# A Web-based Application to Coordinate Operations in A Clinic

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## Declaration and Approval

We declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of our knowledge and belief, the research proposal contains no material previously published or written by another person except where due reference is made in the research proposal itself.

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**Abstract**

This study proposes the design and development of a web-based application to optimize operations in Kenyan outpatient clinics. Using real-time doctor availability tracking, dynamic priority tagging for vulnerable and emergency cases and automated buffer slot insertion, the system aims to reduce overlapping appointments and long waiting times that currently plague level 2-5 facilities. Following an Object-Oriented Analysis and Design paradigm within an agile framework, development will proceed in iterative two-week sprints resulting in a prototype featuring patient profile management, SMS based reminders and notifications and an administrative dashboard. The application's backend and frontend will integrate with an SMS gateway to ensure timely patient communication and seamless clinician schedule updates. Evaluation will assess the system's impact on average waiting times, appointments adherence and staff utilization through simulated clinic data sets. By addressing unpredictable practitioner availability, schedule disruptions caused by emergencies and the absence of automated triage and buffering in existing e-health platforms, this project aims to deliver a unified interface that enhances operational efficiency, improves patient satisfaction especially for the elderly and chronically ill and provides policymakers with actionable service-delivery metrics. The expected outcome is a solution that can be adapted across Kenya's public health network to improve outpatient throughput, reduce financial and emotional burdens on patient and reduce staff workload.

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## List of Abbreviations

CIHEB – Clinton Health Access Initiative

CSS – Cascading Style Sheets

EQMS – Electronic Queue-Management System

ERD – Entity-Relationship Diagram

FCFS – First-Come, First-Serve

IOM – Institute of Medicine

MoH – Ministry of Health (Republic of Kenya)

OOAD – Object-Oriented Analysis and Design

QMS – Queue-Management System

UAT – User Acceptance Testing

**Chapter 1:    Introduction**

**1.1    Background Information**

Kenya's health system is organized into six levels, from community health services (level 1) up to national referral hospitals (level 6), with most outpatient care delivered at dispensaries, clinics, health centres (levels 2–3), and sub-county or county hospitals (levels 4–5) (Republic of Kenya MoH, 2014). Despite this structured framework, clinics routinely struggle with inefficient scheduling, unpredictable practitioner availability, and long waiting times. The combination of these factors means planned appointments overlap and delays compound as the day progresses (Njoroge et al., 2021). Without an efficient system to manage overlaps and communicate changes, clinics find it difficult to maintain an orderly patient flow. By focusing on coordinating operations within outpatient clinics, this study addresses a core operational challenge in Kenya's public health sector.

There are several factors that contribute to this situation, with the first one being unpredictable doctor availability. A doctor may fail to attend an appointment due to unforeseen circumstances or a doctor's strike, leaving patients stranded and forced to return without any assistance (AP News, 2024). A study at the University of Nairobi staff clinic found that the average outpatient waiting time was around 55 minutes; 52% of respondents cited "improving staff availability" as the key way to reduce waiting time (Wafula & Ayah, 2021). Second, the digital systems lack the flexibility to prioritize patients such as the chronically ill and the elderly or manage overlaps through built-in buffers (Wanyee et al., 2019). Third, emergency cases disrupt the schedule of the day, forcing other appointments to start late. In Kenya, Emergency Departments often receive patients with life-threatening conditions. However, most Kenyan EDs operate without a standardized triage protocol, leading to inconsistent assessment and prioritization of patients (Wachira & Martin, 2011). Without a proper triage system, critically ill patients may be left waiting in the queue, increasing their risk of mortality.

These scheduling inefficiencies don't exist in isolation — they have ripple effects across the entire healthcare ecosystem. Vulnerable patients such as the elderly and children are most at risk. In Homa Bay and Kisumu Counties, antenatal clinics reported missed appointment rates of 42% and 35% in 2019; of those, 78% in Homa Bay and 70% in Kisumu cited long waiting times as the primary reason for defaulting on scheduled appointments (Opon et al., 2020). Families must deal with the extra financial and emotional burdens as they travel to and from clinics. According to the Kenya Household Health Expenditure and Utilization Survey (2018),

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individuals incurred an average of Ksh 1,200 per outpatient visit, a significant expense for many low-income households (Ministry of Health, Kenya, 2019). Caregivers of children with tuberculosis in Kenya faced average household costs of USD 120 for non-medical needs, with half reporting catastrophic expenditures just to access free services (Barasa et al., 2017). Healthcare workers also face higher workloads as they attempt to manage overcrowded waiting rooms and make on-the-spot triage decisions. In Western Kenya, 61% of maternal care providers identified high workload as their top stressor (Namusonge et al., 2022). Failure to solve these problems leads to a chain of other issues that affect the entire health system. Patients who miss their scheduled appointments risk delayed detection of complications and interrupted treatment plans. Families end up spending more on travel and missing work just to keep appointments, pushing them further into poverty, and healthcare workers under constant stress face a higher risk of mistakes and fatigue.

Previous efforts such as the 2011–2017 Kenya National eHealth Strategy and the 2016–2030 National eHealth Policy have laid a foundation for electronic health records and mobile health platforms (Republic of Kenya MoH, 2011; Republic of Kenya MoH, 2016). Researchers in Western Kenya found that, while many level 3 and level 4 facilities now have basic e-health services in place, these systems rarely go beyond electronic record-keeping or simple apportionment calendars; they do not dynamically tag high-risk groups such as the elderly, perform real-time triage, or absorb schedule disruptions with buffer slots (Ondulo, 2020). Studies of electronic queue-management systems (EQMS) at Premier Hospital in Mombasa demonstrated modest improvements in patient satisfaction and reduced average wait times by 15%, but the systems did not integrate clinician availability or emergency prioritization, limiting their impact during sudden patient surges (Kuria, 2021). Despite these advances, no current platform in Kenya offers a unified, web-based interface that ensures predictable doctor availability, allows real-time tagging and re-prioritization of patients by emergency status, and manages dynamic queue buffers for inevitable delays. This project proposes a focused web-based application to coordinate operations in a clinic.

## 1.2     Problem Statement

In many Kenyan clinics, the patient appointment process typically follows a first-come, first-serve (FCFS) model. Patients arrive at the facility, select an available time slot and are scheduled accordingly. This approach lacks the flexibility to account for varying patient needs and doctor availability. As a result, it often leads to inefficiencies such as overlapping

appointments, extended waiting times and underutilization of medical staff. The absence of automated queueing based on the nature of consultation and doctor availability further complicates scheduling and service delivery (CIHEB, 2023).

A study conducted at the University of Nairobi Staff Clinic in late 2021 found that prolonged waiting times negatively affected patient behaviour. Patients often missed or arrived late for appointments, delayed starting treatment and struggled to follow care plans. The findings highlight that long wait times can significantly impact treatment adherence and the overall quality of healthcare delivery (Wafula & Ayah,2021).

A third delay analysis in Kenyan secondary-level public hospitals demonstrated that suboptimal patient flow management, inadequate continuity of care resources and scheduling inefficiencies directly contributed to delays starting essential treatments, compounding risks for time sensitive conditions (Onyango et al., 2024). If left unchecked, these pending appointments increase the burden on the administration and elevate patient mortality rates, especially among the elderly or chronically ill who miss critical treatment windows.

## 1.3    Aim/ Specific Objectives

To develop a web-based application to coordinate operations in a clinic that optimizes patient scheduling, enhances queue management and improves service delivery in outpatient healthcare settings.

### 1.3.1   Specific Objectives

i.     To assess factors influencing operational efficiency in outpatient clinic settings.
ii.    To review existing appointment management solutions and identify their strengths and weaknesses.
iii.   To implement SMS-based reminders and notifications for patients regarding appointments and schedule changes.
iv.    To design a web-based application that supports real-time doctor availability tracking, patient priority tagging and dynamic queue buffering.

### 1.3.2  Research Questions

i. What are they key operational challenges affecting scheduling and patient flow in Kenyan outpatient clinics.

ii. What limitations exist in the current appointment management systems used in clinics?

iii. How can digital solutions be used to prioritize patients based on urgency and vulnerability?

iv. How effective is a web-based application in reducing waiting times and improving coordination in clinical operations?

## 1.4  Justification

This project addresses a key challenge in Kenya clinic: long delays caused by inflexed appointment system. It will benefit patients by cutting waiting times, especially for the elderly and emergency cases, clinics and doctors by enabling smoother daily operations, fewer missed appointments and better use of their time and heath regulators for policymakers by providing accurate data on booking trends to inform staffing levels and infrastructure planning.

## 1.5  Scope

The system will provide modules for patient profile management, automated appointments booking with dynamic queue prioritization (including urgency tagging for elderly, chronically ill and emergency cases), SMS confirmation and update notifications, a real-time administrative dashboard displaying upcoming appointments and doctors' availability. All driven by simulated yet realistic datasets reflecting typical Kenyan clinic decision support features (e-prescription), billing or insurance processing, or integration with national health information systems.

## 1.6  Limitations

Anticipated challenges include user resistance to adopt new digital workflow and limited access to real-time data from hospitals for testing.

## 1.7  Delimitation

To address these limitations, the application will be user friendly with an intuitive administrative dashboard and the project will use simulated datasets that reflect typical hospital appointment flows, patient categories and doctor availability scenarios.

**Chapter 2:     Literature Review**

## 2.1     Introduction

This chapter reviews the existing literature on outpatient scheduling and queue management in clinics. It begins by describing the current appointment processes and contextual factors, then examines the key challenges that affect efficient patient flow. Next, three representative systems are reviewed to understand their designs, strengths, and limitations. From the review of the existing systems, we identify the gaps present in current approaches. Finally, we look at the technologies commonly used in related solutions and present a conceptual framework that situates our proposed web-based scheduling and priority-management system within the broader health-care context.

## 2.2     Current Processes / Pipelines / Existing Technologies

In most Kenyan clinics, the patient appointment process typically follows a first-come, first-serve (FCFS) model. Patients arrive at the facility, select an available time slot and are scheduled accordingly.

Our study focuses on coordinating operations in a clinic setup. One of these operations is outpatient booking for non-emergency consultations. In this process, clerks allocate 25-minute slots, often without buffers for delays or emergencies. Clinicians manually update their availability at the start of each day. If appointments run over their allocated time or a doctor is unexpectedly absent, subsequent patients are left waiting.

Guidelines from the Institute of Medicine recommend that patients should not wait more than 30 minutes for consultation (Institute of Medicine, 2001). Policies from the Ministry of Health in Kenya similarly recommend timely service (MoH, 2016). In reality, however, the average wait times exceed one hour at major hospitals (Catherine, 2019). The gap between expectation and actual performance stems from inflexible scheduling, lack of real-time clinician updates, and absence of automated reminders—all deficiencies this research aims to address.

## 2.3     Challenges in Appointment and Queue Management

### 2.3.1     Deficiencies and their origin

Key deficiencies include (a) high rates of missed appointments due to lack of reminders, (b) compounding delays when one appointment overruns, and (c) absence of real-time visibility

on doctor availability (Seif et al., 2025). These arise from reliance on manual record-keeping, limited IT infrastructure, and lack of dynamic scheduling algorithms.

### 2.3.2 Impact on Clinic Operations

When appointments overlap, patients experience long waits, staff frustration increases, and the throughput of a clinic declines. Vulnerable groups such as the elderly or chronically ill are heavily affected, often waiting hours beyond their scheduled time (Opon et al., 2020). Extended waits also lead to missed follow-up visits and treatment interruptions.
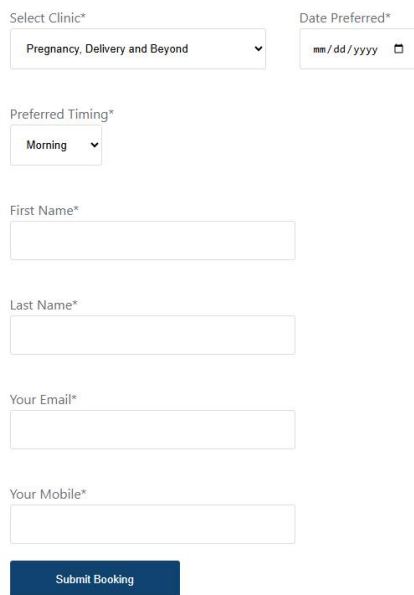
### 2.3.3 Consequences

Unaddressed, these issues contribute to poorer health outcomes, increased operational costs, and patient dissatisfaction. Some clinics have experimented with SMS reminders to reduce the rate of missed appointments, with studies showing that this approach can significantly improve attendance rates (Kuria et al., 2025), but these efforts have not been integrated with real-time scheduling or priority tagging.

## 2.4 Related Works

### 2.4.1 Premier Hospital EQMS

Premier Hospital in Mombasa deployed an Electronic Queue-Management System (EQMS) in 2019 to digitize check-in and notify patients via SMS when their turn approached (Abdulle, 2021). Patients register on arrival; the system calculates an estimated wait time and sends a text reminder before their consultation. It uses PHP backend, MySQL database, and a third-party SMS API. Though it addressed the long wait times and congested waiting areas, it lacks integration with clinician schedules and cannot reprioritize for emergencies or high-risk patients.

Book an Appointment



Figure 2.1 Booking an Appointment (Premier Hospital, 2021)

### 2.4.2 M-TIBA Health Wallet Platform

M-TIBA is a mobile-based health financing platform widely used in Kenya to facilitate digital payments, appointment bookings and patient reminders (Capital FM, 2024). It improves financial access and transparency by enabling patients to save and pay for healthcare via mobile wallets. While it supports appointment booking and SMS reminders, M-TIBA does not integrate real-time clinician scheduling, dynamic queue management or emergency prioritization.
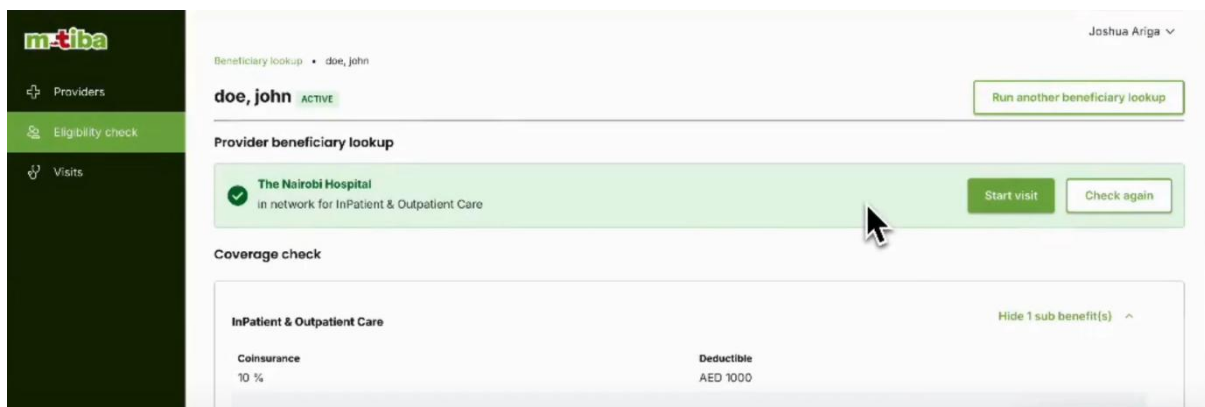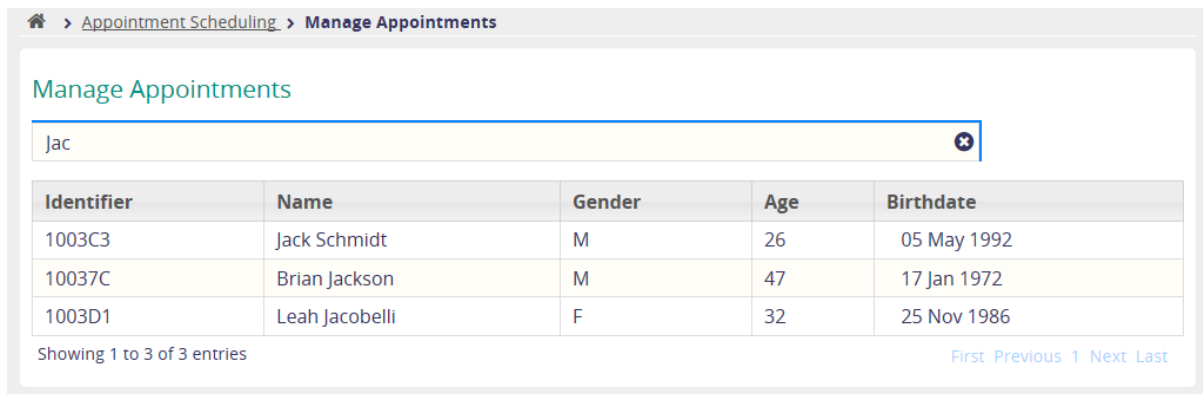


Figure 2.2 Patient Management (M-TIBA, 2025)

### 2.4.3  OpenMRS Appointment Module

OpenMRS, an open-source electronic medical record system used in several Kenyan facilities, includes an appointment module that supports basic booking and reminders (OpenMRS Community, 2020). Clinicians and clerks share a unified patient record; appointment details are stored alongside clinical data. SMS reminders can be configured via plug-ins. It addressed fragmented record-keeping across departments, but its configuration is complex; no built-in priority-tagging or buffer management.



*Figure 2.3 Manage Appointments (OpenMRS, 2020)*

### 2.5     Gaps in Related Works

Although each system offers improvements, none simultaneously provides real-time clinician availability updates to prevent booking conflicts, dynamic priority tagging for elderly, chronic, or emergency cases, automated buffer-slot insertion to absorb overruns without compounding delays, integrated administrator dashboard for end-to-end visibility of patient flow and service metrics.

### 2.6     Technology to be used

Our system will use several technologies to ensure effective coordination of clinic operations. An SMS gateway will be used to send appointment confirmations and reminders to patients, helping reduce missed appointments. The web frontend will be developed using HTML, CSS and JavaScript to ensure responsive design and compatibility with desktops and tablets

commonly used in clinics. The backend will be built using PHP and AJAX to enable real-time asynchronous updates of clinician availability and queue status. For data storage, MySQL will be employed as a reliable relational database to manage patient records, appointments and priority levels efficiently.

**2.7      Conceptual Framework**
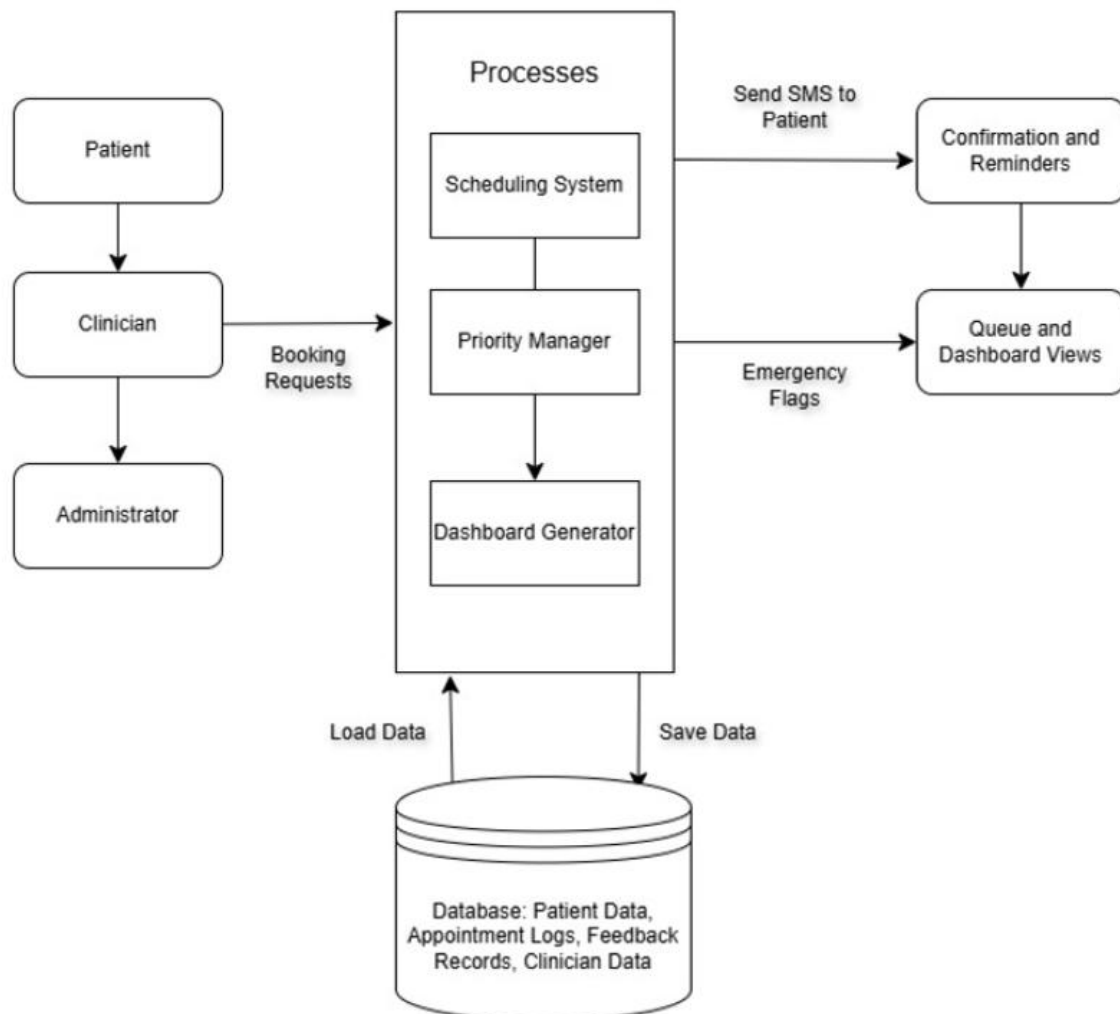


*Figure 2.7 Conceptual Framework of the Application*

## Chapter 3: Methodology

### 3.1 Introduction

This chapter outlines the overall research and development approach for the clinic operations coordination system. It explains the chosen paradigm and software methodology, describes each phase of the development process and details the analysis and design activities. It also presents the tools and techniques that will be used and explains the concrete deliverables that will result from this work.

### 3.2 Applied Development Approach

The project adopts an Object-Oriented Analysis and Design (OOAD) paradigm alongside the Agile Scrum lifecycle. OOAD was chosen because clinic workflows-such as patient bookings, doctor availability updates, queue prioritization, and feedback collection-map naturally to software objects with encapsulated data and behaviour. By modelling patients, appointments, clinicians, and priority managers as distinct classes, the system structure becomes intuitive and maintainable. Additionally, software engineering literature demonstrates that object-oriented approaches improve requirement traceability and support incremental extension of features.

Agile Scrum was selected because coordinating clinic operations requires frequent stakeholder feedback and the ability to adapt rapidly to evolving requirements. Scrum's use of short, time-boxed sprints ensures that working software is delivered early and regularly, allowing clinic staff to validate each increment. This iterative process reduces the risk of building the wrong features and fosters close collaboration between developers and end users. Studies in healthcare software development have shown that Scrum leads to higher user satisfaction, fewer rework cycles, and faster realization of value compared to linear methodologies.

#### 3.2.1 Requirements &Planning (Sprint 0)

In Sprint 0, we will work with clinic staff to gather and refine user stories, establish a clear acceptance criteria, and build a prioritized product backlog. By the end of this phase, we will have a concise feature list ranked by business value, an initial project plan outlining sprint schedules, and a fully configured development environment ready for implementation.

#### 3.2.2 Design & Development (Sprint 1-3)

In sprint 1-3, we will design and develop core system modules in a week. Each sprint begins with planning to select high- priority user stories-such as the appointment booking interface,

priority tagging logic, and SMS notification service-and ends with unit testing to verify that each component meets its acceptance criteria. By the close of sprint 3, we will have working, tested modules for patient scheduling, dynamic prioritization, and automated reminders.

### 3.2.3 Integration & Validation (Sprint 4-6)

During Sprints 4–6, focus shifts to integrating individual modules and validating end-to-end workflows. We will combine the booking, prioritization, notification, and dashboard components, conduct system integration tests, and demonstrate the prototype to clinic staff. Feedback gathered during these reviews will guide refinements, ensuring that the system operates smoothly under real-world conditions.

### 3.2.4 Refinement & Deployment (Sprint 7-8)

In Sprints 7–8, we will refine functionality, optimize performance, and prepare for testing. Based on user feedback, we'll fine-tune interfaces, resolve any remaining defects, and document installation and user procedures. The final output of this phase is a final release complete with deployment scripts, user manuals, and training materials for clinic staff.

## 3.3 System Analysis

This section describes the analytical models that capture system requirements behaviour.

### 3.3.1 Use Case Diagram

Defines primary actors (Patient, Doctor, Administrator) and their interactions -such as "Book Appointment"," Update Availability", and "View Dashboard"-to ensure all functional requirements are captured.

### 3.3.2 Sequence Diagram

Illustrates the step-by-step message flow for keys scenarios. For example, the booking process: Patient → Booking Controller → Scheduling Engine → SMS Gateway → Patient.

### 3.3.3 Entity-Relationship Diagram (ERD)

Specifies data entities (User, Appointment, Feedback, Priority Level), their attributes and relationships. This underpins the relational database design.

### 3.3.4 Class Diagram

Shows system classes (e.g. Patient, Doctor, Appointment Manager, Notification Service), their methods, attributes and associations-guiding object-oriented implementation.

### 3.3.5 Activity Diagram

Maps critical workflows such as "Process New Appointment," including decision points (e.g., "Is slot available?"; "Is patient priority high?").

### 3.3.6 State Diagram

Models the lifecycle of an Appointment object through states: Requested → Confirmed → Completed → Feedback Submitted.

## 3.4 System Design

This section outlines design artifacts that translate analysis models into concrete structures.

### 3.4.1 Database Schema

Derived from the ERD, the schema defines tables (users, appointments, feedback, priorities), columns (datatypes, keys), and indexing strategies to support efficient queries for real-time availability.

### 3.4.2 Wireframes

Low-fidelity sketches of key user interfaces—appointment form, priority settings, administrative dashboard, and feedback survey—illustrating layout, navigation, and data entry flows.

### 3.4.3 System Architecture

A three-tier architecture comprising:

Presentation Layer: HTML, CSS, and JavaScript for responsive web pages.

Application Layer: PHP controllers implementing business logic (OO-based), RESTful endpoints, and integration with the SMS gateway.

Data Layer: MySQL database for persistent storage of clinic data.

## 3.5 System Development Tools and Techniques

Below are the primary tools and justification for their selection.

### 3.5.1 Integrated Development Environment

Visual Studio Code -Chosen for its simple nature, rich plugin ecosystem (PHP, MySQL, JavaScript), and integrated Git support, which streamlines coding and version control.

### 3.5.2 Backend Language & Framework

PHP with Composer - Offers broad hosting support, mature libraries (including SMS gateway SDKs), and easy integration with MySQL. Composer allows structured dependency management.

### 3.5.3 Frontend Technologies

HTML, CSS, JavaScript - Ensure fast load times and compatibility on clinic desktops and tablets. AJAX is used for asynchronous updates (e.g., live queue status).

### 3.5.4 Database Management System

MySQL - Provides robust transaction support and indexing, essential for reliable appointment booking under concurrent access. XAMPP is used for local development.

### 3.5.5 Collaboration & Version Control

Git on GitHub -Facilitates branching for feature development, pull-request reviews, and issue tracking to manage tasks, bugs, and enhancements.

### 3.6 Deliverables

The following deliverables align with the project milestones and examination requirements:

### 3.6.1 Requirements & Design Documentation

Detailed proposal, user stories, use case descriptions, and analysis or design diagrams.

### 3.6.2 Working System Modules

User Management Module : Registration, login, profile updates.

Appointment Module: SMS reminders and confirmations.

Dashboard Module: Real-time schedule overview, queue metrics and visualisation.

Feedback Module: Post-visit surveys and feedback storage.

### 3.6.3 Test Artifacts

Unit, integration and acceptance test cases with execution reports, performance or load testing results.

### 3.6.4 Deployment and User Guides

Deployment scripts, installation instructions and end-user manuals for clinics staff and administrators.

### 3.6.5 Final Report

Comprehensive write-up of methods, implementation details, evaluation of results and recommendation for future work.

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# Appendix

## Appendix 1: Gantt Chart