AI-POWERED DRUG AVAILABILITY, PRICING, AND ACCESSIBILITY INTELLIGENCE PLATFORM FOR LOCAL PHARMACIES

By

Bezyl Mophat Otieno IN16/00003/20

And

Siraj IN16/00001/22

DEPARTMENT OF
SCHOOL OF INFORMATION SCIENCE AND TECHNOLOGY

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CHAPTER ONE

1. INTRODUCTION

1.1. Background

Access to essential medicines remains a fundamental component of effective healthcare delivery and public health stability. However, in many developing regions, particularly across Africa, the unavailability and unaffordability of drugs continue to hinder the realization of equitable healthcare systems. Despite numerous initiatives aimed at improving medicine distribution, patients still face challenges in locating specific drugs, comparing prices, and verifying stock availability in nearby pharmacies. This often results in delayed treatment, financial strain, and in some cases, non-adherence to prescribed therapies.

According to the World Health Organization (WHO), limited access to affordable and quality-assured medicines constitutes one of the principal barriers to achieving Universal Health Coverage (UHC). The pharmaceutical landscape in many African countries is characterized by fragmented supply chains, poor data visibility, and significant price disparities between pharmacies. Consequently, patients are compelled to physically visit multiple drug outlets, leading to inefficiencies and inequities in access to medication. Furthermore, the lack of real-time monitoring and forecasting mechanisms contributes to frequent stockouts, wastage, and inconsistent drug distribution across urban and rural settings.

In recent years, technological innovations—particularly Artificial Intelligence (AI)—have shown immense potential in transforming healthcare systems through predictive analytics, automation, and intelligent data interpretation. AI can analyze pharmacy inventory data to forecast drug shortages, detect price anomalies, and predict regional demand patterns based on demographic and temporal factors. Moreover, the integration of Natural Language Processing (NLP) enables the development of interactive, user-friendly platforms that allow patients to query systems in natural language—for instance, asking, *"Where can I find affordable amoxicillin near me?"*—and receive real-time, location-based responses.

An AI-powered platform for predictive drug availability and pricing transparency would therefore serve as a vital tool for enhancing medication accessibility, promoting affordability, and strengthening supply chain coordination among stakeholders. Beyond empowering patients, such a system would provide valuable insights to pharmacies, healthcare administrators, and policymakers—facilitating data-driven decisions that align with Africa's ongoing digital health transformation agenda.

1.2. Problem Statement

Access to affordable and readily available medicines remains a persistent challenge across many African nations. Despite significant strides in digital transformation and healthcare infrastructure, inefficiencies in pharmaceutical supply chains continue to limit the equitable distribution of essential drugs. Patients frequently experience difficulty locating prescribed medications, often resorting to visiting multiple pharmacies or relying on informal information networks. This not only delays treatment but also exposes them to financial exploitation, counterfeit drugs, and preventable health complications.

The absence of centralized systems for monitoring drug availability and price variations has created a fragmented pharmaceutical ecosystem. Many pharmacies still rely on manual stock management and lack real-time visibility into regional supply and demand trends. Consequently, it becomes difficult for patients, healthcare providers, and policymakers to make informed decisions regarding medication access, affordability, and inventory planning. These gaps also result in recurrent stockouts of critical drugs, wastage of near-expiry medicines, and unpredictable fluctuations in market prices.

Furthermore, existing online platforms that attempt to provide drug information often focus on e-commerce or generic listings rather than localized, data-driven solutions tailored to public health needs. They fail to incorporate intelligent search capabilities or predictive analytics that could support proactive decision-making. As a result, patients remain underserved, and pharmacies lack tools to efficiently manage supply chains or anticipate future demand.

There is, therefore, a critical need for an AI-powered platform capable of aggregating pharmacy inventory data, enabling natural language search for drug availability and prices, and applying predictive analytics to forecast potential shortages. Such a system would bridge the information gap between pharmacies and patients, promote transparency in drug pricing, and enhance access to affordable medication—contributing to the broader goal of equitable healthcare delivery in Africa.

1.3. Objectives Of The Study

1.3.1. General objective

The main objective of this study is to develop an **AI-powered platform for predictive drug availability and pricing transparency** that enhances patient access to affordable medicines while improving supply chain efficiency among local pharmacies.

1.3.2. Specific objectives

1. **Design and implement** a web-based platform that aggregates data from local pharmacies to provide real-time visibility into drug availability and pricing information.

2. **Integrate Artificial Intelligence (AI)** and **Natural Language Processing (NLP)** capabilities to enable intelligent, conversational search for drugs, prices, and nearby pharmacies using user-friendly natural language queries.

3. **Utilize existing AI and data services** (such as Azure Cognitive Search or OpenAI APIs) to interpret search intent, enhance query accuracy, and return context-aware results to users.

4. **Develop a structured database and integration framework** that allows pharmacies to update inventory and pricing data seamlessly, ensuring system reliability and timeliness.

5. **Evaluate the system's effectiveness** in improving accessibility, information accuracy, and decision-making for both patients and pharmacies.

6. **Enhance transparency and accountability** in the pharmaceutical ecosystem by providing an open, data-driven platform for price comparison and drug availability tracking.

1.4. Research Questions

Based on the objectives of this study, the following research questions will guide the investigation:

1. How can a web-based platform be designed to effectively aggregate and present real-time drug availability and pricing information from multiple pharmacies?

2. How can Artificial Intelligence (AI) and Natural Language Processing (NLP) be applied to enable accurate and user-friendly conversational search for drug-related information?

3. What role do existing AI and data services, such as Azure AI Search or OpenAI APIs, play in enhancing the accuracy, contextual understanding, and responsiveness of the system?

4. How can pharmacies be integrated into the platform to enable seamless and efficient updating of inventory and pricing data in real time?

5. To what extent does the proposed platform improve accessibility, information accuracy, and transparency for patients and pharmacies?

6. How can the system contribute to promoting price transparency, accountability, and data-driven decision-making within the local pharmaceutical ecosystem?

1.5. Scope

This study focuses on the conceptualization, design, and development of an **AI-powered platform for predictive drug availability and pricing transparency**. The project seeks to address the challenges faced by patients in locating affordable and available medicines while promoting data-driven decision-making among pharmacies and other healthcare stakeholders. To maintain focus and feasibility, the scope of the study is defined through the following dimensions:

1.5.1 Geographical Scope

The study is contextualized within the **African healthcare environment**, with particular reference to regions experiencing recurrent challenges in medicine accessibility, pricing inconsistency, and fragmented pharmaceutical supply chains. While the system may be designed to accommodate a broader application across different countries, the prototype implementation will simulate conditions typical of **urban and peri-urban areas in developing economies**, where pharmacy data fragmentation is prevalent.

1.5.2 Content Scope (System Scope)

The project will involve the development of a **web-based prototype** that allows users to:

- Search for medicines by name or description using a conversational interface.
- View nearby pharmacies that stock the requested medicines, along with pricing information.
- Access summarized information regarding drug availability trends.

The system will provide an administrative interface for pharmacies to manage and update inventory data. Data used in testing and evaluation will be **sample or simulated datasets**, representing real-world pharmacy records.

The study's focus will be limited to demonstrating the feasibility and utility of AI integration for **search, retrieval, and pricing transparency** within pharmaceutical access — not the full-scale commercialization or nationwide rollout of the solution.

1.5.3 Technological Scope

The study will utilize **existing Artificial Intelligence (AI)** and **Natural Language Processing (NLP)** technologies to enable intelligent search and query interpretation. Specifically, the project will explore services such as **Azure AI Search**, **Azure Cognitive Services**, and **OpenAI APIs** for natural language understanding, context matching, and semantic search.

The system will be implemented using the **.NET framework** for the backend, **Vue.js** for the frontend, and relevant APIs for AI integration. The focus will be on **system integration and intelligent data access**, rather than developing new AI or predictive models from scratch.

1.5.4 Boundaries and Limitations

The study will not cover e-commerce functionalities such as online purchasing, payment gateways, or logistics management for drug delivery. It will also not include pharmaceutical regulation, authentication of drug quality, or prescription validation mechanisms.

Additionally, the study's evaluation will focus primarily on **usability, accuracy, and performance** within a prototype setting. External factors such as limited access to real pharmacy datasets, infrastructure constraints, and internet reliability may also affect the system's demonstration scope.

By maintaining these defined boundaries, the research ensures a realistic and focused implementation that can later be expanded into a scalable solution for improving transparency and access in the pharmaceutical sector.

1.6. Significance

Access to affordable and readily available medicines remains one of the most pressing challenges within healthcare systems, particularly in developing countries. Patients often struggle to identify where specific drugs are stocked or compare prices across pharmacies, resulting in delayed treatment, financial strain, and inefficiencies in care delivery. This study seeks to address these challenges by leveraging **Artificial Intelligence (AI)** and **Natural Language Processing (NLP)** to enhance transparency, accessibility, and decision-making within the pharmaceutical ecosystem.

1.6.1 Contribution to Healthcare Service Delivery

The proposed system will contribute to more **efficient healthcare delivery** by simplifying the process through which patients and healthcare providers identify where essential medicines can be found and at what price. By reducing the time spent searching for drugs and improving the accuracy of availability information, the system will help reduce treatment delays and improve patient outcomes. This aligns with the broader goal of **Universal Health Coverage (UHC)** and improved access to essential medicines.

1.6.2 Technological Innovation

From a technological standpoint, this research demonstrates the **practical integration of AI services and NLP technologies** within healthcare information systems. Rather than building new predictive models from scratch, the study showcases how **existing AI APIs** and cloud-based cognitive services (e.g., Azure AI Search, OpenAI models) can be configured to support real-world decision-making. This approach contributes to **innovation through system design and intelligent integration**, highlighting how emerging technologies can bridge long-standing data and accessibility gaps in healthcare.

1.6.3 Policy and Pharmaceutical Industry Impact

The system's transparency mechanisms could support **policy formulation** by providing insights into price variation and stock trends across regions. By enabling data-driven visibility, it offers a foundation for **pharmaceutical regulators and health ministries** to monitor disparities and design interventions for equitable medicine distribution. For pharmacies and distributors, the platform provides an avenue to **increase visibility, build trust, and promote fair competition** through transparent pricing.

1.6.4 Academic and Research Contribution

This study also contributes to the **academic discourse on AI applications in healthcare**, particularly in resource-constrained contexts. It provides a framework for understanding how intelligent systems can improve service accessibility without necessitating high-end infrastructure or proprietary datasets. Future researchers can extend this work to explore predictive analytics, real-time stock monitoring, or broader integration with national health information systems.

1.6.5 Societal and Economic Significance

Ultimately, by empowering patients with real-time information on drug availability and pricing, the system enhances **health equity** and **economic efficiency**. It can help households minimize costs associated with medicine searches and overpricing while promoting trust and accountability within the healthcare supply chain. In the long term, such a platform has the potential to **reduce out-of-pocket expenditures**, improve treatment adherence, and strengthen community health resilience.

1.7. Definition of Key Terms

To ensure conceptual clarity and a shared understanding of the study's scope, the following key terms are defined as used in this research:

Artificial Intelligence (AI)

Artificial Intelligence refers to the capability of computer systems to perform tasks that typically require human intelligence. In this study, AI is employed to process large sets of drug and pharmacy data, interpret user queries, and generate intelligent responses regarding drug availability and pricing.

Natural Language Processing (NLP)

Natural Language Processing is a branch of AI that enables computers to understand, interpret, and respond to human language. It allows users to search for drugs and pharmacies using conversational language, improving accessibility for non-technical users.

Drug Availability

This term refers to the state in which a particular medicine or pharmaceutical product is in stock and accessible to consumers at a given pharmacy or medical outlet. Within this study, drug availability is determined through data aggregated from participating pharmacies.

Pricing Transparency

Pricing transparency refers to the open and accessible presentation of drug prices across pharmacies. It allows patients to compare costs and make informed purchasing decisions, promoting fairness and competition in the pharmaceutical market.

Affordability

Affordability denotes the degree to which the cost of medicine is reasonable and within the purchasing power of individuals or households. The system seeks to promote affordability by exposing price disparities and helping users locate lower-cost alternatives.

Pharmacy Information System

A pharmacy information system is a digital platform used by pharmacies to manage inventory, prescriptions, and sales data. This study's proposed system extends this concept by integrating AI capabilities to share and analyze such data across multiple pharmacies.

Predictive Analytics

Predictive analytics involves the use of data, statistical algorithms, and AI techniques to identify the likelihood of future outcomes based on historical data. Although this study does not develop new predictive models, it leverages available AI services capable of forecasting trends such as stock depletion or price fluctuations.

Healthcare Access

Healthcare access refers to the ability of individuals to obtain appropriate health services — including medicines — without undue financial or logistical barriers. This research focuses on improving access through digital and AI-driven solutions.

Digital Health

Digital health encompasses the use of information and communication technologies to improve healthcare delivery and patient outcomes. The proposed system falls under this domain by using AI and NLP to facilitate efficient access to essential medicines.

Pharmaceutical Supply Chain

This term refers to the sequence of processes involved in the production, distribution, and delivery of medicines from manufacturers to end users. By providing visibility into stock levels and pricing, the study aims to enhance transparency and coordination within this chain.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Access to affordable and essential medicines remains a major public health challenge in many developing countries, particularly across Africa. Despite the increasing number of pharmacies and advancements in digital health, disparities in drug availability and pricing persist. Patients often move between multiple pharmacies to find necessary medications, facing inconsistencies in costs, shortages, and lack of accurate information.

Globally, the World Health Organization (WHO) emphasizes that medicine availability and affordability are critical determinants of effective healthcare delivery. Studies have shown that up to 30% of populations in low- and middle-income countries face barriers in obtaining prescribed medicines due to unregulated pricing, inadequate inventory management systems, and fragmented pharmaceutical supply chains.

Recent technological developments — including Artificial Intelligence (AI), Natural Language Processing (NLP), and cloud-based systems — are transforming healthcare service delivery. AI-driven tools are now being applied to tasks such as medical record analysis, pharmacy automation, and predictive healthcare management. However, while much focus has been placed on diagnosis and treatment support systems, relatively little attention has been given to AI applications that improve access to medicines and transparency in pharmaceutical pricing.

This chapter reviews existing research, systems, and technological innovations that inform the design and development of the proposed **AI-Powered Drug Availability and Pricing**

Transparency Platform. It explores global and regional studies on digital pharmacy systems, AI in healthcare, drug supply chain management, and relevant theoretical frameworks supporting intelligent information systems.

2.2. Theoretical Framework

A theoretical framework provides the academic lens through which this study is grounded. It identifies and explains the theories that guide the design, development, and evaluation of the proposed AI-powered drug availability and pricing transparency platform. The framework serves to link existing knowledge with the objectives of this research, offering a conceptual foundation for understanding how technology can improve access to essential medicines and enhance healthcare efficiency.

2.2.1 Information Asymmetry Theory

The **Information Asymmetry Theory**, proposed by economist George Akerlof (1970), explains how markets can fail when one party in a transaction has more or better information than the other. In healthcare, particularly in the pharmaceutical market, pharmacies and distributors often have more knowledge about drug availability, pricing, and stock levels than patients or consumers.

This imbalance results in unfair pricing, limited consumer choice, and poor access to essential medicines. The proposed AI-driven system seeks to minimize this asymmetry by making drug information — including availability, location, and price — easily accessible to the public. By ensuring transparency, the system helps level the information field between pharmacies and patients, leading to more equitable and efficient healthcare access.

2.2.2 Technology Acceptance Model (TAM)

The **Technology Acceptance Model (TAM)**, developed by Davis (1989), explains users' acceptance and adoption of new technologies. It identifies two main determinants of adoption: **Perceived Usefulness** (the degree to which a user believes that a system enhances their performance) and **Perceived Ease of Use** (how effortless the system is to use).

In this study, TAM is relevant as it provides a basis for understanding how patients, pharmacists, and healthcare practitioners may adopt the AI-based platform. For patients, the perceived usefulness lies in the convenience of finding affordable medicines nearby, while for pharmacies, it is in the increased visibility and customer trust. Ensuring intuitive interfaces and accurate AI responses will enhance ease of use, encouraging widespread adoption.

2.2.3 Diffusion of Innovation Theory

Developed by Everett Rogers (1962), the **Diffusion of Innovation Theory** describes how innovations spread within a social system over time. It identifies five adopter categories — innovators, early adopters, early majority, late majority, and laggards — and five key factors influencing adoption: relative advantage, compatibility, complexity, trialability, and observability.

In the context of this project, the AI-powered platform represents a technological innovation aimed at transforming how patients and pharmacies interact. The system's **relative advantage** lies in reducing time, cost, and effort associated with drug searches. Its **compatibility** with mobile and web platforms makes it easily accessible, while **observability** — through visible user benefits like time savings — promotes further adoption across communities and regions.

2.2.4 Systems Theory

Systems Theory, initially developed by Ludwig von Bertalanffy (1968), views any organization or process as an interconnected system of components working together to achieve a common goal. In healthcare, this means that pharmacies, suppliers, and patients are all part of a larger ecosystem where information flow is critical.

The proposed platform aligns with this theory by acting as an integrative component that connects different entities within the pharmaceutical value chain. By facilitating data exchange and visibility among pharmacies and consumers, the system enhances overall efficiency, reduces redundancies, and promotes coordination within the healthcare system.

2.2.5 Human-Computer Interaction (HCI) Theory

The **Human-Computer Interaction (HCI)** theory focuses on designing systems that are user-friendly, intuitive, and responsive to human needs. It emphasizes usability, accessibility, and the alignment of system behavior with user expectations.

Since the platform will utilize Natural Language Processing (NLP) for drug searches and conversational interactions, HCI principles are vital in ensuring that the AI responses are accurate, natural, and contextually relevant. The goal is to design an interface that fosters trust and ease of communication between the user and the system, ensuring inclusivity for users with varying levels of digital literacy.

2.3. Empirical Review

2.3.1 Overview: drug availability and pricing in low- and middle-income countries

Access to essential medicines — in terms of both availability and affordability — remains a cornerstone challenge for achieving Universal Health Coverage (UHC) in many low- and middle-income countries (LMICs). Systematic reviews and policy studies show mixed results for traditional price-transparency initiatives: while transparency can increase consumer awareness, it does not automatically lead to price reductions without regulatory or market mechanisms in place. Several reviews highlight that implementation contexts, market structure, and the role of government mediation significantly determine outcomes of price-transparency policies. PubMed+1

Empirical evidence from sub-Saharan Africa underscores structural issues — fragmented supply chains, weak stock monitoring, and large urban-rural disparities — which together produce frequent drug stockouts and wide price variation. These system characteristics create both public-health and economic burdens for households who must travel, pay more, or skip treatment altogether. PMC+1

2.3.2 Digital pharmacy platforms and market solutions in Africa (practice & precedent)

A number of private-sector solutions and startups have emerged across Africa to address aspects of medicine access, inventory digitization, and e-pharmacy services. Examples include:

- **MyDawa (Kenya)** — an integrated health platform combining telehealth and medicine delivery; it demonstrates demand for digital pharmacy services and the feasibility of combining health services with drug fulfillment. Google Play

- **MaishaMeds** and other POS/clinic management tools — these solutions show that pharmacy digitization (inventory and POS) is both feasible and used in African contexts; some can operate offline and are tailored for low-connectivity environments. Maisha Meds

- **LiviaHealth / Livia for Chemists** and other pharmacy networks — platforms that enable pharmacies to gain an online presence and receive orders, showing commercial viability for pharmacy-focused software. LiviaHealth

More recent Africa-centric initiatives explicitly exploring AI for supply-chain efficiency and demand prediction (e.g., Famasi Africa) indicate growing traction for AI in pharmaceutical logistics and access, and show an emerging industry interest that your project aligns with. blog.google

These commercial examples validate that: (a) digitizing pharmacy inventory is practical in African settings, and (b) a market exists for services that improve visibility and customer access. However, many current solutions focus on e-commerce and order fulfilment rather than public transparency, conversational search, or AI-enabled decision support for price comparison and availability discovery.

2.3.3 AI and NLP in pharmacy and healthcare — empirical findings and capabilities

AI, particularly NLP and large language models (LLMs), is increasingly applied within pharmacy practice and broader healthcare workflows. Recent reviews and studies document practical uses of NLP for clinical note processing, adverse drug event detection, and conversational assistants that support clinicians and patients. These works demonstrate that NLP can successfully identify drug mentions, extract structured information from free text, and support user-facing conversational interfaces when properly constrained and validated. PMC+1

Beyond individual studies, broader reviews of AI in healthcare in Africa describe both opportunity and challenge: while AI can support service delivery and decision-support, successful deployment depends on local data, governance, infrastructure, and engagement with local stakeholders. This context is crucial for any AI-driven pharmacy solution in African settings. PMC+1

2.3.4 Predictive analytics and stock forecasting: evidence and methods

Predicting drug shortages and demand is an active area of research. Empirical studies from high-income countries and a growing body of work in LMICs demonstrate that machine learning and time-series methods can forecast medication demand and detect imminent stockouts given adequate historical sales/inventory data. For example, recent peer-reviewed work has produced models that effectively predict shortages and provide actionable alerts to pharmacies and health systems. While model performance depends heavily on data quality and feature design, these studies indicate that forecasting is feasible and valuable for supply-chain resilience. PMC+1

However, many of these studies assume access to reliable longitudinal pharmacy sales or dispensing records — data that may not be uniformly available in fragmented African markets. This motivates design choices that rely first on integration with existing pharmacy POS systems or lightweight periodic sync, and on leveraging pre-trained AI services for search and interpretation rather than investing heavily in local model training during an initial prototype phase.

2.3.5 Cloud search and cognitive services (practical examples)

Modern cloud search and cognitive services (e.g., Azure Cognitive Search and Azure OpenAI) have proven effective in enterprise healthcare contexts for indexing heterogeneous documents, enabling semantic search, and building responsive conversational experiences. Case studies — such as the NHS use of Azure Cognitive Search and Kry's use of Azure OpenAI for patient-facing services — illustrate that cloud search provides clinicians and patients with fast, accurate retrieval across complex data. These services can also ingest structured data (e.g., inventory tables) and combine it with semantic layers for natural-language query handling. Microsoft+1

Additionally, document processing tools (e.g., Azure Form Recognizer) and cognitive search pipelines have been documented as effective for extracting structured information from semi-structured documents, which may be helpful when digitizing legacy pharmacy records. ResearchGate

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2.3.6 Evaluation & outcomes from transparency initiatives — mixed evidence

Systematic reviews of drug price transparency initiatives reveal nuanced outcomes: transparency alone does not guarantee lower prices or improved availability unless accompanied by complementary policy or market actions. Some country studies show limited or no price reductions from simple transparency measures, while others report localized improvements when transparency is combined with regulatory responses. This suggests that technology solutions must be designed with implementation pathways to stakeholders (policymakers, regulators, pharmacy associations) rather than relying solely on consumer information to change market behavior. PubMed+1

2.3.7 Summary of empirical findings & relevance to this study

Putting the literature together yields the following points directly relevant to the proposed project:

1. **Need & feasibility:** Empirical studies and industry practice confirm a significant unmet need for improved medicine availability and price visibility in LMICs, and show that

digitization of pharmacy workflows is feasible in African contexts. Maisha Meds+1

2. **AI utility:** NLP and cloud AI services can enable user-friendly, conversational search and can extract and reconcile heterogeneous inventory data, aligning well with your platform's core features. However, careful validation and contextualization are required. PMC+1

3. **Predictive potential with caveats:** Forecasting and shortage prediction have been demonstrated as useful, but depend on data availability. For an initial prototype, leveraging existing pre-trained services and integrating with point-of-sale data sources will be more practical than training bespoke models from scratch. PMC+1

4. **Policy and market dynamics matter:** Transparency initiatives have mixed effects in practice; coupling technical transparency with stakeholder engagement (pharmacy associations, regulators) increases the likelihood of system impact. PubMed+1

2.3.8 Research gap and positioning of the current study

While several platforms and studies address components of pharmacy digitization, e-commerce, and AI in clinical settings, there is a gap at the intersection of:

- **consumer-facing, conversational search for drug availability and pricing**,
- **lightweight integration with existing pharmacy systems in low-connectivity environments**, and
- **a research-backed, prototype approach that emphasizes transparency and policy relevance over immediate commercialization**.

Existing e-pharmacies often target urban, app-connected users or focus on order fulfilment, while many research efforts concentrate on diagnosis or clinical NLP. Few projects and studies combine semantic search (NLP), cloud cognitive search services, and practical inventory integration to create a public utility for pricing transparency and availability that is tailored to African market constraints. This study aims to fill that niche by designing, implementing, and evaluating a prototype that leverages off-the-shelf AI services to provide conversational, location-aware drug search and price comparison for patients — while enabling pharmacies to participate with minimal technical burden.

2.3.9 Implications for methodology and system design

The empirical evidence suggests a pragmatic, integration-first approach for the prototype:

- **Use cloud cognitive search (Azure Cognitive Search / OpenAI)** for semantic, natural-language search rather than building LLMs locally. Microsoft+1

- **Integrate with existing pharmacy POS / inventory tools** or collect representative sample datasets when full integration is not feasible (e.g., MaishaMeds, LiviaHealth). Maisha Meds+1

- **Design evaluation metrics** around usability, query accuracy, timeliness of availability information, and perceived usefulness (aligned with TAM).

- **Engage stakeholders (pharmacies, regulators)** early to ensure the transparency data will be actionable and credible. PubMed
- Owoyemi A. *Artificial Intelligence for Healthcare in Africa*. 2020. PMC

- Ahmad NS, et al. *Drug price transparency initiative: A scoping review*. 2020. PubMed

- MaishaMeds – App & platform (company website). Maisha Meds

- Chalasani SH, et al. *Artificial intelligence in the field of pharmacy practice*. 2023. PMC

- Pall R, et al. *Predicting drug shortages using pharmacy data and ML*. 2023. PMC

- Microsoft case study: *NHS makes data more discoverable using Azure Cognitive Search*. Microsoft

- Famasi Africa (Google blog): *African startup unlocking access to medication with AI*. 2025. blog.google

- MyDawa (app page) — Kenya's integrated health platform.

2.4. Knowledge Gap

Despite the growing body of research on artificial intelligence and digital health systems, several notable gaps persist within the African pharmaceutical context.

Existing studies on drug availability primarily focus on **inventory management within hospitals or national drug supply chains**, often neglecting the realities faced by **local and**

community pharmacies, which serve as the first point of access to essential medicines for the majority of citizens. Many of these studies have been descriptive or policy-driven, lacking the integration of **real-time, data-driven monitoring systems** that can provide actionable insights to both consumers and stakeholders.

Furthermore, while predictive analytics and AI-based forecasting models have been extensively applied in developed regions, their **adoption in Africa remains minimal** due to limited infrastructure, fragmented data sources, and lack of interoperable systems. Current platforms that attempt to map or track drug prices rarely incorporate **context-aware insights** such as regional price variations, local supply chain disruptions, or the influence of economic factors like inflation and import dependency.

In addition, previous research has not adequately addressed the issue of **pricing transparency** from the consumer perspective. While affordability is a recognized public health challenge, there is little emphasis on empowering patients and pharmacists with **accessible tools** that reveal real-time drug availability, comparative pricing, and nearby alternatives. This lack of transparency perpetuates inequities in access to essential medicines, especially in underserved rural areas.

Finally, most existing studies and digital solutions are **limited in their use of modern AI capabilities** such as natural language processing (NLP) for unstructured data extraction (e.g., pharmacy reports, social media discussions, or user feedback). These technologies could offer valuable insights into market trends, shortages, and consumer sentiment but remain largely untapped in this domain.

Therefore, this study seeks to bridge these gaps by proposing and developing an **AI-powered platform** that leverages existing APIs, data analytics, and NLP techniques to improve visibility, accessibility, and transparency in the pharmaceutical ecosystem. Unlike prior works, the proposed solution emphasizes **local adaptability**, **scalability**, and **user-centered design** — enabling both pharmacies and consumers to make informed, data-driven decisions about medicine availability and affordability.

CHAPTER THREE

3. METHODOLOGY

3.1. System Development Methodology

The research design adopted for this study follows a **System Development Methodology**, which focuses on the structured and iterative process of designing, developing, and evaluating a functional software solution. Since the project aims to implement an intelligent, user-centered application, the **Agile Software Development Methodology**, specifically the **Scrum framework**, was selected.

The Agile approach emphasizes flexibility, collaboration, and incremental progress — all essential in building an AI-powered system that requires iterative refinement through testing and feedback. Unlike traditional models such as the Waterfall approach, Agile allows adaptive planning and continuous improvement throughout the development lifecycle, making it well suited for modern software projects that integrate artificial intelligence and cloud services.

3.1.1 Justification for Choosing Agile/Scrum

The Agile methodology was chosen because:

1. **Iterative Development:** The system can be developed in small, manageable sprints, enabling progressive integration of AI functionalities such as natural language search and pharmacy data aggregation.

2. **Flexibility and Adaptability:** Changes in requirements or improvements can easily be accommodated as the project evolves and new user insights emerge.

3. **Continuous Feedback:** Frequent stakeholder and user evaluations ensure that the developed features meet real-world needs effectively.

4. **Early Testing and Quality Assurance:** Each sprint includes testing and validation, ensuring early identification and resolution of system defects.

5. **Collaborative Approach:** Agile encourages collaboration between developers, AI model integrators, and end-users, leading to a more practical and user-friendly product.

3.1.2 Scrum Framework in Context

Under the Scrum framework, the system development will be organized into **sprints** of approximately **two to three weeks** each. Each sprint focuses on completing a specific module or functionality, such as:

- Sprint 1: Requirement gathering and system design documentation.

- Sprint 2: Development of pharmacy and drug data ingestion APIs.

- Sprint 3: Implementation of AI/NLP search and ranking module.

- Sprint 4: Frontend integration with Vue.js for user interaction.

- Sprint 5: Testing, feedback, and deployment of the first working prototype.

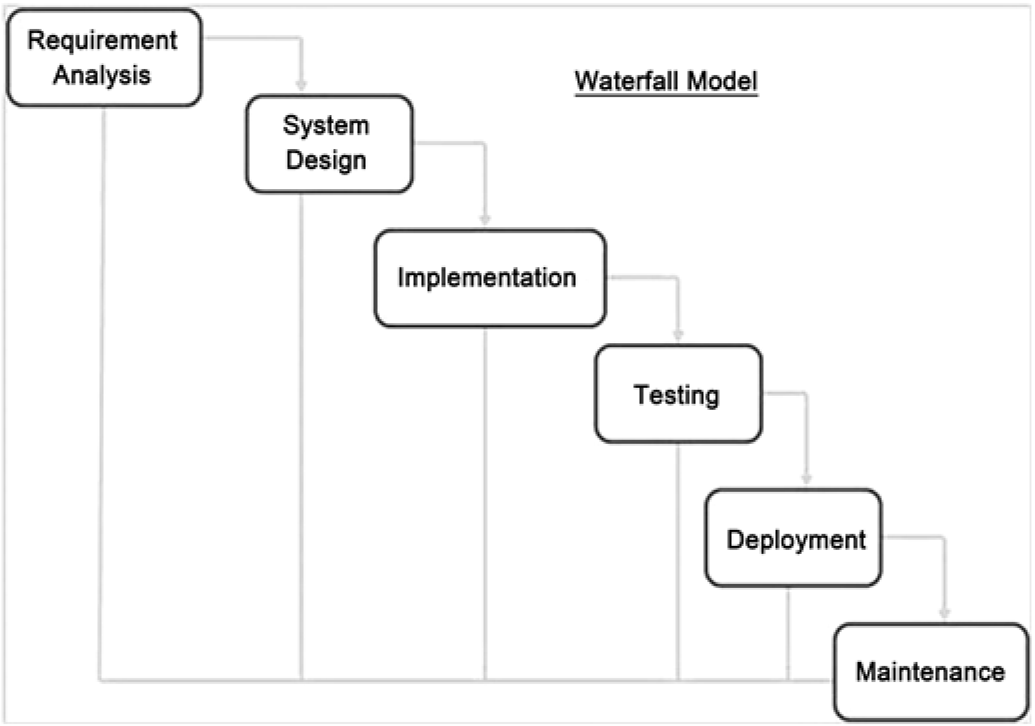

Figure 1.1 Waterfall Model

3.2. System Requirements Specification

The **System Requirements Specification (SRS)** outlines the essential capabilities and performance expectations of the **AI-Powered Drug Availability and Affordability Tracking Platform**. This section defines both **functional** and **non-functional** requirements necessary to ensure the system performs effectively, efficiently, and securely.

The goal of this specification is to provide a clear understanding of the platform's intended behavior from both the user's and developer's perspectives.

3.2.1 Functional Requirements

Functional requirements define what the system should do — the specific behaviors, operations, and services it must provide to meet the project's objectives.

ID	Requirement	Description
FR1	**User Registration and Authentication**	The system should allow users (patients, pharmacists, or healthcare workers) to register, log in, and manage their accounts securely.
FR2	**Drug Search using Natural Language**	The system should allow users to search for drugs using natural language queries (e.g., "Where can I find affordable Amoxicillin near Nairobi?").
FR3	**Pharmacy Data Integration**	The system should integrate with pharmacy databases or APIs to retrieve drug availability, stock levels, and pricing information in real-time.

FR4	**Drug Affordability Comparison**	The system should compare prices of the same drug across multiple pharmacies and display the most affordable options.
FR5	**Location-based Pharmacy Suggestions**	The platform should utilize geolocation services to recommend nearby pharmacies that have the searched drug in stock.
FR6	**AI/NLP Search Optimization**	The system should use AI techniques and NLP models to interpret user intent, extract drug names, and provide accurate responses.
FR7	**Drug Information Display**	Each drug result should include essential information such as brand name, dosage forms, manufacturer, and indicative price range.
FR8	**User Feedback and Reporting**	Users should be able to rate pharmacies, report inaccurate data, and provide feedback on search results.
FR9	**Admin Dashboard**	Administrators should manage pharmacy data, user accounts, and view analytics on drug availability and usage trends.
FR10	**Notification System**	Users can opt-in to receive alerts when a drug becomes available or when prices drop at nearby pharmacies.

3.2.2 Non-Functional Requirements

Non-functional requirements define the system's operational characteristics, ensuring performance, security, reliability, and maintainability.

Category	Requirement	Description
Performance	Response Time	The system should process user queries and return results within 3 seconds on average.
Scalability	Expandability	The architecture should support adding more pharmacies, locations, and AI models without major reconfiguration.
Security	Data Protection	User data and authentication details must be securely stored and transmitted using HTTPS and encryption.
Usability	User Experience	The interface should be intuitive, mobile-responsive, and accessible to users with varying technical literacy.
Reliability	System Uptime	The platform should maintain 99% uptime for public accessibility.
Maintainability	Code Structure	The system should adopt modular, well-documented code to facilitate easy updates and debugging.
Interoperability	API Compatibility	The system must be able to integrate with third-party pharmacy management systems and open APIs.
Ethical Compliance	AI Transparency	AI components must provide explainable and unbiased results aligned with responsible AI principles.

3.3. System implementation techniques

The **System Design** phase translates the defined requirements into a structured blueprint for implementation. It outlines how data flows through the system, how the different components interact, and how the AI layer integrates to enable intelligent and context-aware drug searches.

The design ensures that the platform is modular, scalable, and capable of accommodating future enhancements such as predictive analytics and API expansion.

3.3.1 System Architecture Overview

The system adopts a **three-tier architecture** consisting of:

1. **Presentation Layer (Frontend):**
   Built with **Vue.js**, this layer handles all user interactions. It allows users to input queries, view search results, compare prices, and manage their profiles. It communicates with the backend through secure RESTful APIs.

2. **Application Layer (Backend):**
   Implemented using **.NET Core Web API**, this layer processes requests from the

frontend, interacts with the database, and manages business logic. It also integrates with external APIs (e.g., pharmacy inventory systems) and AI/NLP services for language understanding and search optimization.

3. **Data Layer:**
   A **SQL-based database** (such as Microsoft SQL Server or Azure SQL Database) stores structured data about drugs, pharmacies, user accounts, and transactions. This layer ensures efficient querying, indexing, and backup.

4. **AI and NLP Layer:**
   Leveraging **Azure AI Search** and **Language Services**, this layer interprets user input in natural language, extracts drug names and intent, and retrieves relevant results. The AI agent enhances user experience by handling ambiguous or incomplete queries.

3.3.2 Logical Architecture Diagram

```
┌─────────────────────────────┐
|        User Interface        |
| (Vue.js Web & Mobile App)    |
└─────────────┬───────────────┘
              |
              ▼
┌─────────────────────────────┐
|  .NET Core API Backend       |
|  - Authentication             |
|  - Search & Price Logic       |
|  - Feedback Management        |
```

```
└─────────────┬──────────────┘
              │
              ▼
┌────────────────────────────┐
│   Azure AI & NLP Services  │
│  - Query Interpretation     │
│  - Contextual Search        │
│  - Drug Info Matching       │
└─────────────┬──────────────┘
              │
              ▼
┌────────────────────────────┐
│     Database Layer         │
│  (Azure SQL / MSSQL)       │
│  - Users                   │
│  - Pharmacies              │
│  - Drugs & Prices           │
│  - Logs / Feedback          │
└────────────────────────────┘
```

3.3.3 Data Flow Description

1. **User Query Submission:**
   The user types a query in natural language, e.g., *"Where can I get affordable insulin near*

Kisumu?"

2. **Query Processing:**
   The backend sends this query to the **Azure AI/NLP service**, which extracts key entities such as *drug name*, *location*, and *intent* (availability, price).

3. **Database and API Querying:**
   The system queries the local pharmacy database or integrated external APIs to fetch relevant information.

4. **Result Aggregation and Ranking:**
   The results are ranked based on proximity, availability, and price using backend logic.

5. **Response Delivery:**
   The results are returned to the frontend and displayed in an easy-to-read, user-friendly format.

6. **User Feedback Loop:**
   Users can rate the accuracy of results, improving the AI's future query handling through reinforcement feedback.

3.3.4 Database Design Overview

Main Entities:

- **Users** (patients, pharmacists, admin)

- **Pharmacies**

- **Drugs**
- **Drug Prices**
- **Inventory**
- **Feedback/Reports**

Relationships:

- A pharmacy can have many drugs.
- Each drug can have multiple price entries (per pharmacy).
- Users can provide feedback for multiple pharmacies or search results.

3.3.5 Security Design Considerations

- **JWT authentication** for secure access to APIs.
- **HTTPS encryption** for all communications.
- **Role-based access control (RBAC)** for admin and user permissions.
- **Data validation and sanitization** to prevent injection attacks.
- **Secure key management** for API and AI service credentials.

3.3.6 Scalability Considerations

- The backend and database can be hosted on **Azure App Services** and **Azure SQL**, supporting horizontal and vertical scaling.

- Caching layers can be added (e.g., **Azure Redis Cache**) for high-performance search responses.

- The AI/NLP service can be fine-tuned or replaced with custom models as usage grows.

3.4. Technology Stack and Tools

The success of this project depends on selecting an appropriate combination of technologies that ensure **efficiency, scalability, security, and maintainability**. Each tool and framework was carefully chosen to align with the project's technical requirements and the desired user experience.

The platform is built on a **modern, full-stack ecosystem** combining the robustness of the **.NET framework**, the interactivity of **Vue.js**, and the intelligence of **Azure AI Services** for natural language search capabilities.

3.4.1 Frontend Technologies

Technology	Description	Justification
Vue.js 3	A progressive JavaScript framework for building responsive user interfaces.	Chosen for its lightweight structure, reactivity, and easy integration with RESTful APIs. Vue's component-based architecture enhances maintainability and performance.
Tailwind CSS	A utility-first CSS framework for styling.	Ensures a clean, consistent, and mobile-responsive interface with minimal CSS overhead, improving design speed and consistency.
Axios	JavaScript HTTP client for API communication.	Used for secure, asynchronous communication between the frontend and backend.
Leaflet.js / Azure Maps	Mapping library for geolocation and visualization.	Enables users to view nearby pharmacies and visualize search results on a map.

3.4.2 Backend Technologies

Technology	Description	Justification
.NET 8 (ASP.NET Core Web API)	Backend framework for building secure and high-performance REST APIs.	Provides robustness, scalability, and seamless integration with Azure cloud services. Its middleware support simplifies authentication, logging, and validation.
Entity Framework Core	Object-relational mapper (ORM) for database access.	Simplifies database interaction through object-based querying, reducing boilerplate SQL code.
C# Programming Language	The primary language for backend logic.	Offers strong typing, performance, and excellent integration with Azure SDKs.
Azure SDK for .NET	Set of tools for interacting with Azure services.	Facilitates integration with Azure AI, Azure SQL, and Cognitive Search APIs within the backend logic.

3.5.3 Database and Data Management

Technology	Description	Justification
Azure SQL Database	Cloud-hosted relational database service by Microsoft.	Offers reliability, scalability, and high availability for storing structured pharmacy, drug, and pricing data.
Microsoft SQL Server (Development Environment)	Local version of the production database.	Enables offline development and testing before cloud deployment.

Azure Blob Storage (optional)	Cloud storage for non-relational data such as images or pharmacy documents.	Supports scalability and easy integration with Azure-based applications.

3.4.4 AI and NLP Technologies

Technology	Description	Justification
Azure Cognitive Search / Azure AI Search	Intelligent search-as-a-service solution.	Enables natural language search and semantic ranking, allowing users to query the system conversationally.
Azure Language Service (Text Analytics + Entity Recognition)	NLP service for understanding and extracting meaning from user text.	Used to interpret user intent, extract drug names, detect locations, and disambiguate similar terms.
OpenAI / Azure OpenAI Integration (Optional)	Provides access to advanced LLMs (e.g., GPT models).	Enhances contextual understanding, allows conversational interfaces, and supports future intelligent assistants or chatbots.

3.4.5 Development and Collaboration Tools

Tool	Description	Justification
Visual Studio / Visual Studio Code	Integrated Development Environments (IDEs) for coding and debugging.	Provide comprehensive debugging, IntelliSense, and seamless integration with Git and Azure DevOps.

Git & GitHub	Version control and collaboration platform.	Ensures version tracking, code safety, and collaborative contributions.
Azure DevOps / GitHub Actions	CI/CD pipeline for automated builds and deployments.	Automates testing and deployment, ensuring reliable and repeatable releases.
Postman	API testing tool.	Used to test and document backend endpoints before frontend integration.

3.4.6 Hosting and Deployment Environment

Service	Description	Justification
Microsoft Azure App Service	Cloud platform for hosting web apps and APIs.	Provides scalability, managed runtime, and built-in monitoring tools for seamless deployment.
Azure Monitor & Application Insights	Monitoring and performance analytics service.	Helps in detecting performance bottlenecks, tracking API latency, and ensuring uptime.
Azure Key Vault	Service for managing secrets, keys, and credentials.	Ensures that sensitive keys and connection strings are stored securely.

3.4.7 Summary

The combination of **.NET Core**, **Vue.js**, and **Azure AI** technologies establishes a robust foundation for developing a scalable, intelligent, and user-friendly platform. This stack ensures a balance between performance, usability, and maintainability, while the integration with Azure services enables advanced AI-driven functionalities without requiring complex custom model training.