A FRAMEWORK FOR OPTIMIZING PHARMACY INVENTORY MANAGEMENT SYSTEM PERFORMANCE USING CLOUD COMPUTING AND MACHINE LEARNING A CASE STUDY OF NAIROBI COUNTY

KELVIN CHEBET

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been presented for the award of a degree or any other award in any other University.

7/10/2024

Kelvin Chebet Date

CIS-3-0419-3/2021

RECOMMENDATION

We confirm that the work reported in this thesis was carried out by the candidate under our supervision.

7/10/2024

Peter Waweru Date

Department of computer science

Kenya Methodist University

7/10/2024

Vincent Mbandu Date

Department of computer science

Kenya Methodist University

DEDICATION

To my loving family, whose unwavering support has made this dream a reality.

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ABSTRACT

The purpose of this study was to address how pharmacy inventory management systems can be improved using cloud computing and machine learning. The main aim was to enhance efficacy, accuracy and efficiency in inventory management practices within the pharmaceutical sector. The problem identified was about the inefficiencies and challenges present in conventional stock control methods such as manual tracking mechanisms and outdated ones. Because of these inefficiencies, issues such as stock-outs, excesses, and lack of real-time information critical for decision-making processes arise. To overcome this challenge, a quantitative research design was used where data was collected through questionnaires and interviews from a diverse group of pharmacy personnel. The sample included public and private pharmacies in Nairobi County through stratified random sampling. The methodology involves the use of questionnaires for quantitative data collection on ongoing inventory management practices as well as technological readiness. This study expects that by utilizing cloud computing and machine learning algorithms there will be an inclusive framework created for optimizing pharmacy inventory management systems. The results indicated a need for the implementation of the proposed machine learning and cloud computing framework as the respondent indicated a high dissatisfaction it their current inventory management systems which were indicated to have major challenges that contributed to financial losses, customer dissatisfaction among other. Additionally, this research provides practical recommendations for implementing cloud computing platforms or machine learning solutions which could transform the traditional approach to inventory management thereby enhancing patient care outcomes.

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LIST OF ABBREVIATIONS AND ACRONYMS

KPIs	Key performance indicators
IT	Information technology
CC	Cloud computing
ML	Machine learning
SPSS	Statistical packages for the social sciences
HIPAA	Health Insurance Portability and Accountability Act
TGA	Therapeutic Goods Administration
GDPR	General data protection regulation
ANOVA	Analysis of variances
PIPEDA	Personal Information Protection and Electronic Documents Act
OTC	Over the counter
PAAS	Platform as a Service

OPERATIONAL DEFINITION OF TERMS

Pharmacy A healthcare setting where qualified pharmacists are licensed to distribute medicines and give pharmaceutical care to patients, guaranteeing the safe and proper use of pharmaceuticals via prescription distribution, medication counseling, and other services (Johnson et al., 2023).

Inventory management Monitoring and regulating the movement of products and commodities inside a company. Maintaining accurate product availability, saving costs, and preventing stockouts and overstocking, entails effectively controlling inventory levels, monitoring stock movements, and optimizing inventory ordering, storage, and distribution (Sohrabi et al., 2023).

Cloud computing The on-demand provision of computer resources and services, including storage, computing power, and applications, through the internet (Bell, 2024). Without relying on local infrastructure, users may now access and use these services from any place with an internet connection.

Machine learning A branch of artificial intelligence where computers may autonomously learn from data and enhance performance on specific tasks without explicit programming (Kufel et al., 2023). Computers can foresee the future, make decisions, and learn from past errors much obliged to this analysis and interpretation of information designs using models and algorithms.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Inventory management is invaluable for businesses in several diverse domains, such as the pharmaceutical industry. Its optimal execution results in adequate product availability while reducing expenses and improving resource utilization (Alkhouri, 2024). The importance of inventory regulation amplifies considerably when it comes to supplying medicines and medical equipment without any disruption within the pharmaceutical sector. Effective inventory control ensures patient well-being while strengthening healthcare processes (Mensah et al., 2021). In addition, efficient stock management lessens the likelihood of overstocking, which may incur extra costs and waste resources. Another importance of inventory management (Gizaw and Jemal, 2021) is that it plays a role in the overall efficacy of healthcare systems and patient care concerns. Healthcare organizations may simplify operations, lower administrative responsibilities, and make informed decisions about purchasing, storing, and distributing pharmaceutical items by storing correct and up-to-date inventory information. As a result, supply chains become more effective, lead times are shortened, and overall operational performance is improved.

The pharmaceutical industry's appropriate inventory management is strongly linked to requirements for regulatory compliance and quality assurance (Organization, 2024). Pharmaceutical inventory must be tracked, documented, and traceable to satisfy regulatory standards and guarantee product integrity and safety. Pharmacy operations that maintain these standards and thorough records are better equipped to withstand audits, inspections, and the general management of quality control procedures. Finally, efficient inventory management aids pharmacies' internal quality control procedures. It makes stock rotation easier to control, lowering the chance of dispensing tainted or outdated items (Bekele et al., 2022). Pharmacies may reduce the possibility of pharmaceutical mistakes and guarantee patient safety by quickly identifying and correcting any inconsistencies with a thorough inventory-level overview.

The pharmaceutical industry confronts various obstacles that reduce the efficiency of inventory management. Using traditional procedures that include manual tracking techniques is one such difficulty. These procedures are vulnerable to human errors, such as incorrect input and inconsistencies between recorded data and actual inventory. Such errors may seriously impair the availability of medications and jeopardize patient treatment (Rashid et al., 2020). The challenges in inventory management are made much more difficult using outdated methods. It might be challenging for healthcare practitioners to receive the most recent information on medicine availability and inventory levels since these systems often need more real-time insights with which pharmacists would find it easier to decide when and how much to restock their inventory, which might lead to stockouts or overstocking (Chebet & Mbandu, 2024)

These difficulties with inventory management have far-reaching effects. Stockouts, when necessary, pharmaceuticals are not accessible when required, may harm patient care, perhaps jeopardizing both patient safety and treatment results. Conversely, significant inventory levels caused by overstocking tie up critical financial resources that may be used to fund other crucial aspects of healthcare delivery (Du Plessis, 2020). Moreover, having too many pharmaceuticals on hand increases the likelihood that they may wastefully expire before being used. Luckily, the advancement of technology has introduced a wave of innovative approaches to address the obstacles in inventory control. Scholars and professionals have investigated diverse technological resources, such as cloud computing and machine learning, to transform inventory management methodologies. According to Unhelkar et al. (2022) cloud computing allows businesses to access computational resources instantly, facilitating efficient data storage and processing due to its scalable features. This technological advancement provides the capacity to efficiently manage substantial quantities of data while enhancing the allocation of resources.

Machine learning algorithms, on the other hand, are crucial in the analysis of past sales data and the detection of patterns. According to Borges et al. (2021), machine learning can enable organizations to derive significant insights and produce practical recommendations to enhance inventory management. The algorithms can automate decision-making procedures, forecast demand patterns, and enhance inventory levels. Cloud computing and machine learning have improved inventory management in different industries. For example, machine learning and cloud computing have improved stock management in the retail sector. Retailers can estimate demand, adjust inventory levels, and reduce stockouts and surplus inventory via data analysis and real-time processing, which results in cost savings and enhanced operational efficiency. Within the pharmaceutical industry, implementing these technologies has the potential to improve inventory precision, facilitate instantaneous monitoring, automate decision-making procedures, and optimize the allocation of resources (Barbosa-Povoa & Pinto, 2020). A comprehensive framework is required to incorporate machine learning and cloud computing to handle pharmacy inventory management's unique needs and problems.

By suggesting a unique framework to enhance pharmaceutical inventory management utilizing cloud computing and machine learning, this study intends to add to the body of current knowledge. The approach solves erroneous inventory levels, real-time data analytics monitoring, and other significant problems with conventional inventory management techniques (Srinivasan et al., 2021). Leveraging the power of cloud computing and machine learning, this system will give a robust and scalable solution to improve pharmacy inventory management systems' performance, efficiency, and effectiveness.

By creating and assessing this Framework, this research aims to provide healthcare companies with valid perceptions and suggestions for implementing and using cloud computing and machine learning technologies in their pharmacy operations (Khan et al., 2020). The results of this study will help the pharmaceutical sector upgrade its inventory management procedures, eventually improving patient care, safety, and overall operational effectiveness.

1.2 Statement of the Problem

Pharmacies in Nairobi County often grapple with inefficiencies in their current inventory management systems. In an ideal scenario, pharmacies would have a seamless flow of medications, ensuring patients can access the medications they need without encountering stockouts or delays. Ordering would be streamlined, maintaining optimal stock levels to avoid unnecessary overstocking that ties up capital and risks medication expiration. This would create a more efficient system that benefits both pharmacies and patients.

Unfortunately, traditional methods introduce a multitude of hurdles. Inaccurate demand forecasting can lead to stockouts, leaving patients frustrated and pharmacies unable to fulfill prescriptions. This can also result in lost sales opportunities. Conversely, overstocking occurs when pharmacies hold excessive inventory due to miscalculations or unforeseen changes in demand patterns. This not only consumes valuable capital but also increases storage costs and the risk of medications expiring before they can be sold.

Additionally, these manual processes are labor-intensive and time-consuming, requiring pharmacy staff to dedicate significant effort to data analysis and order placement. This can lead to human error and further hinder optimal inventory management, ultimately reducing efficiency.

These limitations have a cascading effect on the entire healthcare ecosystem. Stockouts can inconvenience patients and potentially delay necessary medical treatment, leading to poorer health outcomes. Overstocking represents wasted resources that could be used to improve patient care or invest in new technologies. Furthermore, manual processes require significant staff time and effort, diverting valuable resources from providing direct patient care. Pharmacists and pharmacy technicians could be spending more time interacting with patients and ensuring they receive the medications they need, but instead, they are bogged down with tedious data analysis and order placement tasks. This inefficiency not only reduces overall pharmacy productivity but also contributes to potential job dissatisfaction among staff. These challenges highlight the urgent need for innovative solutions to optimize pharmacy inventory management in Nairobi County. By implementing a more efficient system, pharmacies can improve patient care, reduce costs, and free up staff resources to focus on what matters most – their patients' well-being.

1.3 Purpose of the Study

This study aimed to develop a framework for optimizing pharmacy inventory management system performance using cloud computing and machine learning.

1.4 Research Objectives

1.4.1 Main Objective

The main objective of this study is to establish a theoretical structure for pharmacy inventory management systems that leverages Amazon web services (AWS) PaaS

(Platform as a Service) and XGBoost model. The primary goals entail enhancing efficacy and proficiency, patient welfare, and operational efficiency within the pharmaceutical industry.

1.4.2 Specific Objectives:

i. To assess the current user requirements in pharmacy inventory management.

ii. To examine key components and functionalities are required in a framework that integrates PaaS and the XGBoost model to optimize pharmacy inventory management.

iii. To develop a framework for optimizing pharmacy inventory management using cloud computing and machine learning.

iv. To provide recommendations for implementation of the proposed framework

1.5 Research Questions

i. What are the current user requirements for effective pharmacy inventory management?

ii. What are the essential components of a PaaS framework that can effectively support the integration of XGBoost for pharmacy inventory management?

iii. How can a cloud computing and machine learning framework be developed to optimize pharmacy inventory management?

iv. What are the key considerations and best practices for implementing and adopting the developed Framework in real-world pharmacy settings?

1.6 Justification of the Study

The proposed research is essential for several reasons. First, examining the possible advantages of combining cloud computing and machine learning technologies will add to the existing literature on inventory management systems. Secondly, the research presented recommendations for the realistic adoption of a PaaS cloud-based inventory management system and identify the difficulties pharmacies face managing their inventory. Thirdly, the research will assist inventory management in becoming more accurate and efficient, which may result in cost savings and improved customer service. Additionally, the suggested XGBoost Framework will offer a new solution to pharmacy inventory management, specifically in Kenya, as this is the first research to develop this model in the setting. Overall, the study has the potential to advance inventory management significantly and provide practical suggestions for enhancing the procedures used in pharmacies and other businesses.

1.7 Limitations of the Study

It is essential to acknowledge some limitations of the research. For example, the study's generalizability to other regions may be limited due to its focus on a specific location with diverse healthcare systems and practices. In addition, the accessibility and cooperation of participants may impose constraints on the sample size, potentially impacting the study's representativeness. The reliance on interviews, surveys, and secondary data also adds the possibility of response bias and restricts access to specific and current data. Besides, the study's emphasis on the pharmaceutical business and inventory management, in particular, obscured other essential elements affecting pharmacy management. Lastly, the research overlooks any possible technical constraints or implementation difficulties that can materialize when integrating cloud computing and machine learning into current pharmaceutical inventory systems. Despite these drawbacks, this research offers a valuable starting point for additional study and the creation of efficient frameworks for pharmacy inventory management.

1.8 Delimitation of the Study

The study is based on real-world experiences and viewpoints since primary data from pharmacy managers, inventory management specialists, and IT experts were be gathered via surveys and interviews. The depth of research and comprehension is improved by including secondary material from scholarly publications and industry reports. Concentrating on a particular geographic place makes it possible to examine local customs more deeply. It makes it easier to identify problems and solutions that are unique to that area.

1.9 Significance of the Study

This study addresses current issues to improve efficiency, effectiveness, and patient care in the pharmaceutical sector. It offers workable solutions by creating a framework that optimizes inventory management utilizing cloud computing and machine learning. This research fills a gap in the literature by giving a novel viewpoint on enhancing inventory management techniques by integrating cutting-edge technology and data-driven methodologies. The results will support healthcare organizations and industry experts' adoption of cloud computing and machine learning technologies by offering insightful analysis and suggestions. Ultimately, this research contributes to our knowledge of pharmacy inventory management and encourages creative solutions, which boost operational efficiency, save costs, and improve patient safety and happiness.

1.10 Assumptions of the Study

First, this research assumes that all interviewees and survey takers, including pharmacists, stockroom managers, and IT specialists, were honest and forthright in their responses. Secondly, the study assumes that the secondary data from scholarly publications, industry reports, and other relevant literature sources accurately portray the current status of pharmacy inventory management and the uses of cloud computing and machine learning. Better inventory control and resource utilization are expected outcomes of the suggested Framework for improving pharmaceutical inventory management using these technologies. Finally, comparable situations in the pharmaceutical sector may benefit from the results and suggestions of this research, with due consideration given to any variances and geographical discrepancies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This literature review gives a detailed evaluation of the challenges faced in pharmacy stock management, specifically focusing on the potential solutions given by cloud computing and machine learning. The paper researches the challenges in controlling inventory within the healthcare industry, such as managing products with various expiration dates, controlling items with different pricing, and maintaining regulatory compliance. It examines how combining cloud computing and machine learning technologies may help pharmacies increase efficiency, reduce waste, and optimize their stock levels. By examining significant articles and scholarly discussion, this literature review evaluates the benefits, limitations, and potential knowledge gaps around using cloud computing and machine learning in pharmacy inventory management. This review's findings will benefit researchers, practitioners, and industry decision-makers, paving the way for more research and the efficient use of cutting-edge inventory management strategies in pharmacies.

Assessing Current User Requirements in Pharmacy Inventory Management

The first objective is to identify pharmacists' challenges in managing their inventory while enhancing patient care, productivity, and effectiveness in the pharmaceutical sector. It is crucial to understand existing stock management to create a paradigm that effectively solves the particular constraints faced by pharmacies (Kho et al., 2017). To better comprehend their challenges, it is intended to thoroughly analyze the current issues and restrictions of the pharmacy management method. The study aimed to pinpoint specific issues that pharmacies have with managing their inventory. This information guided the development of the Framework, ensure that it solves problems, and provides practical feedback.

Through an intensive assessment of the existing literature and surveys with stakeholders within the pharmaceutical industry, the study gathered essential information on the challenges experienced by pharmacies. It also considered case studies, review industry publications, and consult with experts to understand pharmacy inventory management comprehensively to add to the information on pharmaceutical industry-specific inventory management difficulties. The objective of recognizing current issues served as the basis for developing a framework that satisfies pharmacies' particular inventory management requirements, resulting in increased productivity, decreased costs, and better patient care.

Developing a framework for optimizing pharmacy inventory management using cloud computing and machine learning and examining the benefits of implementing the proposed framework

Improving pharmacy inventory management via cutting-edge technology, such as cloud computing and machine learning, aims to overcome the sector's current challenges and inefficiencies. The goal is to create a state-of-the-art system that enhances pharmacy stock management accuracy, effectiveness, and efficiency. The proposed framework is XGBoost, a model used in other fields and not in a pharmacy setting. Among machine learning models, XGBoost stands out for its accuracy and efficacy. It produces better predictions by addressing complex patterns and handling huge datasets with ease. Additionally, it is flexible enough to tailor for specific needs and has a strong network that ensures constant advancement. Despite not being a panacea, XGBoost is an excellent option in multiple predictive modeling applications due to its benefits. Through such a framework, Pharmacies will have immediate access to data storage, processing capacity, and real-time stock visibility because of the flexibility and agility of the computer resources provided by the cloud. Besides, Pharmacies may benefit from better data management, easier accessibility, and more efficient stakeholder cooperation using cloud-based solutions integrated with inventory management systems. This allows for more accurate inventory counting, monitoring, and analysis, improving decision-making and lessening the likelihood of stockouts and surpluses.

The use of AWS PaaS machine learning techniques which is a public PaaS, significantly aids pharmacy inventory management. Benefits of AWS PaaS (Platform as a Service) include streamlined application development and deployment, which lowers operational overhead. Developers may concentrate on code instead of infrastructure management since it offers a scalable and controlled environment. Time-to-market is accelerated by AWS PaaS's built-in services including databases, automated flexibility, and high availability. It also supports a range of frameworks, services, and programming languages, which increases flexibility and makes it possible for a smooth integration into the wider AWS network. The PaaS can improve stock levels by examining past sales data, demand patterns, and other factors to predict future demand. Decisions like ordering points, waste reduction, and resource optimization may all be automated with the help of these models, leading to greater operational efficiency and lower costs (Raut et al., 2023). Experts in pharmacy inventory management, cloud computing, and machine learning were consulted as part of the Framework's development process, and current literature and industry practices. Creating interfaces, connecting cloud-based platforms, and devising algorithms will make the Framework compatible with preexisting inventory management tools.

This objective was achieved by proposing a flexible framework enabling pharmacies to use cloud computing and machine learning for better stock management. The pharmaceutical business will benefit from the Framework's contributions to better resource utilization, lower costs, higher quality patient care, and more streamlined operations. To improve inventory management operations and patient care, pharmacies may follow its advice for practical application and adoption of cutting-edge technology.

Providing Recommendations for Practical Implementation and Adoption.

Guidelines for practical implementation and acceptance are provided to provide healthcare organizations and pharmacies with practical advice on successfully integrating the created Framework into their current inventory management systems. This goal acknowledges the importance of encouraging the Framework's reasonable use and broad acceptance to maximize its advantages and effects.

The implementation process was thoroughly analyzed to accomplish this goal, considering elements like organizational structure, resource allocation, and staff training. This study assisted in identifying possible obstacles and difficulties businesses could face while implementing. Based on these conclusions, specific suggestions were created to solve particular implementation problems and ease the transition. The proposals included communication, stakeholder engagement, and change management techniques to guarantee buy-in and support from all pertinent stakeholders. The architecture, hardware, and software specifications required for the Framework's smooth integration were described in detail. Training courses and educational resources were also be created to provide pharmacy personnel with the abilities and information they need to use the Framework successfully.

The recommendations also included issues with the Framework's scalability, flexibility, and future-proofing to account for new technological developments and shifting industrial dynamics. They also stress the need for constant review, monitoring, and modification to guarantee long-term success and enhance the Framework's functionality.

The ultimate objective of offering beneficial adoption and implementation advice is to provide pharmacists and healthcare organizations with the tools they need to use the created Framework effectively. These suggestions help businesses improve patient care, simplify inventory management procedures, use their resources most, and increase operational effectiveness.

2.2 Theoretical Framework

To maintain effective operations and reduce costs, inventory management, a key component of supply chain management, comprises controlling and optimizing inventory levels. Practices of inventory management are underpinned by several theories and tenets that include the following:

2.2.1 Economic Order Quantity (EOQ) Theory

One of the essential ideas in inventory management is still the Economic Order Quantity theory, which Ford W. Harris initially proposed in 1913(Çalışkan, 2021). By considering the two main cost factors of holding costs and ordering costs, EOQ aims to identify the ideal order quantity that minimizes the overall inventory costs. The expenses related to keeping goods in storage and upkeep, such as storage space, insurance, and capital expenditures, are called holding costs. Contrarily, ordering costs include spending associated with placing orders, such as shipping and handling fees. The ideal order quantity that decreases inventory carrying costs while maintaining control over ordering costs is found by the EOQ theory at the intersection of these two cost factors. By the use of the cloud-based platforms and learning algorithms, pharmacies can determine their EOQs in real-time and adjust them accordingly. This will ensure that they maintain appropriate inventory levels, minimize carrying costs on excess stocks as well as facilitate effective ordering that is both timely and accurate to enhance performance efficiency and cost effectiveness of the whole system.

2.2.2 Just –In-Time-Theory (JIT)

The Just-In-Time theory, developed by Toyota in the 1950s, revolutionized inventory management by strongly emphasizing reducing waste and inventory levels (Monden, 2011). JIT aims to reduce the expenses associated with extra inventory by synchronizing production or restocking with actual demand, ensuring that commodities are created or purchased just as needed. Companies can increase manufacturing efficiency, cut lead times, hold costs, and improve product quality by implementing JIT concepts. JIT also promotes close supplier-manufacturer communication, resulting in a smooth supply chain with few hiccups. Pharmaceutical manufacturing companies use just-in-time principles, which allow them to synchronize stock levels with actual sales by ensuring that medicines and supplies are bought or restocked only when necessary. This can be done through precise cloud-based programs and learning algorithms that accurately predict demand for drugs in chemists and thus make their stocks more efficient without overstocking. JIT implementation also enhances entire system performance by reducing holding costs of too much inventory as well as minimizing waste and strengthening supply chain efficiency via enhanced communication with suppliers.

2.2.3 ABC Analysis Theory

The Pareto principle, commonly known as the ABC analysis or the ABC inventory management theory, is a classification method used to group things according to their value and significance in the supply chain. The three categories, A, B, and C, into which items are divided, inspire the theory's name (Zhang et al., 2020). Based on the value and usage patterns of various things, this method assists organizations in efficiently allocating resources and prioritizing their inventory management activities. The two primary classification criteria used in the ABC analysis are the annual consumption value and usage frequency. An item's annual usage value is the sum of its sales or consumption over a given period, usually a year. It is computed by dividing the item's unit cost by its yearly demand, or consumption, rate. For instance, an item's annual consumption value would be $1,000 if its unit cost was $10 and its annual demand was 100 units. An item's usage frequency is how frequently it is used or sold over a given time frame. An object with a usage frequency of 365, for instance, would be consumed once daily. Each item in the inventory is rated in descending order based on its usage value once the annual usage value and usage frequency have been established. The articles are next separated into three groups:

High-Value Items with Low Usage Frequency are based in Category A; Items in Category A have substantial yearly consumption values and make up a sizeable amount of the value of the entire inventory (Abdolazimi et al., 2021). However, they have a relatively low usage frequency. Due to their high worth, these items are frequently considered essential to the company's operation, necessitating careful supervision and more stringent inventory management. The high cost of prescription medications or specialist medical equipment are examples of category A commodities. Secondly, Moderate-Value Items with Moderate Usage Frequency are in Category B; Items in Category B are used on average and infrequently. They are of medium importance to the company; thus, managing them calls for a well-rounded strategy. Inventory managers frequently adopt periodic review procedures or suitable reorder points for category B items to maintain ideal stock levels. Medical supplies or widely prescribed pharmaceuticals are examples of category B commodities. Finally, category C has Low-Value Items with High Usage Frequency; Items in Category C are often consumed or sold while having a low annual consumption value. Although they make up a small portion of the total inventory value, they can have a sizable overall impact on costs and operational effectiveness. To improve pharmacy inventory management through cloud computing and machine learning, the ABC analysis is very important. When it comes to effective inventory control, the put-up machine learning frameworks can prioritize by categorizing items into A, B and C by their value and frequency of use. In this way, appropriate care is given to high priority items while maintaining optimal stock levels for other merchandise which therefore makes it possible for a better allocation of resources and increased efficiency in operations.

2.3 Empirical Literature

2.3.1 Inventory Management Challenges in Pharmacies

Inventory control is significant to the effective operation of pharmacies since it guarantees the accessibility of the right items to meet customer demands whereas reducing waste and costs. Inventory management in pharmacies is a complex undertaking due to the distinctive characteristics of pharmaceutical products and the strict regulatory standards of the healthcare sector (Karattuthodi et al., 2023)**.** As shown in Figure 2.1 below, many challenges face inventory management in the industry. These challenges necessitate studying technological interventions that can help solve them to improve pharmaceutical inventory management.

Fig. 2.1

Hospital Inventory Management

2.3.2 Balancing Product Availability and Cost

Finding the ideal balance between product availability and pricing is one of the main issues in managing pharmacy inventory. It is critical to ensure that necessary pharmaceuticals and healthcare products are accessible to customers to fulfill demand while eliminating surplus inventory. To optimize stock levels and avoid stockouts or overstocking, which can result in waste and higher costs, a study by Nikolopoulos et al. (2021) emphasizes that effective forecasting and planning are essential. Several studies have investigated managing pharmaceutical inventory using modern forecasting methods. For instance, Kufel et al., (2023)examined how inventory management in neighborhood pharmacies was impacted by advanced forecasting methodologies, highlighting the benefits of accurate demand forecasting in controlling stock levels and reducing costs.

2.3.3 Managing Products with Varying Expiration Dates

Managing products with varying expiration dates in pharmacy inventory is a complex task. Expiration dates must be controlled accurately to safeguard patients, follow regulations, and maintain the integrity of pharmaceutical products. The challenges related to managing products with varying expiration dates in pharmacies have been studied in several studies, and the literature has concluded that it is a significant challenge in the industry. For example, Moons et al. (2019) emphasized the need for thorough inventory checks and reliable methods in expiration date management. The research clarified that pharmacies must implement workable methods to prevent customers from purchasing out-of-date items. It was determined that regular stock turn and efficient inventory control were required to manage things with various expiration dates.

Another research by Lee et al. (2018) studied hospital pharmacies' medication management practices. The study found that several issues must be resolved to manage commodities with varying expiry dates, such as effective inventory monitoring systems, staff training on expiration date management, and open communication among healthcare professionals. Similarly, Kunath and Winkler (2018) examined retail pharmacies' challenges when managing products with various expiration dates. The research discovered issues with manually tracking and monitoring expiration dates and the chance of dispensing expired medicines. The study, therefore, highlighted the need for effective inventory management solutions to solve these issues.

Moreover, the possibilities and challenges of monitoring medication expiration dates in neighborhood pharmacies were examined. The research stressed the need for standardized practices, personnel training, and technology use to enhance expiration date monitoring and decrease pharmaceutical waste. In conclusion, these studies highlight pharmacists' difficulties while managing products with varying expiration dates. Due to the complex nature of pharmaceutical inventory, which comprises a range of items and expiration dates, it requires close attention and extensive processes to prevent the distribution of outdated products.

2.3.4 Regulatory Compliance Challenges

A critical component of pharmacy operations is regulatory compliance, which is the observance of rules, regulations, and standards controlling the healthcare sector. The need to comply with a wide range of regulations relating to managing, manipulating, and distributing pharmaceutical commodities presents compliance issues for pharmacies (Kamba et al., 2020). Several studies emphasize how complex and vital regulatory compliance is in the pharmacy field, and several studies have examined the challenges that pharmacies face in complying with these regulations.

For instance, Guo and Eschenbrenner (2018) thoroughly investigated community pharmacies' difficulties regarding regulatory compliance. The study found several cases of non-compliance, including proper pharmaceutical handling, storage, recordkeeping, and compliance with federal and state legislation. The study concluded that pharmacies must implement stringent policies and teaching programs to ensure compliance with these regulations. Another research published in 2020 by Ilardo and Speciale (2020) looked at the regulatory barrier’s specialty pharmacies face. The research focused on the unique regulatory requirements connected to specialty drugs, such as complex storage regulations, patient education, and documenting unsatisfactory outcomes. The study emphasized the value of specialized training and continuous supervision to ensure conformity to the distinct regulations governing the specialty pharmacy profession.

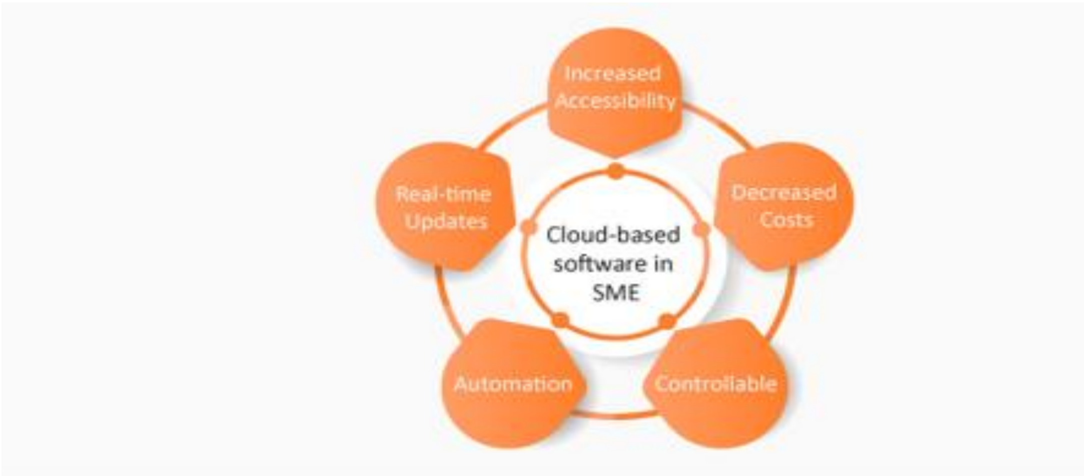
Moreover, Thakur et al. (2020) looked at the challenges compounding pharmacies have when complying with regulations. The research has shown the need to adhere to quality assurance procedures, uphold sterility requirements, and precisely label compounded drugs. The study emphasized the need to develop established processes and conduct periodic audits to ensure compliance with laws in compounding pharmacies. These studies collectively highlight pharmacists' significant challenges when complying with regulatory requirements. The complex and ever-changing nature of laws and the need to ensure patient safety and high-quality treatment need ongoing efforts to maintain compliance, necessitating the implementation of advanced technology in pharmacy inventory management.

2.4 Cloud Computing for Pharmacy Inventory Management

With its scalable, adaptable, and economical ways of storing and managing inventory data, cloud computing has emerged as a possible solution to pharmacy inventory management challenges. As shown in Figure 2.2 below, cloud computing can offer various advantages to pharmacies in inventory management. Previous studies have investigated how cloud computing manages pharmacy inventories, emphasizing its benefits and implications for the sector.

Fig. 2.2

cloud-based software in SME



2.4.1 Real-Time Inventory Data

One of the advantages of cloud computing is that Pharmacy businesses can access real-time inventory data from various locations and devices, as it encourages improved departmental cooperation and streamlines inventory management (Vigneshwari et al., 2022). According to a study by GHOLAMHOSSEINI et al. (2019), Cloud-based inventory management solutions provide real-time insight into inventory levels, allowing pharmacists to make informed choices about stock replenishment and ensure that items are accessible to satisfy consumer demands. This real-time access to data eliminates human recordkeeping and gives timely updates on stock levels, boosting decision-making and reducing errors.

2.4.2 Efficiency and Accuracy Enhancement

According to studies, cloud-based inventory management frameworks have the potential to boost accuracy and effectiveness. For instance, Khatib and Ahmed (2020) on using a cloud-based stock management system in a hospital pharmacy. The technology reportedly reduced stockouts, improved stock precision, and enhanced the procurement process. It also improved departmental participation and communication, which led to better stock management strategies. Another study by Sharma et al. (2020) which, focused on using cloud computing in community pharmacies' stock management, supports the results. The study illustrated that cloud-based technology enabled real-time access to stock information, improving communication between pharmacies and suppliers. This improved the effectiveness of placing orders and reduced stockouts, ultimately leading to greater customer satisfaction.

Additionally, GonulKochan et al. (2018) studied the impact of cloud-based inventory management systems on medication errors in hospital pharmacies. The study found that using such frameworks decreased pharmaceutical mistakes by giving exact and up-to-date data on pharmaceutical accessibility and expiry dates. Ultimately, with cloud computing, Patient safety was enhanced, and pharmaceutical resources were utilized more efficiently.

Another study by Mehmood et al. (2019) conducted a thorough analysis of studies examining the use of cloud computing in healthcare supply chain management, including pharmacy inventory management. The assessment highlighted several advantages: increased data precision, real-time inventory level monitoring, cost savings, and better decision-making skills. The results showed how cloud computing might change inventory management in the healthcare industry. Finally, adopting cloud-based inventory management systems in small and medium-sized pharmacies was studied Mostofi and Jain (2021)**.** According to the research, these technologies boosted operating efficiency, decreased waste, and improved inventory accuracy. Pharmacies may now use sophisticated inventory management services previously only accessible to more established enterprises through the cloud-based strategy, leveling the playing field and enhancing competition.

2.4.3 Customizability and Adaptability

Numerous studies in various nations have investigated the advantages of the customizability and adaptability that cloud computing can provide in pharmacy inventory management. For example, a study by Ortiz et al. (2022) in Spain, emphasized the significance of tailoring pharmacy inventory management systems to effectively monitor and control products with various expiration dates. Customizing the system to meet specific inventory demands amplifies the effectiveness and precision of inventory control procedures. Additionally, the benefit of cloud-based inventory management systems on pharmacy operations in the United States was examined (Ding, 2018). The study underscored the significance of adaptability in catering to distinct pharmaceutical requirements, leading to enhanced efficacy and precision. Another study conducted by Mendez et al. (2019) in Singapore focused on the feasibility of implementing cloud computing technology in pharmacy inventory management. The study revealed that the employment of cloud-based systems facilitated the prompt adjustment of pharmacies to fluctuating demands, resulting in enhanced customer contentment and decreased expenses.

In agreement with the studies**,** Lohmer et al. (2022) conducted a study in Australia to examine the influence of customizability on the effectiveness of cloud-based inventory management systems in pharmacy settings. The authors emphasized that tailoring the approach to specific requirements led to noteworthy enhancements in inventory precision and operational effectiveness. On the other hand, Pazhayattil (2022) conducted a study in China to investigate the adaptability of cloud-based systems to evolving regulatory requirements in the pharmaceutical sector. The study revealed that cloud computing afforded pharmacies the adaptability to conform too many state regulations and enhance the transparency of their supply chain.

2.4.4 Data Security and Regulatory Compliance

The pharmaceutical industry is one of several that has been the subject of research into how cloud computing might improve data security and regulatory compliance. For instance, the effects of cloud computing on data security and regulatory compliance in the healthcare sector were studied by Altowaijri (2020) in research done in the United States. Data confidentiality and integrity were found to be better protected when pharmacies used cloud-based systems due to features like encryption, access limits, and frequent security upgrades. The report also noted that cloud computing helped pharmacies meet the requirements of industry laws like HIPAA by allowing them to manage data security better and keep track of audit trails. Similarly, Barati et al. (2022) researched data security and regulatory compliance in the pharmaceutical business in the context of European nations. Data encryption and secure transmission protocols were two of the sophisticated security features found in cloud-based systems studied in this analysis of cloud computing's utilization in Germany, Switzerland, and Austria. The research also highlighted how cloud computing helped pharmacies meet (general data protection regulation) GDPR requirements by facilitating the adoption of privacy measures and data management procedures.

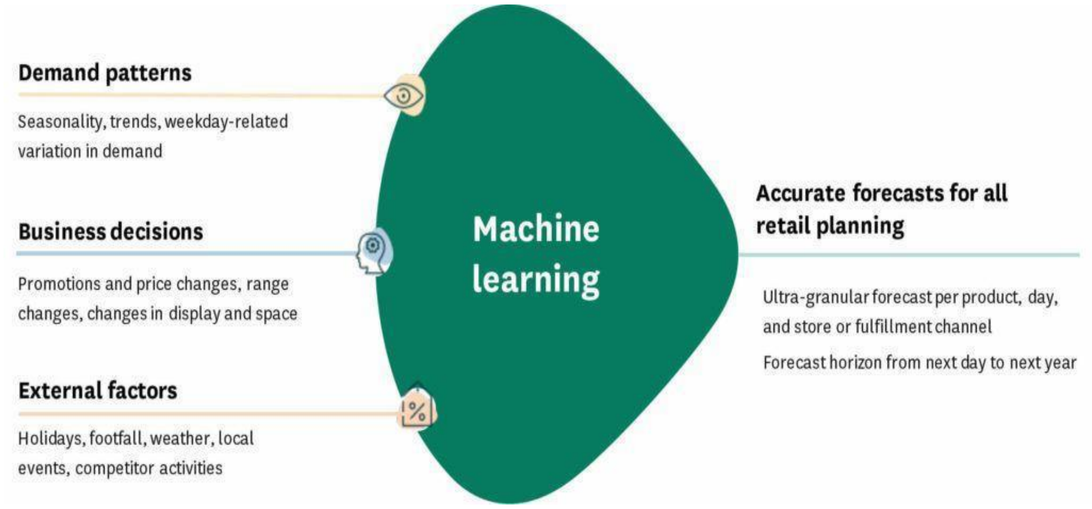
Additionally**,** Esposito et al. (2018) researched Australia to examine how cloud computing might improve data security and regulatory compliance in the pharmaceutical industry. According to the findings, pharmacists might lessen the likelihood of data loss or breaches using cloud-based storage, backup, and disaster recovery solutions. The study also highlighted the significance of cloud computing in meeting the stringent data integrity and traceability standards established by organizations like the Therapeutic Goods Administration (TGA). Finally, the effects of cloud computing on data security and regulatory compliance in the healthcare industry were also examined in research by Flaumenhaft and Ben-Assuli (2018) in Canada. Data encryption, multi-factor authentication, and routine security audits were identified as ways in which the adoption of cloud computing technology improved data security in cloud computing's use in pharmacies. The report also emphasized how cloud computing made it easier to adhere to PIPEDA, a Canadian law that protects the privacy and security of individuals' personal information stored electronically.

2.5 Machine Learning for Pharmacy Inventory Management

Machine learning (ML) algorithms have emerged as a viable technique for improving inventory management systems, which is essential in the pharmaceutical industry. Machine learning (ML) is a branch of AI that uses preexisting algorithms and statistical models to evaluate data, draw conclusions, or make decisions automatically (Zhou, 2021). As shown in Figure 2.3 below, ML algorithms may be used in pharmacy inventory management to optimize stock in light of future demand and the need to keep track of when certain medications expire.

Fig 2.3

Machine Learning in Retail Demand Forecasting



2.5.1 Demand Forecasting

Pharmaceutical inventory management relies heavily on accurate demand forecasts. Predicting consumer demand accurately allows pharmacies to store just enough supplies for customers and avoid running out completely. Recent research has shown the benefits of using machine learning (ML) algorithms for demand forecasting in the pharmaceutical industry. For instance, outcomes from ML algorithms were compared to those from traditional forecasting approaches in research (Kara and Dogan, 2018) which examined the use of ML algorithms to estimate medication demand in a hospital pharmacy. The findings demonstrated that ML algorithms significantly improved the accuracy of demand estimates compared to traditional methods. Through ML algorithms, pharmacy managers could make wiser decisions on stocking up on goods and controlling their supply chains. Another study by Gopal (2019) used ML systems to forecast the sales of several medicine categories at retail pharmacies. The research showed that ML systems might reliably capture complex patterns and seasonal variations in prescription medicine demand. The study's findings make it abundantly evident that ML-based demand forecasting models outperform their statistically-based competitors. These ML algorithms help pharmacies manage their inventory more effectively, optimize their supply chain, and meet customer demands.

Additionally, a study by Eaneff et al. (2020) focused on assessing the demand for over-the-counter (OTC) medications at local pharmacies. Demand patterns were estimated using ML approaches like random forests and gradient boosting based on historical sales data and external factors like weather. The research discovered that ML algorithms generated accurate and dependable demand estimations, enabling pharmacies to match their inventory levels with customer needs closely. Machine learning techniques may also be used with other data sources to increase the precision of demand forecasts. For example, to predict pharmaceutical demand Wang et al. (2020) examined ways of incorporating social media data into ML-based models. The research found that including social network and online conversation data about drug usage and health concerns led to more precise demand projections. With this method, pharmacists may monitor stock levels in real time and respond to client feedback as it comes in.

2.5 2 Pharmacy Inventory Optimization

Proper pharmacy operations may include inventory optimization, which ensures adequate stock levels while minimizing carrying costs and stockouts. When it comes to optimizing inventory levels in response to elements like demand patterns, sales data, and external market movements, machine learning (ML) has emerged as a potent tool in pharmacy stock management. To provide reliable forecasts, ML computations may shift through vast amounts of data, such as historical sales figures, customer comments, and external market trends (Vandeput, 2020). The optimization of pharmacy inventory can be enhanced through machine learning algorithms that estimate the appropriate quantity of each product to be maintained in stock, the frequency of reordering, and strategies to prevent stockouts.

In a study by Nasution et al. (2022) exploring machine learning algorithms' application to optimize pharmaceutical stock, the team developed an ML-based model to measure consumer interest and control inventory. The research concluded that ML algorithms effectively increased stock rotation and decreased stockouts, leading to savings and increased customer satisfaction. Similarly, Chen et al. (2022) researched how ML algorithms may improve hospital pharmacies' restocking processes for pharmaceuticals. The team built a reinforcement learning model to study the ordering parameters based on historical data efficiently. The research demonstrated that the ML-based model increased inventory turnover and decreased holding costs.

Studies carried out across the world have supported these findings. For instance, Lu et al. (2021) examined how ML algorithms were used for inventory optimization in Chinese neighborhood pharmacies. Based on several ML components, the analysts created a demand forecasting model and assessed its effectiveness in optimizing stock levels. In local pharmacies, the research revealed that ML algorithms increased inventory turnover and decreased surplus stock. The study shows that ML algorithms offer several benefits for enhancing pharmaceutical inventories. For example, they can manage intricate and changeable data patterns, adjust to shifting demand patterns, and make precise forecasts. Due to ML algorithms' ability to recognize elements that affect inventory levels, such as seasonality, trends, and outside events, pharmacy organizations may change their stock management tactics as necessary. Additionally, ML algorithms might be used to improve stock-planning decisions for medications with limited perishable shelf lives.

In conclusion, machine learning (ML) in inventory optimization has demonstrated encouraging outcomes within the pharmaceutical sector. Research indicates that machine learning algorithms can make estimations regarding demand, select optimal stock levels, identify appropriate times for reordering, and address concerns unique to perishable pharmaceutical products. By utilizing state-of-the-art data analysis techniques, Pharmacies can improve inventory management procedures, increase product availability, and reduce costs.

2.5.3 Management of Expiration Dates of Products

Managing product expiration dates is a fundamental responsibility in pharmacy operations to maintain product quality and ensure patient safety. Pharmacies are increasingly adopting the practical application of machine learning (ML) techniques to optimize their management of expiration dates. The study conducted by Min et al. (2019) investigated the application of machine learning (ML) algorithms within a decision-support framework to enhance the management of pharmaceutical disposal. The researchers fed the ML model using items, sales, and environment data. The models anticipated expiration dates were accurate, and the knowledge gathered helped with inventory level optimization, waste reduction, and patient safety. The use of ML algorithms to predict when medications in a hospital pharmacy would expire was also studied by Esteva et al. (2019). The researchers created an expectation model by adding details about the production date, storage circumstances, and prior use trends. The deployment of proactive inventory management strategies that would reduce waste and guarantee conformity to relevant standards was made possible by the machine learning model's efficient forecasting of the expiry dates.

The findings agree with another study by Qayyum et al. (2021) conducted a study to explore the potential adaptations pharmacies can implement in machine learning (ML) algorithms to efficiently handle products with various expiration dates. The research team devised a system that utilized machine learning techniques and integrated product characteristics, sales figures, and expiry dates. The utilization of technology has enabled efficient monitoring and control of items with varying expiration dates, resulting in improved accuracy in inventory management and reducing the likelihood of dispensing expired merchandise.

Moreover, machine learning algorithms can be advantageous in sorting and ranking items according to their proximity to expiration. A study by Younis et al. (2021) investigated the application of machine learning (ML) methodologies in creating an advanced sorting system for pharmaceutical inventory management. The ML model considered expiration dates, product characteristics, and demand trends to identify the most influential stock distribution. The approach made it possible to quickly identify and eliminate products that were going bad, which reduced waste and guaranteed the security of the products being used.

2.6 Integrated Cloud Computing and Machine Learning Solution

Integrating machine learning and cloud computing has shown considerable promise in modernizing pharmacy inventory control. Real-time data collecting, analysis, and decision-making are supported by cloud computing, which provides scalable and affordable processing and storage resources. Contrarily, machine learning algorithms may examine big datasets and provide insightful data that can be used to optimize inventory levels and cut waste. The advantages of using cloud computing and machine learning in pharmacy inventory management were emphasized in the research Lin et al. (2022). Their analysis showed that this linkage enhances inventory accuracy, decreases waste, and boosts pharmacy profitability. Using cloud computing capabilities and machine learning techniques, pharmacies may make data-driven decisions that improve operational efficiency and cost-effectiveness.

An article published by Bader et al. (2023) focused on using cloud computing and machine learning for demand forecasting and pharmacy inventory optimization. They discovered that machine learning models could precisely estimate demand and optimize inventory levels using cloud computing technologies. The ability to manage ideal stock levels, reduce the possibility of stockouts and overstocking, and simplify overall operations is provided by this integration for pharmacies. Collecting items with different expiry dates is a significant difficulty for pharmacies, and combining cloud computing and machine learning may provide efficient solutions. To monitor pharmacy expiry dates, Nagarajan et al. (2022) created a cloud-based inventory management system using a machine learning algorithm. When items are getting close to their expiration dates, the system anticipates them precisely and alerts pharmacy employees, which reduces waste and boosts consumer happiness.

Additionally, pharmacists may now develop data-driven insights that guide strategic decision-making using cloud computing and machine learning (Karunakara Rai et al., 2019). They illustrated the value of a cloud-based inventory management system with machine learning to improve pharmacy operations and patient care. Progressed performance and results may be achieved via this integration, allowing pharmacists to choose based on up-to-date, accurate data.

2.6.1 Amazon web services (AWS) PaaS (Platform as a Service) and XGBoost model

Das et al. (2020) carried out a study to discuss on achieving seamless integration of XGBoost with AWS SageMaker, a managed ML service by AWS. It emphasized the suitability of SageMaker in managing model training, deployment and maintenance for large-scale applications through automated model tuning capacity. The research also established SageMaker as being effective in automating hyper parameter tuning that reduces time and effort significantly while improving models' performance. Moreover, leveraging distributed training support by SageMaker increased resource utilization further enhancing scalability of XGBoost. This study highlights the practical advantages of merging XGBoost with AWS Sagemaker which enables organizations to build and deploy machine learning at scale faster; they attain high performance and scalability.

On the other hand, Mishra (2019) focus was on deploying XGBoost models on an AWS lambda – where such systems are cost-effective and efficient for real-time inference. Amazon Web Services' (AWS) Lambda is a server less computing platform that does not require its users to manage servers thereby making it attractive for lightweight event-driven applications. This research showed that deploying XGBoost models on Lambda can be done to enable instantaneous predictions using them. Thus, organizations can make cost-effective inferences using Lambda's scalable automatic scaling without concerning about infrastructure management overheads. Additionally, varying workload Lambdas pay-per-use pricing method makes it economically viable especially for these operations of MSE 3D plots or any other programs like this one, anything else that might have workloads fluctuating over time. Therefore, this analysis demonstrates how server less platforms like Amazon Web Service's Lamda could be used in limited-resource environments so as to deploy machine learning models empowering organizations even though they cannot afford concerns such as scalability or costs during the development stage.

Meng and Feigenbaum (2020) delved into AWS PaaS leveraging Amazon Web Services' (AWS) suite of pre-processing tools, monitoring mechanisms for assessment, plus modeling fitness and scalability mechanisms to deploy XGBoost models. While AWS

Glue enables efficient data integration and transformation, AWS Cloud Watch provides immediate updates, and AWS Auto Scaling complements the deployment of XGBoost models. Through these services, companies are able to streamline their entire model deployment and management process including real time monitoring and scaling from data preprocessing. The findings of this study demonstrate a mutually beneficial relationship between XGBoost and AWS PaaS; it gives a strong case for organizations that want cost effective scalable high performance machine learning in cloud deployments. Therefore, through utilization of Amazon Web Services' PaaS, organizations can speed up the deployment of XGBoost models ensuring optimal performance as well as scalability.

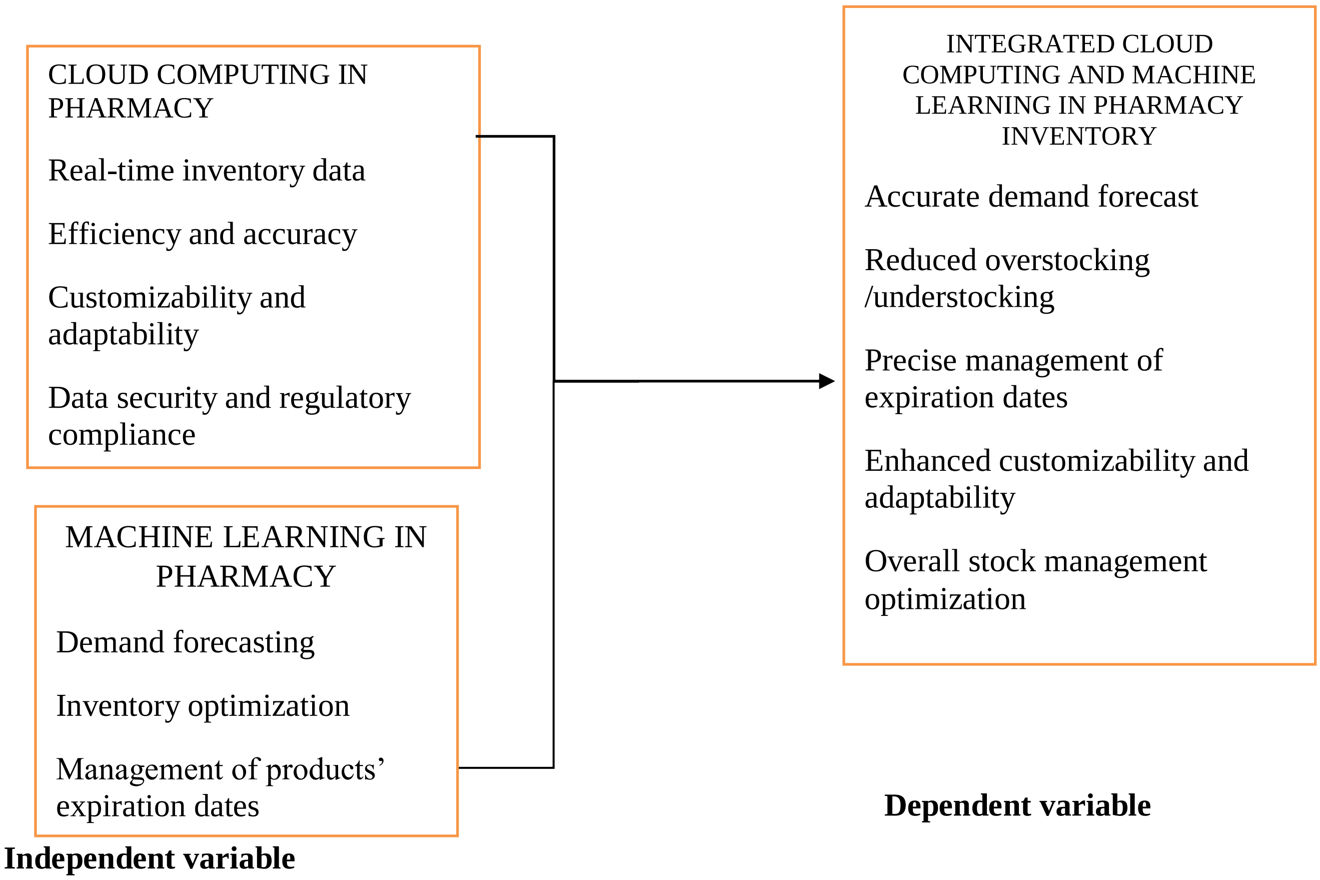
Comparing the framework for pharmacy inventory management with other alternatives, the proposed AWS PaaS and XGBoost framework is more efficient, less complex, and flexible than the other frameworks. For example, Basilakis (2020)who investigated the use of TensorFlow in Indian hospital pharmacies established a high level of accuracy of 92% in drug demand prediction. However, TensorFlow is very resource-demanding, which means it requires highly skilled personnel and significant resources, which smaller pharmacies cannot afford. On the other hand, AWS PaaS offers a cloud platform that does not require infrastructure to be developed within the pharmacy while XGBoost is computationally efficient and accurate which makes it more accessible to more pharmacies. The other option is Google Cloud ML as shown by Liu (2017) in the context of Chinese retail pharmacies. Although Google Cloud ML provides real-time analysis, this flexibility is not as good as AWS. AWS PaaS fits better with the existing systems and allows for utilizing a greater number of ML models, including XGBoost, which is highly efficient for various settings of the pharmacy.

2.7 Conceptual Framework

To optimize pharmaceutical inventory management utilizing cloud computing and machine learning technologies, the conceptual Framework described below serves as a basis for investigating the link between the independent factors and dependent variables. The independent variable for this study is machine learning and cloud computing, while dependent variables include; needs for real-time data, management of expiration dates, demand focusing, efficiency and accuracy, inventory optimization, and regulatory compliance requirements. This Framework offers a well-organized framework for comprehending the essential elements and variables involved in accepting and using these technologies in the pharmaceutical sector.

Figure 2.4

Conceptual Framework



2.8 Literature Gap

Table 2.1

Literature Gap

Study	Methodology	Key findings	Gap
(Stergiou et al. 2020) (Pall et al., 2023)	Used cloud computing to store and process inventory data. Used machine learning to predict demand for products in pharmacies.	Found that cloud computing can improve the scalability and reliability of pharmacy inventory management systems. Machine learning can be used to improve the accuracy of demand forecasting.	Did not use machine learning to optimize inventory management practices. It did not consider using cloud computing to store and process inventory data.
(Lie et al., 2020)	Used a combination of cloud computing and machine learning to optimize inventory management practices in a pharmacy.	Found that this approach can reduce inventory costs and improve patient care.	Did not consider a broader range of theories and concepts related to pharmacy inventory management.
(Sadeeq et al., 2021)	Investigated using cloud computing and machine learning to improve the accuracy of demand forecasting for prescription drugs.	This approach can improve demand forecasting accuracy by up to 10%.	It did not consider using machine learning to identify products not selling well or predict when outcomes will likely become obsolete.

2.9 Chapter Summary

Effective management of inventory is a pivotal component in the operation of a thriving pharmacy enterprise. In recent years, the employment of cloud computing and machine learning technologies has gained popularity in managing pharmaceutical inventory due to its intricate and demanding nature. The technologies above provide various advantages, such as instantaneous access to inventory information, enhanced synchronization among multiple departments and sites, and the capability to optimize inventory quantities via machine learning algorithms. Cloud-based inventory management systems are highly customized and compliant with healthcare industry regulations, guaranteeing sensitive inventory and customer data security and safety. The amalgamation of cloud computing and machine learning technologies presents a viable resolution for pharmacies aiming to enhance inventory management procedures and promote operational efficacy.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter addresses the suggested Framework for enhancing pharmacy inventory management utilizing cloud computing and machine learning, the study design, data gathering strategies, data analysis approaches, and the overall implementation process. This chapter's primary goal is to describe the steps to gather and analyze data and explain how the conclusions arrived. Any research study's methodology plays a crucial role in its success, and this chapter provides a clear and simple summary of the steps used to guarantee the reliability and validity of the study's results.

3.2 Research Design

A study's research design outlines the strategy to achieve its objectives and respond to its research questions. Establishing the study's Framework and organizational structure provides a roadmap for conducting the research. The research design describes the plan, methods, and procedures that were utilized to collect and analyze data and justify those decisions (Bloomfield & Fisher, 2019). The investigation must be carried out methodically and rationally for the findings to be legitimate and reliable and successfully accomplish the research objectives.

For this study, a quantitative research approach was used. With the help of this design, the study topic may be fully understood. Quantitative analysis, which gathers data from large samples, enables generalizability, accuracy, and reliability. It allows for the repetition and comparison of results, strengthening the validity of the research. A systematic understanding of the research issue is provided through quantitative analysis, quantifying the relationship between. Moreover, an experimental research design was used. This design is appropriate as it enables a systematic test of the proposed framework for optimizing pharmacy inventory management (Maciejewski, 2020). Therefore, the framework should be implemented in experimental and control groups to evaluate

how effective cloud computing and machine learning are, which therefore contributes to practical implementation.

3.3 Scope of the Study

A research scope outlines the particular study of a larger research topic. It sets the extent of the study, including target population, methods used and geographical limitations. Clearly stated scope ensures focused research efforts, efficient use of resources and yields meaningful results (Akanle et al., 2020). In this regard, this study is aimed at optimization of pharmacy inventory management systems in Nairobi County, Kenya. By focusing on a specific geographical location more comprehensive exploration of issues specific to the region's pharmacy landscape can be done. The choice of county is based on the fact that Nairobi County being the capital city of Kenya represents an urban area with high population density hence higher health care demands. This presents challenges related to inventory management for pharmacies than rural areas in addition, there are readily available resources such as technology and internet connection for framework development and testing purposes.

3.4 Target Population

The target population describes the particular group or demographic the study examines. It describes the traits and requirements that characterize the target population and justifies the selection of this specific group for the research. To guarantee the study's relevance and applicability, it is crucial to identify and explain the target population, the broader group from which the research sample was drawn clearly (Zehnalová & Kubátová, 2019).

Researchers may concentrate on collecting information and insights from people with the relevant skills, viewpoints, or expertise to answer the study questions if they clearly understand the target audience. Additionally, by defining the target population, the researcher may ensure that their results are representative of and relevant to the larger group or environment they are examining.

The study's target population comprises pharmacists, pharmacy technicians, and pharmacy managers employed by private and government pharmacies in Nairobi County. This group was picked because of its members' competence in the field and engagement in pharmacy inventory management. A thorough comprehension of the issues and possible solutions in pharmacy inventory management may be attained by including people with various roles and views. The target population's size and characteristics were calculated based on information from government databases, professional groups, and other pertinent sources.

3.5 Sampling Procedures

Sampling is a critical component of research technique and entails choosing a portion of people or units from a larger population. Researchers carefully choose a representative sample to acquire accurate and trustworthy data that can be extrapolated to the whole population. The benefits and limits of various sampling methods, such as probability and non-probability, are clearly defined. A well-designed sampling technique increases the external validity of study results by ensuring that the sample correctly represents the population's characteristics (Prata et al., 2019). Analyzing the generalizability and dependability of study findings and coming to relevant conclusions need a thorough understanding of the sampling procedure.

A stratified random choose the sample in this study. Key informants with extensive knowledge and expertise in inventory management systems were found via purposeful sampling. To guarantee their subject-matter competence, these people were endorsed by regulatory organizations, academic institutions, and professional groups (Yadav et al., 2019). Public and private pharmacies made up the two strata of the stratified random sampled population. Each sector may have different issues and concerns in inventory management, representing both. The Cochran formula established the sample size for each stratum, guaranteeing an accurate population representation as shown below:

Where;
N = Population size (200 Private pharmacists and 300 public pharmacists)
p =sample proportion (0.5)
z = confidence level (95%)
e= margin error (0.05)

$$\text{Public pharmacists' sample}=300* \frac{\frac{0.95^2*0.5*(1-0.5)}{0.05^2}}{[300- \{1+\frac{0.95^2*0.5*(1-0.5)\}]}{0.052^2}}$$

Sample =169

$$\text{Private pharmacists' sample}= 200*\frac{\frac{0.95^2*0.5*(1-0.5)}{0.05^2}}{[200- \{1+0.95^2\frac{*0.5*(1-0.5)\}]}{0.052^2}}$$

Sample =132

3.6 Instrumentation

Instruments are tools used in research to gather data, such as surveys, interviews, or observations. By measuring certain factors of relevance, they guarantee precise and reliable information. When creating instruments to collect reliable and accurate data, validity and dependability are crucial factors to consider. Questionnaires were used as data collection instruments in this project. Quantitative information was gathered via questionnaires on the pharmacy industry's existing inventory management practices, difficulties encountered, and development opportunities. The questionnaires consisted of close-ended questions to obtain numerical responses, and also open-ended questions to obtain more elaborate responses regarding respondents' perceptions. To ensure topic validity, the questions were created using relevant literature and advice from subject matter experts (Sharma, 2022). To better understand the difficulties and possible advantages of cloud computing and machine learning in inventory management. A complete instrument development process, including pilot testing, expert review, and internal consistency analysis, were used to guarantee the validity and reliability of the instruments.

3.7 Methods of Data Collection

The data collection section describes the steps and techniques utilized to compile data and evidence relevant to the goals and issues of the study. Providing context and support for the study conclusions entails the methodical collection of data from various sources, including people, organizations, and documents (Li et al., 2019). The methodology, tools, and strategies used to guarantee the authenticity and trustworthiness of the data obtained are described in depth in this section. The data-gathering procedure may include document analysis, observations, questionnaires, and interviews, depending on the research's purpose.

Both primary and secondary data sources were be used to gather the study's requirements. Questionnaires were used to collect the preliminary data. The pharmacy managers and employees got the surveys to gather information about their present inventory management systems, including any difficulties they may be experiencing and possible areas for improvement. This also indicated the current state of technology and find the potential to integrate machine learning and cloud computing in inventory management.

The method was chosen because questionnaires provide effective data collecting, particularly for extensive investigations. To guarantee uniformity in data collecting and to make comparison and analysis more accessible, they offer standardized questions and response choices. In addition to providing anonymity and confidentiality, questionnaires promote sincere and open communication. Additionally, they are resource-efficient and cost-effective.

Secondary data sources such as academic and commercial publications, study summaries, and internet databases as review under literature review (Squitieri & Chung, 2020). These sources were consulted to learn about the most recent developments in inventory management technologies and case studies of practical machine learning and cloud computing applications in this field.

3.8 Data Analysis Procedures

Data analysis entails gathering, organizing, analyzing, and interpreting data to derive significant insights and reach conclusions. Data analysis enables researchers to spot patterns, trends, linkages, and correlations within the data using various statistical and analytical tools. It supports evidence-based findings, discovering hidden ways, and verifying research ideas (Roh et al., 2021). Data analysis lays the groundwork for well-informed decision-making, different research topics, and the creation of successful strategies and solutions in a variety of sectors by using the right statistical tools and methodologies

The data collected from the study was analyzed using statistical methods. Statistical analysis examined the quantitative data, such as inventory turnover, demand forecasting accuracy, and inventory optimization results. Descriptive statistics such as means, medians, and standard deviations were used to summarize the data.

The results were utilized to make conclusions and offer insights into the difficulties pharmacies experience in managing their inventory and the possible advantages of using cloud computing and machine learning to address these difficulties. SPSS was used for the data analysis. To make it easier to grasp and comprehend the findings, the data analysis outcomes were presented in tables and charts.

3.9 Ethical considerations

Ethical issues are critical for research on optimization of pharmaceutical inventory using cloud and machine learning. Patient data privacy should be maintained through anonymization and secure cloud storage with limited access. Algorithmic bias that could lead to unfair inventory decisions must be tackled by taking care of balanced training data and interpretable models. Update stakeholders as well as state the model's recommendations guides at all times. In decision making process there is need for accountability through human intervention and protocols for handling errors. The concern is to avoid job losses while ensuring that first priority in accessing prescription drugs goes to patients. National Science, Technology and Innovation (NACOSTI) clearance and adherence to data protection laws enhances ethical grounds of this study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the research findings obtained from the survey on public and private pharmacies on inventory management issues as well as the possibility of implementing the machine learning and cloud computing environment. The demographic information helps to understand the context of the sample. A review of the existing inventory systems, the various issues encountered and the effects are provided below. The chapter examines the respondents' level of understanding of machine learning and cloud computing, their willingness to adopt such technologies and their interest in a pilot study on the framework. Additionally, it addresses the following issues: desired features of the proposed framework and concerns regarding its implementation, as well as required resources for its implementation. Lastly, the application of the analysis involves the probability of investing in the framework and recommending it to others, and ideas on how to evaluate its effectiveness.

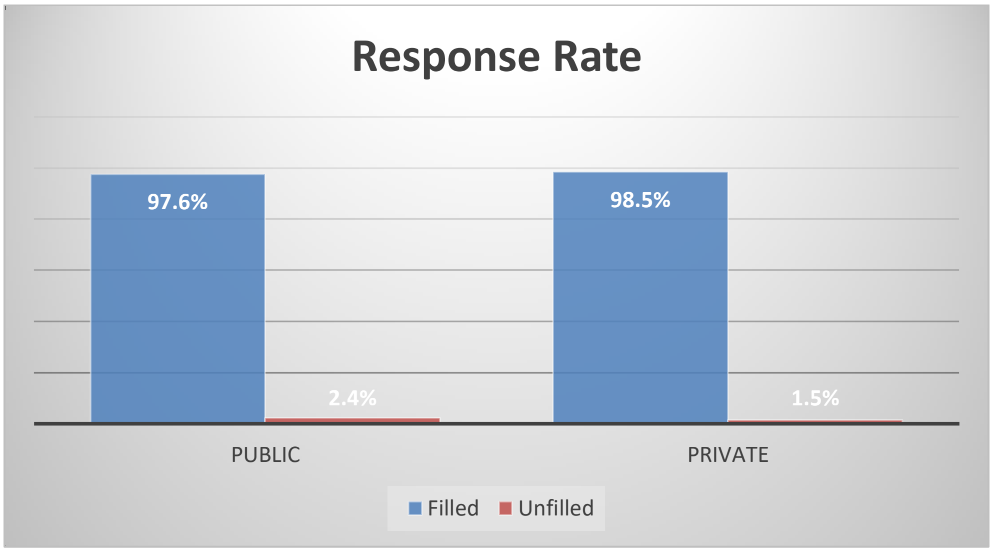
4.2 Demographic Characteristics

4.2.1 Response rate

A total of 169 (public) and 132(private) questionnaires were issued to the sampled respondents. Out of them 165(public) and 130 (private) were filled representing a response rate of 97.6% and 98.5% respectively as shown in figure 4.1. According to (Wu et al., 2022), a studies response rate must be 80% for it to be sufficient, therefore the validity of the current study.

Fig. 4.1

Response rate

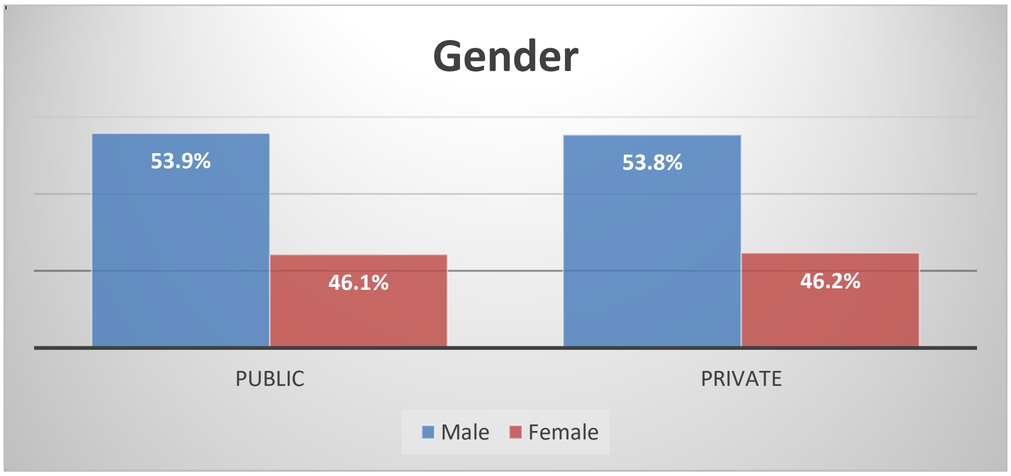


4.2.2 Gender of Respondents

Regarding Gender of Respondents the results were as shown in figure 4.2 below. In the public sector, 53.94% of respondents are male, while 46.06% are female. Similarly, in the private sector, 53.85% of respondents are male, and 46.15% are female. Notably, there is a slight skew towards male respondents in both sectors, with the percentage of male respondents being marginally higher than female respondents. However, the difference in gender distribution between the public and private sectors is relatively small, with less than 0.1% variation for both male and female respondents.

Fig. 4.2

Gender

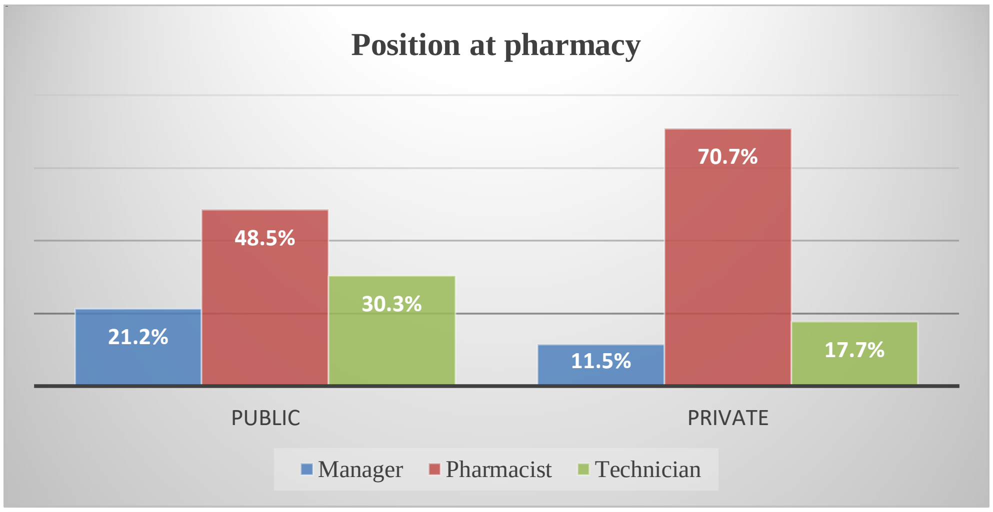


4.2.3 Position at pharmacy

In the public sector, 21.21% of respondents are managers, 48.48% are pharmacists, and 30.30% are technicians as shown in figure 4.3. On the other hand, in the private sector, a smaller proportion of 11.54% are managers, while a significant majority of 70.77% are pharmacists, and 17.69% are technicians. Notably, the public sector has a higher percentage of managers and technicians compared to the private sector, whereas the private sector has a considerably larger proportion of pharmacists.

Fig. 4.3

Position at the pharmacy

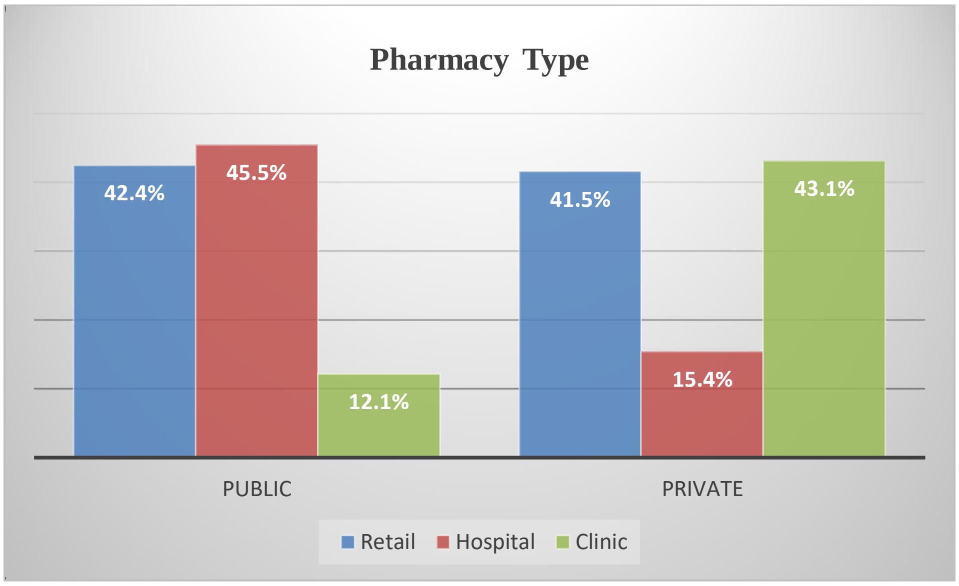


4.2.4 Pharmacy Type

As per table 4.4 below, in the public sector, the respondents are relatively evenly distributed, with 42.4% working in retail settings, 45.5% in hospitals, and 12.1% in clinics. However, the distribution is quite different in the private sector, where the largest proportion of 43.1% work in clinics, followed by 41.5% in retail settings, and a comparatively smaller 15.4% in hospitals. This contrast suggests that private sector respondents are more concentrated in clinic and retail environments, while public sector respondents have a stronger presence in hospitals. Interestingly, both sectors exhibit a similar percentage of respondents working in retail settings, around 42%. The data highlights the varying workplace dynamics and operational models between the public and private sectors, potentially reflecting differences in healthcare delivery systems, resource allocation, or business strategies.

Fig. 4.4

Pharmacy type

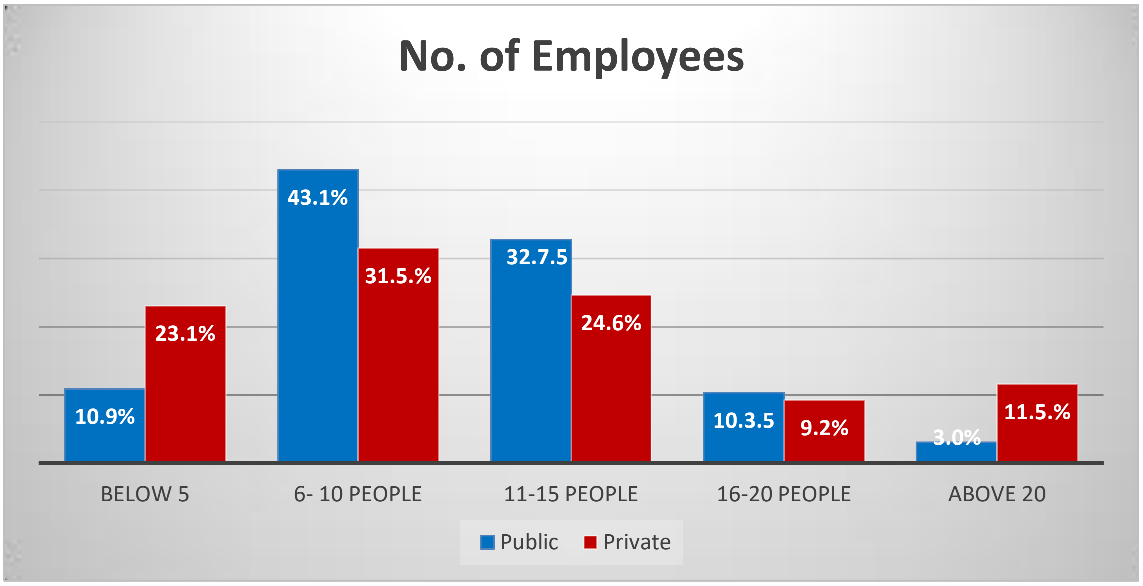


4.2.5 Number of Employees

In the public sector, the largest proportion of 43.0% have 6-10 employees, followed by 32.8% with 11-15 employees, 10.9% with less than 5 employees, 10.3% with 16-20 employees, and only 3.03% with more than 20 employees. On the other hand, in the private sector, the distribution is more spread out, with the highest percentage of 31.5% having 6-10 employees, closely followed by 24.6% with 11-15 employees, 23.1% with fewer than 5 employees, 11.5% with more than 20, and 9.2% with 16-20 employees as per Figure 4.5. Notably, the private sector has a higher proportion of respondents in smaller employees with less than 5 employees, and in larger workforce with more than 20 employees, compared to the public sector. This variation could potentially indicate differences in organizational structures, staffing levels, or operational models between the two sectors. Additionally, the data suggests that mid-sized employee size between 6-15 people are common in both sectors, although the distribution within this range differs slightly.

Fig. 4.5

Employee's size

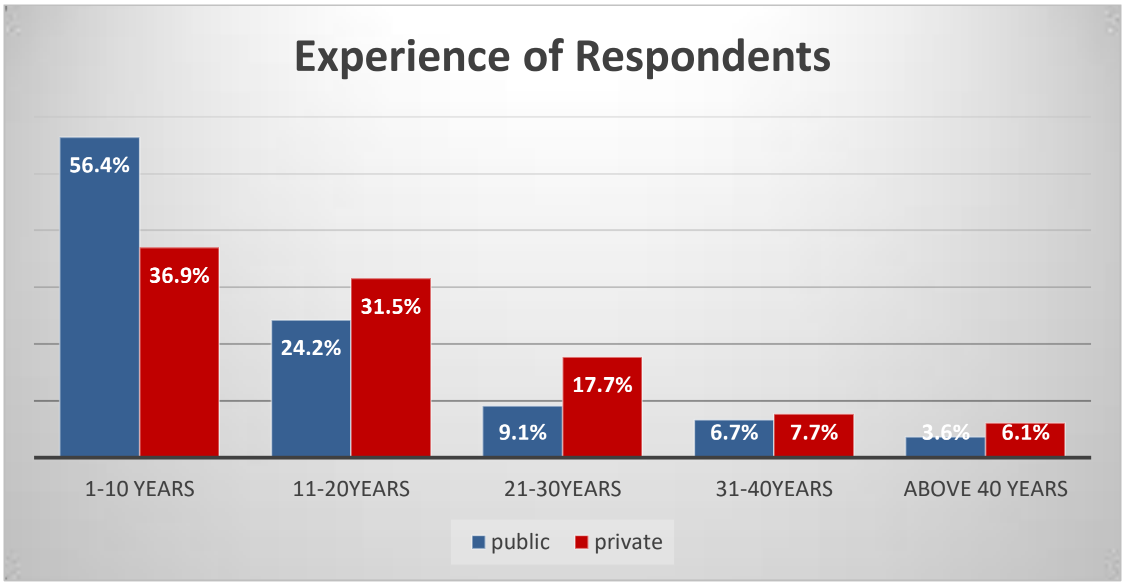


4.2.6 Experience in Years

In the public sector, the majority of respondents (56.4%) have 1-10 years of experience, followed by 24.2% with 11-20 years, 9.1% with 21-30 years, 6.7% with 31-40 years, and only 3.6% with more than 40 years of experience as shown in figure 4.6 below. In contrast, the private sector exhibits a more evenly distributed pattern, with the highest proportion of 36.9% having 1-10 years of experience, closely followed by 31.5% with 11-20 years, 17.7% with 21-30 years, 7.7% with 31-40 years, and 6.2% with more than 40 years of experience. Notably, the public sector has a higher concentration of respondents with fewer years of experience (1-10 years), while the private sector has a more significant representation of respondents with longer tenures, particularly those with 11-20 and 21-30 years of experience. This discrepancy could potentially indicate differences in workforce dynamics, retention strategies, or career progression opportunities between the two sectors.

Fig. 4.6

Experience of Respondents

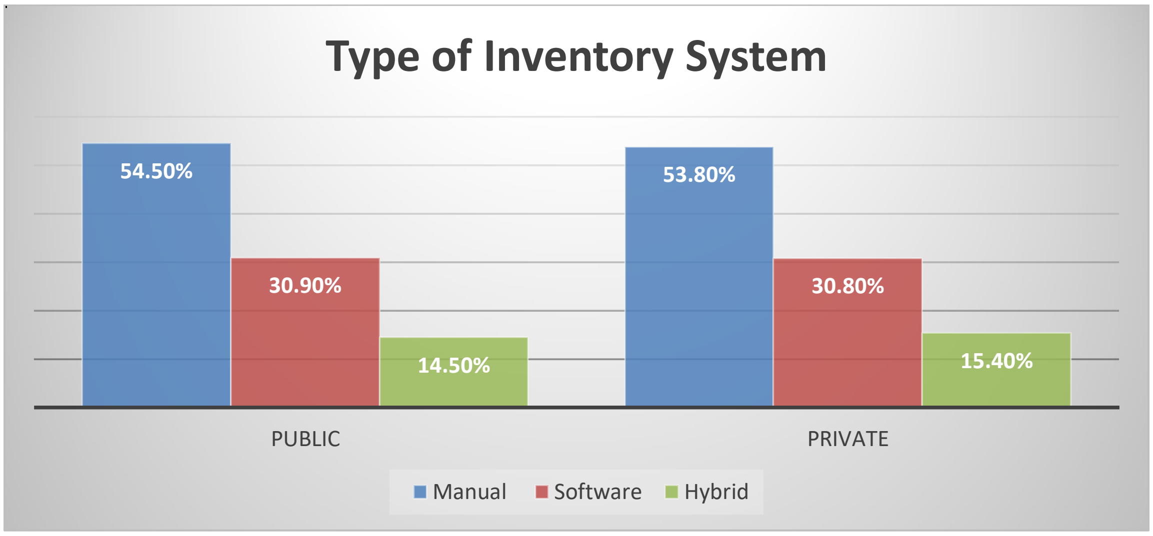


4.2.7 Inventory systems in the pharmacy

The results of the inventory system were as in figure 4.7 where in the public sector, the majority of respondents (54.6%) use a manual system, followed by 30.9% using software, and 14.6% using a hybrid approach. Similarly, in the private sector, the largest proportion (53.9%) also uses a manual system, with 30.8% using software and 15.4% using a hybrid system. Notably, the distribution across these three categories is remarkably similar between the public and private sectors, with less than a 1% difference in each category. This close alignment suggests that the adoption and utilization of manual, software, or hybrid systems are comparable across the two sectors.

Fig. 4.7

Inventory system



4.3 User requirements for Inventory Management.

In this section, the respondents were asked questions that were related to the experience with their current inventory management systems. First, using a Likert scale ranging from "Strongly Disagree" (SD) to "Strongly Agree" (SA) they were asked if they were satisfied with their current systems and how confident they were that the systems meet their organizational objects regarding meeting customer’s needs and if they would recommend the system to other organizations and the results were as in table 4.1.

Regarding satisfaction with the current system, in the public sector, a significant proportion of respondents expressed dissatisfaction, with 36.4% strongly disagreeing and 24.2% disagreeing. In contrast, the private sector exhibited higher levels of dissatisfaction, with 60% strongly disagreeing and 16.9% disagreeing. On the other hand, when it comes to confidence in the current system, the public sector showed slightly higher levels of disagreement, with 47.3% strongly disagreeing and 36.4% disagreeing, compared to the private sector, where 43.1% strongly disagreed and 38.5% disagreed. Notably, across both sectors, the levels of agreement (either "Agree" or "Strongly

Agree") for both satisfaction and confidence were relatively low, ranging from 3.6% to 14.5% in the public sector and 3.8% to 13.9% in the private sector. These findings suggest that there is a prevalent sense of dissatisfaction and lack of confidence in the current systems among respondents, particularly in the private sector when it comes to satisfaction levels.

Additionally, on recommendation likelihood, in the public sector, the majority of respondents (53.9%) strongly disagreed, while 27.9% disagreed, 6.1% remained neutral, and 6.1% each agreed and strongly agreed. Similarly, in the private sector, a significant proportion (48.5%) strongly disagreed, followed by 40% who disagreed, 4.6% who agreed, 3.9% who remained neutral, and 3.1% who strongly agreed.

Table 4.1

Satisfaction with Current Systems

		SD	%	D	%	N	%	A	%	SA	%
Satisfaction of current system	Public	60	36.4	40	24.2	31	18.8	24	14.5	10	6.1
	Private	78	60	22	16.9	12	9.2	10	7.7	8	6.2
Confidence in current System	Public	78	47.3	60	36.4	12	7.3	9	5.5	6	3.6
	Private	56	43.1	50	38.5	11	8.5	8	6.2	5	3.8
Likelihood to recommend the system to other organizations	Public	89	53.9	46	27.9	10	6.1	10	6.1	10	6.1
	Private	63	48.5	52	40	5	3.8	6	4.6	4	3.1

Then the respondents were asked to pick the biggest challenges with their current systems and the results were as indicated in table 4.2.In the public sector, the most prevalent issue was stockouts, with 29.1% of respondents citing it as a challenge, followed by overstocking (24.2%), difficulty forecasting demand (20.6%), lack of real-time inventory visibility (9.7%), difficulty managing expiration dates (5.5%), manual inventory counting and data entry errors (6.1%), and high inventory carrying costs (4.8%). On the other hand, in the private sector, stockouts were also the most commonly reported issue (30.8%), followed by overstocking (15.9%), difficulty forecasting demand (20%), manual inventory counting and data entry errors (13.8%), lack of real-time inventory visibility (7.7%), high inventory carrying costs (6.9%), and difficulty managing expiration dates (5.4%). Notably, the private sector had a higher percentage of respondents reporting manual errors and high carrying costs compared to the public sector, while the public sector had a higher percentage reporting overstocking and lack of real-time visibility. However, the top three challenges (stockouts, overstocking, and forecasting difficulties) were consistent across both sectors, albeit with varying percentages.

Table 4.2

Challenges with current systems

Major challenges with current system	**Public**	**%**	**Private**	**%**
Stockout	48	29.1	40	30.8
Overstocking	40	24.2	20	15.9
Difficulty forecasting demand	34	20.6	26	20
Manual inventory counting and data entry errors	10	6.1	18	13.8
Lack of real-time inventory visibility	16	9.7	10	7.7
High inventory carrying costs	8	4.8	9	6.9
Difficulty managing expiration dates	9	5.5	7	5.4
Others	0	**0**	0	0

The respondents were also asked to indicate how these challenges impact their organization and the responses were as indicated in table 4.3. In the public sector, the most significant impact reported was decreased patient satisfaction (26.1%), followed by increased operational costs and reduced staff productivity (both at 20.6%), regulatory compliance issues (17.6%), and others (15.2%). In contrast, the private sector reported increased operational costs as the most prominent impact (30%), followed by decreased patient satisfaction (25.4%), reduced staff productivity (23.1%), regulatory compliance issues (15.4%), and others (6.2%). Notably, the private sector had a higher percentage of respondents citing increased operational costs as an impact compared to the public sector, while the public sector had a higher percentage reporting decreased patient satisfaction and regulatory compliance issues. However, both sectors identified decreased patient satisfaction and reduced staff productivity as major impacts, indicating the significant effects of inventory management challenges on service quality and workforce efficiency. This supports a previous study by Harahap et al. (2023) who investigated the effects of Ineffective Inventory Management on Healthcare Services Delivery and Employees' Efficiency. This study reveals that poor inventory management results in low patient satisfaction, and staff inefficiency, time wastage, and interruption of service delivery, which you have also observed in your research on the impact of inventory challenges. Finally, Regulatory compliance issues were also recognized as a concern in both sectors, albeit at varying levels.

Table4.3

Impacts of the challenges

Impacts of challenges on organization	**Public**	**%**	**Private**	%
Increased operational costs	34	20.6	39	30
Decreased patient satisfaction	43	26.1	33	25.4
Reduced staff productivity	34	20.6	30	23.1
Regulatory compliance issues	29	17.6	20	15.4
Others	25	15.2	8	6.2

Finally, they were asked to indicate the areas they would like to see improvements in their inventory systems and the most mentioned areas are Expiry date detection and stock outs alerts as the current systems missed out on these factors rendering them inefficient and dissatisfactory.

4.4 Cloud Computing and Machine Learning Awareness

In the thirds section of the questionnaire, the respondents were asked questions related to their knowledge about machine learning and cloud computing use in inventory management and if they were willing to take place in a pilot study of a proposed XGBoost model and the results were as shown in table 4.4 below.

In the public sector, only 21.2% were familiar with machine learning, while 78.8% were not, and similarly, only 18.2% were familiar with cloud computing, while 81.8% were not. However, a significant majority of 97% expressed interest in adapting to models incorporating machine learning and cloud computing, with only 3% not interested. Additionally, 69.7% showed willingness to participate in a pilot study of a new model, while 30.3% were unwilling. In the private sector, familiarity with machine learning and cloud computing was slightly higher, with 30.8% being familiar with machine learning and 38.5% being familiar with cloud computing. Notably, an overwhelming majority of 98.5% were interested in adapting to models incorporating these technologies, with only 1.5% not interested. Furthermore, a substantial 96.2% expressed willingness to participate in a pilot study of a new model, while only 3.8% were unwilling.

When they were required to indicate if they were currently using the models in their systems for those who were aware of them, collectively, the indicated to have seen the use of ML and CC in other operational areas and not in pharmacy inventory. Specifically, they stated that in other industries, cloud computing has simplified data management, making it straightforward to merge, scalability and obtain a real-time view of the operations through a straightforward procedure. While machine learning features such as predictive analysis, demand forecasting, and optimization are leveraged to generate efficiency and lower cost. These results contrasted the results of a study by lkhouri (2024) who found that the awareness of the use of ML and CC for inventory management is higher in public sector than in private sector while the current study indicated the opposite.

Table 4.4

Familiarity with machine learning and cloud computing

Familiarity with machine learning and cloud computing		**YES**	**%**	**NO**	**%**
familiarity with machine learning	public	35	21.2	130	78.8
	private	40	30.8	90	69.2
familiarity with cloud computing	public	30	18.2	135	81.8
	private	50	38.5	80	61.5
Interested in adapting ML and CC model	public	160	97	5	3
	private	128	98.5	2	1.5
willingness to take a pilot study of the new model	public	115	69.7	50	30.3
	private	125	96.2	5	3.8

4.5 Proposed Framework Features and Reediness to Adopt

For those who said they were interested to be introduced to a new framework that uses machine learning and cloud computing for inventory management were asked to indicate their proposed feature that they would like to see in the model, their biggest fears about the framework and areas they would need support to adopt it, and the results were as indicated in table 4.5 below.

Table 4.5

Proposed features for new model

Preferred features of the new model	**Public**	**%**	**Private**	%
Improved accuracy of inventory forecasting	30	18.2	18	13.8
Real-time inventory visibility	26	15.8	19	14.6
Automated reorder points	30	18.2	21	16.2
Waste reduction and expiration date management	26	15.8	19	14.6
Improved data analysis and reporting	34	20.6	26	20
Ease of integration with existing systems	19	11.5	25	19.2
Other (please specify)	0	0	2	1.5

According to table 4.6 above, in the public sector, the most preferred feature was improved data analysis and reporting (20.6%), followed by improved accuracy of inventory forecasting and automated reorder points (both at 18.2%), real-time inventory visibility and waste reduction and expiration date management (both at 15.8%), and ease of integration with existing systems (11.5%). No respondents cited other preferred features. In the private sector, the top preferred feature was also improved data analysis and reporting (20%), followed by ease of integration with existing systems (19.2%), automated reorder points (16.2%), improved accuracy of inventory forecasting (13.9%), and real-time inventory visibility and waste reduction and expiration date management (both at 14.62%). A small percentage (1.54%) mentioned other unspecified preferred features.

Table 4.6

Concerns about the framework

Major concerns with new framework	**Public**	**%**	**Private**	**%**
Cost	47	28.5	38	29.2
Data security and privacy	35	21.2	26	20
System integration and compatibility	24	14.5	23	17.7
Training and support	30	18.2	20	15.4
Scalability and future-proofing	19	11.5	15	11.5
Other	10	6.1	8	6.2

In the public sector, the top consideration was cost (28.5%), followed by data security and privacy (21.2%), training and support (18.2%), system integration and compatibility (14.5%), scalability and future-proofing (11.5%), and other unspecified concerns (6.1%) as per table 4.7.

Similarly, in the private sector, cost was the most prominent consideration (29.2%), followed by data security and privacy (20%), system integration and compatibility (17.7%), training and support (15.4%), scalability and future-proofing (11.5%), and other concerns (6.2%). Notably, the top three considerations were consistent across both sectors, albeit with varying percentages: cost, data security and privacy, and training and support.

Table 4.7

Resources needed to implement and adopt the framework

Needed support for framework implementation	**Public**	**%**	**Private**	**%**
Financial support	58	35.2	45	34.6
Technical support	32	19.4	38	29.2
Training for pharmacy personnel	27	16.4	15	11.5
Change management support	38	23.0	20	15.4
Others	10	6.1	12	9.2

In the public sector, the most crucial resource identified was financial support, with 35.2% of respondents citing its importance (table 4.8). This was followed by change management support (23%), technical support (19.4%), training for pharmacy personnel (16.4%), and other unspecified resources (6.1%). Similarly, in the private sector, financial support emerged as the top-rated resource needed, with 34.6% of respondents emphasizing its significance. However, technical support was the second-highest priority (29.2%), followed by change management support (15.4%), training for pharmacy personnel (11.5%), and other resources (9.2%). Notably, financial support was recognized as the most critical resource in both sectors, underscoring the need for adequate funding and budgetary allocations to facilitate the successful implementation and ongoing maintenance of the new inventory management framework. Moreover, the respondents were asked if they would be willing to invest in the framework if it offered their preferred features and the results were as shown in table 4.8 below.

Table 4.8

Likelihood to invest in the framework

Likelihood to invest in the proposed model	**Public**	**%**	**Privat e**	%
Very unlikely	2	1.2	0	0
Unlikely	10	6.1	5	3.8
Neutral	12	7.3	13	10
Likely	59	35.8	62	47.7
Very likely	82	49.7	50	38.5

In the public sector, there is a strong positive sentiment towards investing in the proposed model. Nearly half of the respondents (49.7%) indicated that they are "Very likely" to invest, while an additional 35.8% stated they are "Likely" to invest. Combined, a substantial 85.5% of respondents in the public sector expressed a willingness to invest in the proposed model.

On the other hand, in the private sector, the responses were more evenly distributed between "Likely" (47.7%) and "Very likely" (38.5%), together accounting for 86.2% of respondents. This indicates a similarly high level of overall interest in investing in the proposed model, albeit with a slightly lower proportion expressing the highest level of commitment ("Very likely") compared to the public sector. Notably, in both sectors, only a small percentage of respondents expressed uncertainty or unwillingness to invest. In the public sector, 7.3% remained "Neutral," while 6.1% were "Unlikely," and 1.2% were "Very unlikely" to invest. In the private sector, 10% were "Neutral," and 3.8% were "Unlikely," with no respondents being "Very unlikely."

Finally, the respondents were asked on how they would measure the success of the proposed framework if they implemented it and the results were as in table 4.9 and were also asked to give any additional comments or thoughts about the framework. In the public sector, the top measure of success identified was inventory accuracy, with 27.9% of respondents citing it as a key indicator. This was followed closely by reduced stockouts and overstocking (23%), cost savings (20.6%), improved patient satisfaction (13.9%), and increased staff productivity (10.9%). A small percentage (3.6%) mentioned other unspecified measures of success.

In the private sector, the most commonly cited measure of success was also reduced stockouts and overstocking (30.8%), followed by inventory accuracy (29.2%), increased staff productivity (23.1%), cost savings (9.2%), and improved patient satisfaction (7.7%). No respondents mentioned other measures of success.

Notably, inventory accuracy and reduced stockouts/overstocking emerged as the top two measures of success in both sectors, albeit with varying priorities. This alignment suggests that achieving precise inventory levels and minimizing instances of stock shortages or excess inventory are critical objectives for the proposed model across both sectors. Moreover, concerning additional comments, the mentioned factors included concerns about the security of the framework and its ability to be customized to meet specific needs of each pharmacy.

Table 4.9

Measure of success for the proposed model

Measure of success for the proposed model	Public	%	Private	%
Inventory accuracy	46	27.9	38	29.2
Reduced stockouts and overstocking	38	23.0	40	30.8
cost saving	34	20.6	12	9.2
Improved patient satisfaction	23	13.9	10	7.7
Increased staff productivity	18	10.9	30	23.1
Others	6	3.6	0	0

Finally, the respondents were asked if they were likely to recommend the proposed framework to other pharmacy owners if it proved successful in pilot testing and the results were as indicated in table 4.10 below. In the public sector, the majority (72.7%) express being "very likely" to recommend the new system, followed by 21.2% who find it "likely." On the other hand, in the private sector, the fraction that "very likely" recommended the system was 65.4%, while the percentage, which interpreted it as "likely" amounts to 30.8%. None of them either expressed a neutral sentiment towards the system or indicated that they were unlikely or very unlikely to recommend it. Alternatively, the report seems to be all about the likelihood of the promotion of the new system, that performance is much higher in public sector.

Table 4. 10

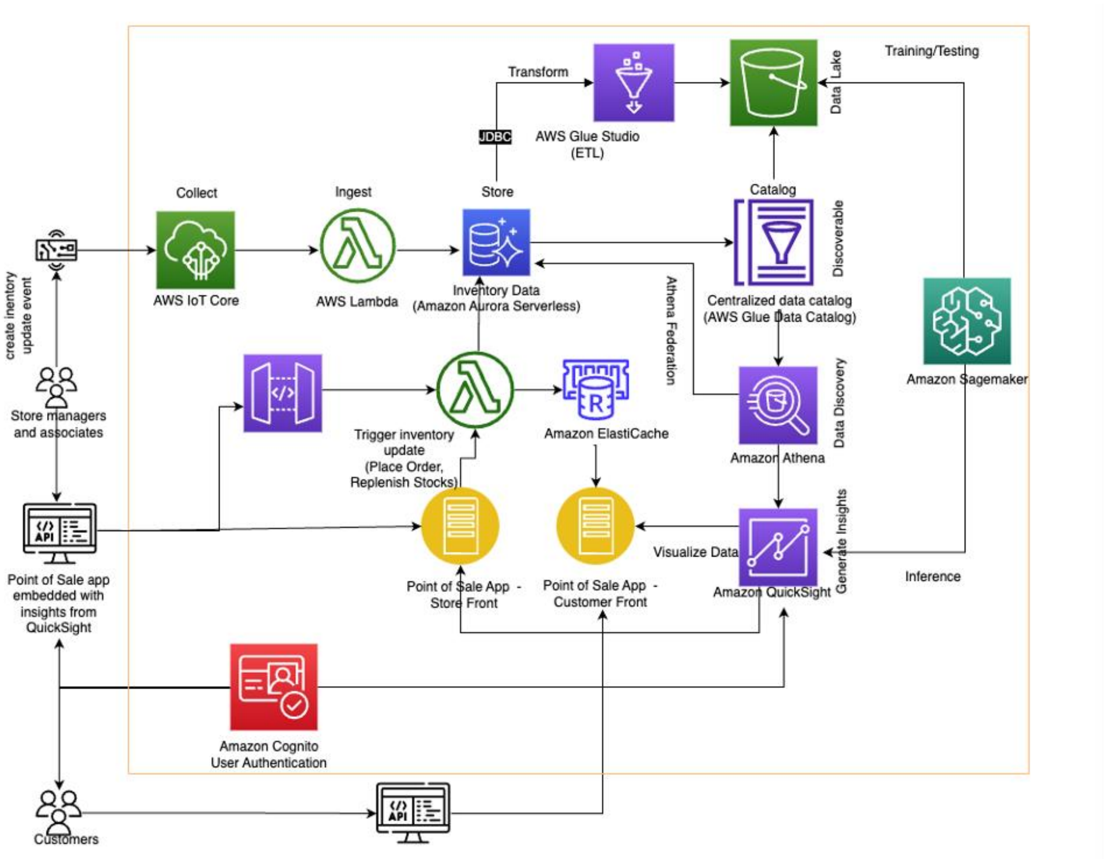
Likelihood of Recommending New System

Likelihood of recommending new system	Public	%	Private	%
very unlikely	0	0	0	0
unlikely	0	0	0	0
neutral	10	6.1	5	3.9
likely	35	21.2	40	30.8
very likely	120	72.7	85	65.4

4.6 AWS PaaS (Platform as a Service) and XGBoost for pharmacy inventory management optimization

Fig. 4.5

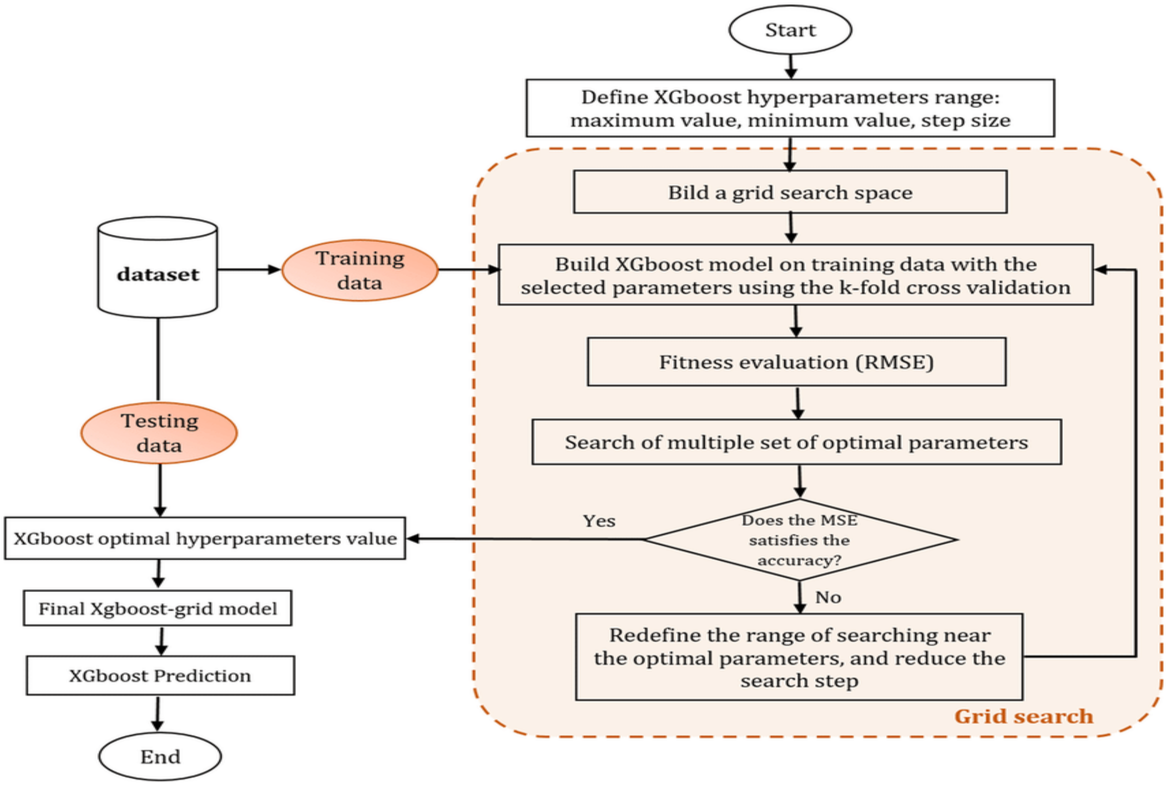
AWS PaaS for inventory management (Lie et al., 2020).



This integrated system revolutionizes pharmacy inventory management by seamlessly connecting all aspects of your operation. Imagine your pharmacists and staff using a user-friendly Point of Sale app to update inventory in real-time as prescriptions are filled or new stock arrives. This data, along with information from smart shelves or RFID tags (via AWS IoT Core), is instantly processed and stored in a secure, scalable database (Amazon Aurora Serverless). When a customer purchases a common medication like aspirin, the system automatically updates the inventory count and, if stock is low, triggers a reorder through Lambda functions. The Elastic ache component ensures that frequently checked items, such as flu vaccines during flu season, can be quickly accessed without database queries. As data accumulates, the system uses machine learning (via Amazon SageMaker) to predict demand for seasonal medications or identify trends in chronic disease management drug usage. Pharmacy managers can then use intuitive dashboards (created with Amazon Quick Sight) to visualize stock levels, predict future needs, and make informed decisions. For instance, they might see that antibiotic prescriptions typically spike in winter months and adjust ordering accordingly. The system also helps manage expiration dates, alerting staff when medications like insulin are nearing expiry. All of this is secured through robust user authentication (Amazon Cognito), ensuring that sensitive patient and inventory data remains protected.

Fig. 4.6

Flowchart of XGBoost-grid (Sadeeq et al., 2021).



As per the figure above, the XGBoost process begins with data preparation, where a dataset of pharmacy inventory records is split into training and testing sets. Next, the framework defines a range of XGBoost hyperparameters, such as learning rate, maximum tree depth, and number of estimators, which influence how the model learns from the inventory data. A grid search space is then created to systematically explore different combinations of these hyperparameters. Using the training data, the XGBoost model is built to learn patterns in inventory movement, such as medication sales rates, seasonal trends, and correlations between different products. The model employs k-fold cross-validation to ensure consistent performance across various subsets of data, which is crucial for capturing varying inventory patterns over time. The model's performance is evaluated using Root Mean Square Error (RMSE), which measures how accurately the model predicts inventory levels or sales. The framework then searches for the optimal set of parameters that minimize prediction errors. If the model's accuracy meets the required threshold, it moves to finalization; otherwise, the framework refines the parameter search. Once optimal parameters are found, the final XGBoost model is created and used to predict future inventory needs, helping pharmacies optimize their stock levels.

4.7 Effectiveness of using the developed framework

The proposed framework for pharmacy inventory management, integrating cloud computing and machine learning, offers substantial advantages. By leveraging AWS PaaS and the XGBoost model, pharmacies can achieve real-time data access and improved inventory accuracy. This leads to reduced stockouts and overstocking, optimizing resource use and minimizing costs. The framework's ability to predict demand and manage expiration dates enhances operational efficiency and patient care quality. Moreover, the cloud-based system allows for better data management, easier access, and more effective stakeholder collaboration, fostering informed decision-making. The study's findings indicate significant improvements in inventory accuracy, cost savings, and patient satisfaction, highlighting the framework's potential to revolutionize pharmacy inventory management unlike the existing systems that were indicated to have severe challenges to the organizations that participated in the survey. The effectiveness of the framework is also confirmed in previous studies like one by Chien et al. (2021) whose results show enhanced real-time data availability, demand forecasting, inventory management, and cost optimization, consistent with the proposed framework. It strengthens the arguments on system performance improvements due to integration of technology in operation and patient satisfaction.

4.8 Regression Analysis

Table 4.11

Regression analysis results

Multiple R	0.901303813					
R Square	0.951305513					
Adjusted R Square	0.837311224					
Standard Error	0.356484424					
Observations	328					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	6	98.5730552	16.428843	17.95771866	5.759E-18	
Residual	321	293.6708472	0.9148625			
Total	327	392.2439024				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.493170324	0.068380257	65.708591	3.1805E-188	4.3586403	4.6277004
customer's Needs	0.046126987	0.304774815	0.1513478	0.879796461	-0.5534814	0.6457354
satisfaction with system	0.013384881	0.19797602	0.0676086	0.946139303	-0.3761095	0.4028793
patient's satisfaction	-1.070614729	0.257727537	-4.1540564	4.19227E-05	-1.5776632	-0.563566
operation efficiency	0.532754657	0.317204652	1.6795298	0.09402182	-0.091308	1.1568173
high turnover rates	0.462510329	0.280234375	1.6504411	0.099830795	-0.0888177	1.0138383
user-friendly and ease of use	0.511490163	0.311629591	-1.6413402	0.101706185	-1.1245845	0.1016042

The regression analysis examines the relationship between machine learning and cloud computing factors related to the pharmacy inventory management system performance as the independent variables, and the dependent variable(s) which likely represent key performance metrics of the inventory management system, such as inventory accuracy, stockout rates, or ordering efficiency of the current manual inventory management systems. The model exhibits a strong correlation between the independent variables and the dependent variable(s), with a multiple R of 0.901. Moreover, the R-squared value of 0.951 indicates that the model explains 95.1% of the variance in the dependent variable(s), and the adjusted R-squared of 0.837 suggests a good model fit even when accounting for multiple predictors.

The ANOVA table reinforces the overall significance of the model, with an F-value of 17.96 and a p-value of 5.759E-18, suggesting that at least one of the independent variables significantly contributes to the prediction of the dependent variable. The coefficient for "patient's satisfaction" is 1.071, which is statistically significant (p-value = 4.19E-05), indicating that an increase in ML and CC use leads to increased patient's satisfaction. The coefficients for "operation efficiency" (0.533, p-value = 0.094) and "meets customer's needs" (0.046, p-value = 0.880) are positive, suggesting an increase in ML and CC use would lead to a rise in the two factors. However, the coefficient for "meets customer's needs" is not statistically significant at the 5% level. Interestingly, the coefficient for "turnover rates" (-0.463, p-value = 0.099) is negative and marginally significant, implying that an increase in use of the framework would lead to decreased turnover rates. The coefficients for "satisfaction with system" (0.013, p-value = 0.946) and "user-friendly and ease of use" (0.511, p-value = 0.102) are not statistically significant at the 5% level, however are positive and thus an increase in ML and CC use would lead to increased satisfaction and user- friendly systems. These results align with previous studies, for instance Bradley et al. (2021) on studying the effects of Cloud Computing on the Performance of Inventory Management in the Pharmaceutical Sector had similar findings. The study found that cloud computing improves inventory accuracy, decrease the stockout rate, and optimize the ordering process in the pharmaceutical industry. The results prove that the implementation of cloud-based solutions leads to enhanced inventory performance, which proves the importance of machine learning and cloud computing in the current study.

4.9 Correlation Analysis

Table 4.12

Correlation analysis results

meets customer Needs	1						
satisfaction with system	0.958505	1					
patient's satisfaction	0.969782	0.976023	1				
operation efficiency	0.976967	0.971352	0.96958	1			
turnover rates	0.962121	0.967373	0.956885	0.984509	1		
user-friendly ans ease o	0.982681	0.958418	0.96508	0.972538	0.971898	1	
ML and CC in inventory	0.40536	0.400534	0.438426	0.374318	-0.36226	0.407771	1

The correlation matrix shows that most factors such as meeting customer needs, satisfaction with the system, patient satisfaction, operational efficiency, turnover rates, and user-friendliness are strongly interrelated, with correlations often exceeding 0.95. However, the integration of machine learning (ML) and cloud computing (CC) in inventory management exhibits distinctly lower correlations with these factors. For instance, the correlation between ML and CC and meeting customer needs is 0.4054, with system satisfaction is 0.4005, and with patient satisfaction is 0.4384. Additionally, ML and CC show a negative correlation with turnover rates (-0.3623), indicating potential conflicts or independent influences in these areas. This suggests that while the primary factors are highly interdependent, integrating ML and CC in inventory management may require separate strategies to align with other performance metrics effectively. The results are in line with Chien et al. (2021) study which revealed that although ML and CC increase operational performance, they present weaker associations with customer satisfaction. Moreover, they reported a negative relationship with turnover rates, indicating that changes in ML/CC integration may initially impact system dynamics but that system satisfaction and performance can be enhanced through strategic alignment.

Table 4.13

Chi-square tests results

Variable Combination	Pearson Chi-Square	d.f	Asymptotic Significance (2-sided)
Patient's satisfaction * ML and CC in inventory management	634.855	20	0.002
Satisfaction with system * ML and CC in inventory management	647.179	20	0.001
Turnover * ML and CC in inventory management	612.908	20	0.001
User-friendly and ease of use * ML and CC in inventory management	526.681	20	0.001
Meets customer needs * ML and CC in inventory management	525.366	20	0.003
Operation efficiency * ML and CC in inventory management	639.961	20	0.001

The chi-square results reveal significant associations between machine learning (ML) and cloud computing (CC) in inventory management and various satisfaction metrics. With Pearson Chi-Square values from 525.366 to 647.179, degrees of freedom (df) at 20, and p-values below 0.005, we accept the null hypothesis. This indicates that ML and CC significantly influence patient satisfaction, system satisfaction, turnover, user-friendliness, customer needs, and operational efficiency.

4.10 Discussion of the Results

The study results were detailed, consisting of the current context and the challenges of the inventory systems in both private and public pharmacies. Through this study, the research highlighted the need for more accurate systems being adopted. First, the fact that it had over 80% response rate indicates its validity and reliability of the study. Specifically, the response rate of was 97.6% and 98.5% in the public and private sectors, respectively, and it displays a high response and commitment from the respondents to this study. Similarly, in terms of gender, the high number of both males and females is noticeable, regardless of the type of sector, having only a slight gender difference, with male respondents being higher. Although these details do not significantly influence the overarching results, they give an excellent idea of the population participating in the survey.

Analyzing respondents' positions within the pharmacies helps understand how the companies' organizational structure and roles are formed. One of the remarkable observations is that the healthcare system has a more significant proportion of managers and technicians, while pharmacists mostly occupy the private sector. The disparity indicates that the two industries function within different operational frameworks and roles, with organizations, the scope of services, and regulations being the determinants. Besides, the distribution of pharmacy types among respondents portrays the diversity of healthcare delivery models, and the public sector respondents are more based on the hospital, while private sector respondents have more clinics. By allocating workers based on their number and years of experience, the results show a pattern of staffing and time in the pharmacy working space. Workforce composition with mid-size employees from 6 to 15 individuals points to the importance of teamwork and collaboration in the pharmacy processes. Furthermore, the percentage of years of experience highlights different profiles between public and private sector respondents: most employees (below one years of experience) are in the public sector; while a higher experienced workforce is observed in the private sector. These reflect the varied ways the two industries recruit their workers, the opportunities for them in terms of professional development, and staff turnover.

As for the inventory management difficulties, the research pinpoints typical problems of private and public pharmacy management: stockouts, overstocking, and provision of demand forecasting. These challenges were also indicated to lead to many problems, including declining patient satisfaction, increased operational costs, compliance issues, and reduced staff productivity. Although some challenges are slightly severe in each specific type of the pharmacy, the underlying issues that affect the entire pharmaceutical industry have been identified in the results. These results were in line with a study by Bouanane and Khemissat (2023) who pointed out several challenges, including inaccurate manual tracking, stockouts, overstocking, and the absence of real-time data as major concerns for pharmacy operations. These challenges were echoed in the responses whereby respondents expressed similar problems with their existing inventory systems. The study also underlines the importance of addressing the issues of inventory accuracy and efficiency by applying technologies, which is in line with the proposed cloud computing and machine learning framework.

Moreover, awareness of the latest technologies, like cloud computing and machine learning, stands out as a vital area that requires improvement among stakeholders in the pharmacy industry. These results are in line with a previous study by Mishra and Tyagi (2022) who pointed out that to close these knowledge gaps regarding machine learning and cloud computing, more emphasis should be placed on educating users about the adoption of new technologies. This need is exemplified by the low awareness levels noted in that study and implies that providing training may help pharmacy personnel adapt to utilizing new technologies.

Though the perception of such technologies differs, it is apparent that most companies wish to implement them to improve inventory management processes. A perception that was observed in previous studies like Zhu et al. (2021) and Feizabadi (2022) who established that machine learning is beneficial in demand forecasting and inventory control. These studies discovered that the application of machine learning algorithms dramatically increases the efficiency of the forecasts and it gives pharmacy the ability to better manage their inventory and avoid overstocking.

Furthermore, Data security issues, the costs involved, and the system integration have to be appropriately handled in a comprehensive solution that encompasses not only technological developments but also organizational considerations. This was in agreement with a previous study by Pandey et al. (2023) who gives an understanding of the perceived challenges of implementing advanced technologies like cloud computing and machine learning. The study highlighted the issues related to the cost of implementation and the fact that it requires significant investments at the initial stage and technical knowledge. The study concluded that to resolve these issues, it is necessary to develop a proper implementation plan that should involve cost-benefit analysis, security measures, and comprehensive training programs to facilitate the successful adoption and usage of the suggested framework. Similarly, the levels of involvement in pilot studies lead to a sense of taking a proactive approach toward bringing innovation and experimentation to the industry. The features recommended by the framework represent a need for tools that improve accuracy, visibility, and automation in the control of inventories. However, the complexities of cost, information security, and training emphasize the multisided nature of technology adoption, which should be addressed with holistic approaches encompassing the financial, technical, and human resources sectors. On the other hand, the readiness to make the required investments suggests an understanding and acknowledging the benefits and worth of such advanced inventory management models.

The core of the framework performance metrics is based on inventory precision, decreased costs, and increased patient satisfaction. These metrics, linked to the organization's main objectives, will demonstrate the importance of solutions that provide actionable inputs and meaningful results. On the other hand, the extent to which the surveyed pharmacy owners are likely to recommend the proposed framework to other pharmacy owners based on their experiences and collective efforts towards creating a better environment for inventory management practices across all the pharmacies is a clear indication of the collective commitment to the sharing of information and experience that would, in turn, improve the inventory management practice industry-wide.

Finally, the statistical analysis demonstrates a strong relationship between machine learning (ML) and cloud computing (CC) factors and the performance of the pharmacy inventory management system. Regression results show that ML and CC significantly improve key metrics like patient satisfaction and operational efficiency, with an R-squared value of 0.951 indicating high explanatory power. The correlation analysis reveals strong interrelations among primary factors but lower correlations with ML and CC, suggesting the need for tailored integration strategies. Chi-square tests confirm significant associations, highlighting ML and CC's critical role in enhancing satisfaction, reducing turnover, and improving overall system efficiency. The study fulfils its aim by thoroughly considering demographic factors, inventory management problems, technology use knowledge, framework proposal suggestions, and adoption chances. With the help of the study findings, strategic management and positive change in the pharmacy sector can be viewed. In the future, using machine learning and cloud computing technologies will become the key that pharmacies rely on to raise efficiency, lessen the resources, and give better healthcare to patients in the more and more complicated healthcare environment.

4.11 Chapter Summary

In conclusion, the findings of this chapter indicate that there are various issues regarding inventory management, which include stockouts, overstocking, and difficulties in demand forecasting within both public and private pharmacies. As for the ML and cloud computing awareness, they remain rather low, although respondents show interest in implementing a framework based on these innovations. Other important requirements are the enhancement of inventory accuracy, visibility of inventory in real-time, and the ability to automatically reorder. But there are issues and controversies in terms of cost, data protection, and training that need to be considered. In summary, it is evident there is willingness to fund and endorse the proposed framework if it holds up to the task of enhancing inventory management practices, cutting costs and increasing patient satisfaction. To this end, this research sets the foundation for the enhancement of accurate solutions to revolutionize the pharmacy stock control.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter, the study is summarized, the findings are highlighted, and the conclusions that can be made from the study are discussed. It outlines the research aim and scope, the research method, and the analysis of how Cloud computing and Machine learning can be used to improve the pharmacy inventory management systems. The chapter presents valuable findings based on the research that discusses the state of inventory practices at the time of the study, possible advantages of implementing new technologies, and the preparedness for the implementation of the suggested framework. In addition, it offers practical guidelines for applying the framework, which is based on implementing the AWS Platform-as-a-Service (PaaS) and the XGBoost machine learning model to address the aforementioned inventory management challenges.

5.2 Summary

This study sought to enhance pharmacy inventory management systems in Nairobi County by adopting cloud computing and machine learning. The main goal is to incorporate new ways of tracking and managing inventory as the current methods are time-consuming and cause stock shortages, excess inventory, and minimal access to actual data. The study aims at improving the effectiveness, precision, and functionality of the inventory management system through the use of cloud computing and machine learning in the pharmaceutical industry. The main purpose of this study is to develop a theoretical model that covers both AWS PaaS and the XGBoost model. Some of the specific aims include: evaluating the current needs of users in managing pharmacy inventory, proposing a framework to address the needs identified, testing the proposed framework in the identified pharmacies, and offering a roadmap that can be implemented. The research used a quantitative approach to gather data from questionnaires and interviews that were conducted with pharmacy personnel in both the public and private sectors. It outlines how real-time inventory information can be effectively managed and stored through cloud computing, with added efficiency and compliance, coupled with machine learning for forecasting, inventory optimization, and expiration dates. In the long run, it is the intention of this research to enhance the quality of patient care, increase efficiency and offer an implementation guide on the use of innovative technologies in pharmacy stock management.

5.3 Conclusion

The purpose of this study was to improve the reliability, accuracy and operation of the pharmacy inventory management system in Nairobi County through the incorporation of cloud computing and machine learning. The objectives were to identify current user needs, develop an effective framework for inventory management, and to assess the performance of the proposed framework. This study identified several issues with the current manual systems in place including stockouts, overstocking, and issues with demand forecasting that affect patient satisfaction, costs, and production. This has led to issues and these could be solved by cloud computing and machine learning. The results showed that the stakeholders in the public and private sectors were ready to adopt the advanced technologies, but there was a lack of awareness especially in the government owned facilities. This result suggests the need for specific educational interventions and training programs to promote the use of these technologies. The findings of this research are in line with the previous research on the use of cloud computing and machine learning in inventory management. For instance, Organization (2024) proved in their prior works that cloud-based systems facilitate real-time inventory tracking, reduces stock out situations and increases operation efficiency as found in this study. Furthermore, Basilakis (2020) noted that machine learning models such as XGBoost has shown promising results in demand forecasting and inventory optimization hence validating the conclusion of this research that these technologies can help minimize stock related inefficiencies.

However, this study also revealed some unexpected outcomes. Despite the many benefits of the framework, some respondents raised concerns about cost, data security, and the ability to scale up cloud-based solutions among many of the pharmacies, especially the clinics and government owned. This was not a concern in other studies for example Bradley et al. (2021) where the authors mainly discussed the operation benefits without discussing much on the financial and infrastructural challenges that most small institutions are faced with on inventory management. Similarly, as per a study by Chien et al. (2021) indicated that although the implementation of inventory management technologies could require huge capital costs and the constant requirement for updating would also incur some costs, overall, the frameworks saves more money that is lost through stock outs and overstocking challenges encountered when using manual systems. Another difference observed was that the respondents in the public sector had less awareness of machine learning and cloud computing. Contrary to the findings of Glyptis et al. (2020) who found out that public sector pharmacies in various geographical locations had moderate to high awareness of such technologies in a study conducted in France on the use of machine learning in inventory management in manufacturing industry.

As a result of the identified use requirements a framework was designed with cloud computing AWS PaaS and the machine learning model XGBoost. This framework was intended to correct these inefficiencies by providing real-time tracking of stock, demand forecasting, and decision-making. The framework provided the scalability, flexibility, and improved accuracy which are in line with the user needs identified during the assessment. The last object was to assess the efficiency of the given framework to enhance the pharmacy stock management. The AWS PaaS and XGBoost-based framework, based on the feedback of respondents and regression analysis, was found to have had a positive impact on stockout and overstocking, inventory accuracy, and operational efficiency. It was established that the system was more helpful in real-time inventory tracking and forecasting, and provided the pharmacies in Nairobi County with an effective solution to their inventory problems. This concurs with Chebet and Mbandu (2024) who demonstrated that it is possible to achieve a high level of optimization of inventory using the XGBoost machine learning models. Nonetheless, unlike Alkhouri (2024) which failed to capture financial constraints, this study identified cost and capacity issues as highlighted by the small pharmacies especially from the public domain. Therefore, the study not only confirms the effectiveness of the proposed framework, but also establishes the importance of the use of differential solutions according to the organizational capacity.

5.4 Recommendations

In light of the research results, the AWS PaaS and XGBoost model should be implemented by the pharmacy owners and management in public and private pharmacies to improve inventory management systems. This framework will allow pharmacies to reach the goal of real time inventory tracking, accurate demand forecasting, and predictive analytics for expiration dates. These benefits underscore the importance of the public and private sectors to not only implement these technologies but also train personnel to enable the framework to be effectively implemented. Moreover, the research established that, while the level of awareness of the opportunities of machine learning and cloud computing was relatively high, government-owned pharmacies were less aware of them than other types of pharmacies. To fill this gap in knowledge, it is recommended that healthcare policymakers and pharmacy management implement specific educational initiatives. These programs would encompass awareness creation, capacity development, and the eventual migration to cloud-based inventory systems. Since data security and regulatory compliance were identified as critical issues, particularly in clinics, the pharmacies must adhere to the legal requirements such as HIPAA and GDPR. Additionally, AWS PaaS platform comes with security features that include encryption and access controls to protect the patient data. Hence, pharmacy management has to commit resources in systems that will enhance stock control, and patient record protection. The other important recommendation of the research is that pharmacies should conduct cost-benefit analysis to counter arguments of high initial cost of cloud-based systems. Finally, Pharmacy owners and managers should compare the long-term benefits of implementing the economic order quantity model in terms of costs of stockouts and overstocking with the initial costs. This will help in arriving at the right decision on the feasibility of implementing cloud-based inventory management systems.

5.4.1 Recommendations for Future Studies

Besides the recommendations deduced from the research study, this study also presents recommendations for future research. One key area that needs further research is on the evaluation of AWS PaaS and XGBoost framework with a bigger sample and in other counties than Nairobi. This should include the actual implementation of the framework using sample pharmacies to evaluate the effectiveness of the framework. Expanding the study to other regions and other aspects of the pharmacy functioning would allow to generalize the results and evaluate the transferability of the proposed framework. Another area that needs further research is the applicability of machine learning algorithms in other important functions of pharmacy other than inventory. For instance, some of the areas that XGBoost can be applied is to include customer management and medication compliance. Since some private pharmacies complained that cloud-based inventory management systems were expensive and not easy to implement in their stores, further studies should focus on finding affordable solutions for such pharmacies. This may include exploring the possibilities of deploying a combination of on premise and cloud-based solutions which would make it easier for these small pharmacies to adopt the various advanced technologies in a cheaper way. Finally, the potential loss of jobs in pharmacy management due to the use of automation, and the use of algorithms in decision-making are other areas that should be explored in future studies. It will be relevant to understand how these technologies can be applied in a way that would keep the essential decision-making in the hands of experienced healthcare professionals.

REFERENCES

Abdolazimi, O., Shishebori, D., Goodarzian, F., Ghasemi, P., & Appolloni, A. (2021). Designing a new mathematical model based on ABC analysis for inventory control problem: A real case study. *RAIRO - Operations Research*, *55*(4), 251–273. https://doi.org/10.1051/ro/2021104

Aginako, Z., Peña-Lang, M. B., Bedialauneta, M. T., & Guraya, T. (2021). Analysis of the validity and reliability of a questionnaire to measure students' perception of inclusion of sustainability in engineering degrees. *International Journal of Sustainability in Higher Education*, *22*(6), 1402–1420. https://doi.org/10.1108/IJSHE-09-2020-0355

Akanle, O., Ademuson, A. O., & Shittu, O. S. (2020). Scope and limitation of study in social research. *Contemporary Issues in Social Research*, *105*, 114-205. https://doi.org/10.1109/TII.2021.3100152

Albaroodi, K. A. I. (2019). Pharmacists' Knowledge Regarding Drug Disposal in Karbala. *Pharmacy*, *7*(2)15-57. https://doi.org/10.3390/pharmacy7020057

Alkhouri, M. (2024). *Pharmaceutical supply chain–new obstacles and challenges*. https://dspace.lib.uom.gr/handle/2159/30186

Altowaijri, S. M. (2020). An Architecture to Improve the Security of Cloud Computing in the Healthcare Sector. In R. Mehmood, S. See, I. Katib, & I. Chlamtac (Eds.), *Smart Infrastructure and Applications: Foundations for Smarter Cities and Societies* (pp. 249–266). Springer International Publishing. https://doi.org/10.1007/978-3-030-13705-2_10

Bader, D., Innab, N., Atoum, I., & Alathamneh, F. (2023). The influence of the Internet of things on pharmaceutical inventory management. *International Journal of Data and Network Science*, *7*(1), 381–390. http://m.growingscience.com/beta/ijds/5797-the-influence-of-the-internet-of-things-on-pharmaceutical-inventory-management.html

Barati, M., Aujla, G. S., Llanos, J. T., Duodu, K. A., Rana, O. F., Carr, M., & Ranjan, R. (2022). Privacy-Aware Cloud Auditing for GDPR Compliance Verification in Online Healthcare. *IEEE Transactions on Industrial Informatics*, *18*(7), 4808–4819. https://doi.org/10.1109/TII.2021.3100152

Barbosa-Povoa, A. P., & Pinto, J. M. (2020). Process supply chains: Perspectives from academia and industry. *Computers & Chemical Engineering*, *132*, 106606. https://doi.org/10.1016/j.compchemeng.2019.106606

Baruffaldi, G., Accorsi, R., & Manzini, R. (2018). Warehouse management system customization and information availability in 3pl companies: A decision-support tool. *Industrial Management & Data Systems*, *119*(2), 251–273. https://doi.org/10.1108/IMDS-01-2018-0033

Basilakis, J. (2020). *Cloud-based homomorphic encryption for privacy-preserving machine learning in clinical decision support*. https://researchdirect.westernsydney.edu.au/islandora/object/uws:60555/

Bekele, A., Kumsa, W., & Ayalew, M. (2022). Assessment of Inventory Management Practice and Associated Challenges of Maternal, Newborn, and Child Health Life-Saving Drugs in Public Hospitals of Southwest Ethiopia: A Mixed-Method Approach. *Integrated Pharmacy Research and Practice*, *11*, 139–149. https://doi.org/10.2147/IPRP.S378340

Bell, C. (2024). Cloud Computing. In C. Bell, *MicroPython for the Internet of Things* (pp. 413–424). Apress. https://doi.org/10.1007/978-1-4842-9861-9_12

Bloomfield, J., & Fisher, M. J. (2019). Quantitative research design. *Journal of the Australasian Rehabilitation Nurses Association*, *22*(2), 27–30. https://doi.org/10.3316/informit.738299924514584

Borges, A. F. S., Laurindo, F. J. B., Spínola, M. M., Gonçalves, R. F., & Mattos, C. A. (2021). The strategic use of artificial intelligence in the digital era: Systematic literature review and future research directions. *International Journal of Information Management*, *57*, 102225. https://doi.org/10.1016/j.ijinfomgt.2020.102225

Bouanane, K., & Khemissat, A. (2023). *Machine learning tools for hospital pharmacy supply chain: inventory management tasks* [PhD Thesis, Kasdi Merbah University Ouargla]. Algeria. https://dspace.univ-ouargla.dz/jspui/handle/123456789/34539

Bradley, S. W., Kim, P. H., Klein, P. G., McMullen, J. S., & Wennberg, K. (2021). Policy for innovative entrepreneurship: Institutions, interventions, and societal challenges. *Strategic Entrepreneurship Journal*, *15*(2), 167–184. https://doi.org/10.1002/sej.1395

Çalışkan, C. (2021). The economic order quantity model with compounding. *Omega*, *102*(1), 102307. https://www.sciencedirect.com/science/article/abs/pii/S0305048320306617

Chebet, K., & Mbandu, V. (2024). Cloud-Enabled Machine Learning: A Framework for Revolutionizing Pharmacy Inventory Management in Nairobi County. *International Journal of Professional Practice*, *12*(6), 15–27. https://ijpp.kemu.ac.ke/index.php/ijpp/article/view/457

Chen, X., Jasin, S., & Shi, C. (2022). *The Elements of Joint Learning and Optimization in Operations Management*. Springer Nature.

Chien, F., Ngo, Q.-T., Hsu, C.-C., Chau, K. Y., & Iram, R. (2021). Assessing the mechanism of barriers towards green finance and public spending in small and medium enterprises from developed countries. *Environmental Science and Pollution Research*, *28*(43), 60495–60510. https://doi.org/10.1007/s11356-021-14907-1

Das, P., Ivkin, N., Bansal, T., Rouesnel, L., Gautier, P., Karnin, Z., Dirac, L., Ramakrishnan, L., Perunicic, A., Shcherbatyi, I., Wu, W., Zolic, A., Shen, H., Ahmed, A., Winkelmolen, F., Miladinovic, M., Archembeau, C., Tang, A., Dutt, B., … Venkateswar, K. (2020). Amazon SageMaker Autopilot: A white box AutoML solution at scale. *Proceedings of the Fourth International Workshop on Data Management for End-to-End Machine Learning*, 1–7. https://doi.org/10.1145/3399579.3399870

Ding, B. (2018). Pharma Industry 4.0: Literature review and research opportunities in sustainable pharmaceutical supply chains. *Process Safety and Environmental Protection*, *119*, 115–130. https://doi.org/10.1016/j.psep.2018.06.031

Du Plessis, M. (2020). *Reinforcement learning for inventory management in information-sharing pharmaceutical supply chains* [Master's Thesis, Stllenbosch University]. South Africa. https://scholar.sun.ac.za:443/handle/10019.1/107996

Eaneff, S., Obermeyer, Z., & Butte, A. J. (2020). The Case for Algorithmic Stewardship for Artificial Intelligence and Machine Learning Technologies. *JAMA*, *324*(14), 1397–1398. https://doi.org/10.1001/jama.2020.9371

Esposito, C., De Santis, A., Tortora, G., Chang, H., & Choo, K.-K. R. (2018). Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy? *IEEE Cloud Computing*, *5*(1), 31–37. https://doi.org/10.1109/MCC.2018.011791712

Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., Cui, C., Corrado, G., Thrun, S., & Dean, J. (2019). A guide to deep learning in healthcare. *Nature Medicine*, *25*(1), 14-25. https://doi.org/10.1038/s41591-018-0316-z

Feizabadi, J. (2022). Machine learning demand forecasting and supply chain performance. *International Journal of Logistics Research and Applications*, *25*(2), 119–142. https://doi.org/10.1080/13675567.2020.1803246

Flaumenhaft, Y., & Ben-Assuli, O. (2018). Personal health records, global policy and regulation review. *Health Policy*, *122*(8), 815–826. https://doi.org/10.1016/j.healthpol.2018.05.002

Gholamhosseini, L., Sadoughi, F., & Safaei, A. (2019). Hospital Real-Time Location System (A Practical Approach in Healthcare): A Narrative Review Article. *Iranian Journal of Public Health*, *48*(4), 593–602. https://doi.org/10.3390/pharmacy7020057.

Gizaw, T., & Jemal, A. (2021). How is Information from ABC–VED–FNS Matrix Analysis Used to Improve Operational Efficiency of Pharmaceuticals Inventory Management? A Cross-Sectional Case Analysis. *Integrated Pharmacy Research and Practice, 10*, 65–73. https://doi.org/10.2147/IPRP.S310716

Glyptis, L., Christofi, M., Vrontis, D., Del Giudice, M., Dimitriou, S., & Michael, P. (2020). E-Government implementation challenges in small countries: The project manager's perspective. *Technological Forecasting and Social Change*, *152*, 11980. https://doi.org/10.1016/j.ijpe.2017.10.007

Gonul Kochan, C., Nowicki, D. R., Sauser, B., & Randall, W. S. (2018). Impact of cloud-based information sharing on hospital supply chain performance: A system dynamics framework. *International Journal of Production Economics*, *195*, 168–185. https://doi.org/10.1016/j.ijpe.2017.10.008

Gopal, M. (2019). *Applied Machine Learning* (1st Ed.). McGraw-Hill Education. https://www.accessengineeringlibrary.com/content/book/9781260456844

Guo, K. H., & Eschenbrenner, B. L. (2018). CVS Pharmacy: An instructional case of internal controls for regulatory compliance and IT risks. *Journal of Accounting Education*, *42*, 17–26. https://doi.org/10.1016/j.jaccedu.2017.11.001

Harahap, A. T. J., Ginting, C. N., Nasution, A. N., & Amansyah, A. (2023). The Effect of Lean Approach on Hospital Service Quality and Inpatient Satisfaction. *Unnes Journal of Public Health*, *12*(1), 12–20. https://doi.org/10.1016/j.ijpe.2017.10.008

Ilardo, M. L., & Speciale, A. (2020). The Community Pharmacist: Perceived Barriers and Patient-Centered Care Communication. *International Journal of Environmental Research and Public Health*, *17*(2), 542-607.https://doi.org/10.3390/ijerph17020536

Johnson, J. L., Arif, S., Bloom, T. J., Isaacs, A. N., Moseley, L. E., & Janke, K. K. (2023). Preparing Pharmacy Educators as Expedition Guides to Support Professional Identity Formation in Pharmacy Education. *American Journal of Pharmaceutical Education*, *87*(1), ajpe8944. https://doi.org/10.5688/ajpe8944

Kamba, P. F., Mulangwa, J., Kaggwa, B., Kitutu, F. E., Sewankambo, N. K., Katabira, E. T., Byakika-Kibwika, P., Adome, R. O., & Bollinger, R. C. (2020). Compliance of private pharmacies in Uganda with controlled prescription drugs regulations: A mixed-methods study. *Substance Abuse Treatment, Prevention, and Policy*, *15*(1), 16-67. https://doi.org/10.1186/s13011-020-00261-x

Kara, A., & Dogan, I. (2018). Reinforcement learning approaches for specifying ordering policies of perishable inventory systems. *Expert Systems with Applications*, *91*, 150–158. https://doi.org/10.1016/j.eswa.2017.08.046

Karattuthodi, M. S., Krishnan, G., Aiswarya, A. V., Sarath Chandran, C., Nair, S. S., Thorakkatil, S. A., & Arain, S. (2023). A systematic review on pharmacist-led pharmaceutical care optimization through virtual platforms. *Journal of Pharmaceutical Health Services Research*, *14*(1), 2–13. https://doi.org/10.1093/jphsr/rmac054

Karunakara Rai, B., Harshitha, J. P., Kalagudi, R. S., Priyanka Chowdary, B. S., Hora, P., & Sahana, B. (2019). A Cloud-Based Inventory Management System Using a Smart Trolley for Automated Billing and Theft Detection. In H. S. Saini, R. K. Singh, G. Kumar, G. M. Rather, & K. Santhi (Eds.), *Innovations in Electronics and Communication Engineering* (pp. 491–500). Springer. https://doi.org/10.1007/978-981-13-3765-9_51

Khatib, M. M. E., & Ahmed, G. (2020). Robotic pharmacies potential and limitations of artificial intelligence: A case study. *International Journal of Business Innovation and Research*, *23*(3), 298–312. https://doi.org/10.1504/IJBIR.2020.110972

Kho, B. P., Hassali, M. A., Lim, C. J., Saleem, F., Kho, B. P., Hassali, M. A., Lim, C. J., & Saleem, F. (2017). Challenges in the management of community pharmacies in Malaysia. *Pharmacy Practice (Granada), 15*(2), 1154- 6534. https://doi.org/10.18549/pharmpract.2017.02.933

Kufel, J., Bargieł-Łączek, K., Kocot, S., Koźlik, M., Bartnikowska, W., Janik, M., Czogalik, Ł., Dudek, P., Magiera, M., & Lis, A. (2023). What is machine learning, artificial neural networks and deep learning?—Examples of practical applications in medicine. *Diagnostics*, *13*(15), 2582. https://doi.org/10.1109/ACCESS.2020.2988563

Kunath, M., & Winkler, H. (2018). Integrating the Digital Twin of the manufacturing system into a decision support system for improving the order management process. *Procedia CIRP*, *72*, 225–231. https://doi.org/10.1016/j.procir.2018.03.192

Lee, C. K. M., Lv, Y., Ng, K. K. H., Ho, W., & Choy, K. L. (2018). Design and application of Internet of things-based warehouse management system for smart logistics. *International Journal of Production Research, 56*(8), 2753–2768. https://doi.org/10.1080/00207543.2017.1394592

Li, T., Higgins, J. P., & Deeks, J. J. (2019). Collecting data. In *Cochrane Handbook for Systematic Reviews of Interventions* (pp. 109–141). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119536604.ch5

Lie, W., Jiang, B., & Zhao, W. (2020). Obstetric Imaging Diagnostic Platform Based on Cloud Computing Technology Under the Background of Smart Medical Big Data and Deep Learning. *IEEE Access, 8*, 78265–78278. https://doi.org/10.1109/ACCESS.2020.2988563

Lin, H., Lin, J., & Wang, F. (2022). An innovative machine learning model for supply chain management. *Journal of Innovation & Knowledge*, *7*(4), 100276. https://doi.org/10.1016/j.jik.2022.100276

Lohmer, J., Ribeiro da Silva, E., & Lasch, R. (2022). Blockchain Technology in Operations & Supply Chain Management: A Content Analysis. *Sustainability*, *14*(10), 29-84. https://doi.org/10.3390/su14106192

Lu, H., Xie, M., Liu, X., Liu, B., Jiang, M., Gao, Y., & Zhao, X. (2021). Adjusting prediction of ozone concentration based on CMAQ model and machine learning methods in Sichuan-Chongqing region, China. *Atmospheric Pollution Research*, *12*(6), 101066. https://doi.org/10.1016/j.apr.2021.101066

Mehmood, A., Mehmood, F., & Song, W.-C. (2019). Cloud based E-Prescription management system for healthcare services using IoT devices. *2019 International Conference on Information and Communication Technology Convergence (ICTC)*, 1380–1386. https://doi.org/10.1109/ICTC46691.2019.8939916

Mendez, K. M., Pritchard, L., Reinke, S. N., & Broadhurst, D. I. (2019). Toward collaborative open data science in metabolomics using Jupyter Notebooks and cloud computing. *Metabolomics*, *15*(10), 125. https://doi.org/10.1007/s11306-019-1588-0

Meng, X., & Feigenbaum, J. (2020). *Privacy-Preserving XGBoost Inference* (arXiv:2011.04789). arXiv. http://arxiv.org/abs/2011.04789

Min, Q., Lu, Y., Liu, Z., Su, C., & Wang, B. (2019). Machine Learning based Digital Twin Framework for Production Optimization in Petrochemical Industry. *International Journal of Information Management*, *49*, 502–519. https://doi.org/10.1016/j.ijinfomgt.2019.05.020

Mishra, A. (2019). *Machine learning in the AWS cloud: Add intelligence to applications with Amazon Sagemaker and Amazon Rekognition*. John Wiley & Sons. https://books.google.com/books?hl=en&lr=&id=G36mDwAAQBAJ&oi=fnd&pg=PR23&dq=XGBoost+with+AWS+SageMaker,+a+managed+ML+service+by+AWS&ots=mgN3T14sa-&sig=Bb0RI6Nmg1OQVL1hUTDjJF44SrA

Mishra, S., & Tyagi, A. K. (2022). The Role of Machine Learning Techniques in Internet of Things-Based Cloud Applications. In S. Pal, D. De, & R. Buyya (Eds.), *Artificial Intelligence-based Internet of Things Systems* (pp. 105–135). Springer International Publishing. https://doi.org/10.1007/978-3-030-87059-1_4

Monden, Y. (2011). *Toyota Production System: An Integrated Approach to Just-In-Time (*4th Ed.). CRC Press.

Moons, K., Waeyenbergh, G., & Pintelon, L. (2019). Measuring the logistics performance of internal hospital supply chains – A literature study. *Omega*, *82*, 205–217. https://doi.org/10.1016/j.omega.2018.01.007

Mostofi, A., & Jain, V. (2021). Inventory Management and Control Of Deteriorating Pharmaceutical Products sing Industry 4.0. *2021 IEEE 8th International Conference on Industrial Engineering and Applications (ICIEA)*, 394–400. https://doi.org/10.1109/ICIEA52957.2021.9436744

Nagarajan, N. R., Balaharini, S., Balaji, J., Binoshlin, C., & Prabha, P. C. (2022). Framework to find expiry of Medicinal Drugs in Pharmacy. *Journal of Pharmaceutical Negative Results*, 28(4), 2296–2301. https://doi.org/10.1186/s13011-020-00261-x.

Nasution, A. A., Matondang, N., & Ishak, A. (2022). Inventory Optimization Model Design with Machine Learning Approach in Feed Mill Company. *Jurnal Sistem Teknik Industri*, *24*(2),181-209. https://doi.org/10.32734/jsti.v24i2.8637

Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., & Vasilakis, C. (2021). Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. *European Journal of Operational Research*, *290*(1), 99–115. https://doi.org/10.1016/j.ejor.2020.08.001

Ortiz, G., Zouai, M., Kazar, O., Garcia-de-Prado, A., & Boubeta-Puig, J. (2022). Atmosphere: Context and situational-aware collaborative IoT architecture for edge-fog-cloud computing. *Computer Standards & Interfaces*, *79*, 103550. https://doi.org/10.1016/j.csi.2021.103550

Pall, R., Gauthier, Y., Auer, S., & Mowaswes, W. (2023). Predicting drug shortages using pharmacy data and machine learning. *Health Care Management Science*.59(1), 190-1012.https://doi.org/10.1007/s10729-022-09627-y

Pandey, N. K., Kumar, K., Saini, G., & Mishra, A. K. (2023). Security issues and challenges in cloud of things-based applications for industrial automation. *Annals of Operations Research*,93(5), 11095. https://doi.org/10.1007/s10479-023-05285-7

Pazhayattil, A. B. (2022). *Machine Learning and Artificial Intelligence Strategies for the Pharmaceutical Industry*. https://doi.org/10.1016/j.jretconser.2020.102326

Prata, J. C., da Costa, J. P., Duarte, A. C., & Rocha-Santos, T. (2019). Methods for sampling and detection of microplastics in water and sediment: A critical review. *TrAC Trends in Analytical Chemistry*, *110*, 150–159. https://doi.org/10.1016/j.trac.2018.10.029

Qayyum, A., Qadir, J., Bilal, M., & Al-Fuqaha, A. (2021). Secure and Robust Machine Learning for Healthcare: A Survey. *IEEE Reviews in Biomedical Engineering*, *14*, 156–180. https://doi.org/10.1109/RBME.2020.3013489

Rashid, A., Mohd Noor, N. A., Yusof, Y., & Tuan Abdullah, T. N. (2020). Exploring the Dimensions Using Exploratory Factor Analysis of Disruptive Factors and Inventory Control. *The Economics and Finance Letters*, *7*, 247–254. https://doi.org/10.18488/journal.29.2020.72.247.254

Raut, S., Moharana, S., Sahoo, S., Jena, R., & Patra, P. (2023). Design and Usage of a Digital E-Pharmacy Application Framework. In H. K. Thakkar, C. K. Dehury, P. K. Sahoo, & B. Veeravalli (Eds.), *Predictive Analytics in Cloud, Fog, and Edge Computing: Perspectives and Practices of Blockchain, IoT, and 5G* (pp. 91–105). Springer International Publishing. https://doi.org/10.1007/978-3-031-18034-7_6

Sadeeq, M. M., Abdulkareem, N. M., Zeebaree, S. R. M., Ahmed, D. M., Sami, A. S., & Zebari, R. R. (2021). IoT and Cloud Computing Issues, Challenges and Opportunities: A Review. *Qubahan Academic Journal*, *1*(2), 16-76. https://doi.org/10.48161/qaj.v1n2a36

Saha, E., & Ray, P. K. (2019). Modelling and analysis of inventory management systems in healthcare: A review and reflections. *Computers & Industrial Engineering*, *137*, 106051. https://doi.org/10.1016/j.cie.2019.106051

Saha, S., Chatterjee, D., & Sarkar, B. (2021). The ramification of dynamic investment on the promotion and preservation technology for inventory management through a modified flower pollination algorithm. *Journal of Retailing and Consumer Services*, *58*, 102326. https://doi.org/10.1016/j.jretconser.2020.102326

Sharma, A., Kaur, J., & Singh, I. (2020). Internet of Things (IoT) in Pharmaceutical Manufacturing, Warehousing, and Supply Chain Management. *SN Computer Science*, *1*(4), 232-430 https://doi.org/10.1007/s42979-020-00248-2

Sharma, D. N. K. (2022). *Instruments Used in the Collection of Data in Research*. https://doi.org/10.2139/ssrn.4138751

Sohrabi, M., Zandieh, M., & Shokouhifar, M. (2023). Sustainable inventory management in blood banks considering health equity using a combined metaheuristic-based robust fuzzy stochastic programming. *Socio-Economic Planning Sciences*, *86,* 101462. https://doi.org/10.1016/j.apenergy.2020.114683

Squitieri, L., & Chung, K. C. (2020). Deriving Evidence from Secondary Data in Hand Surgery: Strengths, Limitations, and Future Directions. *Hand Clinics*, *36*(2), 231–243. https://doi.org/10.1016/j.hcl.2020.01.011

Stergiou, C. L., Plageras, A. P., Psannis, K. E., & Gupta, B. B. (2020). Secure Machine Learning Scenario from Big Data in Cloud Computing via Internet of Things Network. In B. B. Gupta, G. M. Perez, D. P. Agrawal, & D. Gupta (Eds.), *Handbook of Computer Networks and Cyber Security: Principles and Paradigms* (pp. 525–554). Springer International Publishing. https://doi.org/10.1007/978-3-030-22277-2_21

Thakur, T., Frey, M., & Chewning, B. (2020). Pharmacist roles, training, and perceived barriers in naloxone dispensing: A systematic review. *Journal of the American Pharmacists Association*, *60*(1), 178–194. https://doi.org/10.1016/j.japh.2019.06.016

Unhelkar, B., Joshi, S., Sharma, M., Prakash, S., Mani, A. K., & Prasad, M. (2022). Enhancing supply chain performance using RFID technology and decision support systems in the industry 4.0–A systematic literature review. *International Journal of Information Management Data Insights*, *2*(2), 100084. https://doi.org/10.1016/j.jjimei.2022.100084

Vandeput, N. (2020). Inventory Optimization: Models and Simulations. In *Inventory Optimization*. De Gruyter. https://doi.org/10.1515/9783110673944

Vigneshwari, N., Dhineshkumar, M., Anuvarshini, K. S., Anisha, M., Sushmitha, M., & Nithila, E. E. (2022). Design of Cloud Computing based Digital Inventory for Administration and Supervision of Hospices Patient Data. *2022 International Conference on Augmented Intelligence and Sustainable Systems (ICAISS)*, 562(2),864–870. https://doi.org/10.1109/ICAISS55157.2022.10010923

Wang, Z., Hong, T., & Piette, M. A. (2020). Building thermal load prediction through shallow machine learning and deep learning. *Applied Energy*, *263(1), 3545-3889*114683. https://doi.org/10.1016/j.apenergy.2020.114683

Wu, M.-J., Zhao, K., & Fils-Aime, F. (2022). Response rates of online surveys in published research: A meta-analysis. *Computers in Human Behavior Reports*, *7*, 100206. https://doi.org/10.1016/j.csi.2021.103550

Yadav, S. K., Singh, S., & Gupta, R. (2019). Sampling Methods. In S. K. Yadav, S. Singh, & R. Gupta (Eds.), *Biomedical Statistics: A Beginner's Guide* (pp. 71–83). Springer. https://doi.org/10.1007/978-981-32-9294-9_9

Younis, H., Sundarakani, B., & Alsharairi, M. (2021). Applications of artificial intelligence and machine learning within supply chains:systematic review and future research directions. *Journal of Modelling in Management*, *17*(3), 916–940. https://doi.org/10.1108/JM2-12-2020-0322

Yu, D., & Yan, Z. (2022). Combining machine learning and main path analysis to identify research front: From the perspective of science-technology linkage. *Scientometrics*, *127*(7), 4251–4274. https://doi.org/10.1007/s11192-022-04443-1

Zehnalová, J., & Kubátová, H. (2019). From a target population to representative samples of translations and translators. *The Translator*, *25*(2), 87–100. https://doi.org/10.1080/13556509.2019.1642713

Zhang, Z., Li, K. W., Guo, X., & Huang, J. (2020). A probability approach to multiple criteria ABC analysis with misclassification tolerance. *International Journal of Production Economics*, *229*, 107858. https://doi.org/10.1016/j.ijpe.2020.107858

Zhou, Z.-H. (2021). *Machine Learning*. Springer Nature.

Zhu, X., Ninh, A., Zhao, H., & Liu, Z. (2021). Demand Forecasting with Supply-Chain Information and Machine Learning: Evidence in the Pharmaceutical Industry. *Production and Operations Management*, *30*(9), 3231–3252. https://doi.org/10.1111/poms.13426

APPENDICES

APPENDIX A: QUESTIONNAIRE

Questionnaire for Pharmacy Inventory Management Research

General Information

1. Gender

   Male ☐

   Female ☐

2. What is your role in the pharmacy?

Manager	
Pharmacist	
Technician	

3. How many years of experience do you have in pharmacy operations?

No of years	
0-5	
5-10	
10-15	
15-20	
Above 20	

4. Pharmacy type

Retail	
Hospital	
Clinic	

5. How many employees do you have at the Pharmacy?

Below 5	
5-10	
10-15	
15-20	
Above 20	

6. Current inventory management system

☐ Manual ☐ software ☐ hybrid

Inventory Management Challenges

7. I am satisfied with our current pharmacy inventory management system

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

8. I am confident that the current pharmacy inventory management system effectively meets the needs of your patients and staff

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

9. What are the biggest challenges you face in managing your pharmacy inventory? (Multiple choice)

☐ Stockouts
☐ Overstocking
☐ Difficulty forecasting demand
☐ Manual inventory counting and data entry errors
☐ Lack of real-time inventory visibility
☐ High inventory carrying costs
☐ Difficulty managing expiration dates

☐ Other (please specify)

10. How do these challenges impact your pharmacy operations? (Multiple choice)

☐ Decreased patient satisfaction

☐ Increased operational costs

☐ Reduced staff productivity

☐ Regulatory compliance issues

☐ Other (please specify)

11. In Consideration of the challenges you mentioned, I would recommend our current inventory management system to other pharmacies

SD	D	Neutral	A	SA

12. What improvements would you like to see in your pharmacy inventory management system? (Open-ended)

Cloud Computing and Machine Learning Awareness:

13. Are you familiar with cloud computing technology?
☐ Yes ☐ No

14. If yes, how do you currently use cloud computing in your pharmacy operations? ……………………………………………………………………………
…………………………………………………………………………………
……………………………….

15. Are you familiar with machine learning technology?

☐ Yes ☐ No

16. If yes, how do you currently use machine learning in your pharmacy operations?

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………..

Framework Usage and Adoption

17. Would you be interested in using a framework that integrates cloud computing and machine learning (XGBoost model) to optimize your pharmacy inventory management?

☐ Yes ☐ No

18. What features or functionalities would be most important to you in such a framework? (Multiple choice)

☐ Improved accuracy of inventory forecasting

☐ Real-time inventory visibility

☐ Automated reorder points

☐ Waste reduction and expiration date management

☐ Improved data analysis and reporting

☐ with existing inventory management systems

☐ Other (please specify)

19. What are the biggest concerns you have about implementing such a framework? (Multiple choice)

☐ Cost

☐ Data security and privacy

☐ System integration and compatibility

☐ Training and support

☐ Scalability and future-proofing

☐ Other (please specify)

20. What resources would you need to successfully implement and use such a framework? (Multiple choice)

☐ Financial support

☐ Technical support

☐ Training for pharmacy personnel

☐ Change management support

☐ Other (please specify) ………………………………………………….

21. Considering a framework with all the features you listed, how likely would you be to invest in its implementation, with 1 being very unlikely and 5 being very likely?

Very unlikely	Unlikely	Neutral	Likely	Very likely

Framework Performance Evaluation

22. How would you measure the success of a new inventory management framework? (Multiple choice)

☐ Inventory accuracy

☐ Reduced stockouts and overstocking

☐ Cost savings

☐ Improved patient satisfaction

☐ Increased staff productivity

☐ Other (please specify)

23. Are you willing to participate in a pilot study to test the proposed framework?

☐ Yes ☐ No

24. How likely would you be to recommend the proposed framework to other pharmacies, assuming it proves successful in pilot testing? (1 = Not at all likely, 5 = Very likely)

Very unlikely	Unlikely	Neutral	Likely	Very likely

25. Please feel free to share any additional thoughts or comments you have about pharmacy inventory management or the proposed framework.

APPENDIX B: INTRODUCTION LETTER

KENYA METHODIST UNIVERSITY

P. O. Box 267 Meru - 60200, Kenya
Tel: 254-064-30301/31229/30367/31171
Fax: 254-64-30162
Email: deanrd@kemu.ac.ke

DIRECTORATE OF POSTGRADUATE STUDIES

Our Ref: KeMU/NACOSTI/CIS/01/2024 May 30, 2024

Commission Secretary
National Commission for Science, Technology and Innovations
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: KELVIN CHEBET (REG. NO. CIS-3-0419-3/2021)

This is to confirm that the above named is a bona fide student of Kenya Methodist University, in the Department of Computer Science, undertaking a Master's Degree in Computer Information Systems. He is conducting research on: **"A Framework for Optimizing Pharmacy Inventory Management System Performance Using Cloud Computing and Machine Learning. A Case Study of Nairobi County".**

We confirm that his research proposal has been defended and approved by the University.

In this regard, we are requesting your office to issue a research license to enable him collect data.

Any assistance accorded to him will be highly appreciated.

Yours sincerely,

KENYA METHODIST UNIVERSITY
31 MAY 2024
DIRECTORATE OF POSTGRADUATE STUDIES

Dr. John M. Muchiri (PhD)
Dean, Postgraduate Studies

Cc: Dean, SST
CoD – Computer Science
Postgraduate Coordinator - CIS
Supervisors

APPENDIX C: NACOSTI LICENSE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **841294**

Date of Issue: **26/September/2024**

RESEARCH LICENSE

This is to Certify that Mr.. kelvin CHEBET Chebet of Kenya Methodist University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: A FRAMEWORK FOR OPTIMIZING PHARMACY INVENTORY MANAGEMENT SYSTEM PERFORMANCE USING CLOUD COMPUTING AND MACHINE LEARNING A CASE STUDY OF NAIROBI COUNTY for the period ending : 26/September/2025.

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Director General
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