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Development and Quality Evaluation of a Web-Based Drug Inventory System for Pharmacy Management

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ABSTRACT

Manual drug inventory management in pharmacies that rely on spreadsheets is prone to stock recording errors, unmonitored expiration dates, and reporting delays, and these problems compound as the drug variety and transaction volume grow. This study developed a web-based drug inventory system for pharmacy operations using the Waterfall model and evaluated its quality through Black Box Testing and User Acceptance Testing (UAT). Black Box Testing across thirteen test scenarios confirmed that every feature functioned according to its specification. UAT involved two pharmacy users, a pharmacy manager and an administrative staff member, who evaluated the system across nine criteria after operating its core functions in the actual work environment. The total UAT score was 71 out of 72, an overall average of 98.61%, classified as Very Good. One criterion, the stock depletion and expiry alert feature, scored 87.50% and was the only result below the maximum, pointing to notification responsiveness as the main area for further work. The system is functionally sound and well-received in this operational context, with the caveat that the two-respondent sample limits broader generalizability. Unlike prior pharmacy IS studies that handle stock recording, sales, or expiry management separately, this system combines batch-level tracking, automated expiry alerts, and integrated reporting in one platform designed for small pharmacy operations.

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1. INTRODUCTION

Pharmacies carry a core responsibility in the public health system, namely ensuring that safe and effective medicines reach patients in the right condition and at the right time. Regulation of Ministry of Health of the Republic Indonesia No. 73 of 2016 formalizes this responsibility by requiring pharmacies to meet standards across procurement, storage, distribution, and drug information provision. In practice, many pharmacies still manage drug inventory through manual methods such as stock cards and spreadsheets. These methods fail in predictable ways as drug variety and transaction volume grow: recording errors accumulate, stock data drifts away from the physical inventory, and expiration dates go unmonitored until a problem surfaces [1], [2]. The downstream effect is a persistent mismatch between what the system shows and what is actually on the shelf, which disrupts service continuity and creates patient safety risks [3], [4].

As drug portfolios expand, manual recording becomes structurally inadequate for the decisions pharmacies need to make about stock replenishment timing, procurement volume, and expired-drug prevention [5], [6], [7]. Several studies identify weak inventory recording as a primary driver of pharmacy operational inefficiency [8]. A recent systematic review of digital technologies in hospital pharmacy reports consistent improvements in dispensing efficiency, medication safety, and inventory control across the studies it examined [9]. A separate review of pharmacy automation versus traditional systems reports a moderately positive effect on reducing medication errors across thirty-two comparative studies [5]. Web-based inventory systems address the same problem at the small-pharmacy level by integrating drug data, batch records, sales transactions, and reports in a single accessible platform [8], [10], yet implementation evidence at the level of small, independent pharmacies remains limited.

Prior research has documented the general case for digital drug inventory systems. A web-based drug supply information system developed for Wyata Guna Polyclinic Bandung demonstrated real-time data access, improved stock tracking accuracy, and automated notifications as concrete operational benefits [11]. A scoping review of health supplies inventory management IS further confirmed that digital systems improve data accuracy, accelerate reporting, and strengthen information security [12]. Work on automated expiry detection has shown that batch-level tracking combined with alert mechanisms can reduce the risk of dispensing expired drugs in pharmacy settings [6]. What these studies do not address collectively is the integration of batch-level drug tracking with automated expiry monitoring and sales transaction management in a single system, nor do they evaluate user acceptance empirically with pharmacy operational staff as the testing population.

System quality cannot rest on development alone. Black Box Testing is a practical method for verifying that each system feature produces the correct output for a given input, without requiring access to the underlying code [13], [14]. UAT complements this by measuring whether the system meets the actual working needs of its intended users, covering ease of use, functional fit, and operational suitability [15]. Economic evaluations of digital health interventions also point to measurable benefits in reducing medication errors and adverse drug events, which supports the case for digital transformation in pharmacy operations [7]. This study addresses two objectives: first, to develop a web-based drug inventory system for pharmacy operations using the Waterfall model, covering drug data management, batch stock tracking, sales transactions, automated expiry monitoring, and report generation; second, to evaluate the system through Black Box Testing for functional verification and UAT with pharmacy operational staff for user acceptance assessment. Unlike prior pharmacy IS implementations that treat stock recording, sales, or expiry management as separate concerns, this study integrates all three into one platform and contributes empirical UAT data from direct pharmacy users.

2. METHOD

This study followed the Waterfall development model to build a web-based drug inventory system for pharmacy operations [16]. The Waterfall model suits projects with well-defined requirements and fixed scope, since each phase (requirement analysis, system design, implementation, and testing) must be completed and validated before the next begins [8], [16]. The sequential structure supports thorough documentation and reduces implementation risk when operational needs are stable and pre-specified [5], [17]. Functional quality was verified through Black Box Testing, and user acceptance was assessed through UAT. Each subsection below describes one phase in the order it was executed.

2.1. Requirement Analysis

The requirement analysis phase identified operational failures in the pharmacy's existing drug inventory process and defined the system requirements needed to address them. Data were gathered through direct observation of pharmacy operations and interviews with the pharmacy manager and administrative staff [18]. Observation and interviews confirmed that drug stock recording, sales transaction logging, and report generation were all conducted manually using spreadsheets. Four failure modes were documented: recording errors from manual data entry, reporting delays from non-integrated record-keeping, difficulty monitoring current stock levels across multiple drug categories, and no systematic mechanism for tracking drug expiration dates. From these findings, the functional requirements were established as drug and category data management, supplier data management, sales transaction recording, batch stock management with lot-level tracking, and automated monitoring of stock levels and expiration periods with alert capability. The system also needed to generate stock and sales reports on demand. The non-functional requirements covered ease of use for pharmacy staff without technical backgrounds, acceptable page load speed, and responsive display across desktop and mobile devices. These requirements formed the reference baseline for all subsequent design and testing decisions.

2.2. System Design

The system design phase translated the documented requirements into a structured technical specification using Unified Modeling Language (UML) [19], [20], [21]. UML was chosen because it represents both system structure and operational behavior in a format accessible to developers and non-technical stakeholders alike.

Two categories of UML artifacts were produced. Activity diagrams described the step-by-step operational flow for drug data management and sales transaction processing. A class diagram defined the data structure and relationships between system entities, including the User, Medicine, MedicineCategory, Supplier, MedicineBatch, SalesTransaction, SalesTransactionDetail, and Report classes. Database design specified table structures, inter-table relationships, and field attributes needed to support inventory tracking and transaction management. The user interface was designed for daily operational use by pharmacy employees, with priority placed on clarity, minimal navigation steps, and consistent layout across all modules.

2.3. Implementation

The system was developed as a web-based application using PHP and MySQL as the database management system. Visual Studio Code served as the code editor, and XAMPP provided the local server environment for development and testing. Bootstrap was used as the front-end framework to ensure a responsive interface accessible across desktop and mobile devices.

Implementation covered all functional modules established in the requirement phase: drug and batch data management, sales transaction processing with automatic stock deduction, expiry and low-stock monitoring with visual alert indicators, and PDF and Excel report generation. Development followed a staged sequence aligned with the Waterfall phase structure, in which each module was completed and internally reviewed before integration testing began.

2.4. Testing

System testing addressed two evaluation objectives: verifying that all features functioned according to their specified requirements, and determining whether the system met the working needs of pharmacy operational staff. Black box testing was applied to each system module by comparing the actual system outputs against the expected outputs defined in the requirements documentation [20], [21]. This method focuses on the relationship between user-provided inputs and system-generated responses, which makes it practical for verifying functional compliance from the perspective of actual use [16], [20]. Testing was conducted by the development team together with one pharmacy staff member acting as an independent evaluator. Coverage included login and authentication, drug data management, batch stock input, sales transaction processing, expiry and low-stock alerts, data filtering, report generation, and logout. A total of thirteen test scenarios were executed across two testing tables: six for the Home and Dashboard module, and seven for the Login and Transaction module. Pass/fail determination used the functional specifications from the requirement analysis phase as the acceptance benchmark.

User acceptance testing was conducted with two pharmacy users: the pharmacy manager and one administrative staff member who uses the system for daily drug recording and transaction logging [22]. These respondents were selected because they represent the two primary user roles the system was designed to serve [23], [24]. UAT used a structured questionnaire covering nine evaluation criteria adapted from usability assessment frameworks for information systems: login process ease, dashboard information clarity, interface color and display comfort, master data management ease, drug and batch data input ease, stock depletion and expiry alert performance, sales transaction input ease, report output quality, and overall system performance. Each criterion was rated on a four-point scale: Excellent (4), Good (3), Sufficient (2), and Not Good (1). The maximum possible score per criterion is 8, calculated as two respondents giving the highest rating (2×4). Respondents completed the questionnaire after operating the system through each of its core functions in the actual pharmacy environment.

3. RESULTS AND DISCUSSION

3.1. System Design Results

System design produced two categories of artifacts: activity diagrams that document operational process flows, and a class diagram that defines the system data structure. Each artifact is presented below with an explanation of its role in the system.

3.1.1. Activity Diagram for Drug Data Management

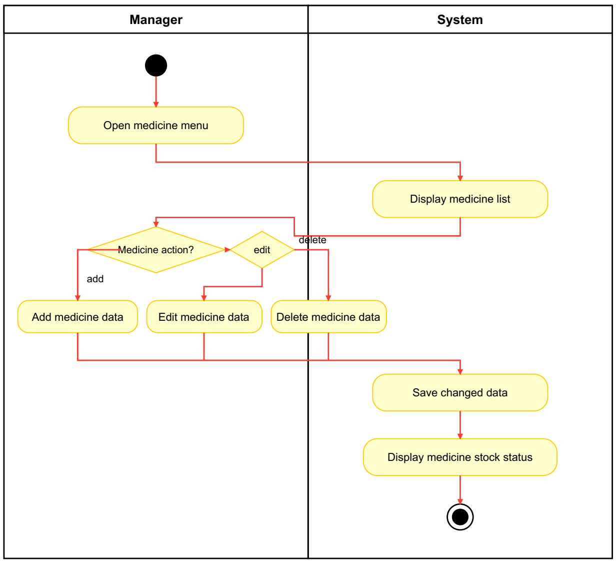

Figure 1. Activity diagram of drug data management

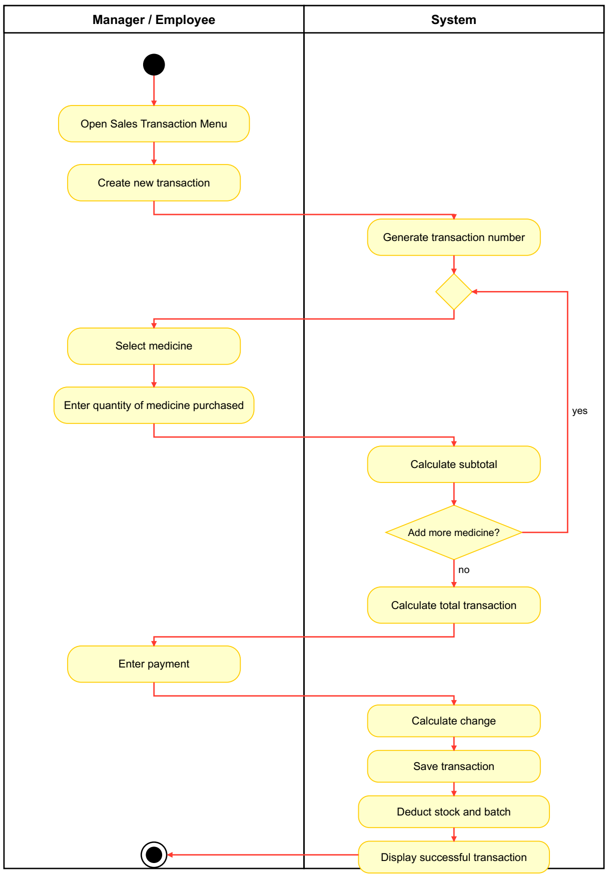

Figure 2. Activity diagram of sales transaction

Figure 1 presents the activity diagram for drug data management, which shows the sequence of steps executed by the Manager or Employee role when adding, editing, or deleting drug records. The workflow starts when the user opens the drug menu and selects an action. The system routes the request through validation before writing to the database, then updates the displayed stock status automatically. The decision point at action selection covers three paths (add, edit, delete), each processed through the same validation and storage sequence. Once the database update completes, the current stock condition is displayed without requiring the user to manually refresh or recheck. This removes the re-verification step that characterizes manual spreadsheet-based recording.

3.1.2. Activity Diagram for Sales Transaction

Figure 2 presents the activity diagram for the sales transaction process, which shows how a transaction moves from initiation to stock update. The user creates a new transaction, selects the drug and quantity, and the system calculates the subtotal and total payment automatically. Once payment is confirmed, the transaction is stored and the drug stock is reduced by the exact quantity sold. Because each transaction writes directly to the inventory database, stock figures and sales records stay synchronized in real time. This removes the lag between sales recording and stock adjustment that manual systems produce when the two records are maintained separately.

3.1.3. Activity Diagram for Sales Transaction

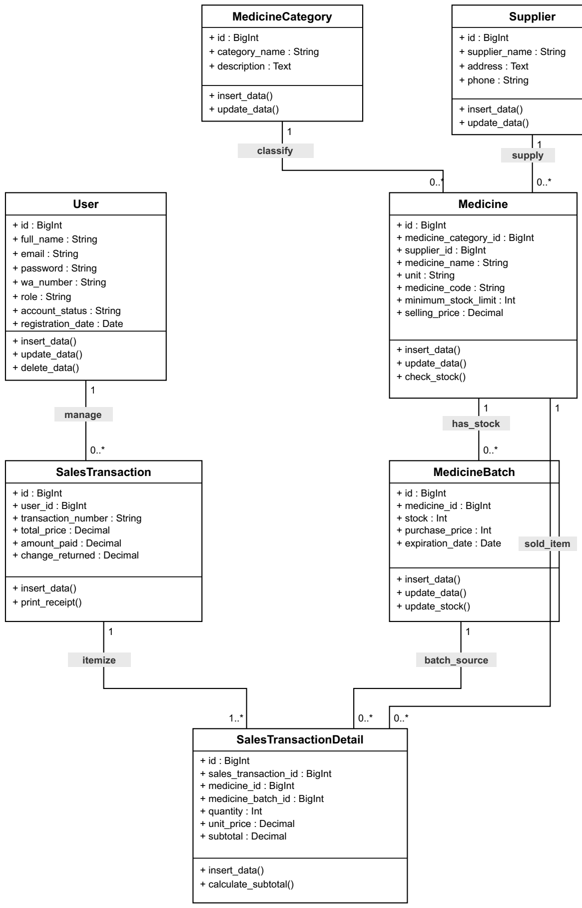

Figure 3. Class diagram

Figure 3 presents the Class Diagram for the pharmacy inventory system, showing the eight classes and their relationships. The system comprises eight classes: User, Medicine, MedicineCategory, Supplier, MedicineBatch, SalesTransaction, SalesTransactionDetail, and Report. The User class manages authentication and role-based access. Drug, CategoryDrug, and Supplier serve as master data that other classes reference. BatchDrug records stock at the batch level, storing the lot number and expiration date per batch entry, which lets the expiry monitoring feature operate on specific stock units rather than on aggregate drug quantities. SalesTransaction and SalesTransactionDetail capture each sale and its line items. The Report class aggregates transaction and stock data for management review. Relationships between classes follow a normalized structure: one Drug has many BatchDrug entries, one SalesTransaction has many SalesTransactionDetail entries, and each SalesTransactionDetail references one Drug record. This structure keeps data consistent across the inventory, transaction, and reporting functions without duplication.

3.2. Interface Implementation

The system interface was designed for daily operational use by pharmacy employees with no technical background. All screens follow the workflow sequence documented in the requirements phase, so users can complete tasks after an initial walkthrough without further training. The four main pages are presented below.

3.2.1. Dashboard Page

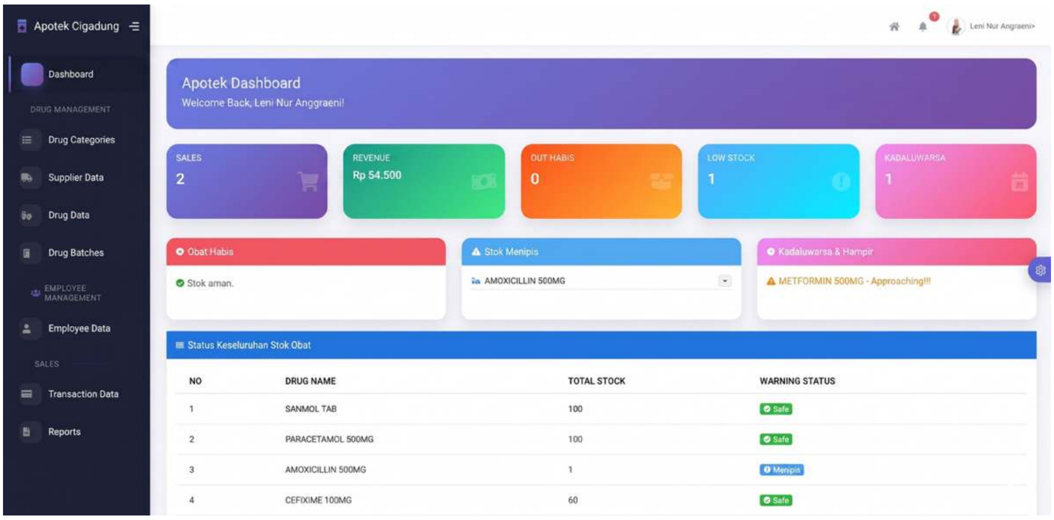

Figure 4. Dashboard page

The Dashboard gives an immediate overview of pharmacy inventory status without requiring the user to navigate into individual menus. It displays the total number of drug records in the system, current stock conditions by category, and a list of drugs either at zero stock or below the defined minimum limit. Shortcut buttons to drug management, sales transactions, and reports are available from this screen, which reduces the steps needed to reach core functions during busy operational periods. Figure 4 shows the dashboard the first screen displayed after login.

3.2.2. Drug Data Management Page

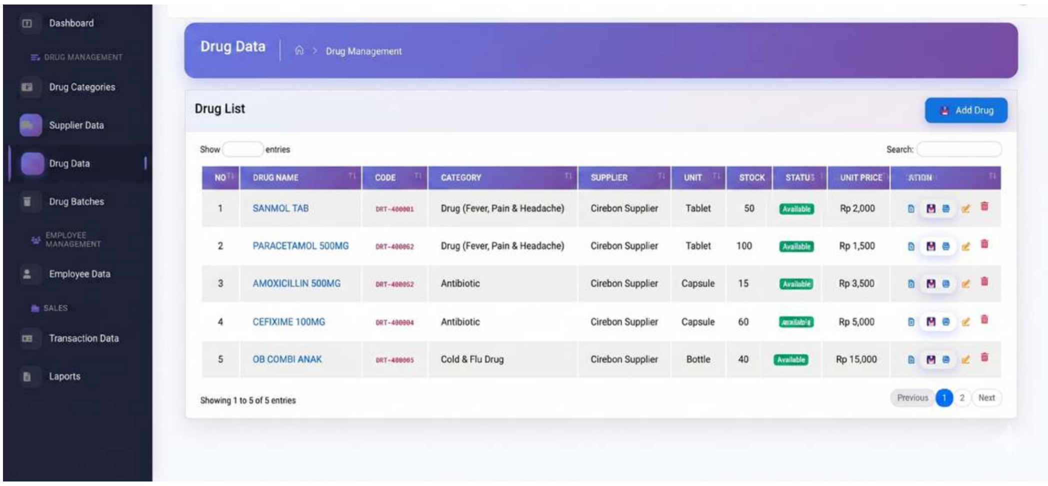

Figure 5. Drug data management page

This page handles the full data lifecycle for drug records: adding new drugs, editing existing records, and removing drugs that are no longer stocked. Each drug entry stores the name, category, unit, selling price, and minimum stock threshold. The page also displays current stock quantity and expiration status alongside the data management functions, so users can monitor inventory conditions while updating records without switching between screens. This replaces the separate stock card and spreadsheet files that the manual process required. Figure 5 shows the drug data management page, used by the admin and manager roles.

3.2.3. Sales Transaction Page

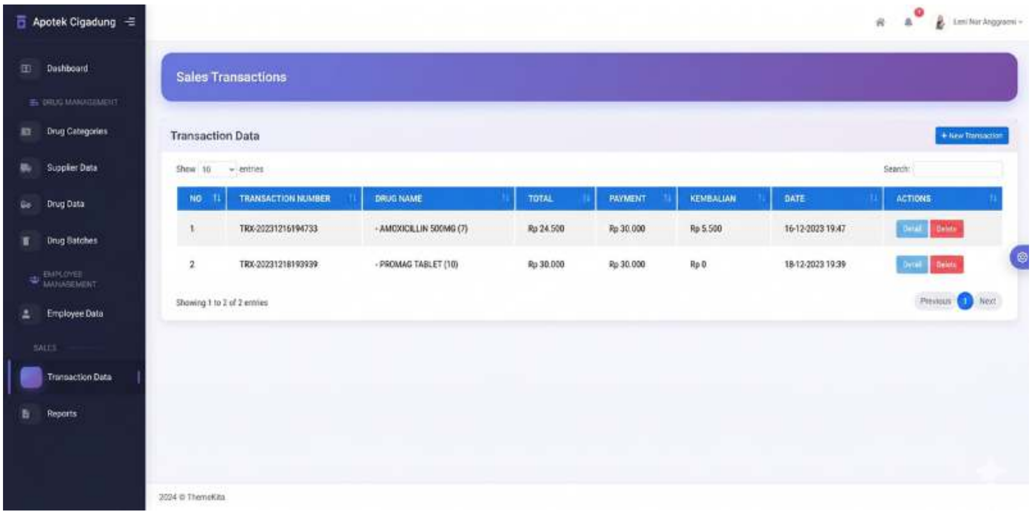

Figure 6. Sales transaction page

Users open a new transaction, select the drugs and quantities, and the system calculates subtotals and total payment automatically. Once the transaction is saved and the payment is confirmed, stock quantities update immediately without a separate entry step. Transaction data is stored with a timestamp and linked to the batch record, so inventory figures remain consistent with the actual dispensing activity. The automatic calculation and stock deduction remove two manual steps that were the main sources of recording errors in the prior spreadsheet-based process. Figure 6 shows the sales transaction page.

3.2.4. Report page

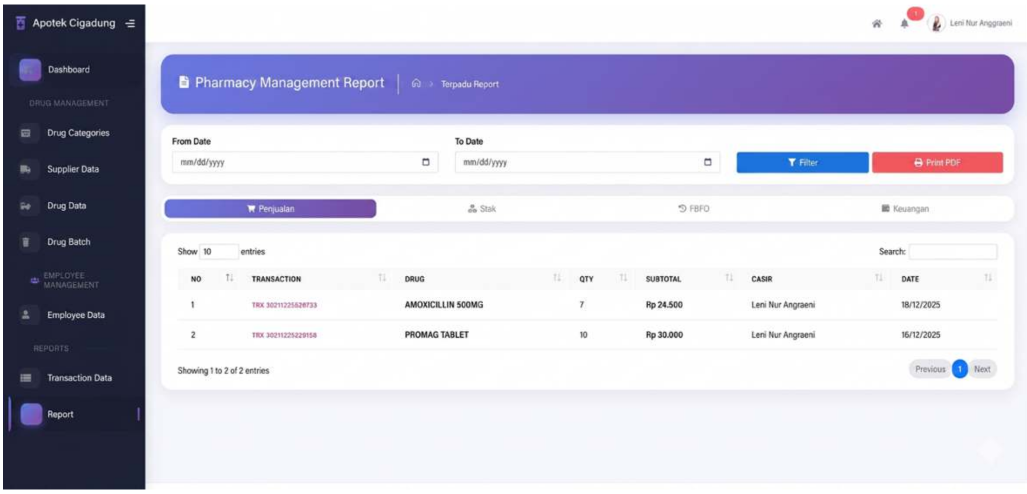

Figure 7. Sales report page

The Report page generates recapitulations of stock data and sales transactions over a user-selected time period, with daily, monthly, and custom date range options. Reports are available for export in PDF and Excel formats. Stock reports give management a current view of inventory across all drug categories. Sales reports show transaction volume and revenue patterns over the selected period. Both report types pull directly from the transaction and inventory database, so the figures reflect actual system activity without manual compilation. Figure 7 shows the sales report page.

3.3. Test Results

Functional testing used Black Box Testing to verify that each system feature produced the correct output for its corresponding input, independent of the underlying code structure. UAT then assessed whether the system met the working needs of the pharmacy staff who would use it daily. Results for both testing phases are presented below.

3.3.1. Black Box Testing

All six test scenarios for the Home and Dashboard module returned valid results, as shown in Table 1. The dashboard loaded correctly after login and displayed stock and revenue summaries that matched the specifications. The drug stock table presented category and quantity data in the format defined in the requirements. The expiry notification feature placed visual markers on drugs approaching their expiration date, and the low-stock alert identified drugs at or below the minimum inventory threshold. Report menu access and data filtering both produced outputs consistent with the expected results. No functional defects were identified in this module. Table 1 presents the Black Box Testing results for the Home and Dashboard module.

Table 1. Black box testing results for the home and dashboard module

No.	Scenarios	Testing Steps	Expected Results	Test Results	Status
1	Access the dashboard page	Log in as Manager or Employee and navigate to the dashboard	The dashboard opens, displaying a stock summary and total revenue	As expected	Valid
2	Check the drug stock table	Click the Stock Data or Inventory menu	The system displays a complete drug list with stock quantities and categories	As expected	Valid
3	Check expiration status notifications	View the status column on the drug stock table	Drugs approaching expiry display a visual status indicator	As expected	Valid
4	Check out-of-stock notifications	View the critical stock section on the dashboard	The system lists drugs with zero stock or stock below the minimum limit	As expected	Valid
5	Access the Report menu	Click the Reports menu in the navigation bar	The report page opens and displays time period selection options	As expected	Valid
6	Check the data filter function	Enter a specific category in the filter or search field	The system displays only records matching the selected category	As expected	Valid

All seven test scenarios for the Login and Transaction module returned valid results, as shown in Table 2. The authentication module correctly distinguished valid from invalid credentials and granted access only to users with registered and correct login data. The drug data input function saved new records and updated stock quantities as specified. The sales transaction process calculated totals automatically, reduced stock by the quantity sold, and stored transaction records correctly. PDF report export generated files matching the selected date range, and logout terminated the session and redirected to the login screen as expected. Across both testing tables, all thirteen scenarios returned valid status, which confirms that the system's core functional features meet their specified requirements. Table 2 presents the Black Box Testing results for the Login and Transaction module.

Table 2. Black box testing results for the login and transaction module

No.	Scenarios	Testing Steps	Expected Results	Test Results	Status
1	Access the login page	Open the application URL in a browser	The login page displays an email and password form	As expected	Valid
2	Login with valid credentials	Enter correct email and password, click Login	The system navigates to the main dashboard page	As expected	Valid
3	Login with invalid credentials	Enter incorrect password or unregistered email, click Login	The system stays on the login page and displays an error message	As expected	Valid
4	New drug data input	Complete the drug form (name, batch, expiry, stock) and click Save	A success notification appears and stock quantity increases	As expected	Valid
5	Sales transaction process	Select a drug, enter purchase quantity, click Pay	A success notification appears, stock reduces automatically, and a receipt is generated	As expected	Valid
6	Export PDF report	Select a date range and click Export PDF	The system downloads a PDF file containing a sales data recapitulation	As expected	Valid
7	Logout	Click the Logout button or menu option	The system ends the session and redirects to the login page	As expected	Valid

3.3.2. User Acceptance Testing

UAT was conducted after Black Box Testing was completed. Two pharmacy users participated: the pharmacy manager and one administrative staff member responsible for daily drug recording and transaction logging. These respondents represent the two primary operational roles the system was designed to serve. Each respondent used the system through its core functions before completing the assessment questionnaire. Table 3 presents the rating categories and weight values used in the UAT assessment.

Table 3. UAT rating categories and weight values

Symbol	Category	Weight
XC	Excellent	4
GD	Good	3
SF	Sufficient	2
NG	Not Good	1

The four-point rating scale in Table 3 converts qualitative assessments into numeric scores for quantitative comparison. With two respondents and a maximum weight of 4, the maximum possible score per criterion is 8 (2 × 4). The overall acceptance rate per criterion was calculated as the total score obtained divided by the maximum possible score, multiplied by 100. With nine criteria, the maximum possible total score is 72 (9 × 8). Table 4 presents the UAT questionnaire responses across all nine criteria.

Table 4. UAT questionnaire results

No.	Criteria	XC	GD	SF	NG	Total Score
1	Ease of the login process	2	0	0	0	8
2	Clarity of Dashboard information	2	0	0	0	8
3	Interface color and display comfort	2	0	0	0	8
4	Ease of master data management	2	0	0	0	8
5	Ease of drug and batch data input	2	0	0	0	8
6	Stock depletion and expiry alert performance	1	1	0	0	7
7	Ease of sales transaction input	2	0	0	0	8
8	Report output quality (PDF/Excel)	2	0	0	0	8
9	Overall system performance and features	2	0	0	0	8
					Total	**71**

Eight of the nine criteria in Table 4 received the maximum score of 8, with both respondents rating each as Excellent. Criterion 6, the stock depletion and expiry alert feature, received a score of 7, with one respondent rating it Excellent and the other rating it Good. This was the only criterion where the two responses diverged, and it points to notification responsiveness as the feature most likely to benefit from further development. Table 5 presents the UAT score summary and acceptance rate per criterion.

Table 5. UAT score summary

No.	Total Score	Average	Acceptance Rate (%)
1	8	4.0	100
2	8	4.0	100
3	8	4.0	100
4	8	4.0	100
5	8	4.0	100
6	7	3.5	87.50
7	8	4.0	100
8	8	4.0	100
9	8	4.0	100
	71	Overall average	**98.61%**

The overall UAT score was 71 out of 72, computed as (71/72) × 100 = 98.61%, which places the system in the Very Good acceptance category. Eight criteria reached 100% acceptance, and criterion 6 reached 87.50% as the only result below the maximum. Within this two-respondent evaluation at a single pharmacy site, the results indicate that the system fits the operational tasks it was designed to support.

3.4. Discussion

Black Box Testing confirmed that all thirteen scenarios across two modules produced outputs consistent with their functional specifications. This is consistent with findings from comparable pharmacy IS implementations reported full functional compliance in a web-based drug inventory system using safety stock and reorder point methods [25], and reported similar results for a web-based drug supply IS in a polyclinic setting [11]. The present study adds batch-level tracking and automated expiry monitoring to the feature set evaluated through Black Box Testing, areas that prior studies addressed separately or did not address at all.

The UAT result of 98.61% compares favorably with acceptance rates reported in related IS studies. reported a UAT acceptance rate for a community health center IS, and reported an acceptance rate for an inventory IS evaluated with a larger respondent group. The higher score in the present study likely reflects both the system's close alignment with the specific operational workflow of the evaluation pharmacy and the small respondent pool of two users. The score should be read as strong acceptance within this operational context, not as a generalizable measure across pharmacy settings. The systematic review by Shbaily et al. [5] reports a similar pattern in which pharmacy automation systems show stronger acceptance and lower error rates than traditional systems, although effect sizes vary across implementation contexts.

The practical strengths of this system over the prior manual process are visible at three points. First, the batch-level tracking module links each drug unit to its lot number and expiration date, which lets the expiry alert feature flag specific batches approaching expiry rather than relying on staff to check manually. This is the same operational pattern that Friday and Sorlihu [6] identify as the basis for automated expiry detection in pharmacy operations. Second, the sales transaction module deducts stock automatically at the point of sale, which removes the separate stock adjustment step the spreadsheet process required and that produced the most frequent recording errors. Third, the integrated PDF and Excel report generation draws directly from the transaction database, which eliminates the manual compilation step that caused reporting delays. These three features together address the specific failure modes identified in the requirement analysis phase and are not present as an integrated set in the prior pharmacy IS implementations reviewed in the literature.

4. CONCLUSION

This study developed and evaluated a web-based drug inventory system for pharmacy operations using the Waterfall model. Black Box Testing across thirteen test scenarios confirmed that all core features (drug and batch data management, sales transaction processing, automated expiry and low-stock alerts, and report generation) functioned according to their specifications. UAT with two pharmacy users produced a total score of 71 out of 72 (98.61%, Very Good), with eight of nine criteria at 100% acceptance. The stock depletion and expiry alert feature scored 87.50%, identifying notification responsiveness as the primary improvement target. The system's practical contribution is the integration of three functions the prior manual process handled separately: batch-level stock tracking linked to expiry dates, automatic stock deduction at the point of sale, and on-demand report generation from live transaction data. Three limitations apply: the UAT sample comprised two respondents from a single pharmacy site, which restricts generalizability; Black Box Testing did not include load testing or edge case simulation; and no quantitative baseline of the manual process was measured, so efficiency improvements are described as expected rather than empirically confirmed. Future work should address the expiry alert notification mechanism, expand UAT across multiple pharmacy sites with a larger respondent group, and explore integration with electronic prescription or BPJS claims systems.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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