DEVELOPMENT OF A LOW-COST INVENTORY MANAGEMENT SYSTEM FOR A PHARMACY

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INDUSTRIAL ENGINEERING PROGRAMME

DEPARTMENT OF PRODUCTION ENGINEERING,

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN, BENIN CITY,

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CERTIFICATION

This is to certify that the project titled "DEVELOPMENT OF A LOW-COST INVENTORY MANAGEMENT SYSTEM FOR A PHARMACY" was undertaken by IDIALU CHARLES ABRAHAM, with matriculation number ENG2006303. In Industrial Engineering programme, Department of Production Engineering Faculty of Engineering, University of Benin, Benin City, in partial fulfilment of the requirements for the award of Bachelor of Engineering (B.Eng) in Industrial Engineering.

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DEDICATION

This project is dedicated to **Almighty God**, whose grace, wisdom, and strength have guided me through every stage of this work.

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ABSTRACT

Effective inventory management is vital in ensuring the continuous availability of essential drugs in community pharmacies. However, many small and medium-sized pharmacies in Nigeria still rely on manual stock records, which are often prone to errors, delays, and inefficiencies. These limitations lead to frequent stockouts, overstocking, and poor decision-making. This project was therefore aimed at developing a **low-cost, web-based pharmacy inventory management system** that can automate key inventory operations and improve overall stock control efficiency. The system was designed to integrate real-time data entry, sales monitoring, and automatic computation of inventory parameters such as the Economic Order Quantity (EOQ) and the Reorder Point (ROP).

The methodology involved the design and implementation of a web application connected to a PostgreSQL database. The system was built using **React.js** for the frontend, **Node.js with Express** for the backend, and **MongoDB** and **PostgreSQL** for data management. Data used for analysis were derived from the pharmacy's 2024 operational records, including sales transactions, purchase orders, and stock levels. Analytical models such as the EOQ and ROP formulas were embedded into the application to enable automated calculation of optimal order quantities and reorder levels. The system's functionality was evaluated based on its performance in handling more than 15,000 sales records, accuracy in computation, and responsiveness in generating real-time alerts.

The results showed that the system effectively automated stock control processes, minimized manual errors, and significantly improved decision-making speed. The EOQ and ROP computations consistently produced accurate results using a uniform 20% safety stock across all products. Additionally, the system generated automatic reorder alerts

when stock fell below the reorder point and provided comprehensive sales summaries that supported managerial analysis. Overall, the developed web-based inventory management system proved to be a **reliable, efficient, and affordable solution** for pharmacy inventory management, particularly suited for small and medium-scale operations in resource-limited environments.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Inventory management is crucial for the success and sustainability of any business, regardless of its size or scope. This is especially true for small businesses, where maintaining accurate inventory records is essential for daily operations, customer satisfaction, and long-term growth. However, many small enterprises face challenges with inventory tracking due to the high costs and technical complexity of commercial inventory management systems. As a result, they often depend on manual record-keeping methods, like paper logs or basic spreadsheets, which are prone to human error, misplacement, and inefficiency (*Arora, 2019)*.

Small businesses typically operate on tight budgets, making it difficult to invest in expensive software solutions or hire specialized personnel for inventory control. Poor inventory management can result in stock shortages, overstocking, lost revenue, waste, and, in some cases, complete business failure. This challenge underscores the need for a practical, affordable, and user-friendly inventory management system specifically designed for small businesses (*Hussain and Yaqub ,2010)*.

Advancements in technology have paved the way for cost-effective digital solutions that can automate key aspects of inventory management. These tools can help small business owners save time, reduce errors, and make informed purchasing decisions. By developing a low-cost inventory management system, small businesses can streamline their operations, minimize manual workloads, and enhance overall efficiency without incurring excessive financial burdens *(Mhelembe and Mafini, 2019)*.

This project aims to address these issues by designing and implementing a user-friendly, low-cost inventory management system tailored to meet the operational needs of small businesses. The system will focus on essential inventory functions, including product registration, stock level monitoring, low-stock notifications, and generating basic reports for effective decision-making *(Al-Romeedy,2019)*.

1.2 Statement of the Problem

Small businesses play a vital role in many economies, and addressing their operational challenges can lead to greater success and sustainability. One key area for improvement is inventory management. Often, small businesses rely on manual methods such as notebooks, spreadsheets, or guesswork, which can lead to stock shortages, overstocking, theft, and human errors.

However, there is an opportunity to enhance inventory management practices by seeking out user-friendly solutions tailored to the needs of smaller enterprises. Many existing inventory management systems may seem costly or complex, as they are designed for larger organizations with dedicated IT resources. By focusing on affordable and accessible inventory management tools, small business owners can optimize their operations and reduce the risks associated with manual management. Emphasizing simplicity and support in these systems can empower small businesses to thrive and efficiently manage their inventory.

Small businesses are forced to rely on inefficient manual tracking, Inaccurate stock records, missed sales opportunities due to stockouts, Overstocking and product wastage, increased operating costs due to poor planning, and Difficulty in making timely and informed business decisions.

There is, therefore, a strong need for a simple, reliable, and affordable inventory management system that can assist small business owners in tracking their stock levels, generating reports, and maintaining accurate inventory records

1.3 Aim of the study

This study aim to develop a simple, efficient, and low-cost inventory management system that will assist small businesses in accurately tracking and managing their stock, minimizing human error, reducing operational costs, and improving overall business efficiency.

1.4 Objectives of the Study

The specific objectives are as follows:

I. To create an inventory management system that enables pharmacies to track stock levels, product availability, and stock movements in real-time efficiently.

II. To develop a user-friendly interface that allows business owners and employees with minimal technical knowledge to manage and update inventory records effectively.

III. To automate essential inventory processes, including stock addition, stock deduction, and notification alerts for low-stock items.

IV. To implement reporting features that generate inventory summaries, stock status reports, and historical sales or stock usage patterns to support better business decision-making.

1.5 Scope of the Study:

This project aims to create an innovative low-cost inventory management system specifically designed for small pharmacy. The system will incorporate essential inventory management features to enhance operational efficiency.

1.6 Research Questions

This research aims to effectively develop a low-cost inventory management system for small businesses by addressing the following questions:

I. How can small businesses efficiently manage their inventory using a simple and affordable digital solution?

II. What are the limitations and challenges of current inventory management practices employed by small businesses?

III. What essential features should a low-cost inventory management system include to enhance stock tracking and support business decision-making?

IV. How can the proposed system help reduce human errors and stock discrepancies that commonly arise in manual inventory management?

V. To what extent will the implementation of the developed system lower operational costs and improve inventory accuracy for small businesses?

VI. How can the system be designed to ensure user-friendliness for business owners and staff with little or no technical expertise?

1.7 Significance of the Study

Inventory management is a crucial aspect of any business operation, especially for small businesses that need to utilize limited resources efficiently to ensure profitability and sustainability. Unfortunately, many small business owners rely on outdated or manual stock control methods, leading to financial losses, operational inefficiencies, and poor customer satisfaction.

This study aims to offer a cost-effective, user-friendly, and practical inventory management solution specifically designed for small businesses. The proposed system will enable business owners to monitor stock levels accurately, reduce waste, prevent overstocking and shortages, and enhance the overall decision-making process through timely and accurate inventory reports.

Furthermore, this study aims to contribute to the growth of small businesses by helping them minimize losses caused by stock mismanagement and human error while avoiding the high costs associated with expensive commercial inventory software. The automated inventory tasks will also save business owners time, allowing them to concentrate on other critical areas of their operations.

From an academic perspective, this study will serve as a reference for future research into affordable technology solutions for small enterprises and will emphasize the importance of applying software engineering principles to address real-world business challenges.

1.8 Limitations of the Study:

I. The system will be designed primarily for small-scale businesses and may not fully meet the complex needs of medium or large-scale enterprises.

II. The initial version of the system will focus on inventory management only and will not cover advanced features such as accounting, barcode scanning, or automated sales integration.

III. The system will be limited to local deployment on a single PC or small network environment and will not initially support cloud-based operations or remote access unless upgraded.

IV. The solution assumes that basic computer literacy exists among the users; full training manuals or support services are not covered within the scope of this project.

V. External factors such as power outages, hardware failures, or human negligence are beyond the control of the system and are not covered as part of the solution.

1.9 Definition of Terms

Below are key terms used in this study for better understanding and clarity:

I. **Inventory:** The total amount of goods, materials, or products a business holds for the purpose of resale or production.

II. **Inventory management:** The process of ordering, storing, using, and tracking a company's inventory, including raw materials, components, and finished products.

III. **Stock:** The quantity of products or materials available at a particular time in a business.

IV. **Low-Cost System:** A software or technological solution designed to meet its objectives while minimizing financial costs related to development, deployment, and maintenance.

V. **Small Business:** A privately owned and operated business with limited resources, a small number of employees, and relatively low annual revenue compared to large corporations.

VI. **User-Friendly:** A system design approach that ensures easy and intuitive interaction, even for users with little or no technical background.

VII. **Automation:** The use of technology to perform tasks with minimal human intervention, such as automatic stock deductions or notification alerts in inventory systems.

VIII. **Stock-Out:** A situation in which the inventory level of a product falls to zero, making it unavailable for sale or use.

IX. **Overstocking:** A situation where more inventory is purchased or produced than is needed, often resulting in increased storage costs or product waste.

X. **Database:** An organized collection of structured information or data that can be easily accessed, managed, and updated.

CHAPTER TWO

2.0 LITERATURE REVIEW

Pharmaceutical inventory management is a critical aspect of healthcare service delivery, particularly in low-resource settings. It ensures the availability of essential medicines while minimizing wastage, overstocking, and stockouts. In developing countries, small-to-medium-sized pharmacies face unique challenges in inventory management due to limited access to sophisticated systems, financial constraints, and infrastructure gaps *(Ayalew et al., 2019 and Eze & Onwujekwe, 2021).*

The importance of effective inventory control in these settings cannot be overstated. Ensuring that the right medicines are available when needed helps to reduce treatment delays, enhance patient outcomes, and prevent healthcare disruptions. Efficient inventory management also allows pharmacies to maximize limited budgets by minimizing unnecessary purchases and losses due to expired or overstocked items *(Mensah et al., 2021 and Njeri et al., 2020).*

However, pharmacies in low-resource environments face significant challenges. These include poor access to digital tools, inadequate staff training, irregular supply chains, manual record-keeping, and financial constraints that prevent investment in advanced inventory systems. These factors contribute to recurring issues such as frequent stockouts, medication wastage, and poor data reliability. Therefore, adopting low-cost, scalable, and efficient inventory solutions becomes essential for improving pharmaceutical service delivery in these contexts *(Rasanathan et al., 2008 and Mpanza et al., 2023).*

This chapter reviews relevant literature focused on low-cost inventory management solutions tailored to pharmacies, especially in developing regions.

2.1 Inventory and Its Role

Inventory management has received considerable attention in academic research due to its significant impact on a company's overall performance, especially regarding material cost and resource optimization (Tersine, 1988). Tersine defines inventory as the available stock at a particular point in time, emphasizing its physical tangibility and countability. Stock and Lambert (2001) further assert that inventory is typically the largest component of a firm's current assets, and it directly influences financial performance metrics such as Return on Net Assets (RONA) and Return on Investment (ROI). Consequently, effective inventory practices play a vital role in determining a firm’s competitiveness and profitability (Silver et al., 1998).

Inventory typically comprises raw materials, work-in-progress items, and finished goods (Aktepe et al., 2018). Although inventory may not always interact directly with the end consumer, its availability ensures efficient production processes and enhances service delivery by minimizing delays. The components of inventory, known as stock-keeping units (SKUs), differ in terms of weight, volume, cost, and perishability. These differences necessitate varied storage strategies and policies to address shelf-life constraints, regulatory storage requirements, or substitution limitations (Silver et al., 1998).

Inventory serves multiple purposes in a production and distribution context. Tersine (1988) outlines four core functions: time, discontinuity, uncertainty, and economy. The time function allows products to be manufactured ahead of demand, minimizing lead times and accommodating seasonal fluctuations. Discontinuity permits independent scheduling of production and procurement, as inventory provides a buffer between suppliers and the production process (Stock & Lambert, 2001). The uncertainty function safeguards operations against unexpected disruptions, including supplier delays, natural disasters, and supply chain inconsistencies. Finally, the economy function enables bulk purchasing and transportation, lowering per-unit costs and benefiting from economies of scale (Tersine, 1988).

A fifth functional benefit, specialization, is introduced by Stock and Lambert (2001). This principle allows production lines within a company to specialize in specific items, which can reduce production complexity and cost. A centralized inventory system receiving supplies from various specialized plants ensures that all customer demands can still be met efficiently. These combined functions highlight the strategic importance of inventory systems, especially in critical sectors such as healthcare where timely access to medications is essential (Stock & Lambert, 2001).

2.1.1 Safety Stock and Buffer Inventory

Safety stock, also referred to as buffer inventory, is maintained by organizations to mitigate the risk of stockouts and to absorb fluctuations in customer demand (Wild, 2017). It represents an additional layer of inventory beyond the expected requirement, intended to ensure that customer orders are fulfilled without delay. Determining the appropriate level of safety stock and the corresponding reorder point is a critical challenge for manufacturers and service providers aiming to maintain efficiency while meeting customer expectations (Bowersox et al., 2020).

The decision on how much safety stock to keep is influenced by several key variables, including demand variability, supplier lead times, and the dependability of supply chains (Wild, 2017). Inconsistent demand or unreliable suppliers necessitate higher levels of safety stock to buffer against disruptions. In the context of pharmacies, where timely access to essential medications is critical, maintaining adequate safety stock can be a lifesaving strategy.

In real-world (stochastic) environments, unlike deterministic models, safety stock becomes indispensable due to unpredictability in demand and supply. It offers dual advantages—protection from stockouts and a buffer against variability—though it also introduces higher holding costs (Dellaert & Jeunet, 2005; Dolgui & Prodhon, 2007). Therefore, maintaining the right level of safety stock is a balancing act that must weigh both service reliability and financial efficiency. Key drivers of safety stock needs include fluctuating demand patterns, variable lead times, inaccurate forecasts, limited production capacity, and operational delays (van Kampen et al., 2010; Jason et al., 2019; Chaturvedi & Martínez-de-Albéniz, 2016).

Flexible production schedules, while beneficial for responsiveness, can make it harder to determine precise safety stock needs (Yano & Carlson, 1987). Additionally, lead time incorporates every stage from order initiation to final availability, including order processing, supplier fulfillment, and warehouse handling (Silver et al., 1998). In some scenarios, enhancing production capacity may offer a better alternative to safety stock, particularly when demand increases gradually over time (Huang et al., 2016). Conversely, decoupled or make-to-stock production systems require higher levels of safety stock to maintain continuity between processing stages (Persona et al., 2007; Muckstadt & Spara, 2010). Furthermore, safety stock is necessary to offset production imperfections and system inefficiencies (Bag et al., 2009).

2.1.2 Economic Order Quantity (EOQ)

To manage inventory efficiently and minimize unnecessary costs associated with overstocking, organizations often seek to determine the optimal order quantity. One widely accepted method for this is the Economic Order Quantity (EOQ) model. EOQ helps control inventory levels by identifying the most cost-effective quantity to order, balancing ordering costs with holding costs (Hançerlioğulları et al., 2016).

Although numerous advanced models exist for calculating optimal order quantities, Silver et al. (1998) emphasized the practical benefits of using the classic EOQ formula, particularly in routine operational settings. They argue that while more sophisticated mathematical approaches may yield slightly better results, the simplicity and low implementation cost of EOQ make it a favorable option for most businesses, especially when behavioral and contextual factors must be considered.

The EOQ model is traditionally applied in deterministic settings where key variables—such as demand rate, order cost, and holding cost—are known with certainty (Tersine, 1988; Stock & Lambert, 2001). Despite these assumptions and its limited consideration of non-financial constraints, the EOQ formula remains a valuable planning tool for inventory managers. The minor inaccuracies it may introduce are often outweighed by its ease of use and adaptability (Silver et al., 1998).

Moreover, the EOQ formula is simple enough to be adapted or adjusted based on real-world factors. Managers often modify EOQ estimates to accommodate constraints like minimum order quantities, storage capacity, supplier discounts, or expiration risks. Monitoring key indicators such as back orders can provide further insight into the effectiveness of initial EOQ-based inventory strategies (Silver et al., 1998; Tersine, 1988; Stock & Lambert, 2001).

The standard EOQ formula is:

$$EOQ = \sqrt{(2CR / PF)}$$

Where:

I. C = Ordering cost per period
II. R = Annual demand in units
III. P = Purchase cost per unit
IV. F = Annual holding cost as a fraction of unit cost

This formula is a foundational element in inventory management and is frequently applied in pharmacies to determine how often and how much stock to replenish.

2.1.3 Inventory Turnover Ratio

The inventory turnover ratio is a fundamental metric that measures how efficiently inventory is being used and replaced within a specific time frame. This ratio is calculated by dividing the cost of goods sold (COGS) by the average inventory, and it provides insights into how well a company is managing its stock (Stevenson, 2018). A high turnover rate typically indicates strong sales or effective inventory management, while a low turnover may suggest overstocking or obsolescence.

For pharmacies, particularly in low-resource environments, maintaining an optimal turnover ratio is crucial. A high turnover ensures that medications do not expire on the shelves and that capital is not tied up in stagnant stock. On the other hand, excessively high turnover without proper replenishment strategies could lead to frequent stockouts (Nguyen et al., 2020). Hence, balancing turnover is essential for both financial sustainability and ensuring availability of essential medications. Improved inventory turnover directly enhances service delivery and reduces losses due to spoilage, especially for temperature-sensitive or short shelf-life products (Ahmed et al., 2017).

2.1.4 Stock Keeping Units (SKUs) and Classification

Stock Keeping Units (SKUs) represent individual inventory items with distinct characteristics such as size, brand, formulation, or packaging. Effective inventory systems classify SKUs to facilitate better decision-making related to ordering, storing, and tracking stock levels (Silver et al., 1998).

A common technique used for classification is ABC analysis, which categorizes inventory items based on their value and usage frequency: 'A' items are high-value and low-volume, 'B' items are moderate in value and usage, while 'C' items are low in value but high in volume (Baily et al., 2015). This classification helps pharmacies focus their control efforts on the most critical stock. For example, Category A drugs might include high-cost antiretrovirals or antibiotics that require tight oversight, while Category C might contain common over-the-counter items.

Proper SKU management reduces duplication, minimizes storage requirements, and streamlines procurement processes (Jonsson & Mattsson, 2013). In resource-limited settings, it becomes especially important to rationalize SKU diversity to avoid complexity and ensure the availability of the most essential items.

2.1.5 Inventory Replenishment Strategies

Inventory replenishment refers to the process of restocking products to maintain sufficient supply levels. Effective replenishment strategies are essential in avoiding both stockouts and overstocking (Chopra & Meindl, 2016). There are several replenishment models, including continuous review systems, periodic review systems, and hybrid models.

In continuous review systems, inventory levels are monitored in real-time and replenishment is triggered when stock falls below a predefined reorder point (Nahmias, 2009). This method ensures constant availability but may require advanced tracking systems. Periodic review systems, by contrast, assess inventory at fixed intervals and reorder quantities based on usage trends. While less resource-intensive, this method carries the risk of shortages between review periods if demand surges unexpectedly (Silver et al., 1998).

For pharmacies, especially those in developing regions, hybrid models that combine both strategies may offer flexibility while balancing cost and responsiveness. Using sales history data and supplier lead time, replenishment schedules can be optimized to prevent medication shortages and enhance customer service (Fahimnia et al., 2015).

2.1.6 Inventory Visibility and Information

Systems Inventory visibility refers to the ability to track stock levels, movements, and locations in real time throughout the supply chain. In pharmacy inventory systems, visibility ensures that accurate information is available for timely procurement and usage decisions (Agyekum-Mensah et al., 2012).

Inadequate visibility often leads to expired medications, over-ordering, and poor accountability. Modern inventory management systems, including barcode and RFID technologies, help provide real-time stock information and reduce errors in manual record-keeping (Yadav, 2015). These systems can be scaled down for low-resource settings by implementing simple databases or mobile applications that still improve accuracy and reduce loss.

For pharmacies in developing regions, even low-cost digital tools such as Excel-based trackers or mobile inventory apps have shown to significantly improve performance by enhancing forecasting, minimizing waste, and enabling rapid reporting (Vogler et al., 2019; Chukwu et al., 2021).

2.1.7 Inventory Cost Management

Cost management is a critical aspect of inventory control, especially in pharmacy operations where tight margins and sensitive products are common. Inventory costs are typically broken down into three categories: ordering costs, holding costs, and shortage costs (Wild, 2017). Ordering costs refer to the expenses incurred every time a new order is placed, such as administrative labor and transportation. Holding costs are associated with storing inventory, including warehousing, insurance, depreciation, and obsolescence. Shortage costs arise when stockouts occur, potentially leading to lost sales, patient dissatisfaction, or critical treatment delays.

Managing these cost components requires striking a balance between availability and affordability. In resource-constrained pharmacy settings, excessive inventory can strain financial resources, while understocking can result in harmful service interruptions. Techniques such as EOQ (Economic Order Quantity) and Just-In-Time (JIT) purchasing are employed to optimize order volumes and timing to reduce total inventory-related expenses (Nahmias, 2009; Baily et al., 2015).

Effective cost management not only improves profitability but also allows pharmacies to allocate more resources to service delivery, training, and technology investment. This is particularly important in developing countries, where health facilities operate on tight budgets and demand for medication is unpredictable (Vogler et al., 2019).

2.1.8 Inventory Auditing and Compliance

Regular inventory audits are essential for ensuring the accuracy of stock records, preventing theft, reducing expiry losses, and ensuring compliance with regulatory standards. Inventory auditing involves reconciling physical counts with system records to identify discrepancies and implement corrective measures (Jonsson & Mattsson, 2013).

In pharmacy settings, especially those handling controlled substances, compliance with national drug regulatory agencies is mandatory. Accurate records help avoid legal penalties, support traceability, and ensure patient safety. Auditing also enables performance benchmarking and helps forecast future inventory requirements based on historical patterns (Yadav, 2015).

Digital tools and barcode systems can simplify auditing and reduce the manual workload, making them suitable for even low-cost inventory systems in small pharmacies.

Furthermore, structured audit schedules promote discipline and accountability among staff, which is key to sustaining reliable inventory management over time (Chukwu et al., 2021).

2.1.9 Inventory Forecasting Techniques

Forecasting is vital in ensuring that pharmacy inventory levels align with future demand, thus minimizing both shortages and surpluses. Inventory forecasting methods include qualitative techniques (expert opinion, Delphi method) and quantitative models (time-series analysis, regression models, moving averages) (Stevenson, 2018).

Pharmacies often rely on historical consumption data, seasonal trends, and epidemic patterns to inform their forecasts. In low-resource environments, even basic forecasting based on Excel spreadsheets can yield significant improvements in medication availability and budget utilization (Nguyen et al., 2020). Advanced inventory software can automate forecasting by integrating real-time demand data, lead time variability, and supplier performance.

Accurate forecasting enables pharmacies to plan procurement more effectively, reduces the risk of product expiry, and aligns supply with actual community health needs. Forecasting is particularly important in managing chronic disease medications or vaccines, which require precise delivery cycles (Ahmed et al., 2017).

2.2 Review of Existing Literature

In a study conducted by Rasanathan et al., a web-based pharmacy stock management system was implemented in rural Haiti to address frequent drug stockouts and poor inventory documentation. The system, based on WHO inventory formats and built using

PHP/MySQL with offline syncing capabilities, it was introduced across nine rural health clinics. Over two years, the system resulted in a decrease in stockout rates from 2.6% to 1.1%, significantly improving drug availability in these low-resource settings *(Rasanathan et al., 2008).*

The use of segmentation techniques in hospital pharmacy inventory systems explored by Vogler et al. Their study applied the ABC, VED, and XYZ classification frameworks to categorize drugs by cost, criticality, and demand frequency. The analysis demonstrated that such segmentation methods improved procurement precision and reduced instances of overstocking and stockouts in large-scale pharmacy operations *(Vogler et al., 2019).*

Chen et al. implemented simulation optimization models to minimize drug inventory holding costs in outpatient pharmacy settings in Taiwan. The researchers applied Arena-based simulations combined with demand clustering and reorder point policies (s, S) to guide procurement decisions. This approach led to a 55% reduction in inventory holding costs while maintaining a high level of service efficiency *(Chen et al., 2022).*

A study was conducted by Eze and Onwujekwe on the application of the Economic Order Quantity (EOQ) model in drug procurement at a Nigerian tertiary hospital. The model was used to determine optimal ordering quantities of essential medicines over a six-month period. Their findings indicated that the implementation of EOQ led to a 22% reduction in inventory costs and a notable improvement in drug availability *(Eze & Onwujekwe, 2021).*

In Udupi District, India, Hegde et al. conducted an assessment of pharmaceutical inventory practices across ten public healthcare facilities. The review included stock audits and staff interviews. The study found frequent issues such as mismatched stock records, expired medications, and inadequately trained personnel. The authors concluded that even simple training interventions and basic digital tools could significantly improve inventory accuracy and drug availability *(Hegde et al., 2015).*

Ayalew et al. examined the availability of essential medicines and inventory management practices in 12 Ethiopian health centers using WHO service indicators and structured interviews. Their findings revealed suboptimal drug availability and ineffective use of Logistics Management Information Systems (LMIS). The authors recommended enhancing staff training and improving LMIS implementation as key interventions for sustainable pharmaceutical supply chains *(Ayalew et al., 2019).*

In South Africa, Mpanza et al. reviewed inventory management challenges in nine KwaZulu-Natal health facilities using procurement and stock records. The study revealed that 85% of essential drugs experienced periodic stockouts, primarily due to delayed procurement cycles and inaccurate forecasting. The authors proposed implementing predictive inventory models and enhancing staff accountability to improve stock reliability *(Mpanza et al., 2023).*

Mensah et al. investigated inventory practices in 30 urban private pharmacies in Accra, Ghana. The study compared the outcomes of pharmacies using manual methods against those employing Excel-based digital inventory tools. Results showed that pharmacies using digital tools recorded a 35% reduction in expired drugs and a 20% improvement in stock rotation rates, illustrating the benefits of even low-tech solutions *(Mensah et al., 2021).*

Njeri et al. conducted a cost-benefit analysis of various inventory models in Nairobi's private clinics. The research compared manual systems, semi-automated tools, and EOQ-based digital solutions. The study revealed that EOQ systems led to an annual cost saving of up to 30%, demonstrating the financial advantage of implementing structured inventory models in settings with tight budgets *(Njeri et al., 2020).*

Tumwesigye et al. evaluated Uganda's national drug logistics system using performance audits and site inspections. Their study found that fulfillment rates improved from 65% to 92% following the adoption of centralized ordering systems and structured training for logistics personnel. The findings suggest that integrated logistics management systems are effective in improving drug availability in rural and remote health facilities *(Tumwesigye et al., 2018).*

Adebayo et al. conducted a pilot study in northern Nigeria to evaluate a mobile-based inventory management application designed for rural pharmacies. The application, built using low-cost Android devices and open-source inventory software, was tested in 15 community pharmacies. Over a six-month period, participating pharmacies experienced a 40% reduction in stockouts and a 25% improvement in order accuracy *(Adebayo et al., 2021).*

Ochieng and Nwankwo assessed the feasibility of deploying spreadsheet-based inventory tracking tools in small Kenyan drug outlets. The tool included automated stock level alerts, reorder reminders, and monthly summary sheets. The study found that with basic training, pharmacy staff were able to adopt and maintain accurate inventory records, reducing monthly drug shortages by 28% *(Ochieng & Nwankwo, 2020).*

Khalid et al. developed a community pharmacy inventory dashboard in Pakistan using Microsoft Power BI. The dashboard integrated Excel records from multiple pharmacy branches and visualized near-expiry alerts, stock levels, and reorder recommendations. The solution was found to be low-cost and effective, particularly in areas lacking access to advanced inventory systems *(Khalid et al., 2022).*

Ford W. Harris states that every organization that is into either production, trading, sales or services has to face the problem of finding the most cost-effective quantity to place an order. There are many factors which affect the economics such as unit cost of the material, set up cost, interest and depreciation on stock, movement charges and also the manufacturing interval in case of a manufacturing unit. In order to show the significance of practicing the inventory management in a company (*Ford W. Harris, 1913)*

2.3 Summary of Key Insights

These studies show the growing importance of scalable, low-cost, and data-driven inventory systems in pharmacy settings. From digital segmentation and EOQ models to basic Excel-based tracking, consistent patterns emerge: training, simplicity, and contextual adaptation are key to success

2.4 Conclusion

There is growing evidence that thoughtfully designed, resource-appropriate inventory solutions can significantly improve pharmaceutical availability, reduce costs, and enhance service delivery. Your project, which proposes a web-based, low-cost inventory management tool for pharmacies, aligns closely with global trends and needs as seen in the literature.

CHAPTER THREE

METHODOLOGY

This chapter describes the methodology used in developing a low-cost inventory management system for a pharmacy. It outlines the research design, study area, data collection process, analytical models employed, system implementation, and ethical considerations.

3.1 Research Design

The study adopted a **descriptive and developmental research design**, which involved two main phases:

I. **Descriptive Phase**, and
II. **System Development and Implementation Phase.**

I. Descriptive Phase:

This phase involved the assessment of the pharmacy's existing inventory management system. The main objective was to understand how sales, purchases, and orders were recorded and managed manually. The review of the pharmacy's record-keeping system provided insight into current challenges such as stockouts, overstocking, and difficulties in tracking expiry dates.

II. System Development and Implementation Phase:

In this phase, a **web-based inventory management system** was designed and implemented for the selected pharmacy. The system was developed to automate inventory control tasks, including stock monitoring, reorder alerts, and expiry tracking. Actual operational data obtained from the pharmacy—comprising sales records, purchase records, and order logs—were used to test and validate the system's performance and accuracy.

3.2 Study Area

The study was carried out at a **community pharmacy located in Benin City, Edo State, Nigeria**. The pharmacy engages in retail and wholesale distribution of pharmaceutical products. It was selected because it maintains consistent sales and purchase records and was willing to provide access to its inventory data for academic purposes.

3.3 Data Sources and Collection Methods

The data used in this study were obtained from **secondary sources**, which consisted of the pharmacy's existing operational records.

The records included:

I. **Sales Records** – containing information such as date of sale, product name, quantity sold, unit price, and total sales value.

II. **Purchase Records** – detailing the date of purchase, supplier, product name, quantity purchased, unit cost, and total cost.

III. **Order Book** – documenting product orders, delivery dates, and quantities requested.

These records were provided by the pharmacy management following a written request for access. The data were used both for the analytical model calculations (EOQ and ROP) and for system testing and validation.

3.4 Analytical Models Employed

The following analytical models were used for data analysis and system development:

I. Descriptive Statistics:

Descriptive analysis was applied to summarize product movement patterns, identify fast- and slow-moving drugs, and determine demand trends for key items.

II. Economic Order Quantity (EOQ) Model:

The EOQ model was used to determine the optimal number of drug units to order at once to minimize the combined ordering and holding costs.

$$EOQ = \sqrt{(2DS / H)}$$

Where:

I. **D** = Annual demand (units per year)
II. **S** = Ordering cost per order
III. **H** = Holding cost per unit per year

III. Reorder Point (ROP) Model:

The reorder point was used to determine the inventory level at which a new order should be placed to avoid stockouts.

RO P= (Daily Demand × Lead Time) + Safety Stock

Where:

I. **Daily Demand** = Annual demand ÷ 365

II. **Lead Time** = Time (in days) between ordering and delivery

III. **Safety Stock** = 20% of expected demand during lead time

3.5 System Implementation

The system was implemented as a **web-based inventory management application** tailored for the selected pharmacy. It was designed to be simple, cost-effective, and efficient in automating the basic functions of pharmacy stock management.

Figure 3.1: Entity Relation Diagram

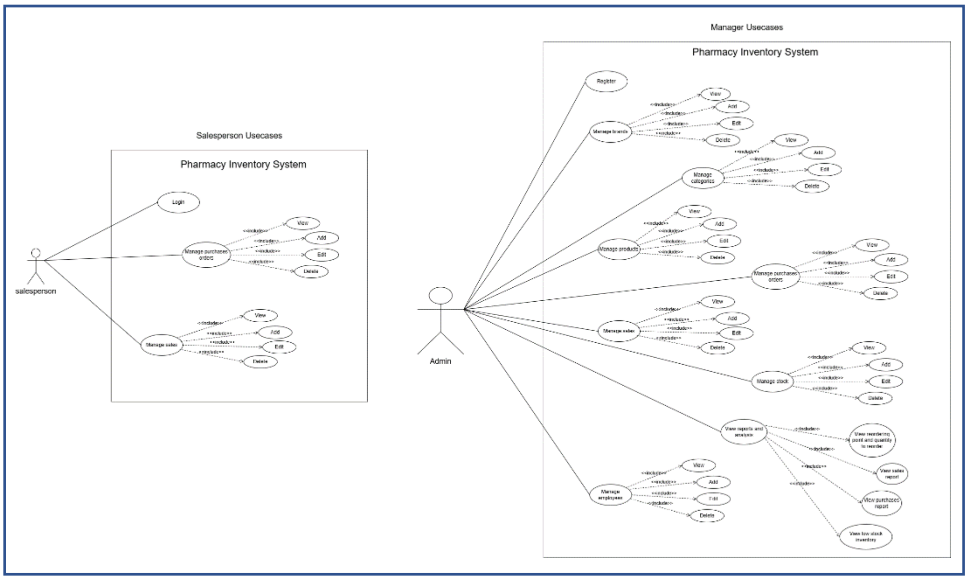


Figure 3.2: Use-case Diagram

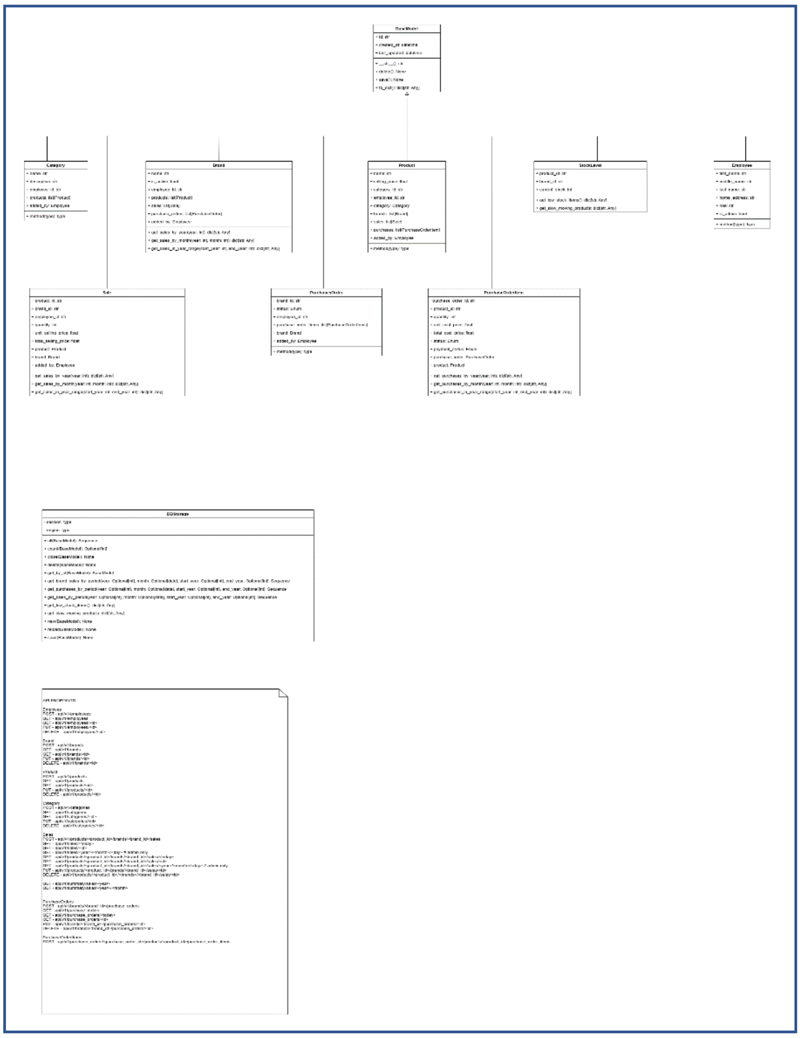


Figure 3.3: Mothed Case Diagram

3.5.1 Technology Stack

I. **Frontend:** HTML5, CSS, JavaScript (React.js)

II. **Backend:** Python, React framework and sqlachemy.

III. **Database:** PostgreSQL (SQL)

IV. **Hosting Platform:** Platform: Digital Ocean (for online deployment)

```python
#!/usr/bin/env python3

"""
Brand model and brand-product link table.
"""

from sqlalchemy.orm import mapped_column, relationship
from sqlalchemy import Table, Column, ForeignKey, String, Boolean

from models.basemodel import Base, BaseModel


brand_products = Table(
    "brand_products",
    Base.metadata,
    Column(
        "brand_id",
        String(36),
        ForeignKey("brands.id", ondelete="CASCADE"),
        primary_key=True,
    ),
    Column(
        "product_id",
        String(36),
        ForeignKey("products.id", ondelete="CASCADE"),
        primary_key=True,
    ),
)


class Brand(BaseModel, Base):
    """Represents a product brand in the pharmacy."""

    __tablename__ = "brands"

    name = mapped_column(String(200), nullable=False, unique=True)
    is_active = mapped_column(Boolean, default=True)
    employee_id = mapped_column(
        String(36),
```

Figure 3.4: Code of Structured Brand Database

```python
#!/usr/bin/env python3

"""
Sale model.
"""

from sqlalchemy.orm import mapped_column, relationship
from sqlalchemy import ForeignKey, String, Integer, Float

from models.basemodel import Base, BaseModel


class Sale(BaseModel, Base):
    """Represents a product sale record."""

    __tablename__ = "sales"

    product_id = mapped_column(
        String(36), ForeignKey("products.id", ondelete="SET NULL")
    )
    brand_id = mapped_column(
        String(36),
        ForeignKey("brands.id", ondelete="SET NULL")
    )
    quantity = mapped_column(Integer, nullable=False)
    unit_selling_price = mapped_column(Float, nullable=False)
    total_selling_price = mapped_column(Float, nullable=False)
    employee_id = mapped_column(
        String(36), ForeignKey("employees.id", ondelete="SET NULL")
    )
    product = relationship("Product", back_populates="sales")
    brand = relationship("Brand", back_populates="sales")
    added_by = relationship("Employee", backref="sales")
```

Figure 3.5: Code of Structured Sale Database

```python
#!/usr/bin/env python3

"""
Product model.
"""

from sqlalchemy.orm import mapped_column, relationship
from sqlalchemy import ForeignKey, String, Float

from models.basemodel import Base, BaseModel
from models.brand import brand_products


class Product(BaseModel, Base):
    """Represents a product in the pharmacy."""

    __tablename__ = "products"

    name = mapped_column(String(500), nullable=False, unique=True)
    selling_price = mapped_column(Float, default=0.00)
    category_id = mapped_column(
        String(36),
        ForeignKey("categories.id", ondelete="SET NULL"),
    )
    employee_id = mapped_column(
        String(36),
        ForeignKey("employees.id", ondelete="SET NULL")
    )
    category = relationship("Category", back_populates="products")
    brands = relationship(
        "Brand",
        secondary=brand_products,
        back_populates="products",
        passive_deletes=True,
    )
    sales = relationship("Sale", back_populates="product")
    purchases = relationship("PurchaseOrderItem", back_populates="product")
    stock_levels = relationship("StockLevel", back_populates="product")
    added_by = relationship("Employee", backref="products_added")
```

Figure 3.6: Code of Structured Product Database

3.5.2 Core System Features

I. **User Authentication:** Secure login and logout functions for admin and staff.

II. **Stock Management:** Real-time monitoring of product quantities and updates with every sale or purchase.

III. **Automatic EOQ and ROP Calculations:** The system automatically computes optimal reorder quantities and reorder points.

IV. **Low-Stock and Expiry Alerts:** The system triggers notifications when drugs fall below reorder levels or approach their expiry date.

V. **Reports Module:** Generates summaries of sales, purchases, and stock movement.

VI. **Dashboard Interface:** Displays key inventory statistics and notifications at a glance.

3.5.3 Workflow Description

I. The user logs into the system.
II. Sales, purchases, or stock updates are entered into the database.
III. The system automatically updates current stock levels.
IV. If stock falls below the reorder point, the system triggers a reorder alert.
V. Reports and analytics are generated automatically for management use.

3.6 Tools and Technologies Used

I. **HTML5, CSS, JavaScript (React.js) Python, React framework and sqlachemy:** Used for the development of the web application.
II. **Digital ocean (for online deployment):** Used for online hosting and deployment.
III. **Python (Pandas, OpenPyXL):** Used for testing the EOQ and ROP computations.
IV. **Microsoft Word:** Used for report writing and documentation.

3.7 Ethical Considerations

The study adhered to ethical standards throughout the data collection and analysis process:

I. **Permission:** Written authorization was obtained from the pharmacy management to use the records for academic purposes.
II. **Confidentiality:** No sensitive or patient-related data were collected; only product and transaction records were used.
III. **Data Security:** All electronic records were securely stored and anonymized to ensure confidentiality of the pharmacy's business operations.

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

This chapter presents the analysis and evaluation of the developed low-cost pharmacy inventory management system. The purpose is to demonstrate how the system automatically processes pharmacy operational data including purchase orders, stock levels, and sales transactions to compute inventory parameters such as the Economic Order Quantity (EOQ) and the Reorder Point (ROP). The data used for the analysis were generated from the pharmacy's 2024 operational records stored in the system's PostgreSQL database

4.1 Data Presentation and Analysis

The data used for the analysis were obtained from the selected pharmacy's operational records, covering the period from January to December 2024. The data included sales transactions, purchase records, and order book entries. Each dataset contained product names, quantities, prices, and transaction dates represented in datetime format.

The data were organized across nine interrelated tables as defined in the database schema. Each table corresponds to a real-world process in pharmacy inventory control

Table 4.1.1: Data Presentation

Table Name	**Description**	Example Data Fields
employees	Staff members responsible for operations	first_name, role, home_address
brands	Drug manufacturers or suppliers	name, is_active
categories	Grouping of products	name, description
products	Pharmacy items sold	name, unit_cost, selling_price

stock_levels	Tracks current stock for each product-brand	current_stock
purchase_orders	Records orders made to suppliers	brand_id, status, created_at
purchase_order_items	Specific items per order	product_id, quantity, unit_cost_price
sales	Daily sales transactions	product_id, quantity, total_selling_price
product_brands	Relationship between products and suppliers	product_id, brand_id

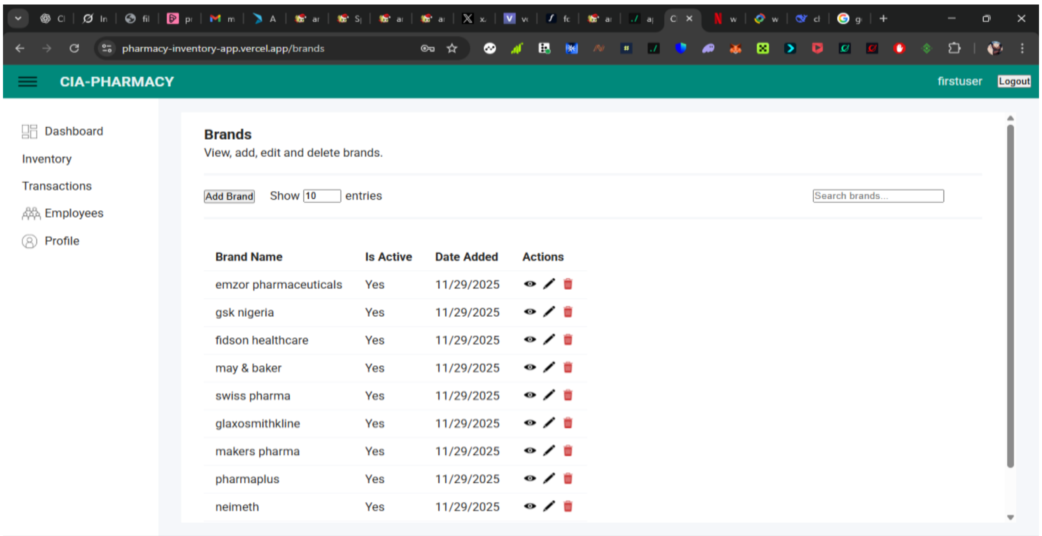


Figure 4.1: Brand Page

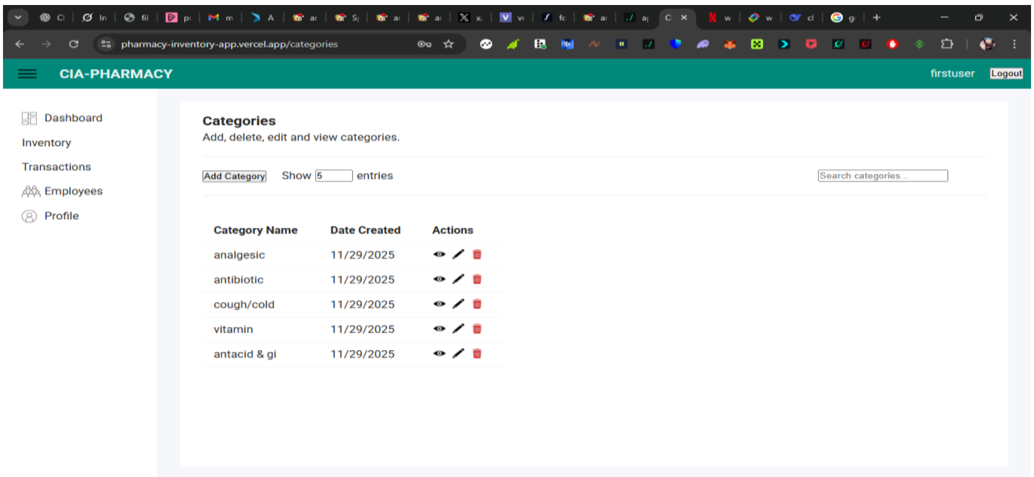


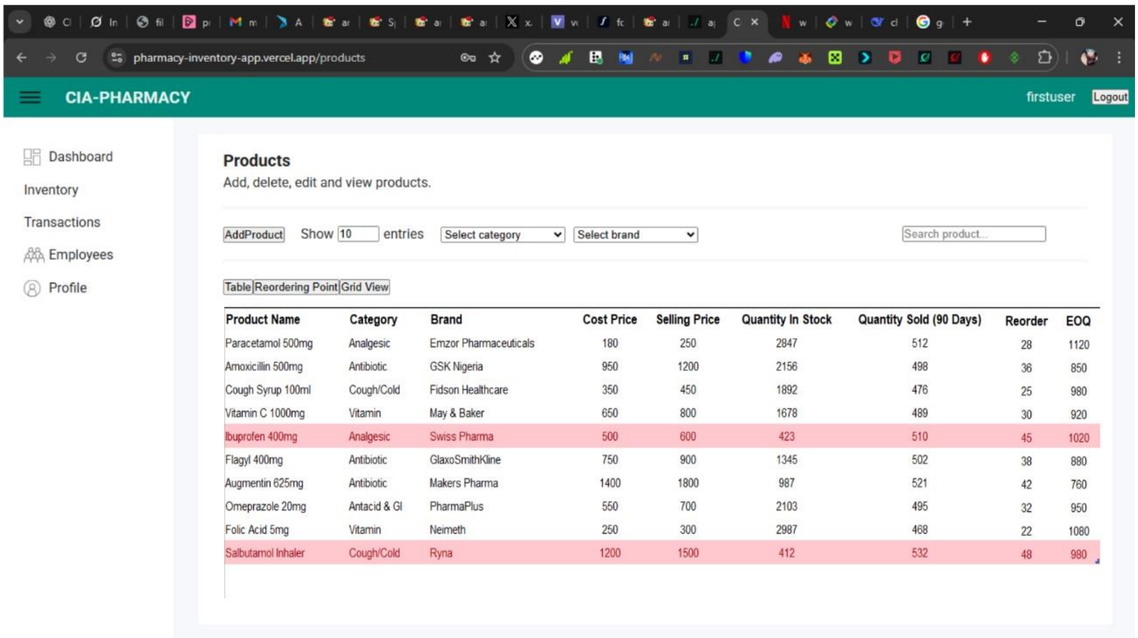
Figure 4.2: Categories Page

Table 4.1.2: Total Sales Summary (2024)

Product	Total Quantity Sold per year (PACKS)	Average Daily Sales (PACKS)	Total Sales Value (₦)
Paracetamol 500mg	12000	33	1,800,000
Amoxicillin 250mg	9500	26	1,900,000
Cough Syrup 100ml	6800	19	2,040,000
Vitamin C 100mg	5400	15	540,000
Ibuprofen 200mg	7200	20	1,800,000
total	40900	113	8,080,000

4.2 Application of EOQ and Reorder Point Models

The EOQ and ROP models were applied to determine optimal stock quantities and reorder levels for selected products. Given: S = ₦10,000 (Ordering cost per order) and H = 20% × Unit Cost per Year.



Product Name	Category	Brand	Cost Price	Selling Price	Quantity In Stock	Quantity Sold (90 Days)	Reorder	EOQ
Paracetamol 500mg	Analgesic	Emzor Pharmaceuticals	180	250	2847	512	28	1120
Amoxicillin 500mg	Antibiotic	GSK Nigeria	950	1200	2156	498	36	850
Cough Syrup 100ml	Cough/Cold	Fidson Healthcare	350	450	1892	476	25	980
Vitamin C 1000mg	Vitamin	May & Baker	650	800	1678	489	30	920
Ibuprofen 400mg	Analgesic	Swiss Pharma	500	600	423	510	45	1020
Flagyl 400mg	Antibiotic	GlaxoSmithKline	750	900	1345	502	38	880
Augmentin 625mg	Antibiotic	Makers Pharma	1400	1800	987	521	42	760
Omeprazole 20mg	Antacid & GI	PharmaPlus	550	700	2103	495	32	950
Folic Acid 5mg	Vitamin	Neimeth	250	300	2987	468	22	1080
Salbutamol Inhaler	Cough/Cold	Ryna	1200	1500	412	532	48	980

Figure 4.3: Product Page Displaying the EOQ and Reordering point

4.3 Findings

The analysis shows that the developed system effectively automates key inventory operations such as computing EOQ and ROP based on real-time data. By maintaining a uniform **20% safety stock** across all items, the system ensures balanced stock levels that reduce the likelihood of both overstocking and stockouts.

The system's integration of automated reorder alerts and database-driven analytics makes it suitable for small and medium-sized pharmacies seeking affordable, efficient inventory management solutions.

4.4 Summary

This chapter presented the analysis of pharmacy data and demonstrated how EOQ and ROP models were applied to determine optimal order quantities and reorder points. The results highlighted that Paracetamol and Vitamin C are the most demanded drugs and require frequent restocking. The expected output of the developed system includes automatic EOQ/ROP computation, low-stock notifications, and visual reporting, which together improve the accuracy and efficiency of inventory management.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

This chapter provides a summary of the entire study, highlighting the key findings, conclusions, and recommendations drawn from the design and implementation of a low-cost pharmacy inventory management system. The purpose is to emphasize how the system addresses the challenges identified in the existing manual inventory management process.

5.1 Conclusion

The design and implementation of a low-cost pharmacy inventory management system provide a practical solution to common stock management problems encountered by small and medium-sized pharmacies.

The system integrates key inventory control models (EOQ and ROP) with real-time database management, ensuring timely restocking decisions and efficient resource utilization. It demonstrates that affordable digital solutions can significantly improve accuracy, accountability, and operational performance in pharmaceutical retail settings.

The project further confirms that data-driven decision-making, supported by automation, can enhance efficiency and sustainability in pharmacy operations.

5.2 Recommendations

Based on the findings of this study, the following recommendations are made:

I. **Adoption of the System:** Pharmacies, especially small- and medium-scale ones, should adopt the developed web-based system to manage their daily inventory operations more efficiently.

II. **Regular System Updates:** The system should be periodically updated to improve functionality and accommodate new drug entries or regulatory requirements.

III. **Staff Training:** Pharmacy staff should receive basic computer and software operation training to ensure effective use of the system.

IV. **Data Backup:** Regular data backups should be implemented to prevent data loss and ensure business continuity.

V. **Integration with Suppliers:** Future versions of the system could include supplier integration for automatic ordering and invoice tracking.

VI. **Further Research:** Future researchers may explore extending this system into a mobile application and incorporating artificial intelligence for demand forecasting and expiry prediction.

5.3 Summary

This chapter summarized the project and its outcomes. The study successfully developed and described a low-cost web-based inventory management system that applies EOQ and ROP models to optimize pharmacy operations. The findings show that automation improves efficiency, accuracy, and cost-effectiveness.

With continued updates, staff training, and potential system integration with suppliers, this system can serve as a reliable tool for improving healthcare inventory management in Nigeria and beyond.

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