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SMART MATERNAL EMERGENCY RESPONSE SYSTEM

PROJECT PROPOSAL

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CHAPTER ONE

1.0 Introduction

This proposal presents the Smart Maternal Emergency Response System (SMERS), a technological solution designed to reduce preventable maternal and neonatal mortality in the urban informal settlements of Kenya. The development of SMERS is necessitated by the persistent and disproportionately high maternal mortality ratio (MMR) and neonatal mortality rate (NMR) in these vulnerable communities. The system is specifically engineered to address the critical gaps in emergency transport logistics, commonly referred to as the "second delay," by leveraging ubiquitously accessible mobile communication channels (USSD and WhatsApp) and a community-based transport network. The subsequent sections will detail the problem, define the project objectives, and justify the significance of implementing this system as a functional prototype.

1.2 Problem Statement

Maternal and neonatal mortality remains a significant public health crisis in Kenya, with rates that substantially exceed global benchmarks and Sustainable Development Goal (SDG) targets. The maternal mortality ratio (MMR) is approximately 355 deaths per 100,000 live births (UNFPA Kenya, 2025), and the neonatal mortality rate (NMR) stands at approximately 21 deaths per 1,000 live births (UNFPA Kenya, 2022). While national health indicators show some improvement, these averages mask acute disparities in urban informal settlements. Research in Nairobi slums, for example, indicates a maternal mortality rate of 706 deaths per 100,000 live births, a figure four times the national average (APHRC, n.d.).

The primary factor driving this elevated mortality rate is the inadequate and often absent emergency response infrastructure, specifically categorized as the Second Delay in Thaddeus and Maine’s Three Delays Model.

This delay refers to the logistical challenge in reaching a health facility once the decision to seek care has been made (Bhattacharjee & Singh, 2023; Maternity Worldwide, n.d.). Within densely populated, unplanned urban informal settlements, barriers include:

1. **Impassable Infrastructure:** Narrow, unpaved, and congested pathways are common in settlements like Kibera, rendering conventional ambulance services impractical or severely delayed.
2. **Lack of Real-Time Dispatch:** A formalized, government-backed emergency medical service (EMS) is often non-existent or inaccessible, forcing mothers and caregivers to rely on costly, unreliable, or slow ad-hoc transport options.
3. **Communication Barriers:** While smartphone penetration is high, consistent internet connectivity can be unreliable. Furthermore, the economic vulnerability of the target demographic necessitates a communication solution that bypasses expensive data costs and smartphone requirements.
4. **Absence of Triage and Prioritization:** In emergency scenarios, there is no standardized, immediate mechanism to assess the severity of a case and efficiently dispatch the nearest and most appropriate community responder.

The lack of a rapid, reliable, and accessible emergency transport and communication system translates directly into lost hours during obstetric emergencies, where minutes are critical for survival. Without a dedicated digital platform to coordinate community-based transport (such as *boda bodas* or *tuk-tuks*), which are better suited for navigating the local infrastructure, the high rate of preventable maternal and neonatal deaths in Kenya’s informal settlements will persist. This project seeks to address this specific technical and logistical failure through the development of the SMERS platform MVP.

1.3 Project Objectives

The main objective of this project is to develop and evaluate a functional prototype of the SMERS platform to validate its technical feasibility and demonstrate its effectiveness in reducing emergency transport response times within a simulated informal settlement environment.

1.3.1 Main Objective

To develop a Smart Maternal Emergency Response System (SMERS) prototype, validated through simulation, to mitigate the "second delay" in maternal health emergencies within urban informal settlements.

1.3.2 Specific Objectives

1. To integrate a dual-channel mobile interface (USSD and WhatsApp) into the SMERS architecture to ensure ubiquitous emergency request initiation across varied connectivity and hardware constraints.
2. To develop a scalable, microservices-based backend and centralized hospital-facing dashboard capable of real-time notification processing and patient data management.
3. To implement a transparent, rule-based Artificial Intelligence (AI) triage algorithm for real-time prioritization of high-risk obstetric cases and optimal allocation of community-based transport responders.
4. To facilitate a simulation-based evaluation of the prototype's performance, measuring the reduction in simulated emergency response times compared to documented historical baselines.

1.4 Justification

The proposed SMERS project holds significant academic, social, and technological value, justifying its implementation:

1.4.1 Social and Public Health Significance

The project directly targets one of the most critical and high-stakes social issues in Kenya, preventable maternal death, in the most vulnerable demographic. By focusing on the Second Delay, the system aims to save lives by addressing a problem that is fundamentally logistical, yet lethal (Rescue.co, 2025). The potential to reduce emergency response times serves as a critical indicator of impact, proving that technological intervention can bridge the gap where traditional EMS fails.

1.4.2 Technological Feasibility and Innovation

The architecture is based on proven, modern technologies (React.js, Node.js, microservices) (AfricaShore, n.d.). The core innovation lies in the integration of the universal USSD protocol with a modern WhatsApp interface via the Twilio API (Twilio, n.d.), ensuring accessibility regardless of smartphone ownership or internet status (Communications Authority of Kenya, 2024; DataReportal, 2024). This multi-channel approach is necessary for high-density, low-income environments.

1.4.3 Ethical and Accountable AI Development

The project utilizes a transparent, rule-based AI system for triage, avoiding the 'black box' issues often associated with complex AI models (Council of Europe, n.d.; World Scientific, 2024). This ethical design choice ensures that the prioritization logic is auditable and explainable, building trust and accountability into a life-critical application.

1.4.4 Academic Contribution

The project provides a demonstrable MVP focused on simulating real-world efficacy (Paz et al., 2023). The resulting deliverables, including the comprehensive report and technical documentation, will contribute a specialized, validated model for emergency dispatch that is specifically tailored for the unique infrastructure and connectivity challenges of sub-Saharan African urban settlements.

CHAPTER TWO

2.1 Overview of Digital Emergency Response Systems

Digital emergency response systems are designed to enhance the speed and efficiency of pre-hospital care, primarily through optimized communication, dispatch, and resource allocation. Globally, such platforms rely heavily on geospatial data and centralized communication hubs. For instance, sophisticated Emergency Medical Services (EMS) systems in developed nations utilize advanced telemetry and Computer-Aided Dispatch (CAD) to coordinate highly trained staff and specialized vehicles. However, these models are often unsuitable for resource-constrained environments due to high operational costs, reliance on standardized infrastructure, and the need for pervasive high-speed internet.

2.2 Global Context: Digital Health and Transport Innovation

The global health community has increasingly focused on the "second delay" in maternal health as a target for innovation (Maternity Worldwide, n.d.). While the majority of developed-world systems prioritize ambulance deployment, a significant body of literature supports the use of mobile technology to circumvent infrastructure deficiencies. For example, the global rise of ride-hailing platforms and their technological architecture (e.g., real-time tracking, optimized route algorithms) provides a proven blueprint for managing localized, dynamic transport networks. This underlying architecture is foundational to the SMERS system's design for managing community responders.

2.2.1 Latin America's Hybrid Approach

In several South American nations, addressing healthcare disparities involves hybrid solutions that combine formal ambulance services with technology-driven citizen interfaces. Cities often employ sophisticated geolocation services alongside community-centric mobile applications to coordinate non-emergency medical transport.

While these systems maintain formal EMS structures, their use of localized Geographic Information Systems (GIS) to map and navigate dense urban areas provides a contextual model for SMERS's need to map informal settlement pathways. This demonstrates a global recognition of the need for digital localization to overcome urban fragmentation.

2.3 African Context: Harnessing Mobile Technology for Emergency Transport

In Sub-Saharan Africa, where mobile penetration is high but formal infrastructure is often lacking, several models have emerged to address the emergency transport gap:

2.3.1 Tanzania's m-mama Program

This highly effective initiative, active in regions of Tanzania, utilizes a centralized, toll-free call center coordinated by Vodafone and local partners. The system is based on digital dispatch that works with local taxi and community drivers, essentially creating a community-powered emergency fleet for obstetric emergencies. Crucially, m-mama's success is attributed to its high acceptance and integration with existing local governance and transport structures, proving that community taxis can drastically reduce the "second delay" (Ndungu et al., 2024). This model provides the primary technical and operational validation for SMERS's concept of integrating *boda bodas* and *tuk-tuks* in Kenya.

2.3.2 Ghana's Zipline

Zipline is a highly advanced, technology-driven approach that is primarily focused on drone delivery of essential medical supplies and blood products to remote hospitals and health facilities. Its success demonstrates the potential of complex automation and bypassing road infrastructure entirely to overcome the challenges of poor road networks and logistics. However, Zipline's complexity, reliance on highly specialized hardware, and centralized maintenance requirements mean its high resource demands make it unsuitable for direct deployment as a low-cost, community-operated transport solution like SMERS.

2.4 Kenyan Context: Emergency Services and Digital Dispatch

Kenya has active private sector solutions and unique challenges that inform the SMERS design:

2.4.1 Flare/Rescue.co

Platforms such as Flare, operated by Rescue.co (Rescue.co, 2025), are a well-established model for digital emergency dispatch in Kenya. These commercial platforms provide a robust framework for aggregating and coordinating formal emergency services, including private ambulances and first responders, through a centralized digital system. They have demonstrated the viability and technical maturity of digital dispatch in the Kenyan context, offering lessons in system resilience, real-time coordination, and user notification protocols. Critically, while highly effective in coordinating conventional services, their model often caters to financially capable populations or operates primarily in areas accessible to conventional vehicles. These services may not penetrate the core, narrow pathways of informal settlements where transport is severely constrained, highlighting the need for SMERS's specialized, localized approach.

2.4.2 Prior Contact with Dispatch Systems

Recent academic work within my cohort has emphasized the urgent need for optimized EMS solutions. For example, a peer student’s concurrent project (SWE3090A) focused on developing a local digital Ambulance Dispatch System, underscoring the shared recognition of this challenge in the regional context. Building on this academic discourse, my own work has included a project report analyzing the catastrophic failure of the 1992 London Ambulance Dispatch System (LADS). This case study highlighted the risks of large-scale, non-phased rollouts and emphasized the critical importance of phased implementation, rigorous testing of real-time logic, and minimizing complexity in initial deployments. Furthermore, I conducted an analysis of a large-scale Ambulance Dispatch System for Nairobi, which provided foundational insights into resource allocation and the operational constraints of urban environments. Together, these experiences provide both theoretical grounding and practical perspective that directly inform the SMERS MVP approach.

2.5 Unique Proposition of the SMERS Project

The SMERS platform distinguishes itself from existing solutions through its integrated, community-focused design, specifically tailored for the technical and logistical constraints of urban informal settlements:

1. **Dual-Channel Ubiquity (USSD Integration):** Unlike most commercial dispatch platforms that rely solely on smartphone apps or internet connectivity, SMERS ensures access via the ubiquitous USSD protocol, making it accessible to the economically vulnerable population using basic feature phones (Communications Authority of Kenya, 2024). This is the core unique advantage over existing, data-intensive solutions.
2. **Specialized Localized Resource Optimization:** While m-mama uses taxis, SMERS specifically integrates *boda bodas* and *tuk-tuks*, which are the only motorized vehicles capable of rapid transit through the highly dense and complex terrain of settlements like Kibera.
3. **Ethical Rule-Based AI Triage:** By implementing a transparent, rule-based AI triage algorithm, the system offers a life-critical decision-making tool that is auditable and accountable, addressing the ethical concerns often raised by complex black-box AI models in sensitive healthcare applications (Council of Europe, n.d.).
4. **MVP Focus on Simulation:** The project scope is unique in its focus on validating the system's core logic and impact through a controlled, simulation-based environment (Paz et al., 2023), proving feasibility before scaling, a critical step often missing in large-scale pilot projects.

CHAPTER THREE

3.0 Methodology

The Smart Maternal Emergency Response System (SMERS) project will adhere to the Agile Development Methodology over a 9-week timeline. This approach is selected for its emphasis on incremental delivery, continuous stakeholder feedback, and rapid adaptation to emerging requirements, which is critical given the time constraint of the capstone project. The methodology ensures that a working Minimum Viable Product (MVP) is delivered and evaluated within the academic term. The solution architecture will be microservices-oriented, utilizing React.js for the dashboard and a Node.js/Express.js RESTful API for the backend.

3.1 Preliminary Investigation and Requirements Analysis

The preliminary investigation phase is essential for defining the scope of the MVP and ensuring the solution effectively addresses the "second delay" in maternal health within urban informal settlements.

3.1.1 User Requirements Analysis and Elicitation Methods

Given the high-stakes, low-resource environment of the target population, a multi-faceted requirements elicitation strategy will be used to gather precise user information:

a) **Interviews and Focus Groups (Simulated):** The primary method will involve simulated interviews and focus groups with surrogate users, representing main stakeholders: expectant mothers, their caregivers, community responders (*boda boda* associations), and healthcare staff (clinicians, dispatchers). The questions will focus on current emergency workflows, communication barriers, and the feasibility of the USSD interface design.

b) **Document Analysis:** Existing documentation from similar digital EMS platforms (e.g., Flare/Rescue.co, m-mama) will be analyzed to benchmark features, identify potential risk points in dispatch logic, and determine industry best practices.

c) **Observation (Simulated):** Simulated scenarios will be defined to model the operational environment, capturing the required speed and data input necessary for emergency response in areas with limited access.

3.1.2 Functional Requirements

The functional requirements define the core actions and capabilities of the SMERS system, organized by user role:

Module	Functional Requirement
User Interface (Mother/Caregiver)	The system must facilitate emergency request initiation via both USSD and WhatsApp channels, collecting minimal necessary triage data (e.g., location, type of emergency).
Responder Interface (Boda Boda/ Tuk-Tuk)	The system must integrate a mobile interface to receive dispatch notifications, update status (en route, arrival), and provide navigation guidance (simulated).
Triage and Dispatch Engine (Backend)	The system must develop a rule-based AI algorithm to prioritize incoming requests based on predefined medical and logistical criteria.
Hospital/Dispatcher Dashboard	The system must enhance the dispatcher's ability to view all incoming, active, and resolved emergency cases on a centralized dashboard in real-time.
Data Management	The system must streamline the logging and storage of all emergency lifecycle events, including response times, triage decisions, and delivery status, into the database.

3.1.3 Non-Functional Requirements

The non-functional requirements define the quality attributes and constraints necessary for reliable performance in the target environment:

Category	Requirement	Justification
Performance	The dispatch process (from user request to responder notification) must complete in under 5 seconds during simulated peak load.	Essential for reducing the "second delay" in life-critical scenarios.
Reliability/ Availability	The system must achieve 99.9% uptime during simulated operational hours, with USSD as a mandatory fallback in case of internet failure.	Ensures access in low-connectivity areas, mitigating a primary challenge.
Security	All patient and location data transmitted over the network must be encrypted using Transport Layer Security (TLS) standards.	Protects sensitive patient data against unauthorized access.
Usability	The mobile interfaces (USSD/WhatsApp) and the dispatcher dashboard must be intuitive and require minimal training for operation.	Essential for rapid adoption by community members and emergency staff.
Maintainability	The code must be well-documented and follow object-oriented design principles to allow for future feature expansion and maintenance.	Supports the long-term scalability and sustainability of the solution.

3.2 Design Phase

The design phase establishes the architectural blueprints necessary for the successful implementation and integration of the system components.

3.2.1 System Architecture

The system utilizes a **Microservices Architecture** to ensure modularity, scalability, and independent deployment of the core components.

1. **Communication Layer:** Utilizes the Twilio API to manage all incoming USSD sessions and WhatsApp messages, routing requests to the API Gateway.
2. **API Gateway:** Acts as the single entry point, handling request routing, authentication, and load balancing for the microservices.
3. **Core Services (Microservices):**
    a. **Triage Service:** Hosts the rule-based AI algorithm for case prioritization and severity assessment.
    b. **Dispatch Service:** Manages responder status, geolocation matching (simulated), and notification routing.
    c. **User/Responder Management Service:** Handles registration and profile management.
4. **Data Layer:**
    a. **PostgreSQL:** Used for structured, relational data (user profiles, dispatch logs, response metrics).
    b. **MongoDB:** Used for unstructured data (raw USSD sessions, WhatsApp message transcripts, and real-time event streams).
5. **Front-End:** A React.js web application serves as the Dispatcher/Hospital Dashboard, providing real-time visualization of active emergencies and responder locations.

3.2.2 Technology Stack Justification

Technology	Rationale
React.js	Provides a modern, component-based framework for building a dynamic and responsive Dispatcher Dashboard.
Node.js / Express.js	Offers a non-blocking, asynchronous runtime environment, ideal for building the high-performance, real-time RESTful APIs required for emergency dispatch.
PostgreSQL	Provides robust transactional integrity and ACID compliance for critical structured data like user accounts and immutable dispatch logs.
MongoDB	Offers flexibility for handling the diverse, unstructured data generated by USSD sessions and real-time event data from responders.
Twilio API	Essential third-party service for handling both USSD (low-connectivity) and WhatsApp (smartphone) communication channels.

CHAPTER FOUR

4.0 System Analysis & Design

This section details the formal analysis and design blueprints of the Smart Maternal Emergency Response System (SMERS), translating the functional requirements (Section 3.1.2) into a structured technical architecture.

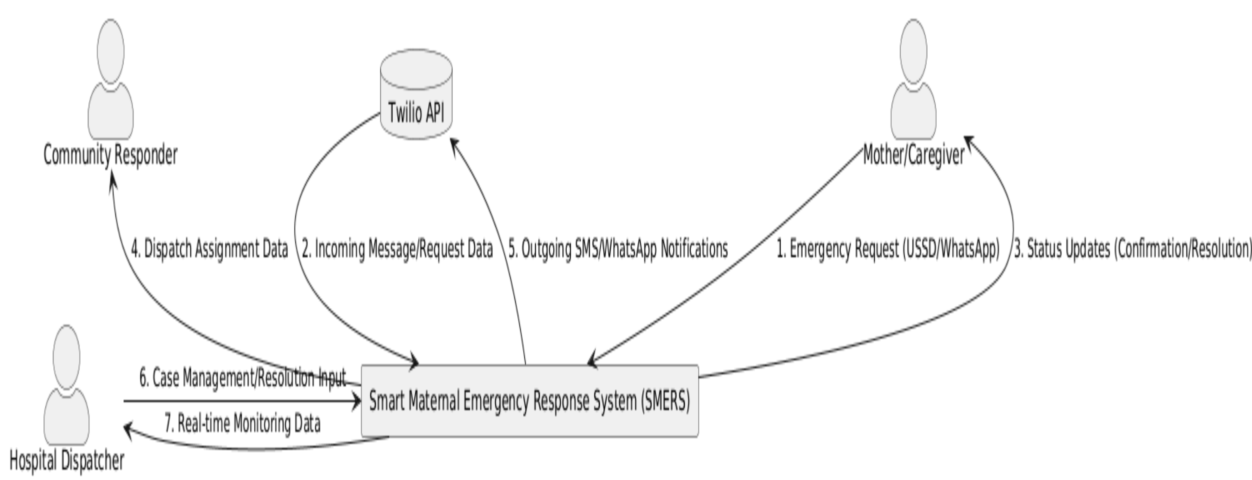
4.1 Data Flow Diagram (DFD)

The Level 0 (Context) and Level 1 DFDs illustrate the flow of critical information through the SMERS system, focusing on the three primary actors: the Mother/Caregiver (Requester), the Community Responder, and the Hospital Dispatcher.

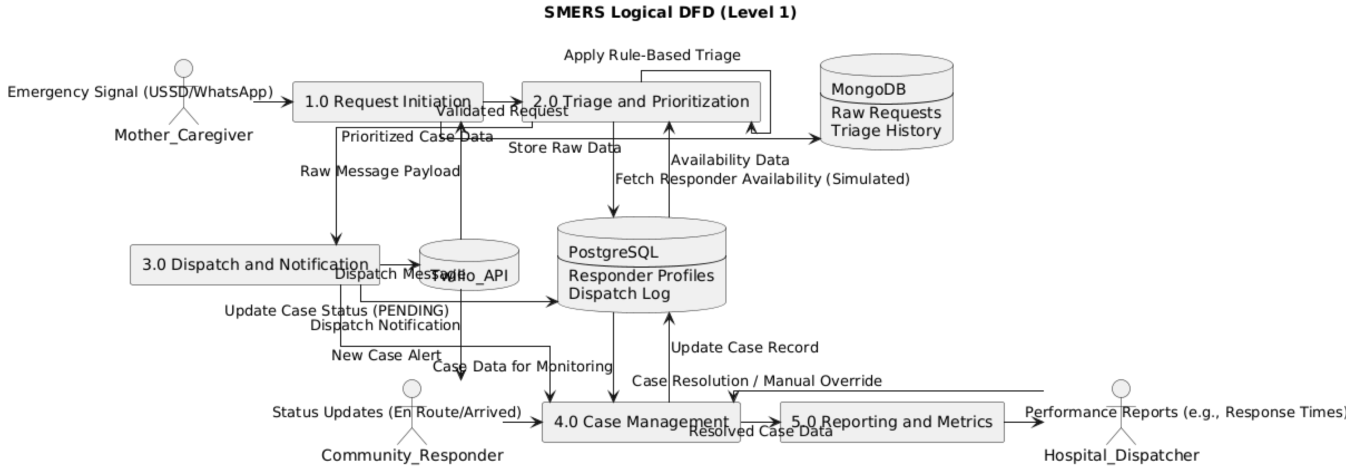
4.1.1 Context Level (Level 0) DFD

The system's context diagram shows SMERS as a single process interacting with external entities:

1. **Mother/Caregiver:** Initiates the request via USSD or WhatsApp and receives status updates.
2. **Community Responder:** Receives dispatch data and sends back status updates (en route, arrival, clear).
3. **Hospital Dispatcher:** Provides case management and system administration.
4. **Twilio API:** The external communication gateway managing message traffic.



4.1.2 Logical Level (Level 1) DFD



The Level 1 DFD delineates the five core processes necessary for emergency lifecycle management:

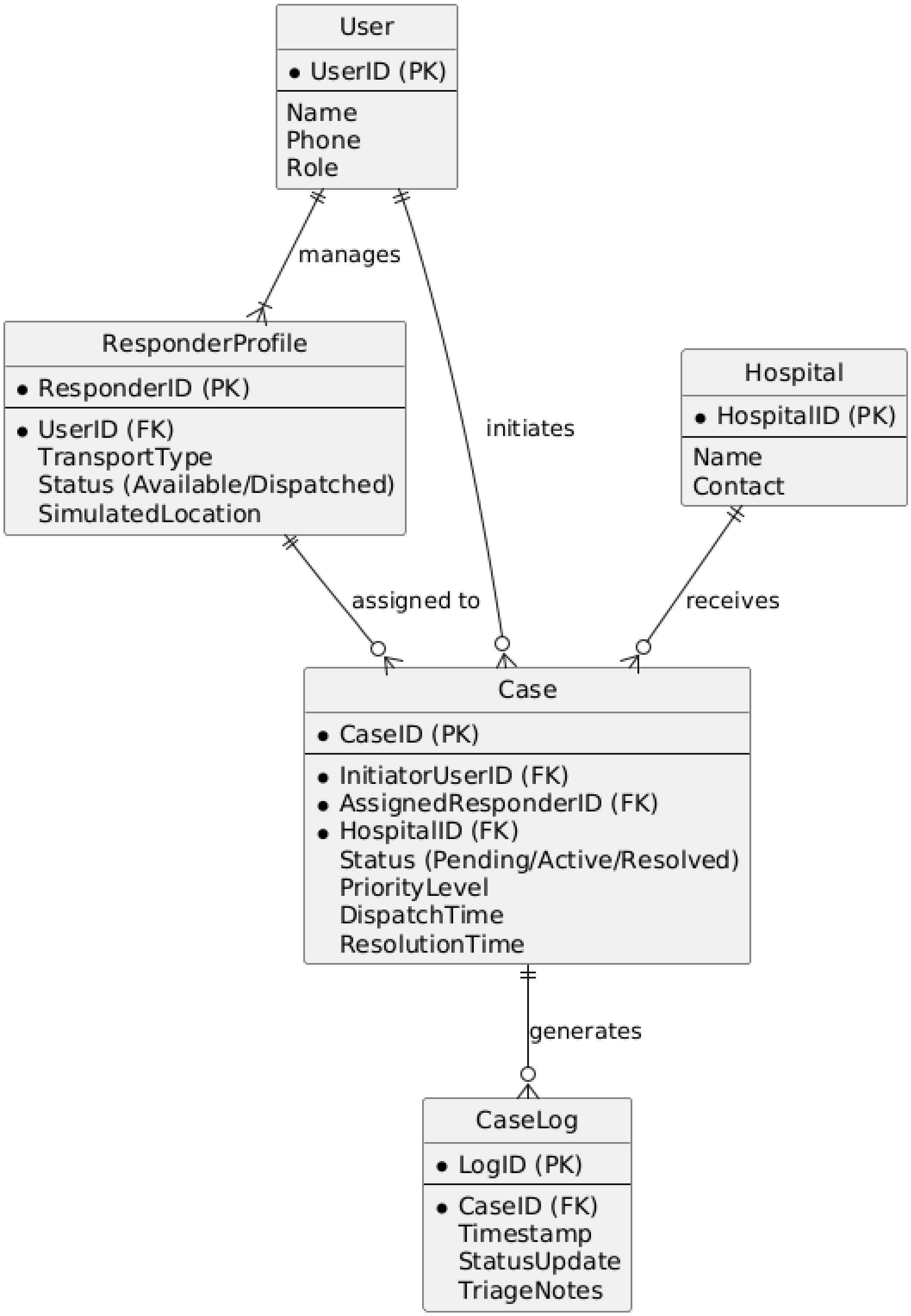
1. **Request Initiation (Process 1.0):** Raw emergency data (phone number, triage response) is received from the Mother/Caregiver via the Twilio API. This data is immediately stored in the Unstructured Data Store (MongoDB) before being passed to the Triage Service.
2. **Triage and Prioritization (Process 2.0):** The Triage Service processes the request data against the rule-based AI algorithm, determines the priority (high-risk or stable), and retrieves available nearby Responders from the Structured Data Store (PostgreSQL).
3. **Dispatch and Notification (Process 3.0):** The Dispatch Service sends the priority case details to the optimal Community Responder (based on simulated proximity) via their mobile interface (WhatsApp). The case status is logged.
4. **Case Management and Monitoring (Process 4.0):** The Hospital Dispatcher monitors all active cases via the React.js Dashboard. They can manually override dispatch decisions or mark cases as resolved. All status changes from the Responder update the case record in real-time.
5. **Reporting and Metrics (Process 5.0):** This process extracts time-stamped data from the Dispatch Log (PostgreSQL) to generate reports on key performance indicators, such as average response time and case resolution rates for simulation-based evaluation.

4.2 Entity Relationship (ER) Diagram

The ER Diagram defines the logical structure of the database, ensuring data integrity and relationships between critical entities. The primary data will be stored in PostgreSQL to enforce ACID compliance for life-critical dispatch logs.

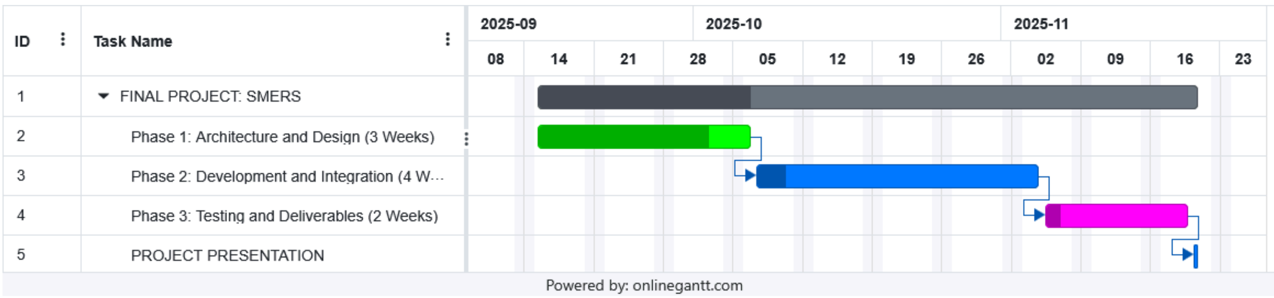
Entity	Attributes	Primary Relationship
User	UserID (PK), Name, Phone, Role (Mother/Responder/Dispatcher)	One-to-Many with Case (Initiator), One-to-One with Responder Profile
Responder Profile	ResponderID (PK), UserID (FK), TransportType (*boda boda/tuk-tuk*), Status (Available/Dispatched), SimulatedLocation	One-to-Many with Case (Assigned Responder)
Case	CaseID (PK), InitiatorUserID (FK), AssignedResponderID (FK), Status (Pending/Active/Resolved), PriorityLevel, DispatchTime, ResolutionTime	Many-to-One with User (Initiator), Many-to-One with Responder Profile
Case Log	LogID (PK), CaseID (FK), Timestamp, StatusUpdate, TriageNotes	One-to-Many with Case
Hospital	HospitalID (PK), Name, Contact	Many-to-One with Dispatcher

SMERS Entity Relationship Diagram



4.3 Proposed Timelines (Gantt Chart)

The project will be executed over 9 weeks using an Agile Methodology. This condensed timeline integrates development and testing within shorter sprints to meet the academic submission deadline.



4.3.1 Timeline Breakdown

Phase	Activity	Duration (Weeks)	Start Week	End Week
Phase 1: Architecture and Design (3 Weeks)			**1**	**3**
P1.1	Finalize Requirements (Functional/Non-Functional)	1	1	1
P1.2	Microservices Architecture and Database Design (ERD/DFD)	2	1	2
P1.3	Setup Repositories and Cloud Environment (AWS/GCP)	1	2	3
Phase 2: Development and Integration (4 Weeks)			**4**	**7**
P2.1	Backend API Core Development (Node.js/Express.js)	2	4	5
P2.2	Triage Service and Logic Implementation (Rule-Based AI)	2	4	5

P2.3	Twilio API Integration (USSD/WhatsApp Handlers)	2	6	7
P2.4	Frontend Dashboard Development (React.js - UI/Monitoring)	3	5	7
Phase 3: Testing and Deliverables (2 Weeks)			**8**	**9**
P3.1	Simulation Testing and Debugging (MVP)	1	8	8
P3.2	Performance Evaluation and Metric Capture	1	8	9
P3.3	Final Technical Documentation and User Guide	2	8	9
P3.4	Final Project Report Compilation and Submission	1	9	9

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