data flow diagrams, and entity relationship diagrams were employed to represent system logic and functionality [17].

3.4.1. Use case diagram.

A use case was defined as a description of system functionality that helped both designers and users understand the functional requirements of the system being developed. The use case diagram, as one type of unified modeling language diagram, illustrated the interactions between system actors and the system itself [16]. The use case diagram for the proposed warehouse management system was presented in Figure 2.

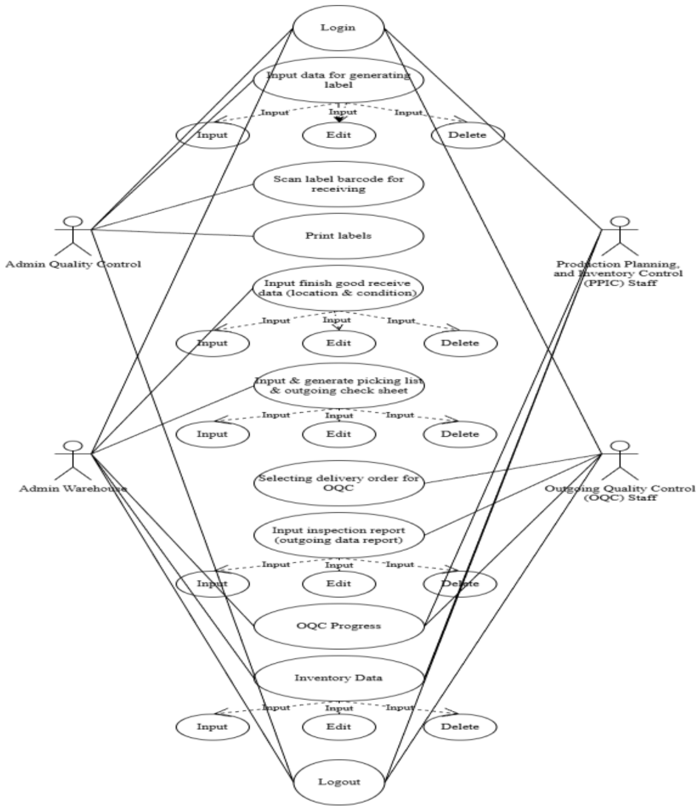

Figure 2. Use case diagram.

3.4.2. Activity diagram.

Activity diagrams were used to illustrate activity flows within the proposed system, including how each process began, possible decision points, parallel activities, and how processes were completed [18]. These diagrams depicted how business processes behaved rather than detailing the internal mechanisms of system components. Therefore, activity diagrams presented process and activity paths from a high-level perspective instead of describing detailed system logic [19].

3.4.2.1. Warehouse administrator.

The process began with user authentication through the login interface. After logging in, the warehouse administrator selected system menus according to operational needs, including receiving, picking, OQC monitoring, and inventory monitoring. The receiving process involved inputting incoming finished goods data using barcode scanning. The picking process included generating picking lists based on the first-in, first-out principle and printing outgoing check sheets. Monitoring of OQC was conducted through a real-time dashboard, while inventory monitoring provided access to stock reports by location, lot, and status.

3.4.2.2. OQC.

The activity diagram for the OQC process was illustrated in Figure 3, which depicted the integrated inspection workflow and coordination among system actors and components. The process began with user login, followed by selection of the inspection queue. The OQC staff scanned the box barcode to automatically populate product and lot information. The system then calculated the required sample size based on the acceptable quality level table. Inspection results were entered into a digital inspection form, including defect classification and photo uploads when defects were identified. After confirmation of the final inspection outcome (pass or fail), the system updated the inspection status and sent automatic notifications to the warehouse.

3.4.2.3. Quality control administrator.

The quality control administrator process began with user login, followed by input of product data for label generation. The system generated unique barcodes for each box and supported batch or individual label printing. The quality control administrator monitored OQC progress across all production batches through the dashboard and accessed consolidated inspection reports and defect analysis summaries.

3.4.2.4. Production planning and inventory control.

After logging in, PPIC staff monitored real-time inventory data using location, lot, and status filters displayed on a visual dashboard. The system provided visibility of OQC progress to support production planning activities. Additional functions included access to stock analytics such as inventory turnover and identification of fast- and slow-moving items, as well as data export features for further analysis.

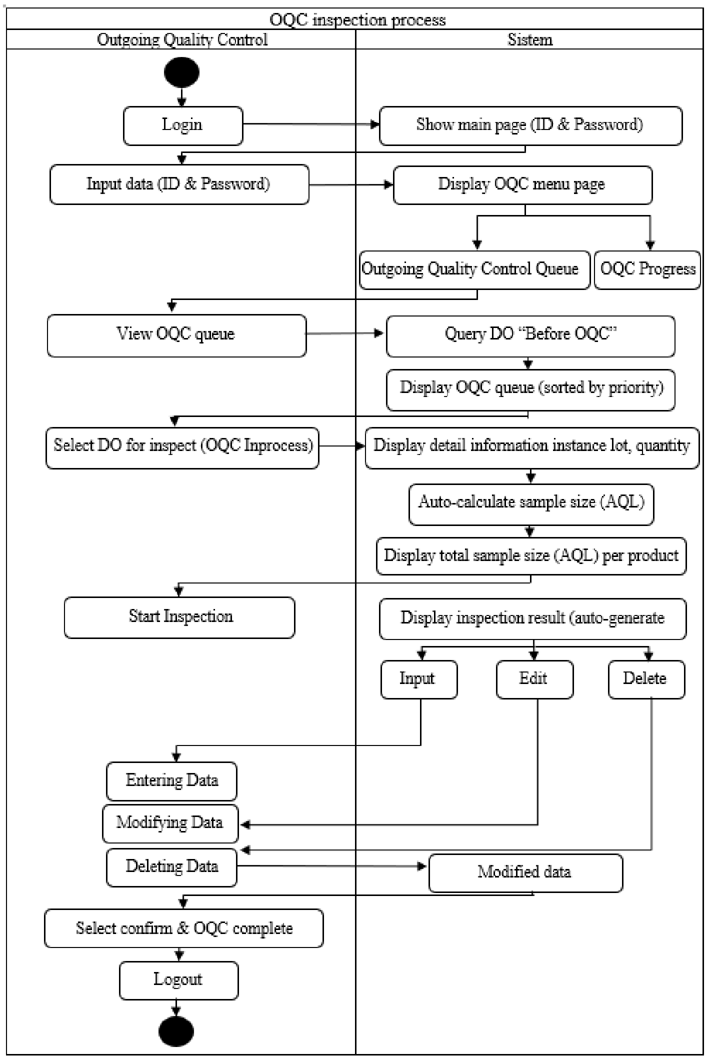

Figure 3. OQC inspection process.

3.4.3. Sequence diagram.

Sequence diagrams in the logical design phase were used to illustrate interactions between objects or system components over time. These diagrams explained object behavior within a use case by describing object lifetimes and the messages sent and received between them. Consequently, the objects involved in each use case and the methods instantiated within those objects were identified to accurately represent the interaction sequence [18].

3.4.3.1. Warehouse administrator.

The warehouse administrator sequence diagram included one actor (warehouse administrator) and five objects: login screen, home page, administrator menu, data processing module, and report module. The process began with the warehouse administrator accessing the login screen and validating user credentials. Upon successful validation, the system displayed the home page. The administrator then accessed the administrator menu, which presented receiving, picking, OQC progress, and inventory options. When a menu option was selected, the system directed the user to the data processing module to perform data input, editing, or deletion. After data processing was completed, the system saved the data to the database and displayed the report module as confirmation.

3.4.3.2. OQC.

The OQC sequence diagram consisted of one actor (OQC staff) and five objects: login screen, home page, OQC menu, data processing module, and report module. After successful login, OQC staff accessed the inspection queue through the OQC menu. The system displayed lot information and automatically calculated sample sizes based on the acceptable quality level table. The staff scanned the box barcode and completed the digital inspection form using predefined inspection criteria. After the inspection result was confirmed as pass or not good, the system updated the inspection status and sent automatic notifications to the warehouse administrator. OQC staff were also able to monitor inspection progress through the OQC progress menu. The sequence diagram for the OQC process was illustrated in Figure 4.

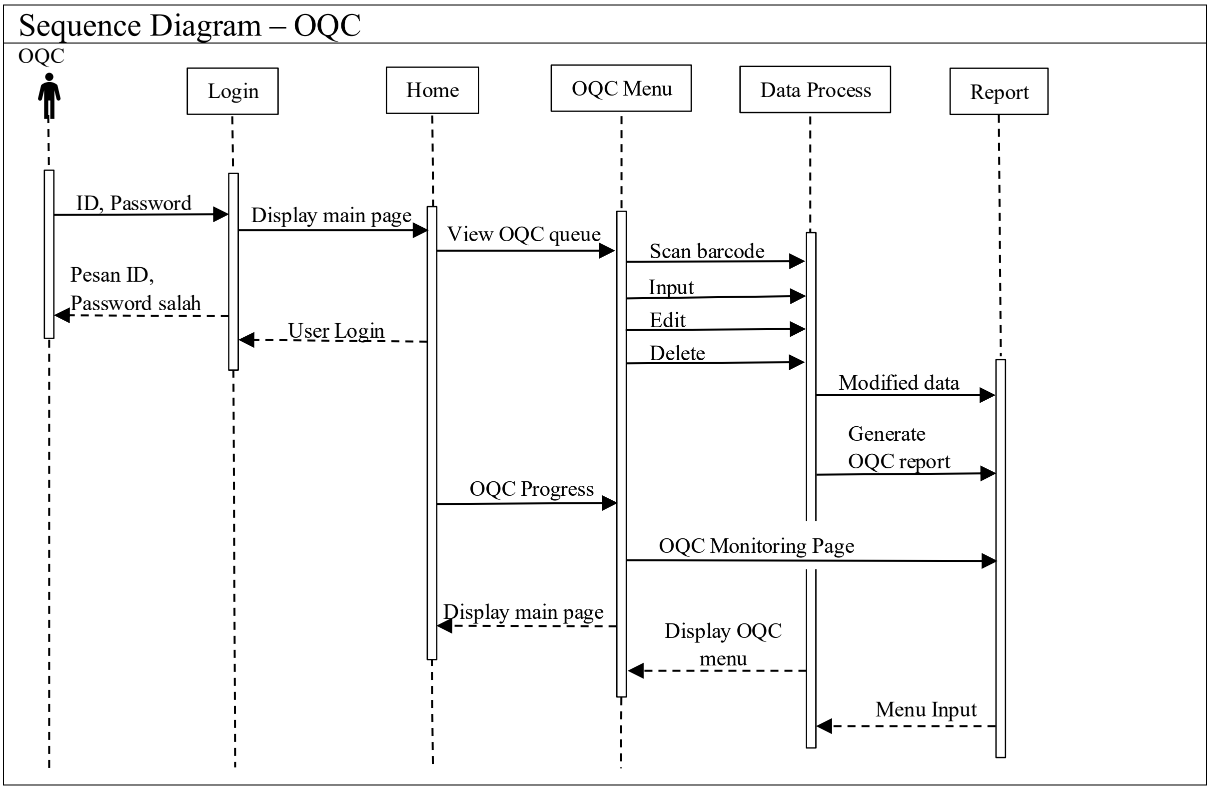

Figure 4. Sequence Diagram OQC.

3.4.3.3. Quality control administrator.

The quality control administrator sequence diagram included one actor (quality control administrator) and five objects: login screen, home page, administrator menu, data processing module, and report module. After logging in, the quality control administrator accessed the label generation menu and entered product data. The system generated unique barcodes for each box and processed label printing. In addition, the quality control administrator monitored OQC progress across all production batches through the dashboard and accessed consolidated inspection reports.

3.4.3.4. PPIC.

The PPIC sequence diagram included one actor (PPIC staff) and five objects: login screen, home page, PPIC menu, data processing module, and report module. After logging in, PPIC staff accessed the inventory dashboard to monitor real-time stock using filters for location, lot, and status. The system displayed OQC progress to support production planning and delivery scheduling. Data export functions were provided to allow inventory and quality data to be exported in Excel, PDF, or CSV formats for further analysis. ERD modeling was conducted using the Visual Studio modeling diagram project, which utilized extracted entities, attributes, relationships, and cardinalities to construct the ER diagrams [20]. ERD served as a tool for database creation and provided an overview of how the database would operate. The three fundamental components of ERD were entities, attributes, and relationships [21].

The Admin Warehouse ERD consisted of six main entities. The Admin Warehouse entity served as the main user with primary key attributes id_admin, username, and password, and it managed the warehouse system. Inventory Data acted as a central entity with primary key id_inventory, foreign key id_admin, and attributes including product_name, lot_number, carton_box_no, quantity, and status. Inventory Data was managed by the Admin Warehouse with a 1:M cardinality, allowing one admin to manage multiple inventory records. OQC Status contained primary key id_oqc, foreign keys id_inventory and id_admin, and attributes inspection_status, oqc_result, inspection_date, and id_inspector. OQC Status was connected to Inventory Data through a “generates” relationship (1:M), enabling one inventory item to have multiple OQC statuses for tracking purposes. It was also related to the Admin Warehouse through an “inspect” relationship (M:1), with multiple OQC statuses monitored by one admin. Location included primary key id_location, foreign key id_inventory, and attributes warehouse_code, area_address, capacity, and status, connected to Inventory Data through a “stores” relationship (1:M), allowing tracking of the physical location of goods. Picking List contained primary key id_picking, foreign keys id_inventory and id_admin, and attributes product_name, lot_number, quantity_picked, picking_date, and FIFO_sequence. Picking List was connected to Inventory Data through a “data” relationship (1:M) and to Admin Warehouse through a “stores” relationship (M:1). Stock Alert included primary key id_alert, foreign keys id_admin and id_inventory, and attributes alert_date, threshold_value, and current_value, connected to Inventory Data through a “triggers” relationship (M:1) and to Admin Warehouse for notification purposes.

The OQC ERD consisted of seven entities. The OQC Inspector entity served as the main user with primary key id_oqc_staff, username, and password, handling multiple OQC queues with a 1:M cardinality. OQC Queue contained primary key id_queue, foreign key id_oqc_staff, and attributes including do_received_date, priority, status, action, and DO_number, functioning as a list of goods queued for inspection based on delivery priority. Before OQC included primary key id_before_oqc, foreign key id_queue, and attributes DO_number, product_name, lot_number, carton_box_number, quantity_carton_box, quantity_pcs, barcode, and outgoing_data_report, with a 1:1 relationship to OQC Queue representing the details of goods before inspection. Inspection Report acted as a central entity with primary key id_report, foreign keys id_queue and id_inspection_report, and attributes inspections_according_aql, checking_1_carton_box, checking_2_label_check, and remarks, connected to OQC Queue through a 1:M relationship to record multiple inspection results. Re Inspection included primary key id_reinspect, foreign key id_report, and attributes re_received_date, priority, and status, with a 1:1 “triggers” relationship with Inspection Report for NG items. OQC Dashboard included primary key id_oqc_dashboard, foreign keys id_before_oqc and id_inspection_report, and attributes compiled_today, pass_rate_today, and blocked_today, with an M:1 relationship to Inspection Report, aggregating multiple inspection reports. Defect Details contained primary key id_defect, foreign key id_report, and attributes defect_type, defect_count, severity, photo_url, and remarks, connected to Inspection Report through a 1:M relationship. Approval Status included primary key id_approval, foreign key id_report, and attributes status, approved_by, and approval_date, with a 1:1 relationship to Inspection Report to record final approvals. The OQC ERD is presented in Figure 5.

The Admin QC ERD consisted of four entities focused on label generation and OQC monitoring. Admin QC included primary key id_admin_qc, username, and password, with responsibilities for generating labels and monitoring OQC progress. Generate Label contained primary key id_label, foreign key id_inventory, and attributes customer_name, product_name, description, quantity, lot_number, carton_box_number, material_name, and label_information, connected to Admin QC through a “generates” relationship (M:1) and to Label History through a “records” relationship (1:M) for traceability. Label History included primary key id_label_history, foreign key id_generate_label, and attributes customer_name, product_name, description, quantity, lot_number, carton_box_number, material_name, print_date, and print_by, storing label printing history for audit and reprint purposes. OQC Progress contained primary key id_oqc_progress, foreign key id_ppic, and attributes period, oqc_pass_rate, ng_rate, total_inspection, trend_data, and defect_summary, with an M:1 “monitors” relationship to Admin QC, providing visibility of OQC status across production batches.

The PPIC ERD consisted of four entities focusing on inventory monitoring and OQC. PPIC User served as the main actor with primary key id_ppic, username, and password, responsible for inventory and OQC monitoring. Inventory Data included primary key id_inventory, foreign key last_modified_by, and attributes product_name, lot_number, carton_box_number, quantity, location_area, status, and remarks, with an M:1 “manages” relationship to PPIC User, and a 1:M “stores” relationship with Location to track inventory movement. Location included primary key id_location, foreign key id_inventory, and attributes warehouse_code, product_name, lot_number, carton_box_number, quantity, location_area, and status_capacity, ensuring each inventory item had a recorded physical location. OQC Progress contained primary key id_oqc_progress, foreign key id_ppic, and attributes period, oqc_pass_rate, ng_rate, total_inspection, trend_data, and defect_summary, with an M:1 “monitors” relationship to PPIC User, providing data for analyzing quality trends and production planning. Inventory Monitoring Dashboard included primary key id_monitor, foreign keys id_inventory and id_ppic, and attributes total_stock, available_stock, blocked_stock, and slow_moving_stock, with an M:1 relationship to both Inventory Data and PPIC User, providing real-time visibility of stock levels, turnover rates, and slow-moving stock alerts necessary for production and delivery planning.

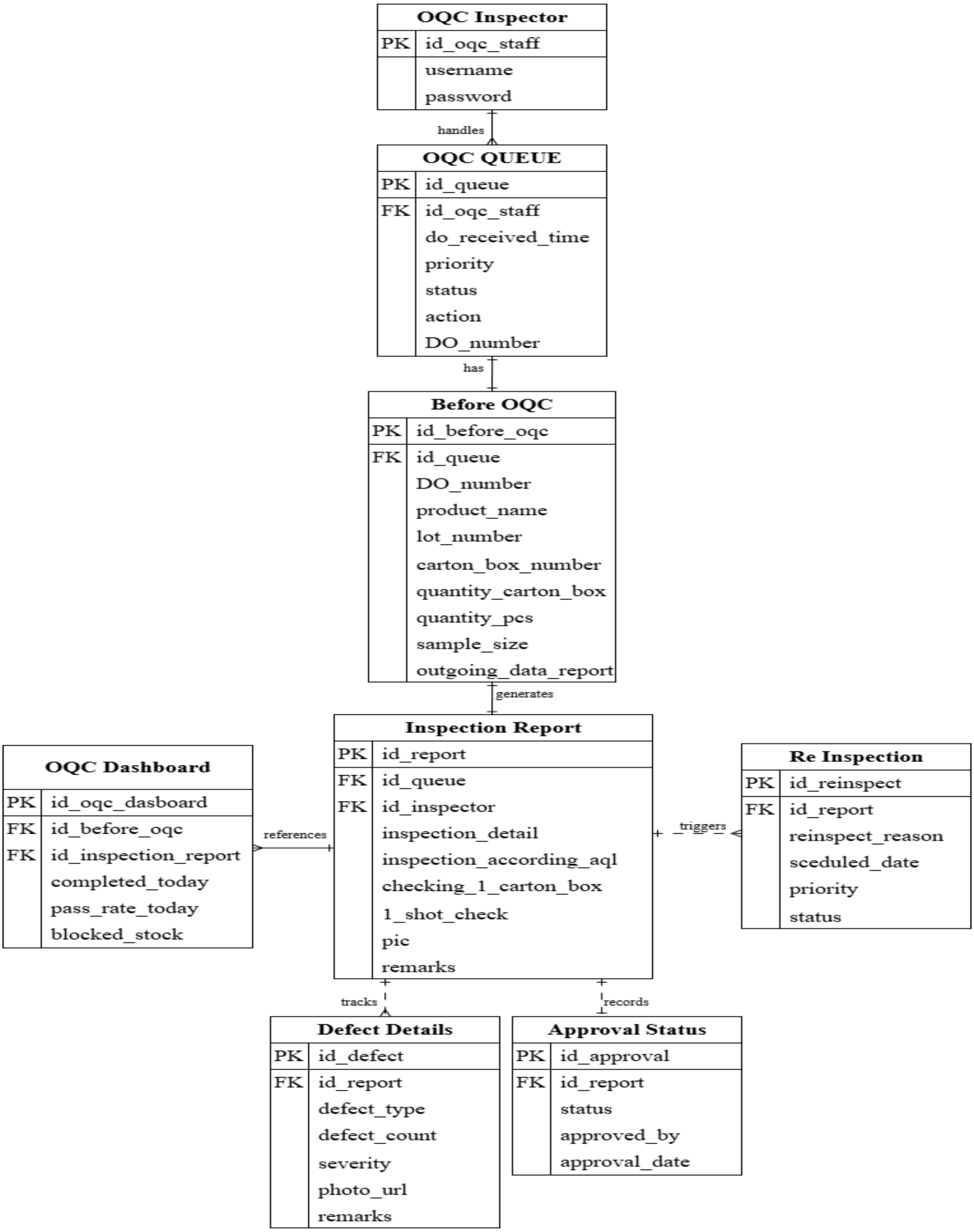

Figure 5. Entity relationship diagram OQC.

3.4.5. DFD (Data Flow Diagram).

The movement of data within the information system and its operations was depicted using a data flow diagram (DFD). The DFD provided a graphical representation of the source and destination of data flows, indicating the origin and the destination of the data [17]. DFD Level 0 illustrated the system at a global level, showing four external entities: Admin Warehouse, OQC, Admin QC, and PPIC, interacting with the WMS Finished Goods Warehouse system. The data flows included Admin Warehouse sending receiving and picking request data and receiving inventory reports, OQC sending inspection results and receiving inspection queues, Admin QC sending label data and receiving OQC reports, and PPIC receiving inventory analytics and OQC monitoring data. The overall structure of the system and data interactions at this level is presented in Figure 6.

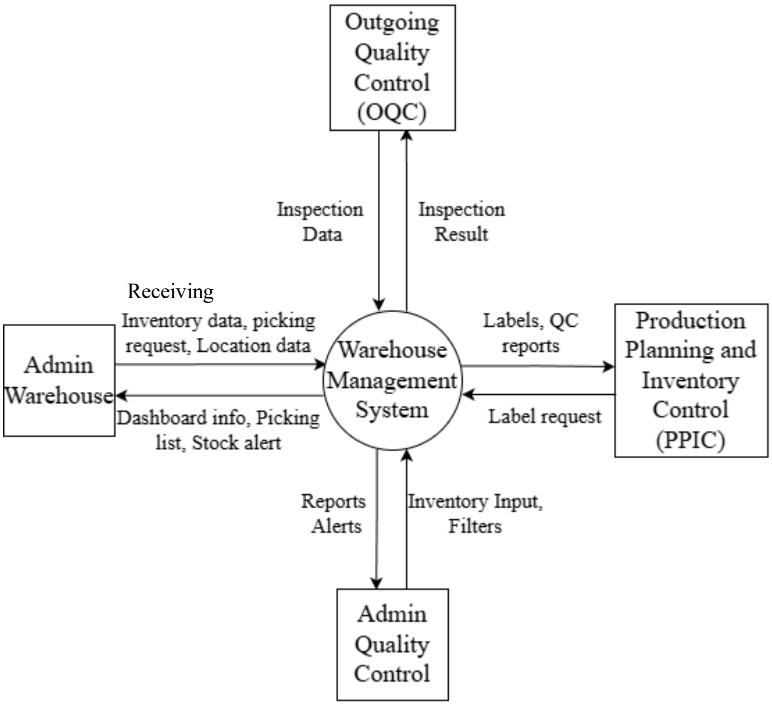

Figure 6. DFD Level 0.

3.5. User interface design.

The prototype described the initial version of the actual system. The prototyping process aimed to gather information on user responses through interaction with the developed prototype. Prototypes were designed to be readily expanded or contracted in accordance with the development process, providing flexibility during system design [22]. The login page served as the initial gateway to the system for all users. It displayed input fields for username and password with a submit button for authentication. The interface was designed to be simple and secure, validating user credentials before granting access to the main menu according to each user's role, including Warehouse Admin, OQC, QC Admin, or PPIC. The login page design is presented in Figure 7.

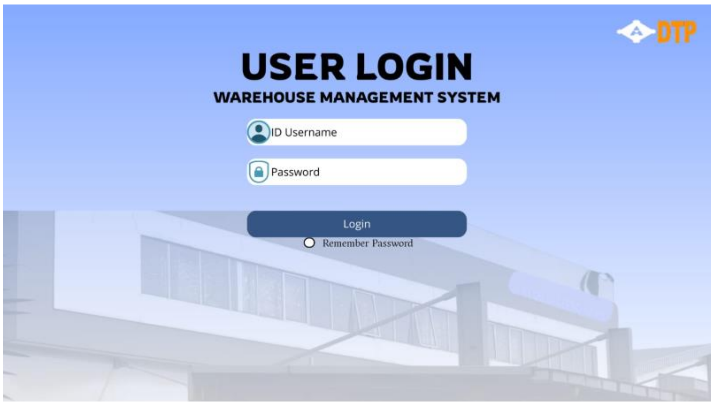

Figure 7. WMS login page for all users.

The user interface for OQC staff included a main page displaying an inspection queue dashboard with priorities determined by delivery schedules. The interface presented a summary of the number of inspections before OQC, blocked inspections, inspections completed today, and the pass rate for the day. Navigation menus led to the OQC queue and OQC progress monitoring. The design of the OQC home page is shown in Figure 8.

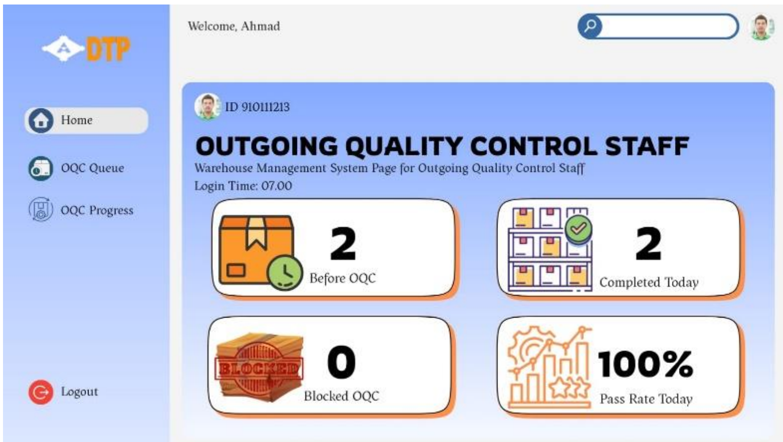

Figure 8. Home page for OQC staff.

4. Conclusions

This study designed an integrated warehouse management system (WMS) with OQC for the finished goods warehouse of PT. XYZ using the FAST methodology. First, the system's limitations and scope were determined through a PIECES analysis, which identified significant gaps in performance, including inconsistent OQC processing times and delays in goods retrieval; in information, such as the absence of a real-time tracking system; in economics, including excessive paper waste in warehouse operations; in control, such as the lack of an automatic blocking mechanism; in efficiency, including time-consuming manual processes; and in service, such as ineffective interdepartmental coordination. Second, the critical issues identified included limited OQC human resources, inconsistent process durations, inadequate location tracking systems, coordination gaps between the warehouse and OQC, the absence of a blocking mechanism for uninspected goods, and poor traceability. Third, system requirements were established for four user categories (Warehouse Admin, OQC, QC Admin, and PPIC), with functional requirements including barcode scanning, automatic AQL sample calculation, digital inspection forms, real-time monitoring, automatic blocking mechanisms, and comprehensive reporting. Non-functional requirements included a web-based system with multi-user access, an integrated database, and a user-friendly interface. Fourth, user requirements validation was conducted through comprehensive system modeling, which consisted of use case diagrams for user-system interactions, activity diagrams for business process flows, sequence diagrams for interactions between objects, ERDs for database structures with eight main entities (User, Product, Lot, Location, Inventory, OQC, Inspection, Defect), and DFD levels 0–1 for data flows within the system. Fifth, the user interface design produced prototypes for all four user categories, with designs prioritizing ease of navigation, real-time data visualization, and efficient data input through barcode scanning and digital forms. The main contribution of this research was the innovative integration of the quality control process as a mandatory component within the warehouse management flow, unlike previous WMS studies that treated quality control as a separate external process. The designed system provided a comprehensive solution for optimizing finished goods warehouse management by ensuring quality assurance, improving operational efficiency, supporting paperless operations, and providing full traceability throughout the finished goods warehouse process.

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Author Contribution

Delia Tri Puspa Wahyuni contributed to conceptualization, research design, and framework development; methodology, including the FAST method and PIECES framework; data collection through observation, interviews, and documentation; data analysis following the FAST methodology phases (Scope Definition, Problem Analysis, Requirements Analysis, and Logical Design); and writing, drafting, and revising the manuscript. Melia Handayani and Ma'ruf served as supervisors, providing guidance, mentorship, and oversight throughout the research process, ensuring academic rigor and adherence to publication standards.

Competing Interest

All authors declare that this research was conducted without any commercial or financial conflicts of interest. The study was part of academic work at Universitas Pendidikan Indonesia and received no external funding. PT. XYZ provided access to their warehouse operations solely for research purposes, without financial compensation or influence over the study's design, execution, analysis, or interpretation. The authors affirm that PT. XYZ had no role in the decision to submit the manuscript for publication. The system design presented is intended for academic purposes and does not represent any commercial product or service. The findings and conclusions reflect the authors' objective analysis of the data collected..

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