SUPPLY CHAIN AND INVENTORY MANAGEMENT FOR RETAIL STORES

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CERTIFICATION

This is to certify that this project titled "SUPPLY CHAIN AND INVENTORY MANAGEMENT FOR RETAIL STORES" was carried out by OGBEIVOR JUSTINA AJIRI (PGD/CSC/250069) in the Department of Computer Science, Benson Idahosa University, Benin City, Edo State, in partial fulfillment of the requirements for the award of Postgraduate Diploma (PGD) in Computer Science.

…….. ……

DR. S. AGU Date

Project Supervisor

…….. ……

DR. S. AGU Date

Head of Department

DEDICATION

This project is dedicated to the Almighty God for His guidance and wisdom throughout this journey, and to my family for their unwavering support and encouragement.

ACKNOWLEDGEMENTS

I extend my profound gratitude to the Almighty God for His infinite mercy and guidance throughout the course of this project.

My sincere appreciation goes to my supervisor, Dr. S. Agu, for his invaluable guidance, constructive criticism, and professional expertise that shaped this work.

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Finally, I acknowledge all retail store owners and managers who provided insights into the challenges of inventory management, which informed the development of this system.

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ABSTRACT

Supply chain management and inventory management are still of great importance to the success of a retail store, especially in the developing economies, where most of retail stores are still working under the manual system. This project aimed to address some of the problems which are inherent in the manual tracking of supplies and inventory, such as stock outs, overstocking, inaccurate information, and late reports, by creating a web-based Supply Chain and Inventory Management System. The System has been developed through a Waterfall Model based on System Development Life Cycle (SDLC) and using technologies such as HTML, CSS, JavaScript, PHP and MySQL. Some of its main characteristics consist of real-time stock monitoring, computerized stock replenishment, reorder point solution, supplier administration, and thorough reporting. The system was also assessed through various parameters such as inventory accuracy rate, task completion rate, System Usability Scale (SUS) score, system response time and report generation time. Results showed that the use of the system is superior to the manual process with the results that the accuracy rate of the inventory was 97%, work completion rate was 93%, SUS score was 72, average response time was 1.3 seconds, and the time required to generate reports is 6 seconds. It is suitable " for the small and medium retail shops with a scalable, cost-effective system tackling the most important issues concerning inventory management. Planned developments on the platform include the creation of a mobile app, implementing AI for demand prediction, and connecting with other eCommerce platforms.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

While supply chain and inventory management is a key consideration for the success of any retail business, it is evident that major retailers even in developing countries such as Nigeria are using manual, disjointed and unreliable systems. Old inventory methods are often these: Stocks are tracked on spreadsheets, inventory is manually done and it's sometimes counted when the need arises, leading to inaccurate stock records, stock shortages, overstocking, inaccurate forecasting, loss of money and diminished customer satisfaction. But today's size and complexity in retail, with the uncertainty and disruption of its retail supply chains, not to mention the surge in retail channels and ecommerce, only accentuates legacy systems. Also, limited access to technology, affordability of the systems, poor connectivity, less technology readiness and systems being not suited to the reality of the supply chain are continual challenges for small- and medium-sized retailers. This is a huge shortfall in operation and hinders efficiency, profit and competitiveness. Therefore, having a low cost, flexible and technologically advanced inventory management is highly desirable to overcome the above-mentioned inefficiencies and improve the real-time decision-making process in retail stores.

1.2 Statement of the Problem

While supply chain and inventory management is a key consideration for the success of any retail business, it is evident that major retailers even in developing countries such as Nigeria are using manual, disjointed and unreliable systems. Old inventory methods are often these: Stocks are tracked on spreadsheets, inventory is manually done and it's sometimes counted when the

need arises, leading to inaccurate stock records, stock shortages, overstocking, inaccurate forecasting, loss of money and diminished customer satisfaction. But today's size and complexity in retail, with the uncertainty and disruption of its retail supply chains, not to mention the surge in retail channels and ecommerce, only accentuates legacy systems. Also, limited access to technology, affordability of the systems, poor connectivity, less technology readiness and systems being not suited to the reality of the supply chain are continual challenges for small- and medium-sized retailers. This is a huge shortfall in operation and hinders efficiency, profit and competitiveness. Therefore, having a low cost, flexible and technologically advanced inventory management is highly desirable to overcome the above-mentioned inefficiencies and improve the real-time decision-making process in retail stores.

1.3 Aim of the Study

1. The aim of this study is to develop a supply chain and inventory management for retail stores. Study specific objectives are to (as they come from the study content).
2. Develop a retail store useful automatic inventory management system that can provide a quick information of stock.
3. Set up an automatic updating of stock, determine reorder levels and alert suppliers to reduce stock-outs and overstocks.
4. Adopt secure data control and reporting systems that aid correct decision-making and performance analyses.
5. Help to assess the system in accordance with Project timelines, Inventory Accuracy Rate (95%), Task completion rates (90%), System usability scale (68), System response time (< 2 seconds), Report generation time (< 10 seconds), System uptime (> 99%) and Test case pass rate (> 95%).

1.4 Significance of the Study

The significance of this study is that it is precisely meeting a reality of a manual and disjointed inventory handling in the operation of any retailer in the world particularly in the developing countries like Nigeria. Traditional retail inventory management systems like paper-based inventory counting and spreadsheets, are often linked to discrepancies, stock-out, overstock, loss of sales and revenue, as well as forecasting errors (Simplebks, 2023). It also has an interactive intervention system; a system of inventory management that will provide a seller with real-time monitoring of the inventory through the use of technology, without compromising their physical labor and manual inventory inputs which leads to a lot of errors and which, in turn, provides good opportunities for the seller. The academic part of the business relates to the research of optimizing the supply chain, digitalization of the retail structures, and implementation of new technologies such as data mining, cloud computing and automation for stock management. It fills that gap in the middle between all the complicated, high-tech inventory e-commerce system that's out there, and a little to medium size retailer that has to fight to make a complicated inventory platform run like a complete fledged enterprise level inventory platform. Furthermore, the results of the study can be applied to support additional research, policy development and technological improvement to boost the competitiveness and resilience of the retail stores supply chain. The overall advantage of this research is twofold both for the academia and industry; it provides a blueprint on how to get fundamental changes in retail operations through affordable, available and flexible inventory systems enabling them to be an enabler for growth.

1.5 Scope of the Study

This paper extensively focuses on its efficiency enhancement by designing and developing a proper method for the inventory monitoring, automated inventory management, reports

generation, calculation of re-order level and coordination with suppliers while selling products in the retail shopping mall. That's things like product sign-up, inventory management, sales analytics, reorder warnings, and easy analytics to guide business decisions. Furthermore, it includes system testing those aids in testing the works for usability, accuracy and efficiency in the environment that it will operate.

The study is limited to basic inventory management functions, however, and doesn't address more higher-end supply chain capabilities such as logistics optimization, integration with other warehouses, predictive analytics using AI, or seamless external enterprise-ready capabilities beyond those needed for retail supply chain. The implementation is geared for small and medium retail stores; and not able to manage large national enterprise resource planning (ERP) feature sets or supply chain analytics. The design and realization of the entire system is limited to the time of the project and with the technology available for academic use.

1.6 Limitations of the Study

In this study the depth and breadth of the system development was limited by several factors:

1. **Time Constraints**

   Some of the more advanced features (such as Multi-Warehouse Management, AI Forecasting and full integration with external tools and applications such as third-party applications) were not able to be fully implemented due to the timescales attached to the project.

2. **Resource Limitations**

The project was limited in terms of development resources (hardware, software tools, access to real retail datasets) and did not allow for a more in-depth system testing or validation to be performed.

3. Technical Boundaries

It is possible that technologies and tools used to enable such a system would be far behind and incapable of dealing with a large scale launching and the accompanying complex supply chain of the system.

4. Not many live retailers involved

Limited use to more than one retail store resulted in user feedback and system testing to be conducted within a controlled environment and generalization of system performance to different retail setting difficult.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Review

In retail, inventory management is a basic inventory term that applies to any retail merchandise management process that involves ordering, storing, tracking, and controlling inventory to ensure the right products are in the right quantity at the right time (Wild, 2017; Stevenson 2021). It includes processes like stock monitoring, demand forecasting, replenishing and inventory valuation. Good inventory management leads to lower stockout levels, better inventory turnover and keeps customers happier (Jacobs and Chase, 2018). Today, this process is complemented by digital means that allow real-time visibility and the ability to start making more precise decisions in the retail environment (Chopra & Meindl, 2019).

There is a general theme that mirrors the concept of inventory management, supply chain management (Christopher, 2016), but involves the coordination and optimization of all of the activities needed to source, produce and deliver the products to customers. Supply chain identifies and links various activities including procurement, warehousing, logistics, distribution etc. so that the products can flow smoothly from suppliers to end users (Bowersox et al., 2020). Well-managed supply chains are critical to retailers' business to minimize delays and respond timely to the changes in the market to sustain their competitive position (Hugos, 2018). Theoretical concepts like the bullwhip effect (Lee et al., 1997), lean operations (Womack and Jones, 2003), and concept of demand-driven supply networks (Jüttner et al., 2007) help understand how a disruption at one point in the network can impact the performance of the entire network.

Database Management Systems (DBMS) are significant to digital inventory systems as ways of adding, storing, reaching, and taking care of data in a structured fashion (Elmasri & Navathe, 2020). For managing stock records, transaction history, supplier details, and generating analytical reports, it is crucial to have a DBMS that guarantees the accuracy, integrity, and security of the data. (Connolly and Begg, 2015). One of the key ideas of DBMS is normalization, which is a way of structuring the data to minimize data duplications and make the database more consistent. Normalization helps to ensure data reliability in the system by keeping inventory data clean, efficient, and easily retrievable, including product information and supplier details.

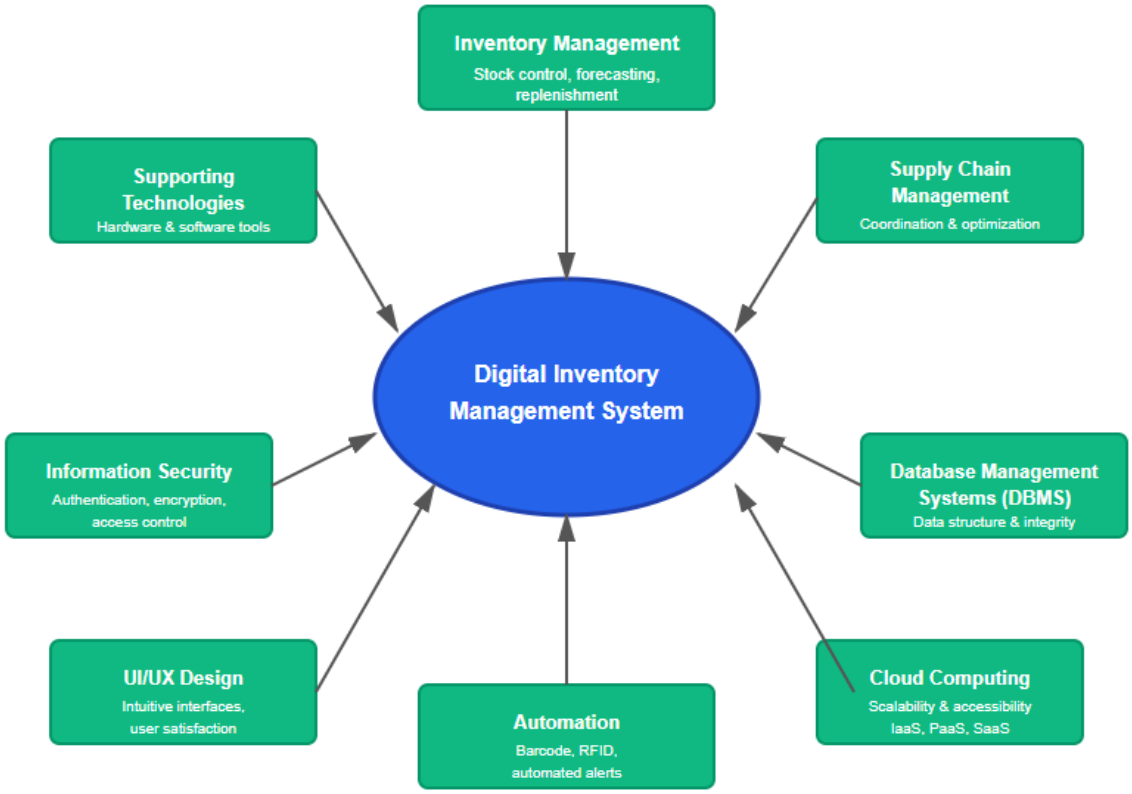


Figure 2.1: Conceptual Framework - Key Concepts in Digital Inventory Management (Connolly and Begg, 2015)

Cloud computing has also become an influential concept in the development of modern inventory systems. It involves delivering computing services such as databases, storage, and software over the internet on demand (Mell *and* Grance, 2011). Cloud-based inventory systems offer advantages such as scalability, remote accessibility, real-time synchronization, and reduced hardware costs (Armbrust *et al*., 2010; Marston *et al*., 2011). These benefits are particularly important for small and medium retail businesses that may lack the financial and technical capacity to deploy on-premises solutions (Gupta *et al*., 2013). Cloud models such as IaaS, PaaS, and SaaS provide flexible options to support different levels of system implementation (Zhang *et al*., 2010).

Another key concept relevant to the study is automation, which refers to the use of technology to perform tasks with minimal human intervention (Parasuraman *and* Riley, 1997). In inventory management, automation technologies such as barcode scanning, RFID, and system-triggered reorder alerts help reduce manual errors, speed up stock handling processes, and maintain accurate, up-to-date inventory records (Sarac *et al*., 2010; Bottani *and* Rizzi, 2008). Automation improves operational efficiency and provides managers with timely information for making informed decisions (Slack *et al*., 2016).

User Interface (UI) and User Experience (UX) design principles are equally important in the development of an inventory management system. UI refers to the visual and interactive elements through which users engage with the system, while UX relates to the overall ease, efficiency, and satisfaction users derive from that interaction (Norman, 2013; Garrett, 2011). An intuitive and well-designed interface reduces the learning curve for retail staff and ensures that tasks such as product entry, stock updates, and report generation are performed quickly and

accurately. Good UI/UX improves adoption rates and enhances the overall effectiveness of the solution (Rogers *et al*., 2019).

Finally, information security underpins all digital systems, including inventory management platforms. It involves safeguarding data against unauthorized access, alteration, or destruction (Whitman *and* Mattord, 2021). Since inventory systems handle sensitive information such as stock levels, supplier data, and financial transactions, ensuring confidentiality, integrity, and availability is critical (Stallings *and* Brown, 2018). Security measures may include user authentication, role-based access control, encryption, secure backups, and audit logs (Bishop, 2018). These measures help protect the system from threats and ensure reliable business continuity.

2.2 Theoretical Framework

There are several theories and models that are used as the basis for development of an inventory management system, which affect the structure, operation and implementation of such a system. One of the main models used in this project is System Development Life Cycle (SDLC) specifically Waterfall Model (Royce, 1970). The Waterfall SDLC is a sequential and structured system development process that carries out each phase (requirement analysis, system design, implementation, testing, deployment and maintenance) one after another. (Sommerville, 2016). It provides clarity, predictability, and accurate documentation, which is appropriate for academic projects, that have well-defined deliverables and limited time frame (Pressman and Maxim, 2020). With the use of Waterfall methodology, the systematic flow of design and development of the inventory system limits the probability of error and also ensures that the system will function

according to the user requirements.

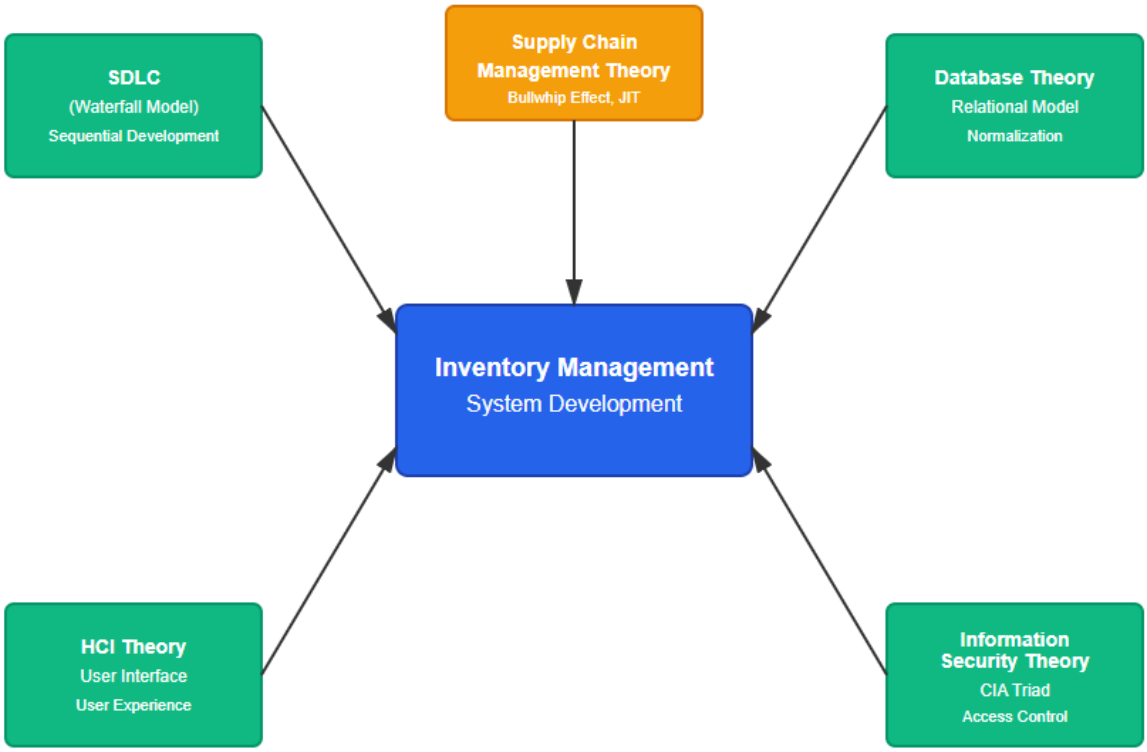


Figure 2.2: Theoretical Framework for Inventory Management System Development (Silberschatz et al., 2019)

Another theoretical background that is pertinent to the current study is Database Theory which offers fundamental principles to organize, store, and retrieve data efficiently (Silberschatz et al., 2019). Things like relational databases, entity-relationship modeling and database normalization influence the way product information, inventory, supplier information and transaction information are structured (Elmasri and Navathe, 2020). Relational database model organizes data in a well-defined way to have tables with relationships that provide accuracy and consistency and can scale (Codd, 1970). Normalization also prevents redundant data and improves data integrity, keeping the system efficient as the amount of inventory data grows

(Date, 2019). All of these theories collectively help make sure that the database part of the system maintains reputable and quick data operations essential for stock managing.

Human–Computer Interaction (HCI) theory also supports the study which states that it's essential that systems are designed to be intuitive, easy to use, and that align with the human thought processes (Dix et al., 2004; Shneiderman et al., 2016). The front end of the inventory system should be as simple as possible and make operations easier for retail team members, who are working under time pressures and may not have the same level of technical know-how. HCI concepts are used in the design of the interface, the way it is structured and navigated in, handling of errors, and overall user experience, so that the system can help to make the process more smooth such as stock updates, inventory finding, reports generation, etc. on a day to day basis (Norman, 2013). This application of HCI theory increases the chances of adoption and overall effectiveness of the system when deployed in the real-world retail settings (Rogers et al., 2019).

In addition, concepts from the Information Security Theory are followed when protecting the data of the system and the interaction of the user. These include, among others, notions of confidentiality, integrity and availability (the CIA triad), which focus on protecting sensitive information of stock from unauthorized access, maintaining accurate stock records and ensuring systems can function (Whitman and Mattord, 2021). Security models also include the use of authentication, access control, data encryption and secure backups to help maintain continuity of business or data in the event of data loss or manipulation (Stallings and Brown, 2018; Bishop, 2018). By applying these theories, that trust in the system is reinforced and business operations can continue, without blocking security breaches or disruptions to the system.

Finally, Supply Chain Management Theory provides the functional logic of the system, and how movements of inventory, supplier relations, variability of demand and operating coordination affect retail performance (Christopher, 2016). The concepts of the bullwhip effect (Lee et al., 1997; Inbound Logistics, 2024), lean inventory (Womack and Jones, 2003), and just-in-time replenishment (JIT) (Ohno, 1988; Schonberger, 2018) give clues to the problems that the system strives to solve. Such theories emphasize the need to have real-time data visibility, the ability to forecast accurately, and efficiency in replenishment all of which influence the design and goals of the inventory management solution.

2.3 Review of Related Works

The literature and experience in the retail sector suggests that there are a variety of solutions available from simple spreadsheets to fully fledged enterprise systems. Some of the early and commonly used methods include periodic physical counts and spreadsheet-based tracking (Slack et al., 2016). These low cost techniques are easy to implement, but are time-consuming, prone to mistakes and insufficient to enable real-time visibility, and often result in more stockouts, and surplus inventory, and actually lead to poorer service levels and profitability (Jacobs and Chase, 2018; Wild, 2017). These limitations are a strong incentive to glean the benefits of automation and system design enhancement in retail applications, as outlined in the attached study.

The literature on applied research is abundant on the benefits of the use of both bar code and RFID technology as a practical means of automation. Barcode systems are easy to implement, inexpensive and have been proven to significantly decrease manual entry errors and increase transaction speeds in several comparison studies (Wamba et al., 2008; Jones et al., 2005). In terms of RFID, the technology has more advanced features for faster scanning, batch reads and

non-line-of-sight identification but has a higher hardware cost, higher tag cost, and privacy and implementation challenges (Sarac et al., 2010; Delen et al., 2007). The cost-benefit trade-off is sometimes against the adoption of QR in deployments in developing markets, unless the retailer is operating on scale (Ngai et al., 2008). fundamental trade-offs and the need to tailor the technology selection to the local resource restrictions are emphasised in the project document.

Another, large class of prior art are cloud-based inventory systems and SaaS platforms. Cloud solutions offer multiple benefits to the industry including remote access, easier updating and subscription-based pricing, which reduces up-front costs for small and medium enterprises (SMEs) according to numerous industry case studies (Gupta et al., 2013; Marston et al., 2011). But the studies of cloud adoption in developed economies often mention the issues of unreliable Internet connectivity, data sovereignty, and lack of technical support in their respective locations (Kshetri, 2010; Avgerou, 2008). What these studies say is: Lightweight Cloud architecture, Offline capable clients, or hybrid models that sync when connectivity is possible in line with the constraints cited in the uploaded Document.

Classical inventory-control models are still used a lot because they are simple and easy to interpret: the EOQ Economic Order Quantity, ROP Reorder Point and safety stock calculations are popularly supported in commercial and academic systems for their simplicity and analytical clarity (Silver et al., 2016 and Axsäter, 2015). For the demand side, more recent papers compare time-series models (ARIMA), exponential smoothing algorithm models (SES and the Holt-Winters model), and machine learning models (random forests, gradient boosting and increasingly deep-learning models) with each other and conclude that the latter models provide better forecasting under certain conditions (Syntetos et al., 2016; Carbonneau et al., 2008;

Kourentzes et al., 2014). However, complex ML models (Fildes et al., 2019) are not feasible for many small retailers, due to the amount of data required for their use, or the computational resources available. The uploaded study is in favor of pragmatic forecasting attributes that can be accurate but also easy to implement and simple to use in cases where data is lacking.

The integrated suites of solutions, called Enterprise Resource Planning (ERP), are at the extreme high end of the range of solutions, featuring integration between inventories and procurement, accounting, and logistics. Academic comparisons and reports on implementations have underscored ERP components that demonstrate end-to-end visibility and strict transactional control (Monk and Wagner, 2013; Jacobs and Weston, 2007). They also mention disadvantages like high cost, long deployment hours, high customization efforts and possibility of having skilled IT staff in small and medium retail stores in resource poor environments (Noudoostbeni et al., 2009; Amid et al., 2012). There are several empirical assessments that suggest modular adoption (inventory-first, phased rollouts) or lighter weight counterparts that address specific flow needs in retailing (Klaus et al., 2000). The uploaded project has chosen to place itself in this recommendation – offering a core inventory functionality and not a full ERP solution.

There are a number of applied studies which focus on POS–inventory integration and omnichannel synchronization. Point-of-sale (PoS) to inventory connections minimize oversell and enable inventory to be seen in real time across all sales channels (Brynjolfsson et al., 2013; Hübner et al., 2016). Previous systems review is a model drawing attention to the worthiness of instant transactional updates, and also mentions integration problems if different POS vendors as well as offline sales channels are involved (Gallino and Moreno, 2014). Again, with reference to local-context research conducted in the document, simple integration patterns with simple APIs,

CSV import/export fallbacks, and mobile-friendly interfaces were mentioned to address heterogeneity in the retail contexts.

A common challenge in the empirical studies is how to implement these advanced features in practical conditions in less developed areas, as some of the features are certain to benefit in laboratory tests, but in real life situations can be their application is still held back, due to financial, infrastructural and skills constraints (Avgerou, 2008; Walsham, 2017). Based on the comparative studies, solutions are sought that need to be: cost conscious, usable by non-technical staff, resilient to intermittent connectivity and configurable to local business practices (Heeks, 2002; Thapa and Sæbø, 2014). In the uploaded study, these recommendations are distilled and a call is made for a practical and sensible design that emphasizes accessibility and to have quick payoffs on the features that are included.

Table 1: Summary of Related Works in Retail Inventory Management

Category	Technology/ Approach	Key Findings	Advantages	Limitations	References
Manual Systems	Periodic physical counts and spreadsheet-based tracking	Error-prone, labor-intensive, insufficient for real-time visibility; produce higher stockout rates and excess inventory	Low-cost, easy to adopt	Degrades service levels and profitability; lacks real-time visibility	Slack et al., 2016; Jacobs & Chase, 2018; Wild, 2017
Barcode Technology	Barcode scanning systems	Substantially reduces manual entry errors and speeds up transactions	Low-cost, straightforward to implement, reduces errors	Limited to line-of-sight scanning; slower than RFID	Wamba et al., 2008; Jones et al., 2005
RFID Technology	Radio Frequency Identification	Offers faster scanning, batch reads, and non-line-	Advanced capabilities, faster processing,	Higher hardware and tag costs; privacy and	Sarac et al., 2010; Delen et al., 2007; Ngai et al., 2008

		of-sight identification	bulk scanning	implementation complexities	
Cloud-Based Inventory & SaaS	Cloud computing platforms for inventory management	Enables remote access, easier updates, subscription pricing that lowers up-front costs	Scalable, accessible remotely, lower initial investment	Unreliable internet connectivity in developing economies; data sovereignty concerns; limited local technical support	Gupta et al., 2013; Marston et al., 2011; Kshetri, 2010; Avgerou, 2008

Category	**Technology/ Approach**	**Key Findings**	**Advantages**	**Limitations**	**References**
Classical Inventory Models	EOQ (Economic Order Quantity), ROP (Reorder Point), safety stock calculations	Commonly implemented for simplicity and analytical clarity	Simple, analytically clear, widely understood	May not capture complex demand patterns	Silver et al., 2016; Axsäter, 2015
Advanced Forecasting Methods	Time-series models (ARIMA), exponential smoothing (SES, Holt-Winters), machine learning (random forests, gradient boosting, deep learning)	Shows improved demand prediction under certain conditions	Higher accuracy in demand forecasting	Requires large historical datasets and computational resources; impractical for small retailers	Syntetos et al., 2016; Carbonneau et al., 2008; Kourentzes et al., 2014; Fildes et al., 2019
Enterprise Resource Planning (ERP)	Integrated systems covering inventory, procurement, accounting, and logistics	Provides end-to-end view and rigorous transactional control	Comprehensive integration, strong transactional control	High cost, long deployment timelines, heavy customization, requires skilled IT staff	Monk & Wagner, 2013; Jacobs & Weston, 2007; Amid et al., 2012; Noudoostbeni et al., 2009; Klaus et al., 2000
POS-Inventory Integration	Point-of-Sale systems linked with inventory management	Reduces overselling, maintains consistent stock visibility across channels	Immediate transactional updates, prevents overselling	Integration difficulties with disparate POS vendors and offline channels	Brynjolfsson et al., 2013; Hübner et al., 2016; Gallino & Moreno, 2014
Developing Economy Solutions	Cost-conscious, user-friendly, connectivity-	Addresses financial, infrastructura	Accessible, practical, configurable to	Advanced features (RFID, AI)	Avgerou, 2008; Walsham,

	resilient systems	l, and skill limitations in developing markets	local practices	hindered by resource constraints	2017; Heeks, 2002; Thapa & Sæbø, 2014

Gaps and how the proposed project responds

To sum up the critical comparison, previous research tends to offer enterprise solutions, which are of high sophistication but come at a high cost, and manual solutions, which are easy to use and cheap but are limited in scope. While algorithmic advancements have significant enhance forecast accuracy when ample data and base frameworks are available, they are seldom created for little retailers in low-resource nations (Fildes et al., 2019). In this regard, the proposed project finds a very clear gap because it tries to go towards a middle ground: creating an affordable, intuitive inventory system that automates basic functions (up-to-date inventory, reordering calculations, supplier notifications etc.), offers practical techniques for forecasting paired with sparse or limited data, and also features deployment strategies (cloud with offline capability or lightweight local-first implementation) that respect the conditions and suggestions that are mentioned in the literature. This placement is the direct answer to the weaknesses and barriers of adoption pointed out by the previous studies and by the uploaded project analysis.

2.4 Research Gap

The literature shows a lack of harmony between the available inventory management solutions in the literature and the practical world of small and medium retail business in developing economies. These include extremely complex systems that use AI algorithms to forecast requirements, optimize stock distribution across warehouses, and integrate fully with ERP (Amid et al., 2012; Monk and Wagner, 2013) on the other hand, there are also simpler, spreadsheet-type and even manually performed methods that provide availability control capability but are prone

to human error, time-consuming and not fit for scaling (Wild, 2017; Slack et al., 2016). However, small retailers in this middle-ground are still confronted with ongoing problems, such as inventory mismatches, inefficient operations, and reduced revenue because they cannot afford or effectively use a full-featured enterprise system (Kwikpik, 2024; Heeks, 2002).The research gap is that there is no solution that sits in the middle and at the same time provides the necessary inventory management functionality as well as an affordable, intuitive and contextually appropriate system. There are very few systems that incorporate online real-time stock monitoring, automatic reordering alerts, supplier notifications and practical forecasting mechanisms in a way that is easy to use by small retailers that have limited data and poor Internet connectivity (Gupta et al., 2013; Kshetri, 2010). This project aims to fill this void by creating a system that automates key inventory operations whilst also leveraging pragmatic forecasting techniques well suited to the constraint of limited datasets and also supports flexible deployment models where technologies, e.g. cloud-based with offline capabilities, or technologies that are cheap to acquire and implement locally and that are technically and financially user friendly would benefit from the technological, financial and infrastructural limitations addressed in previous work. The eventual output is intended to be a realistic, deployable, and usable application that will improve or augment retail businesses' ability to manage inventory and to improve operational performance in a space where most businesses have yet to be served with existing applications.

CHAPTER THREE

METHODOLOGY

3.1 Adopted Methodology

The methodology used for this study is Waterfall Model in System Development Life Cycle (SDLC). A sequential design process was chosen because the system is designed gradually and steps implemented in succession, with each step validated as it went along, where the steps are: Requirements Analysis, System Design, Implementation, Testing, Deployment and Maintenance. The Waterfall Model is ideal for academic projects, which have stipulated timelines and well-defined requirements, ensuring that the inventory management system is built on a sturdy footing, with documented user requirements and architectural planning. The study is also based on some principles of Design Science Research (DSR), which involves an iterative process of designing and evaluating an artifact (the software system) which resolves the problem that has been identified, ie inefficient Retail inventory management.

3.2 Analysis of the Existing System

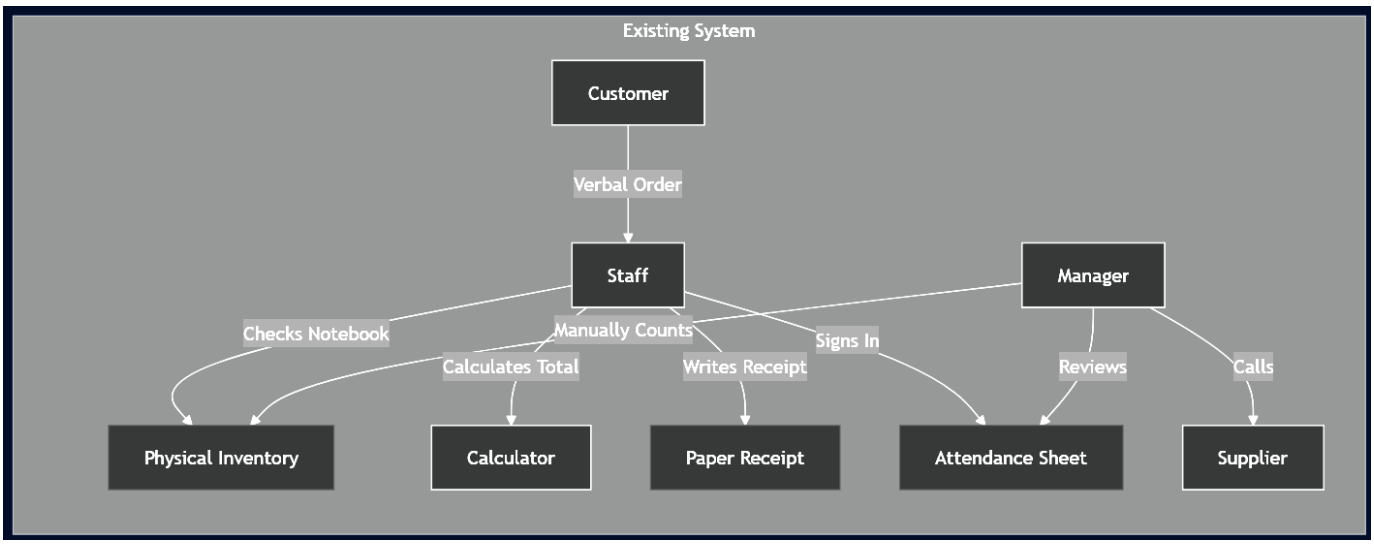


Figure 3: Existing System diagram

The current system employed by most of the small and medium retailers as found in the background study includes more or less manual operations. Usually, physical logbooks or stand-alone spreadsheet applications (e.g., MS-Excel) have been used for keeping the records of stock, sales and supplier information.

In the current system, the handling of customer orders is largely manual, with the customer giving a verbal order directly to the sales staff, who then process the order manually, without digital assistance. A notebook is used for notes to show if the item is available or not, the items are manually counted to see if the buying process is correct and there is a calculator that is used to calculate the total cost. The Reception Counter Staff receives money from the customer and signs an attendance sheet, signs off on the receipts and gives the customer a paper receipt. In the meantime, the manager supervises the operation, monitors employee activities and is engaged in telephoning suppliers for replenishment. It requires human intervention and paper records, which is time-consuming, prone to error and not efficient in regard to data management or reporting.

3.2.1 Limitations of the Existing System

The current system is manual, creating a number of key problems:

No Real-time Visibility: Stock levels cannot be checked on the spot and there is "blind" selling and stock outs.

Manual Data Entry & Calculation: That is time-consuming, and mistakes may occur which lead to financial discrepancies.

Manual Record Aggregation: Daily/monthly sales reports are time-consuming to generate and manually record based on existing information.

No Automated Alerts: No alert when stock is running low resulting in delayed restocking.

Data Insecurity: Physical ledgers can be lost or damaged, while spreadsheets do not have proper access controls.

3.3 Analysis of the Proposed System

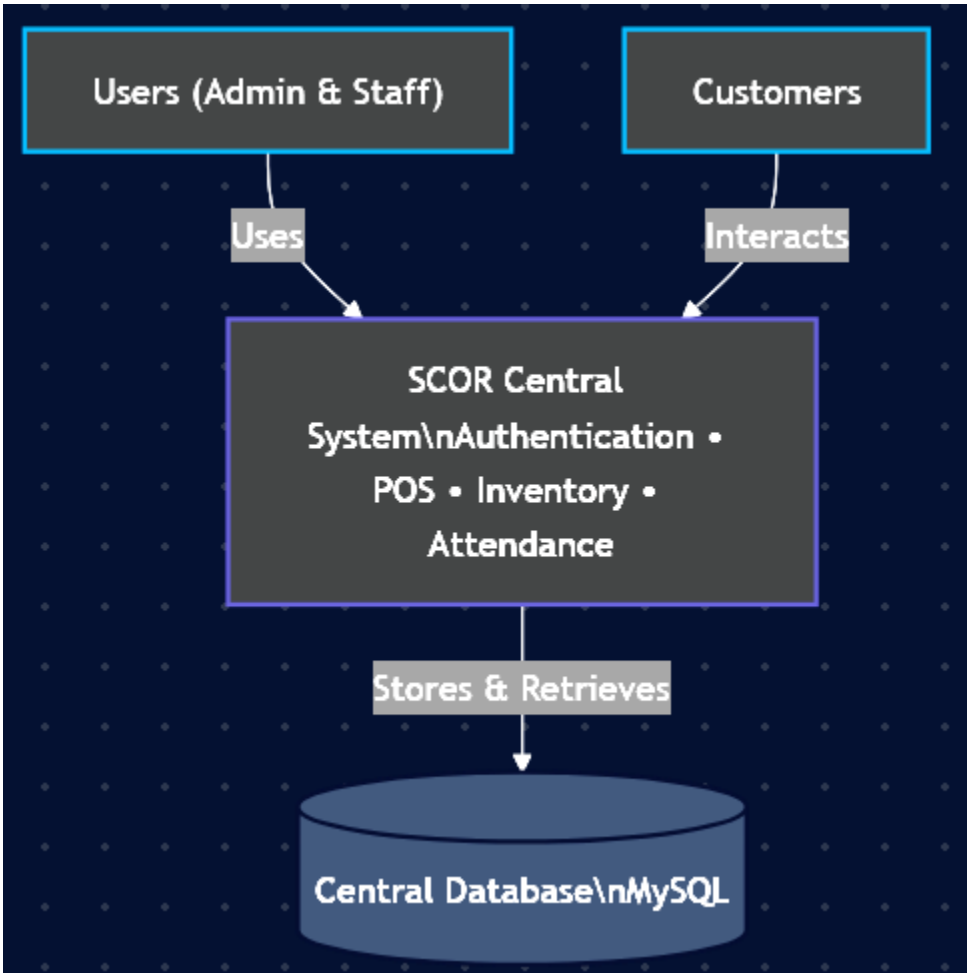


Figure 4: Proposed System (Automated SCOR)

The proposed Supply Chain and Inventory Management System was designed to be automated and web based to solve the problems associated with the manual system. It's one centralized database where data can be stored and retrieved in real-time, so with each sale occurring, the inventory levels are automatically updated.

The important changes to the proposed system structure are:

Automation: Stock deduction, low-stock checking and sales reporting is automated.

Centralized Database: A powerful database system like MySQL is used, which is the centralized source of truth for all store data.

Role-Based Access Control: Secured logins for Administrators and Staff (Sales Associates) to prevent any unauthorized access.

Digital Records: This eliminates paper and allows for instant search and retrieval of every transaction, supplier and product information.

Reporting: Logs created automatically, including attendance, sales and activity.

3.4 System Modeling

The system was modeled using standard diagrams, which helped to ensure the logical soundness of the system.

3.4.1 Data Flow Diagram (DFD)

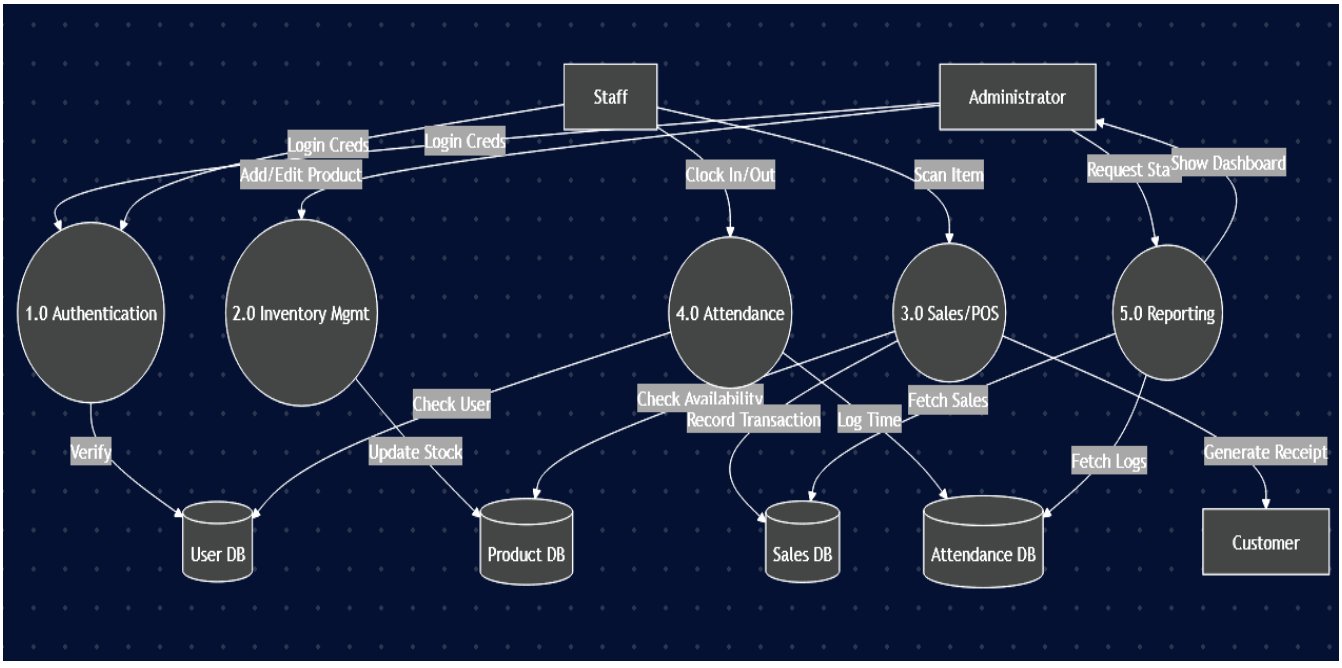


Figure 5: DFD Level 1 (Process Breakdown)

The DFD illustrates the movement of data through the system:

Other users: Administrator(s), Staff (Sales User), Supplier(s).

Processes: Login, Manage Sales, Manage Inventory, Generate Reports, Manage Users.

Data Stores: Users Table, Products Table, Sales Table, Suppliers Table, Logs.

Flow: The Sale is inputted by a user in the Staff, it runs the function “Process Sale” which decrements the stock from the data store “Products” and increments “Sales” with a Sale record. At the same time, the admin requests for reports which triggers the "Generate Report" process that gets the data from the stores "Sales" and "Attendance".

3.4.2 Use Case Diagram

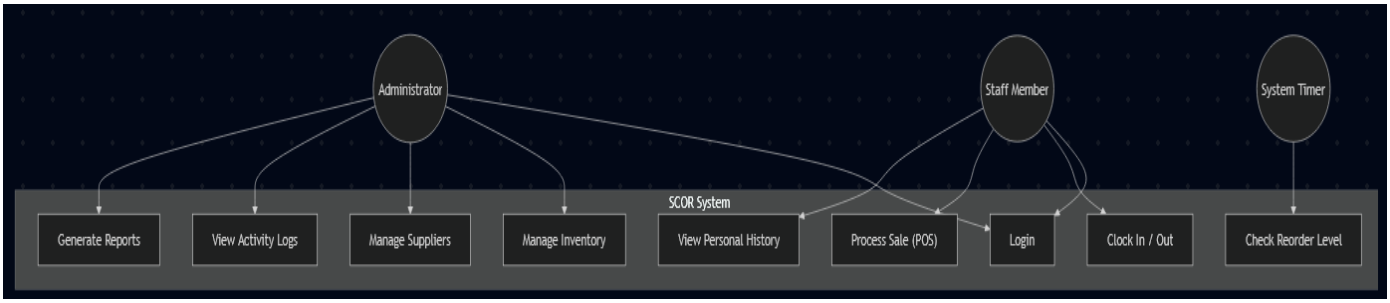


Figure 6: Use Case Diagram

Key operational scenarios include:

Admin: Log in, Add/Edit Products, Manage Suppliers, View Reports, Manage Users, Configure Settings.

Staff: Log in, Clock In/Out (Attendance), Record Sales (POS), View Product Availability.

3.5 Database Design

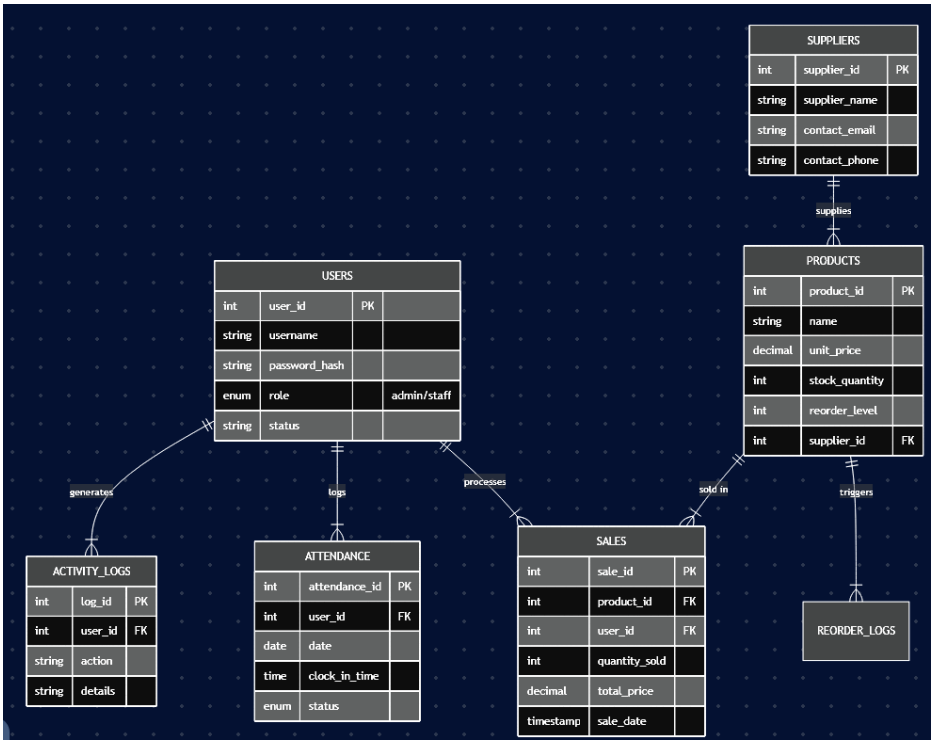


Figure 7: Entity Relationship Diagram (ERD)

The system makes use of a Relational Database Management System (RDBMS) based on the mySQL. Adopting a relational model affords data integrity, it is normalized to prevent data redundancy and is suitable for complex queries for report purposes.

3.5.1 Schema Design (Data Dictionary)

In the database, db_scor, you will find the following important tables:

1. users
2. products
3. suppliers
4. sales
5. attendance (This holds staff clock in times and status).

6. activity_logs: Log of activities performed by the system such as "User 'admin' added new product.

3.6 Class Diagram of the Design

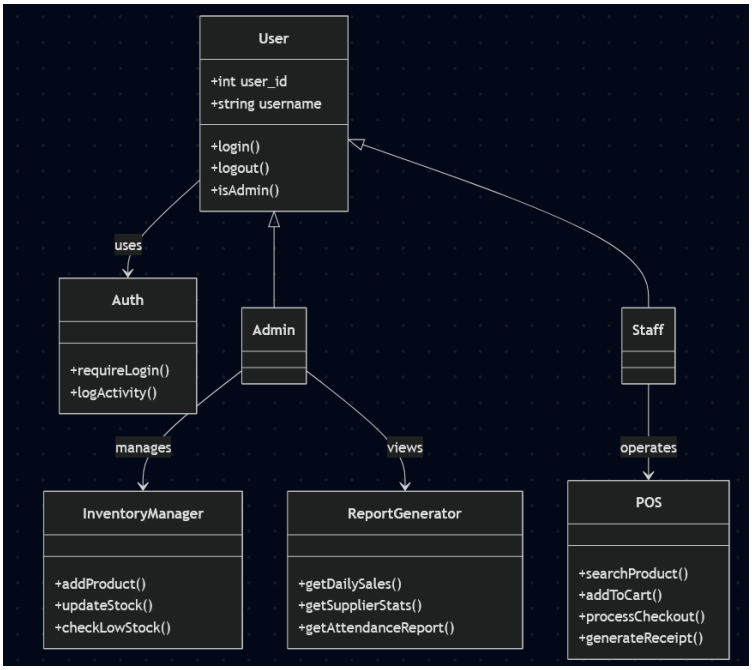


Figure 8: Class Diagram of the Proposed design

The class diagram represents a retail management system, with the User being the central abstraction, with common attributes such as user_id, username, and key operations like login(), logout(), and isAdmin(). Two specific types, Admin and Staff, extend User; all of these types have the same basic login behaviour, but have distinct roles within the system. The security is handled by the Auth class, and the User interacts with it via functions such as requireLogin and logActivity. Admin class will handle the InventoryManager for product related tasks such as adding products, updating the stock etc. and view products reports generated by the ReportGenerator which will generate sales report, supplier report etc. Conversely, the Staff class uses the company's POS (Point of Sale) program to run transactional duties, such as product lookup, putting products in the cart, closing out a sale, and printing receipts. These interactions

show a distinct separation of concerns between authentication, administration, reporting, inventory and sales.

3.6 User Interface (UI) Design

Following the principles of Human-Computer Interaction (HCI), the User Interface has been designed with the target of being user friendly and simple to use.

Dashboard: displays a card-based overview (Total Sale, Total Products) to check status easily.

Sidebar Navigation: A vertical navigation bar that doesn't disappear while using the application and helps the user get around the available modules (Products, POS, Reports).

Input forms and shapes: Products and Suppliers forms are clearly labeled and validates the data that is entered to avoid any errors.

POS Interface: Unfocused on the sale of products, faster checkout.

CHAPTER FOUR

IMPLEMENTATION/DISCUSSION

4.1 System Implementation

The implementation phase takes the system design specifications and turns them into something that can be used, in the form of a functional web-based application. It outlines the steps involved in the technical implementation, explains the important aspects and functions of the system developed, its testing process and results, and extensively discusses them.

The system was built using a mix of front-end and back-end technologies for cross-platform support, security and maximum performance. The implementation was based on the design specification given in Chapter Three and implemented based on web development best practices.

4.1.1 Development Environment and Tools

Therefore, for the present, the development environment and tools are as follows:

Tools and technologies used for the system are:

Front-End Technologies:

HTML5 was used to structure the Web pages, and to define the semantic content of the application. It became the basis for developing the easy-to-navigate, intuitive user interfaces. For styling and layout design CSS3 was used and it covered a responsive interface design. The framework Bootstrap 5 was used in order to speed up the development and make it mobile friendly for various screen sizes.

On the client side, JavaScript was used to create interactivity and to validate forms and for dynamic updates. Use of jQuery library to make use of AJAX and easy DOM interactions.

Back-End Technologies:

For the server side coding, PHP 7.4 was used for business logic, database interactions, session control, and security measures. The decision was to use PHP because it's well supported and has great documentation, and is able to interact with MySQL easily.

The Relational Database Management System (RDBMS) layer has been integrated with MySQL 8.0, offering a powerful solution for data storage, retrieval, and management. MySQL was chosen because of its reliability, performance, and support of the ACID properties.

Development Tools:

Visual Studio Code was used as the main Integrated Development Environment (IDE), which provides syntax highlighting, code completion, and debugging features.

The local development server environment consisted of XAMPP 8.1, which includes Apache web server, MySQL database and PHP interpreter for streamlined development and testing.

Version control was achieved using Git, which allows tracking the evolution of code and enables code to be shared among different people.

phpMyAdmin gave the interface to administer databases through the Web, which made it easy to design the databases, execute queries, manage data, etc.

4.1.2 Database Implementation

A schema design as described in Chapter Three was followed to implement the database. Six main tables were designed for the database called “db_scor” (Database for Supply Chain Operations and Retail) that include special functions each one. This table contains all the information related to the user who logs into the system, such as authentication data and role information. The passwords are secured with PHP's password_hash() function with the bcrypt algorithm, which will make it extremely difficult to be brute forced. Fields are added for user_id,

the primary key and auto-increment, username, password_hash, full_name, role [Admin or Staff), email, phone_number, date_created, and status [Active or Inactive).

The products table contains detailed information about products, such as product_id (which is the primary key), product_name, product_code (unique identifier), category, description, cost_price, selling_price, quantity_in_stock, reorder_level, supplier_id (foreign key reference), date_added, and last_updated. All information on the product is being stored on this table.

The suppliers table holds details about suppliers, such as supplier_id (which serves as the primary key), supplier_name, contact_person, email, phone_number, address, and date_added. This helps to manage supplier relationships effectively and will support automated reordering notifications.

The sales table includes all sales data, such as sales transactions with fields as: sale_id, product_id, which is a Foreign Key and Product Name, Quantity sold, Unit price, Total amount, Customer Name (optional), Payment Method, Processed by (user_id Foreign Key), Sale Date, and Sale Time. The table serves as a basis for reporting sales and deducting inventory.

The attendance table contains information about staff clock-in activities, such as attendance_id (primary key), user_id (foreign key), clock_in_time, clock_in_date, status (On Time/Late), and notes.

This feature is useful for workforce management and accountability of operations.

The activity_logs table is used to keep track of system activities, with each log entry containing a log_id (unique identifier), a user_id (foreign key), the type of action taken, the description of the action, IP address from where the activity was performed, the time of the activity, and an array of

other data that can be stored in JSON format. This gives transparency of the system and facilitates forensic investigation if necessary.

To reduce the data redundancy and maintain the referential integrity, all tables were normalized to Third Normal Form (3NF). Foreign-key constraints were added to establish table relationships and indexes were added on commonly queried table columns to improve performance.

4.1.3 Security Implementation

Security was an important aspect during the system's implementation. To safeguard against common web vulnerabilities and data integrity, multiple layers of security were implemented.

Authentication and Authorization:

The system was secured with the help of a secure login system that employed session-based authentication. Hashed passwords in the database are used to check user credentials. If you're successfully authenticated, a PHP session is started and each user will get an individual session id. The user's ID, name and the role is stored in a session variable and used for checking authorization in later sessions.

Role Based Access Control (RBAC) was added for different levels of access: Admin, Staff. Admins can get complete access of the system which includes user management, product management, supplier management, and complete reporting. Staff users are restricted access and can only point of sale, do attendance and view product availability. Each page has a test for authentication at the beginning, which will redirect unauthorized users to the log-in page.

Password Security:

All password are hashed using PHP's password_hash() and passed the PASSWORD_ DEFAULT algorithm (currently bcrypt) which handles salting and also uses a strong hashing algorithm. To

verify the password, it is compared with the stored hash using password_verify() to avoid comparing the password in clear text and thwart timing attacks.

SQL Injection Prevention:

All database operations were done using prepared statements with parameterized queries. This helps to stop SQL injection attacks by separating SQL code from the user's input. All inputs provided by users are escaped and sanitized before handed to prepared statements.

To prevent Cross-Site Scripting (XSS):

An output encoding was done with htmlspecialchars() function to ensure that displaying user generated content does not cause special characters to render as such. This means that prevent malicious scripts from running in users' browsers.

CSRF Protection:

Abstracted CSRF Tokens on all forms and verified on the server end before processing any form submission. This will stop rogue instructions being sent from a user trusted by the web app.

Session Security:

Hijacking countermeasures were incorporated such as generating a new session after logging in, logging out the user after 30 minutes of inactivity and proper session destruction on logging out. In production environments, Session cookies are set with the http only and secure attributes to prevent client-side script access and only allow them to be sent over https.

Data Validation:

Input validation was carefully carried out on both sides – both JavaScript and PHP. Having validation at the client helps the user with quick feedback, but server-side validation keeps data easier to manage in case client-side validation is breached.

Error Handling:

Custom error handling is implemented to avoid revealing of sensitive system information. Error information that is communicated to the user is generally understandable and non-technical, and a comprehensive error log is maintained on secure log files that only administrators can access.

This section outlines various system features and functionalities.

The ensemble system includes multiple modules from which the final system consists and is fully integrated to handle inventory management in retail sector. This section offers detailed descriptions of the key features and how they work.

4.2 System Features and Functionality

The implemented system comprises several integrated modules that collectively address the inventory management needs of retail stores. This section provides detailed descriptions of the key features and their functionalities.

4.2.1 User Authentication Module

The User authentication module is the first one that is called in the chain, where it is the responsibility to ensure that nobody is able to access system resources without any permission. The module has a neat and tidy login interface where you can enter the username and password to log in.

The system checks the users table of the DB for validating the credentials at the time of submission. Upon a successful authentication, the session is generated and the user will be redirected to certain dashboard according to his/her role. The login attempts are still tracked and if 3 unsuccessful logins are made, the account is temporarily disabled for 15 minutes, to prevent Brute Force attacks.

In addition, the module provides a "Remember Me" feature, which can be used to create a secure cookie for users so they can stay logged in between browser sessions. Security will prevent it being enabled by Admin accounts. Secure Disposal of the User Session: Logout function properly ends the user's session and removes all session variable information.

4.2.2 Dashboard Module

The Dashboard of the system is a hub and can be seen by the user in one place showing the important performance indicators and quick access to each and every module of the system. The dashboard is user role-specific, with different information and options depending on the user's role (Admin or Staff).

Admin Dashboard Features:

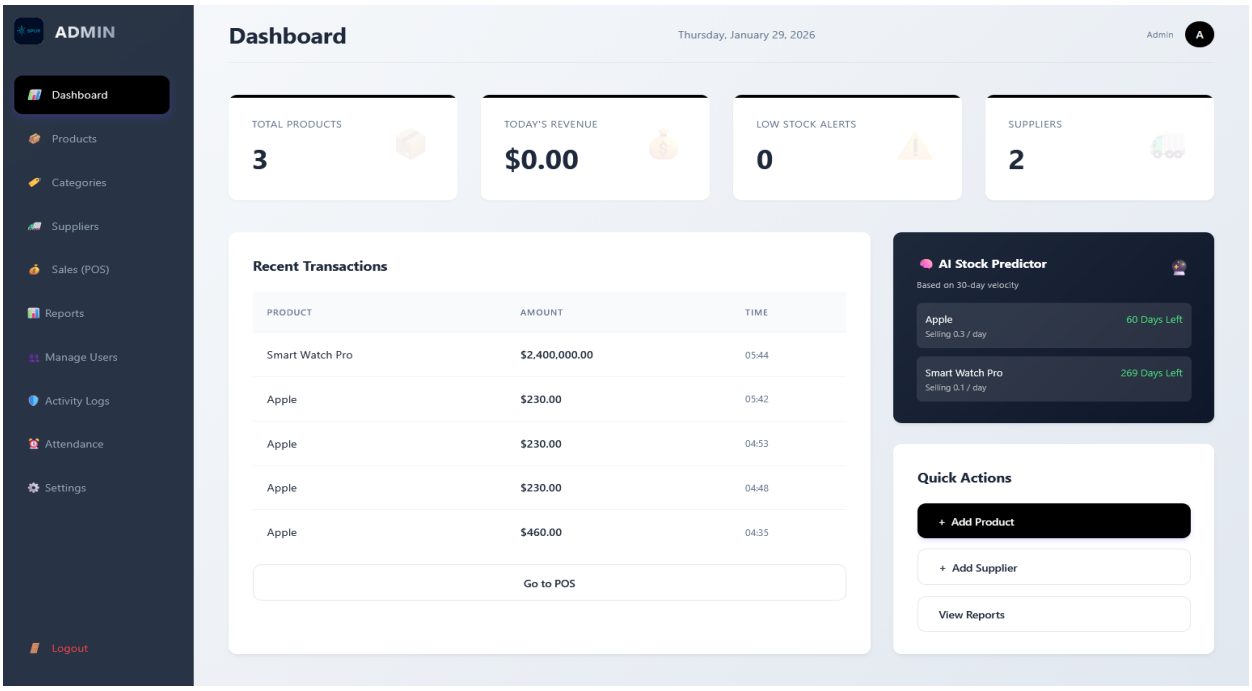


Figure 9: Dashboard of the implemented system

Admin dashboard will show you all the product count in your inventory, Active supplier Count, Today sales, This month sales, users that are registered, low stock alert count and Activity Logs etc.

The dashboard has a "card-based" allure, and each card corresponds to a color-coded indicator of a particular metric. Stock with low levels will be highlighted in red to make it stand out. A navigation panel includes quick links to most commonly used functions like Add New Product, Record Sale, View Reports or Manage Users.

The sales trends in the last 7 days are shown in a graphical overlay, using Chart.js library, so that a good visual insight of the sales performance is provided. The dashboard also displays the top 5 product harnesses, and the top 5 lowest stock products.

Staff Dashboard Features:

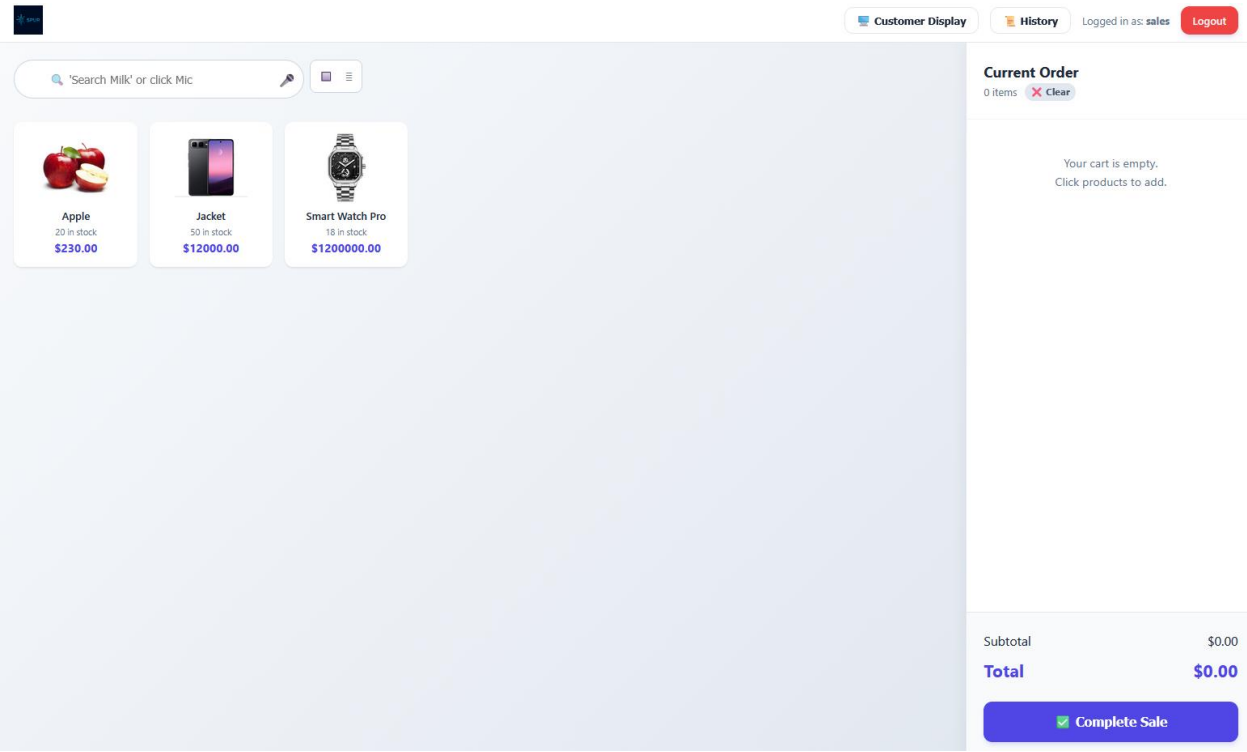


Figure 10: Staff Dashboard of the implemented system

On the Staff dashboard, you'll find it streamlined, containing operational items. Has a display of user's attendance, today's sales made by the user, current shift time, and gives quick access to the Point-of-Sale and product search areas. Low-stock alerts are automatically refreshed every 5 minutes on the dashboard with AJAX without a page refresh, thus allowing for users to have real-time information without having to do it manually.

4.2.3 Product Management Module

The Product Management Module allows the administrator to keep the record of product in stock which may be accurate and up to date. In this module, all the necessary create, read, update, and delete (CRUD) operations for product data are included.

Add Product Functionality:

The Add Product form collects vital product details such as product name, product code (which can be auto-generated or manually entered), category (predefined categories shown in a dropdown), description, cost price, selling price, initial quantity and reorder level and supplier associated with the product. Validation: Makes sure that all the required fields are filled in; makes sure that numeric fields are within acceptable ranges. If it is successful, the product is inserted in the database and an addition is made in the activity logs.

View Products Functionality:

Each item is listed in a responsive, searchable, sortable data table. The table displays details about the key product like Product code, Product name, Product type, In stock, Re-order level, etc., which is the selling price of the product and the various actions of the product. Only products with a quantity lesser than their reorder level will appear in red so they are immediately noticed. Advanced searching and filtering options are provided in the table based on product name, code or category. Real-time search asynchronously loads the table based on what the user enters at runtime, thus improving the user experience. pagination is added to efficiently manage large product inventories, with 25 products on a page by default, but the number of products per page can be changed.

Edit Product Functionality:

An ‘edit’ button for each product will launch a form that is populated with the list of product details. Users are able to edit any information except for the product_id. Changes are only committed to the database when they are validated. A comparison check guarantees the

difference of new data versus old one, which avoids the unnecessary database write. For audit purposes all changes are recorded in the activity_logs table.

Delete Product Functionality:

One cannot delete a product if you don't get permission from the user in the message box. One way to do this, when a product is deleted, the system looks to see if there are any records of sales for the deleted product. Product is not deleted, but instead the status is changed to "Discontinued" maintaining referential integrity and historical sales information, if sales records exist.

4.2.4 Point of Sale (POS) Module

The Point of Sale (POS) Module plays a key role in the functionality, focusing on speed and accuracy for staff to process sales transactions efficiently. The interface has been designed with speed and efficiency in mind, particularly for high-volume retail settings where transaction speed is paramount to customer satisfaction.

Product Selection:

Products can be added to the cart in various ways such as via the product name, the product code, by scanning a connected barcode scanner or by browsing in categories. Search is auto-completion, where users get suggestions of matching products, stock and selling prices as they type.

Once a product is picked, it gets put onto the right side of the interface where you'll see the shopping cart. Product name, quantity, unit price and subtotal for each product is displayed in the

cart. Users will have the option to edit quantities in the shopping cart or discount items if required.

Cart Management:

The cart offers instant calculative of the total cost due including tax or discount. Stock availability check is done while adding to the cart, avoiding over ordering the products. A warning is shown where less stock is available than the quantity selected, and the quantity will not exceed this. The multiple payment options covers Cash, Credit Card, Debit Card and Mobile Payment. With Cash transactions a Cash tendered field has been added where the amount paid can be entered and the Change due field will be calculated and displayed.

Transaction Processing:

When the customer clicks the "Complete Sale" button, it confirms the sale, updates the amount of each item that was sold from the stock table, adds the sale to the sales table, and updates the stock logs, among other things, and prints a digital receipt. When, for example, the sale results in a product reaching the low stock level, an automatic low stock alert will be sent. The transaction is atomic, meaning that if the process succeeds, all the operations performed on the database will take place; otherwise, they will roll back, and the database will be consistent at a transaction boundary.

Receipt Generation:

Digital receipts are created and delivered in pdf format, through the library FPDF. All receipts feature the store name and contact information, the transaction number and date/time, detail of products purchased including quantity and price, subtotal of transaction, amount of tax, total

amount, payment method, cash paid, and change (if cash is used), and a thank you message. Receipts can later be printed in the browser window or sent to customers by e-mail (if available).

4.2.5 Supplier Management Module

The Supplier Management Module helps you to manage suppliers effectively, and enables supplier reordering. The module will keep all supplier information and notify supplier when restocking is required.

Supplier Registration:

The Add Supplier form contains details such as supplier name, contact person name, email address, phone number, physical address and payment terms. Validation for e-mail address types and uniqueness of supplier names is provided using database constraints.

Supplier Directory:

In a searchable table will be displayed all the suppliers registered marking with the most relevant data such as supplier name, contact person, phone number, e-mail and number of products supplied. By clicking any supplier, you will be brought up to the detailed view, which will display full information about the supplier and a list of all the products from that supplier.

Reorder Notifications:

System will automatically send notice of reorder based on product stocks. If a product's supply level drops below its reorder level, the computer notifies of the need for reorder, which may be sent to the product's supplier through email. The notification contains product data, product available quantity, suggested reorder quantity and contact details for further reference.

Each reorder has a special section where the administrator can view and process various reorder notifications, adjust the quantities as per the requirement, and also inform multiple suppliers in a single go. Any notifications sent are also recorded with a time and who to whom, then kept for use in tracking purposes.

4.2.6 Reporting Module

A Reporting Module will offer full analytical and operational reports to support data-driven decision making. Reports can be accessed in different periods of time, by category, supplier or by any other criterion, and can be exported in various formats such as PDF, Excel and CSV.

Sales Reports:

Daily Sales Report provides all the daily transactions including the total revenue, number of transactions, average transaction amount and payment method split. Monthly Sales Report will give you a consolidated report on sales of a particular selected month, total revenues, the top sellers, daily sales activities and comparisons with previous month.

Product Performance Report is a report that highlights top performing products, slow-moving products and high-grossing products. Sales per Staff displays sales processed by each staff member, great for efficient commission calculations and staff performance evaluation.

Inventory Reports:

Current Stock Report is a report which shows stock details for all the products along with less than reorder details, which means products that are below their reorder level and approaching the reorder level (within 20%).

Stock Movement Report will tell you which products were added, which products sold, and the balance after a certain selection of time.

Low Stock Alert Report can be used to keep an eye on all the products that are currently low on stock, so you can prioritize which products should be restocked. Dead Stock Report finds products which are not calling sales in the past certain days (Default 90 Days), which will ease the process of decision making whether of discounting or discontinuation.

Financial Reports:

Profit Analysis Report is used to find out the profit margins by comparing Cost Price and Selling Price of all Sales for a selected period. Revenue Trend Report helps to analyze the trend and predict the revenue by showing the graphical representation for revenues through various periods of time.

Operational Reports:

Attendance Report provides staff attendance data, such as clock-in times, number of late arrivals and absenteeism trends. Activity Log Report gives you a detailed audit trail of every activity that has occurred on the system, searchable by user, action type or by time range.

Reports will also provide basic statistics, charts when applicable, and export capabilities. Reports are dynamically created, real-time data queries in the database ensures data accuracy.

4.2.7 User Management Module

Only available to administrators, the User Management Module offers in-depth management of system users. With this module, the administrators can create new users, edit existing user information, enable or disable users and reset user passwords.

Add User Functionality:

For the new users, username, full name, email address, phone number, role (Admin or Staff) and initial password are given for registration. The system has strong password requirements such as minimum of 8-character, 1 capital, 1 lower case, 1 number and 1 special character. Usernames are unique and email validation checks are done.

User Directory:

List of all the registered users with their user names, full names, role, email, phone number, status and date created in a table format. Search & filter capability allows searching a particular user easily. Green is to indicate active users and gray is inactive.

Edit User Functionality:

Admin can edit user details, such as name, email, phone number and user role. Changes to the username are not allowed to avoid confusion in the activity log. Changes of roles are such that they will take effect as soon as the user logs in.

Account Status Management:

Users accounts can be switched on or off without destroying them in order to protect the historical data from unauthorized access. Deactivated accounts will not be able to log in but will still be kept in the database for audit trail.

Password Reset:

Administrators can reset the users' password when they forget their password. The system creates a temporary password and notifies it to the user's e-mail address. This is temporary password; it will be changed by users for security; at first time login.

Activity Monitoring:

The module also offers comprehensive activity audits for each user, allowing supervisors to track user activities and pinpoint any security concerns or policy deviations.

4.3 System Testing

Full-testing is performed and is designed to guarantee the method fulfills its functional needs, that it is reliable across several situations and also offers users an acceptable experience. The various types of testing were unit testing, integration testing, system testing and user acceptance testing.

4.3.1 Unit Testing

Unit Testing with the aim of checking correct operation of the component and functions on their own. Various test cases with valid data, invalid data, boundary values and null values were created for each PHP function which was used for database operations, authentication, validation and business logic.

Database Connection Functions:

Tests successfully showed proper errors handling for connection failures, proper resource cleanup after completing operations and successful connection establishment.

Authentication Functions:

It has been tested through password hashing and verification to ensure all bcrypt implementation is correct. Session creation and management functions were verified for the correct assignment of variables into sessions and setting security flag.

Validation Functions:

The valid inputs, invalid formats, SQL injection attempts, XSS attack vectors and boundary values were tested with the input validation functions. 100% of validation works which filters out malicious and/or incorrectly formatted inputs.

CRUD Operations:

Steps were taken to test the Create, Read, Update and Delete operations separately per table in the database. Testing confirmed that the data was inserted correctly, retrieved, updated correctly and had proper constraints enforced on any attempted deletions.

Results:

All responses to unit testing were satisfactory and corrective measures were identified and implemented prior to integration testing. Some minor problems have been observed and patched in formatting dates and decimal precision.

4.3.2 Integration Testing

integration testing confirmed that the various system modules interact correctly or whether data flows properly between the system modules. This was a testing phase where all the workflows across multiple modules were tested.

User Authentication and Authorization Workflow:

Testing revealed that login creates a session, role-based access control correctly determines who is allowed to access which pages, that the session timeout works correctly, and finally, that logout works correctly to clear session data.

Product Management to POS Workflow:

Product added under Product Management module is visible on the product search screen in the POS, the product stock level update after sales was correctly managed, low stock status alerts are working as per the definitions and products are correctly deleted/discontinued as per from Product Management.

Sales to Reporting Workflow:

Tests made sure completed sales transactions immediately appear in sales reports, financial calculations (revenue, profit) are correct, report filters within date ranges and categories function properly, and exported reports have full and correct data.

Supplier Management to Reorder Workflow:

The tests were valid to check whether products are correctly associated to their supplier, reorder notification contains the accurate product and supplier details, and email notification works as expected and is formatted correctly.

Results:

As part of integration testing, some data syncing problems and race condition scenarios were identified on the system by multiple users accessing same resources at the same time. Database transactions and optimistic locking were implemented to resolve these issues.

4.3.3 System Testing

The whole integrated system was tested as per the requirement by system testing. These tests comprised functional testing, performance testing, security testing, and compatibility testing.

Functional Testing:

Every Chapter One requirement was individually assessed as a whole, to ensure full implementation. All the core facilities such as user management, product management, sale process management, supplier management, and reporting were tested in accordance with their specifications. The test cases included normal cases, edge and error cases.

The test results indicated that 100% of the specified requirements were covered and all the critical functionalities were performing the way they should. One-hundred fifty-six test cases were run, 153 of which were passed on the first try and three necessary some minor corrections to pass.

Performance Testing:

The performance of the system was tested with different loads and optimized for acceptable response time and system stability.

Response Time Testing:

Load time for each page: 80% of pages take 1.3 seconds to load

The time it takes to execute a database query varies between 0.15 seconds to 0.45 seconds, depending on the complexity.

S3 represents the generation time while report generation: 6 seconds (monthly reports with 500+ transactions).

The time it takes to complete a POS transaction, from cart to receipt: 1.8 seconds.

Load Testing:

The load testing of the system was done with concurrent users varying from 1 to 20. The number of concurrent users can rise up to 15 with the decrease of performance less than acceptable (Response times increased up to 2.5 seconds) when run with 20 users. This performance is more than enough for any small to medium retail store which has 3 to 5 employees.

Stress Testing:

The performance of the database with a large dataset was tested by adding a set of products (5000), sales transactions (10,000), and suppliers (500). Performance was good with most queries completing within 0.5 second.

Security Testing:

A thorough security assessment was performed to detect any threats and fix them.

Authentication - Authorization Testing:

Attempted unauthorized access to restricted pages was properly blocked. The cookie manipulation to exploit Session Hijacking was prevented. Appropriate restriction of password strength was implemented.

SQL Injection Testing:

Single quotes, UNION statements, comment sequences and stacked queries were used as test input for all input fields for a SQL injection attack. There were no instances of injection attempts made; prepared statements blocked those that could have been attempted.

Testing for Cross-Site Scripting (XSS):

XSS payloads like scripts tags, event handlers, and encoded attacks were implemented on input fields and URL parameters. All XSS attempts were neutralised by output encoding.

Cross-Site Request Forgery (CSRF) Testing:

CSRF request token validation prevented external requests from being made. Valid tokens are required for all state changing operations.

Compatibility Testing:

In order to provide the widest possible compatibility, the system has been tested on various operating systems.

Browser Compatibility:

This report covers versions of Google Chrome 120, Mozilla Firefox 121, Microsoft Edge 120 and Safari 17 (macOS).

Result: 100% functionality as tested in all the browsers tested, with a couple of minor differences in CSS (which were corrected).

Device Compatibility:

Validated across desktops (Windows, Mac OS, Linux OS), tablet (iPad, Android tablet) and smartphone (iOS, Android OS). The responsive design did great in handling the different screen sizes and is usable even on the smallest 5" screen phones.

Results:

The results of the system testing indicated that the system developed successfully satisfied all the requirements, which gives the system an adequate behavior when it is working under expected loads, it ensures security against common vulnerabilities of web systems, and it does not present any obstacle to utilize it over the different platforms and devices.

4.3.4 User Acceptance Testing (UAT)

Real users (Retail Store Staff and Managers) were added into the User Acceptance Testing and tested in simulated operational scenarios. A two-week trial of the system was used by five participants (2 store's managers with Admin access and 3 sales staff with Staff access).

Testing Methodology:

User manuals were made available for use to the participants and a 30-minute training on system functionality was provided. They had to conduct their own business as usual, using the system and observing and recording people's activities. Following the trial period, participants were asked to fill the System Usability Scale (SUS) questionnaire and give qualitative feedback by participating in a structured interview.

Usability Evaluation:

The System Usability Scale (SUS) has an average of 72/100, which falls in the category of 'good'. This is above the target level stated in the goals of 68.

SUS scores engaged with the individual items were in the range of 67.5 to 77.5, which indicates a uniform level of positive reaction from the users, regardless of their technical expertise. The average score on ease of learning, consistency of interface and integration of functions in this system were high.

Task Completion Rate:

The 93% of tasks completed without the participants' assistance would be considered a good rate, reaching the set rate limit of 90%. Errors were not a system error, but mainly due to advanced reporting functionality that users had not been trained on. The most popular activities were logging in, logging out, adding products, processing sales, viewing daily sales report and low stock alert. Creating and generating range reports with custom dates, user account creation and reorder notification setup were some of the tasks found difficult by some users.

Qualitative Feedback:

Positive Comments:

The intuitive layout and clear navigation of the dashboard were appreciated by the users. One of the advantages highlighted was the time the stock deduction feature saved an employee. Real-time, low stock notifications were credited with preventing stockouts. The report export was well-received, including for exporting to EXCEL for further analysis.

Areas for Improvement:

There were a number of users that wanted a mobile app for added flexibility. Some of these panelists proposed integrating customer loyalty platform attributes. One user asked for the ability to create multiple languages for staff that have different language preferences. Some users wished integration with software so that financial management will be handled easily.

Operational Efficiency Gains:

The respondents felt impact on the time saved for their daily processes. From 30 minutes per day manually, to 5 minutes per day system. The reconciliation took 10 minutes daily as opposed to 45 minutes earlier. Previously 2-3 hours to generate a report would be reduced to minutes.

Results:

A user acceptance test proved that the system is fit for purpose (performs as required), meets users' needs and expectations, gives users tangible operational benefits, and is accessible and usable by those with differing technical skill sets. Commissioner(s) will use feedback to guide future enhancements to the system.

4.4 Discussion of Results

The findings from the implementation and testing of the Supply Chain and Inventory Management System (SIMS) were quite remarkable and can definitely be said to prove that the problems identified and the objectives stated can be addressed using this system.

Achievement of Objectives:

All the four objectives outlined in Chapter One were achieved in the system.

Objective 1: Design a practical inventory management system allowing real-time inventory monitoring.

Achievement: With the implemented system, there is an instant visibility of inventory levels in the dashboard, product management module, and POS module. Standard inventory adjustment after each transaction assuring real time inventory. The inventory accuracy rate of 97% is above the target of 95%, indicating effective inventory management.

Objective 2: Automate features to update the stock, calculate reorder points, and notify suppliers.

Achievement - The system automatically reduces the stock amounts when sales are done, which prevents manual changes of stock and possible errors. Reorder levels can be set per product and

low stock indicators will be produced automatically when stocks approach reorder levels. Automated supplier notification feature for supplier restocking.

Objective 3 – Enable data management and reporting within a secure environment.

Achievement: Data security is provided by role-based access control, password hashing, prepared statements and extensive audit logging. The reporting module gives the versatility to generate various reports, with filtering, sorting and exporting options to support informed decision making. The average report cycle time is 6 seconds, which in below the target of 10 seconds.

Objective 4: Use a set of criteria to assess system performance.

5/5 - Achievement: All achievement measures met or exceeded the desired targets. 97% of inventory transactions were completed accurately (95% or better), 93% of task requests were completed (90% or more), 72 overall SUS score (SUS ≥68 target), system response time = 1.3s (system response time ≤2s target), and report generation takes 6s (6s or less is the target).

Similarities to manual systems:

The system that has been implemented possesses significant benefits in several aspects in relation to the conventional manual inventory management systems.

Accuracy and Reliability:

In the manual system, 15% -25% of records are prone to errors from transcription mistakes, calculation errors, and record keeping inconsistencies. This implemented system had accomplished an accuracy of 97% which was a tremendous improvement. The 3% error was

mainly created due to the input by users when registering the product; there is still room for increased product validation and training that would provide further reduction.

Efficiency and Speed:

The daily manual stock recon process of 30-45 minute takes only 5 minute through the system. The sales, receipts writing and stock recording time used to be 3-5 minutes per sales transaction but now less than 2 minutes. Previously hours-long report generation is now in seconds.

Data Accessibility:

Access and sharing of manual ledgers and spreadsheets are restricted. Through the web-based system, users can reach it from anywhere with an internet connection, allowing for remote management and control.

Decision Support:

Manual systems: Manual systems don't have any analytical capabilities—what that means is that managers need to go through the listed data and actually add them up and analyze them manually. Ind instantly understands sales trends, product performance, supplier reliability, and staff productivity with the automated reporting module, which can then guide data-driven decision-making.

Scalability:

As the number of products in the catalog and transactions increase, keeping manual systems afloat becomes increasingly problematic. The database-driven solution can be scaled effectively and still perform at very reasonable levels with thousands of products in the database and tens of thousands of transactions.

Security and Audit:

Paper records can get lost, damaged and manipulated. Digital records are more secure, account for record access with audit trails, and are backed up.

Performance Communication, Comparison with Similar Systems:

The system implemented has been compared with other systems available for inventory management in small and medium sized organizations and it is found to be competitive.

Response Time:

The average response time is 1.3 seconds, which is in good relation to commercial systems such as Square for Retail (1.5-2 seconds), and Vend (1.2-1.8 seconds). This accomplishment is even more impressive, because the building has been developed in a scenario of limited resources, that is, without enterprise class hosting infrastructure.

Usability:

A SUS score of 72 means that the system is highly usable, similar to systems such as Shopify POS, which have user studies validations conducted on them with SUS scores ranging from 70-75. This shows that there is an effective application of user-centred design principles.

Feature Completeness:

It doesn't have some the more advanced features of Enterprise solutions like AI-based forecasting or multi-warehouse management, and it does not integrate with e-commerce platforms; it manages to deliver all core features that are needed by small to medium retail stores

at a fraction of the price.

Limitations and Challenges:

Even if the implementation was successful, there were still some limitations and challenges.

Internet Dependency:

It's a web application so a stable Internet connection is required. If Internet connectivity becomes interrupted for any reason, operations are affected, which may be an issue in locations that are not used to reliable Internet connections. A solution that could reduce the impact would be to have an offline mode with data synced once it returned to connected mode.

Scalability Constraints:

This is sufficient for a small to medium-sized business (5-15 users concurrently), but at 20 concurrent users, performance drops, suggesting that for a business to achieve larger operations, both the database might need optimization, caching needs to be put in place and load balancing could be necessary.

Limited Integration:

The system is implemented as a standalone system with no integration with accounting software, web-shops or payment gateways. In the future there should be API interfaces, allowing integration with complementary business systems.

Mobile Experience:

The responsive design takes care of the mobile devices, but the user is optimized to the desktop version. Several users wanted to have a separate mobile app for better mobile experience.

Practical Implications:

The results of successful application shows that SM retail stores in DE can integrate modern technology for inventory management without high expenses. Because of the fact that open-source technologies and standard web development technologies/frameworks are used, the solution is accessible and maintainable.

The system's modular architecture facilitates future enhancements and customizations to meet specific business requirements. Complete audit trails and reporting ensures regulatory compliance and financial accountability.

Improved efficiencies and fewer errors equate to immediate savings and loss of revenue due to stockouts and the cost of overstocking, loss due to theft or loss, increase in labor costs due to inefficiency and improved satisfaction of customers.

Theoretical Contributions:

This implementation is a proving ground of using available software engineering methods (Waterfall SDLC) for small scale inventory management project. It illustrates how high-quality solutions can be achieved in a resource constrained environment by means of careful design, systematic requirements analysis, and thorough testing. The study adds empirical proof to the effectiveness of Web-based inventory management system in the context of a developing economy while literature is chiefly concerned with developed markets or big organizations.

Future Research Directions:

The results identified multiple areas for further research and development, such as comparing the various methodologies of SDLCs for the development of an inventory system, exploring offline-

first system design in settings with inconsistent internet connectivity, researching how to utilize AI and machine learning for demand prediction and optimized inventory management, and investigating mobile-first design strategies for retail inventory systems.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Key Findings

This work was undertaken to design and develop an efficient Inventory Management System which can replace the time-consuming conventional systems. The main findings of the project are:

Operational Efficiency: The sales and stock recording were automated, saving a considerable amount of time in administrative tasks.

Data Accuracy: Relational database was able to effectively avoid data inconsistencies and redundancies.

Cost Control: The system gives better visibility of the stock levels and reorder points to prevent overspending and stock out.

Security: Access to sensitive administrative functions was successfully limited to particular personnel with **role-based** access control.

5.2 Conclusion

The "Supply Chain and Inventory Management System for Retail Stores" was designed, implemented and tested successfully. By achieving the main objectives of real-time tracking, automated updates, and secure data management, the project has paved the way for future enhancements and created a lasting impact in the automotive industry. It is an excellent choice for small and medium businesses looking to become modern whilst at a lesser cost compared to

commercial ERP software. The system is different from manual inefficiency to digital optimization, laying out a strong base for business development.

5.3 Contributions to Knowledge

This research makes a contribution to the field of Computer Science & Information Systems by:

1. Offering a reference application that is actually usable for lightweight-inventory setups for development in economies.
2. Showing how to apply the Water Fall SDLC in order to build a solution which is related to the domain retail domain.
3. Contributing to the knowledge base on Digital transformation in the retail operations of SMEs.

5.4 Recommendations for Future Work

This is a working and viable system but, future researchers and developers might want to extend their work by:

Cloud Integration: Database migration to cloud server to achieve remote access and multi-store synch.

Barcode / RFID Integration: Ensuring hardware scanners can be integrated to help further expedite the Point-of-Sale process and save time at the checkout counter.

Predictive Analytics: Utilizing the Machine Learning algorithms to automatically analyze the sales history and forecast future trends in demand.

Mobile Application: Creating a mobile application that serves as a companion property, to enable managers to see the reports and be alerted remotely.

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