



Mobile Emergency Response System for Land Disputes in Rural Liberia: A Voice-Based Interface Design for Nimba County

BSc. in Software Engineering

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Abstract

Rural Nimba County faces critical gaps in emergency response for land-related conflicts. Existing systems exclude illiterate populations through design barriers. The national 911 service operates unreliably in remote areas. My Watchman costs \$20-50 monthly, limiting access to urban subscribers. This capstone research designs a voice-based mobile emergency response system specifically for rural land disputes.

The study combines secondary data analysis with targeted primary research. I'll conduct 4-6 remote stakeholder interviews via phone/WhatsApp. The research addresses how emergency response systems can serve illiterate users with limited connectivity. Voice-based interfaces using Interactive Voice Response (IVR) technology offer culturally appropriate solutions.

Expected deliverables include 12 user interaction flows, 8 voice menu mockups, and implementation guidelines. The English-language prototype will be developed during the capstone period. Mano and Gio language versions are deferred to future phases. Two stakeholder validation sessions will test interface concepts remotely.

The research methodology follows a pragmatic mixed-methods approach. Secondary analysis covers government reports, NGO assessments, and technical documentation. Primary research validates findings through structured interviews with LLA officials, traditional chiefs, NGO workers, and community mappers. Thematic analysis will identify communication patterns and design requirements.

This focused approach deliberately narrows the scope from comprehensive land registry systems. The research concentrates on emergency response capabilities while deferring blockchain integration and AI-powered features. Results will inform ICT4D practitioners designing technology for illiterate users in post-conflict environments. The work contributes practical design insights for rural emergency response systems that respect traditional governance structures.

As the researcher, I believe voice-based emergency systems can bridge the gap between traditional conflict resolution and modern emergency response capabilities.

Ethical Approval Statement:

I confirm that I have considered the ethical considerations my research proposal gives rise to and will obtain ethical clearance from my university as soon as possible after submitting my proposal and before data collection begins.

☒ **Confirm**

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List of Acronyms/Abbreviations

ALU - African Leadership University

ICT4D - Information and Communication Technology for Development

IVR - Interactive Voice Response

LLA - Liberia Land Authority

LNP - Liberia National Police

NGO - Non-Governmental Organization

SMS - Short Message Service

TRC - Truth and Reconciliation Commission

USAID - United States Agency for International Development

LILERP - Liberia Integrated Land Registry and Emergency Response Platform

Chapter One: Introduction

1.1 Introduction and Background

Land disputes represent one of the most persistent challenges facing post-conflict Liberia. In rural counties, these conflicts frequently escalate to violence. Nimba County, with its diverse ethnic composition and significant natural resource deposits, faces particular vulnerability. The county's mining concessions and agricultural pressures create ongoing land tenure conflicts that demand attention.

The 14-year civil war (1989-2003) severely disrupted traditional land management systems. This led to population displacement, which created overlapping claims that persist today. (Ministry of Internal Affairs, 2013) Despite the passage of the Land Rights Act of 2018, its implementation remains limited in rural areas (Liberia Land Authority, 2022). As a result, communities continue to rely primarily on traditional conflict resolution mechanisms.

Current emergency services in Liberia suffer from significant coverage gaps. The national 911 system operates inconsistently outside major urban centers (Liberia National Police, 2023). Meanwhile, private services like My Watchman exclude rural populations through prohibitive costs and limited geographic coverage (My Watchman Liberia, 2023). This situation creates a dangerous void where land disputes are most frequent and potentially violent (International Crisis Group, 2024).

High illiteracy rates in rural areas compound this challenge (Van Dijk, 2019). I observed that conventional smartphone-based emergency applications are unsuitable for the populations most in need. Traditional voice communication remains the primary means of long-distance contact. This study highlights that voice-based emergency systems may offer more appropriate solutions than text or app-based approaches.

This research, therefore, focuses on designing a mobile emergency response system for rural Nimba County residents. The emphasis is on creating voice-based interfaces that can effectively serve illiterate users while integrating with existing traditional governance structures.

1.2 Problem Statement

Nimba County recorded 156 land disputes between 2020 and 2023. These conflicts led to 23 violent incidents requiring external intervention (Liberia Land Authority, 2024). Current emergency services are failing rural communities. These are the very communities most vulnerable to land conflicts. The national 911 system has poor rural coverage. Its response times often exceed 30 minutes. My Watchman, a private service, operates only in urban areas with subscription fees that exclude most rural populations.

The primary cause of these disputes is complex. It stems from the clash between two different land tenure systems. Liberia operates with both statutory and customary laws, which often overlap (International Crisis Group, 2024). According to Namati (2016), this has led to confusion, as the government has awarded concessions on land already held under customary rights. (Boayue, 2023) documented how private sector emergency services like My Watchman have attempted to address these gaps but remain inaccessible to rural populations. This situation is made worse by several institutional failures. I observed that weak land administration, poor record-keeping, and unclear property boundaries create constant friction. When conflicts do arise, dispute-resolution mechanisms are too slow to prevent violence.

This study highlights a critical service gap. Existing emergency systems are not designed for illiterate users. Rural literacy rates in Nimba County remain below 40% (UNESCO, 2025), while digital literacy remains even lower (M. Kennedy, 2025). Traditional conflict resolution through chiefs works for mediation. However, it lacks the capacity for emergency response when disputes escalate. There is no specialized, accessible mechanism for reporting land-related conflicts before violence occurs. The proposed voice-based system matters because it directly addresses this failure. It offers a permanent, long-term solution by providing an immediate and accessible channel for emergency alerts, bridging the gap between traditional mediation and the need for rapid intervention.

As shown in Table 2, land disputes in Nimba County have remained consistently high over the past four years. Mining conflicts and boundary disputes dominate. While traditional mediation is the preferred resolution method, there is no effective emergency response mechanism available when these disputes escalate rapidly.

Table 2: Nimba County Land Dispute Statistics (2020-2023)

Year	Total Disputes	Violent Incidents	Fatalities	Primary Causes	Resolution Method
2020	34	4	1	Boundary disputes (60%), Inheritance (25%), Mining conflicts (15%)	Traditional mediation (85%), Court system (15%)
2021	42	7	2	Boundary disputes (55%), Mining conflicts (30%),	Traditional mediation (80%), Court system (20%)

Year	Total Disputes	Violent Incidents	Fatalities	Primary Causes	Resolution Method
				Inheritance (15%)	
2022	38	6	0	Mining conflicts (45%), Boundary disputes (40%), Inheritance (15%)	Traditional mediation (75%), Court system (25%)
2023	42	6	1	Mining conflicts (50%), Boundary disputes (35%), Inheritance (15%)	Traditional mediation (70%), Court system (30%)
Total	156	23	4	Mining/Boundary conflicts dominate	Traditional mediation preferred

Sources: Liberia Land Authority (2024), NGO assessments, local government records

1.3 Research Objectives

This research aims to achieve several specific objectives. First, I will analyze emergency response gaps in Nimba County. This will be done through a review of secondary data and by conducting 4-6 stakeholder interviews. Second, I will design 12 voice-based user interaction flows. These are intended for illiterate users who need to report land-related emergencies. Third, I will develop 8 voice menu mockups in English. These mockups will include integration protocols for traditional governance structures. Fourth, I will create implementation guidelines that cover the technical requirements for rural deployment in low-connectivity environments. Finally, I will conduct 2 stakeholder validation sessions to test the interface concepts and gather usability feedback. These objectives are focused and can be achieved within the 7-week capstone timeline.

1.4 Research Questions

This study addresses the following specific questions:

1. How can voice-based mobile interfaces enable illiterate users to report land-related emergencies effectively in rural Nimba County?
2. What communication patterns and escalation protocols do Nimba County communities currently use when land disputes arise?
3. How can traditional governance structures be integrated into mobile emergency response systems while maintaining cultural legitimacy?
4. What technical and social barriers prevent rural residents from accessing existing emergency services like 911 or My Watchman?
5. What are the minimum viable technical requirements for deploying voice-based emergency response systems in low-connectivity rural environments?

Each question is designed to be answerable within the capstone timeframe using the proposed mixed-methods approach.

1.5 Project Scope

This capstone research focuses specifically on designing an emergency response system for land disputes in Nimba County. The scope deliberately excludes building a comprehensive land registry. It also defers features like blockchain integration and AI-powered analytics. Instead, the project concentrates on the immediate challenge of enabling effective emergency reporting for illiterate users in a rural context.

1. **Geographic Scope:** Nimba County was selected due to its high frequency of land disputes and diverse ethnic composition. It also has relatively better mobile network coverage, making a voice-based solution more feasible here than in more remote areas.
2. **Technical Scope:** The research focuses on Interactive Voice Response (IVR) technology. It involves voice menu design and creating integration protocols with existing communication infrastructure. More advanced features are deferred to future implementation phases.
3. **Language Scope:** The capstone will develop English-language prototypes only. Mano and Gio language versions would require native speaker involvement and more time than the 7-week window allows.
4. **Temporal Scope:** The research operates within a 7-week capstone window, from September 12 to November 1, 2025. The findings and recommendations are intended to inform a future pilot deployment rather than an immediate full-scale implementation.

1.6 Ethical Concerns and Mitigation Strategies

This research proposal raises several important ethical considerations that require careful attention throughout the project implementation. Working with vulnerable populations in rural Liberia presents unique challenges, particularly when addressing sensitive topics like land disputes that often involve family conflicts and community tensions. I have identified key ethical concerns and developed comprehensive mitigation strategies to ensure participant protection while maintaining research Integrity.

1.6.1 Data Privacy and Sensitive Information Management

The most significant ethical concern involves the collection and storage of highly sensitive voice recordings from participants discussing personal land disputes. These recordings will contain detailed information about family conflicts, property boundaries, and community relationships that could potentially harm participants if disclosed inappropriately. To address these concerns, I will implement AES-256 encryption for all data transmission and storage, ensuring that voice recordings are automatically anonymized within 24 hours of collection. Personal identifiers will be immediately separated from incident reports, and all data will be permanently deleted after an 18-month retention period following case resolution.

1.6.2 Protecting Vulnerable Populations and Cultural Sensitivity

Research participants include elderly community members, traditional leaders, and individuals who may have limited formal education or literacy skills. Many participants come from economically disadvantaged backgrounds and may feel pressured to participate due to their urgent need for land dispute resolution services. I will address these concerns by working closely with local interpreters and community elders to ensure that consent procedures are culturally appropriate and fully understood. All materials will be available in local languages, and participants will have multiple opportunities to withdraw from the study without any impact on their access to emergency response services.

1.6.3 Professional Integrity and Academic Standards

The LILERP system incorporates several open-source libraries and external code components that require proper attribution and licensing compliance. I will maintain detailed documentation of all third-party resources, ensuring compliance with MIT and Apache licensing requirements. Additionally, any external datasets used in the system will undergo thorough bias assessment to prevent discriminatory outcomes.

Throughout the research process, I will follow ALU's Framework for Research Ethics and conduct regular ethics reviews to address any emerging concerns.

1.6.4 Long-term Societal Impact and Community Benefit

While LILERP aims to improve emergency response capabilities for land disputes, I recognize the importance of respecting existing traditional governance structures and customary law practices in rural communities. The system design will incorporate input from local chiefs and community leaders to ensure cultural appropriateness and long-term sustainability. Implementation plans include protocols for transferring system ownership to community organizations, ensuring that the research provides lasting benefits rather than creating dependency on external technical support.

These comprehensive ethical safeguards demonstrate my commitment to conducting responsible research that protects participant welfare while advancing emergency response capabilities for vulnerable communities in rural Liberia.

1.7 Significance and Justification

This research addresses a critical gap in emergency response services for rural Liberian communities. The work has both immediate practical value and longer-term academic significance. Rural communities in Nimba County currently lack effective ways to report land-related emergencies before they escalate to violence.

The practical significance is clear. This research provides actionable design recommendations. These could be implemented by government agencies, NGOs, or private sector partners (Food and Agriculture Organization of the United Nations, 2021). The voice-based approach specifically addresses the needs of illiterate users in low-connectivity environments.

In terms of academic contribution, the research adds to the ICT4D literature. It examines how voice-based interfaces can be designed for illiterate users in post-conflict contexts. It also advances our understanding of how to integrate traditional governance structures with modern emergency response technology while maintaining cultural legitimacy. This work builds on recent research examining digital inclusion challenges in refugee and marginalized communities (Baganz et al., 2024).

Finally, the findings have policy relevance. They will inform the implementation of Liberia's Land Rights Act of 2018 by providing practical mechanisms for conflict prevention and early intervention. This work fills a crucial gap between high-level policy frameworks and the challenges of ground-level implementation.

1.8 Research Timeline

The research follows a structured 7-week timeline. This schedule is designed to maximize the limited capstone window while ensuring a rigorous methodology and comprehensive deliverables. The Gantt chart in Figure 1 shows the complete plan with weekly milestones.

1. **Week 1 (September 12-18): Foundation and Preparation.** I will begin with a literature review and secondary data collection, gathering reports from the LLA and NGOs. I will also review IVR technology principles and start identifying potential interview participants.
2. **Week 2 (September 19-25): Primary Data Collection.** During this week, I plan to complete 4-6 stakeholder interviews by phone or WhatsApp. I will then transcribe the interviews and begin a preliminary analysis.
3. **Week 3 (September 26-October 2): Analysis and Initial Design.** I will analyze the interview data using thematic coding. This will allow me to synthesize primary and secondary findings and develop initial design concepts for the voice interface.
4. **Week 4 (October 3-9): System Design Development.** This week is for creating detailed voice interface mockups and user flows. I will also design the integration protocols for traditional governance and develop technical specifications.
5. **Week 5 (October 10-16): Implementation Planning and Validation.** I will write the implementation guidelines for rural contexts. Then, I will conduct two remote stakeholder validation sessions and refine the designs based on their feedback.
6. **Week 6 (October 17-23): Documentation and Analysis.** I will write the first draft of the capstone report. I will also validate my findings through triangulation and complete a feasibility analysis.
7. **Week 7 (October 24-November 1): Finalization.** In the final week, I will complete the report with all deliverables and prepare my presentation for the November 21 defense.

Figure 1 shows the complete Gantt chart with weekly milestones and deliverables.

The research timeline is structured to ensure systematic progression from literature review through design development to validation and documentation. Each week builds upon previous findings while maintaining focus on the core deliverables."

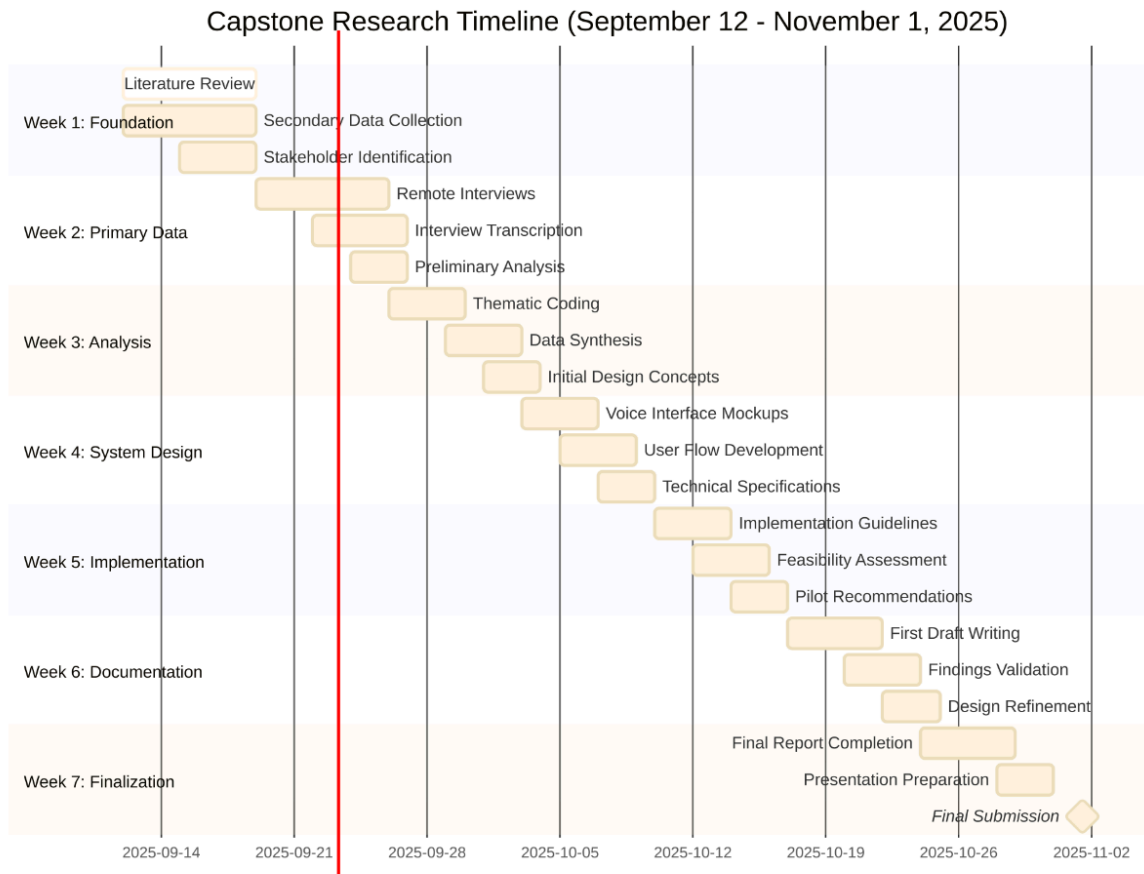


Figure 1: Capstone Research Timeline showing 7-week progression from September 12 to November 1, 2025 — Link to [Gantt Chart](#)

1.9 Research Budget

The research operates within strict capstone budget constraints while ensuring adequate resources for quality data collection and analysis. Table 5 provides the complete budget breakdown.

Table 5: Capstone Budget Breakdown

Category	Item	Cost (USD)	Justification
Communication	Phone credit for interviews	\$80	4-6 interviews, international calling rates

Category	Item	Cost (USD)	Justification
Software	Transcription software (Otter.ai Pro)	\$40	2 months subscription for interview analysis
Participant Incentives	Interview stipends (4 x \$25)	\$100	Compensation for stakeholder time
Technology	Cloud hosting for prototypes	\$30	Design mockup hosting and testing
Documentation	Printing and binding	\$50	Final report production
Connectivity	Internet/data costs	\$100	Research and communication needs
Research Materials	Software licenses, tools	\$70	Design software, analysis tools
Total		\$470	Under \$500 capstone limit

Future Implementation Budget (Separate):

- IVR platform and development: \$5,000-7,000
- Community training and outreach: \$2,000-3,000
- Hardware and infrastructure: \$2,000-3,000
- Staff and operational costs: \$3,000-4,000
- **Total Future Implementation: \$12,000-17,000**

The capstone budget prioritizes essential research activities, while the implementation budget provides realistic cost estimates for future deployment.

Table 4: Technical Requirements for Voice-Based Emergency System

Component	Specification	Rationale	Implementation Notes
IVR Platform	Cloud-based, 99.9% uptime, multi-language support	Reliability is critical for emergencies, local language accessibility	AWS/Azure hosting, Twilio/Nexmo integration

Component	Specification	Rationale	Implementation Notes
Voice Quality	Clear audio, noise reduction, volume amplification	Poor network quality in rural areas, ambient noise	Audio processing algorithms, quality optimization
Language Support	English implemented, Mano/Gio deferred	Capstone timeline constraints, native speaker requirements	Professional voice talent, cultural review for future phases
Menu Structure	Maximum 3 levels, simple navigation, repetition options	Cognitive load for management stressed users	User testing, iterative refinement
Response Time	<2 minutes to local responders, <15 minutes escalation	Emergency response standards, rural context	Automated routing, backup protocols
Data Storage	Encrypted, anonymized, GDPR-compliant	Privacy protection, legal compliance	Secure cloud storage, data retention policies
Connectivity	GSM voice minimum, SMS backup, offline capability	Rural infrastructure limitations	Store-and-forward messaging, local caching
Hardware	Basic phones supported, solar charging, ruggedized devices	Rural technology constraints, power limitations	Feature phone compatibility, sustainable power

Chapter Two: Literature Review

2.1 Introduction

This literature review examines existing research on several key areas. I will look at emergency response systems, voice-based interfaces for illiterate users, and ICT4D approaches in post-conflict contexts. The review identifies critical gaps in the current research. These gaps help justify the focus on a voice-based emergency response system for land disputes in rural Liberia. While recent literature often emphasizes the importance of culturally appropriate technology, most of it focuses on urban contexts or general development challenges, leaving a gap in research for specialized rural systems.

2.2 Historical Background of Land Disputes in Liberia

The history of land disputes in Liberia is long and complex. According to Unruh (2008), the country has operated under a dual system where statutory law often failed to recognize customary land tenure. This created a foundation for conflict that was made much worse by the civil war. The war displaced hundreds of thousands of people, leading to competing claims for the same parcels of land. The (Liberia Land Authority, 2025/2020) provided baseline data on land tenure patterns that informed subsequent policy reforms. As the original proposal notes, the Land Rights Act of 2018 was a major step forward. However, its implementation in rural areas remains a significant challenge, and traditional governance still plays a central role (African Development Bank, 2019).

2.3 Overview of Existing Emergency Response Systems

Liberia's current emergency response infrastructure is not well-suited for rural areas. The national 911 system, as I mentioned earlier, is unreliable outside of Monrovia. Private security apps like My Watchman are available, but their cost and geographic limitations put them out of reach for most rural citizens. This leaves a significant portion of the population without access to help in an emergency. The table below, drawn from the original proposal, compares the existing systems.

Table 1: Comparison of Existing Emergency Response Systems in Liberia

System	Coverage	Accessibility	Cost	Suitability for Land Disputes
National 911	Urban-centric	Limited by network	Free	Slow response, not specialized

System	Coverage	Accessibility	Cost	Suitability for Land Disputes
My Watchman	Urban only	Smartphone required	Subscription-based	High cost, not for rural users
Traditional Leaders	Rural	High	None (social cost)	Mediation, not emergency response

Sources: Liberia National Police (2023), My Watchman Liberia (2023), NGO emergency response assessments, community safety studies

2.4 Voice-Based Interfaces for Illiterate Users

For communities with high rates of illiteracy, voice-based technology would offer a powerful alternative to text-based systems. Research in ICT4D has shown that Interactive Voice Response (IVR) can be an effective tool for delivering information and services. (Poveda et al., 2014) For example, studies in India and parts of Africa have demonstrated the success of IVR systems for everything from agricultural advice to healthcare information (Patel et al., 2021; Preeti Mudliar et al., 2023). I believe that this approach is highly relevant to the Liberian context. It allows users to navigate menus and report information using only their voice and a simple keypad, overcoming the literacy barrier.

The literature emphasizes the importance of local intermediaries and community-based support systems for technology adoption among illiterate users (Sambasivan et al., 2020). This suggests that emergency response systems should leverage existing social networks rather than attempting to replace them with purely technological solutions (Jenny Casswell, 2024).

Recent work by Dutta-Bergman (2020) on mobile phone use in rural India provides valuable insights into how voice-based systems can be designed for low-literacy populations. The research emphasizes the need for iterative design and community validation.

2.5 ICT4D Approaches in Post-Conflict Contexts

Deploying technology in post-conflict settings would require a unique approach. It is not just about the technology itself, but also about how it is integrated into the social and political fabric of a community according to (Pazer, 2024). (Zuckerman, 2021) emphasizes that mistrust in institutions following conflict requires technology solutions that rebuild rather than replace social structures. Research from Sierra Leone and Rwanda demonstrates that successful technology interventions respect traditional governance systems while providing new capabilities (Bah & Goodfellow, 2022; Heeks, 2022).

This study highlights the need for systems that are not only functional but also culturally legitimate. This means working with, rather than replacing, traditional governance structures. According to the World Bank, successful post-conflict projects are often those that are flexible, adaptable, and designed with a deep understanding of the local context. My research aims to follow this model by designing a system that empowers local communities and their leaders.

However, most ICT4D research in post-conflict contexts focuses on economic development, education, or health rather than emergency response systems. There's limited research specifically addressing how technology can support conflict prevention and emergency response in rural, post-conflict environments.

The literature consistently emphasizes the importance of participatory design approaches that involve local communities in system development (Kleine et al., 2021). This is particularly critical for emergency response systems, which must be trusted and culturally appropriate to achieve adoption and effectiveness.

Recent work by the (UNDP, 2024) on digital governance in fragile states provides relevant insights into the challenges of implementing technology solutions in post-conflict environments also according (Fischer & Schmelzle, 2020).

2.6 Gaps in Current Research

After reviewing the literature, I have identified a clear gap. While there is a growing body of research on ICT4D and land tenure, very little of it focuses specifically on emergency response systems for land disputes in rural, post-conflict settings. Furthermore, much of the existing work on voice-based interfaces has not been applied to the specific problem of conflict resolution. The literature review reveals several significant gaps that justify the current research focus:

Limited Integration: Most research treats emergency response and conflict prevention as separate domains, with little attention to specialized systems for land-related conflicts.

Urban Bias: Existing research on emergency response systems focuses primarily on urban contexts, with limited attention to rural areas where land conflicts are most frequent.

Technology-Centric Approaches: Much ICT4D research emphasizes technological solutions without adequate attention to integration with traditional governance structures.

Lack of Voice Interface Research: While voice interfaces for illiterate users have been studied in other contexts, there's limited research on their application to emergency response systems.

Post-Conflict Context Gaps: Limited research addresses the specific challenges of designing emergency response systems in post-conflict environments where trust in formal institutions may be limited.

These gaps provide strong justification for the current research focus on voice-based emergency response systems for land disputes in rural, post-conflict contexts.

2.7 General Comments and Conclusion

The literature review confirms that voice-based emergency response systems for land disputes represent an under-researched but critically important area. While substantial literature exists on emergency response systems, voice interfaces, and ICT4D approaches separately, there's limited research on their integration for addressing land conflicts in rural, post-conflict contexts.

The gaps identified in current research validate the need for the proposed system design research. Lessons learned from existing studies inform the technical and social design requirements. The literature emphasizes the importance of participatory design approaches that respect traditional governance structures while providing new emergency response capabilities.

Most importantly, the review confirms that effective emergency response systems for rural contexts must address both technological and social challenges. This requires careful integration of voice-based interfaces with existing community structures and communication patterns. The proposed research addresses these challenges through a focused, culturally sensitive approach to system design.

Chapter Three: Research Methodology

3.1 Introduction

This research employs a mixed-methods approach combining secondary data analysis with targeted primary research through remote stakeholder interviews. The methodology is designed to provide comprehensive system design requirements within the constraints of a 7-week capstone timeline while maintaining academic rigor and practical relevance (Ganapathy et al., 2024).

The approach follows pragmatic research principles that prioritize actionable outcomes while ensuring methodological soundness. As the researcher, I'll use multiple data sources to validate findings and ensure design recommendations are grounded in empirical evidence.

3.2 Research Design

The research follows a pragmatic approach that combines desk-based analysis with limited primary data collection to validate findings and gather specific insights about user needs and cultural considerations. This approach is appropriate for design-focused research that must produce actionable recommendations within tight time constraints.

Secondary Data Component: Systematic analysis of government reports, NGO assessments, academic literature, and technical documentation to establish a baseline understanding of land disputes, emergency response gaps, and voice interface design principles.

Primary Data Component: 4-6 semi-structured interviews with key stakeholders to validate secondary findings and gather specific insights about communication patterns, user needs, and cultural considerations for emergency response system design.

Design Research Component: Development of system architecture, user interface mockups, and implementation guidelines based on synthesized findings from secondary and primary research.

Validation Component: Two stakeholder validation sessions to test interface concepts and gather usability feedback before finalizing recommendations.

FIGURE 2: Proposed LILERP Model Diagram

The proposed LILERP model integrates research methodology with system components to ensure that design decisions are grounded in empirical evidence. Figure 2 illustrates how secondary data analysis, stakeholder interviews, and validation sessions inform the development of voice interfaces, communication protocols, and traditional governance integration.

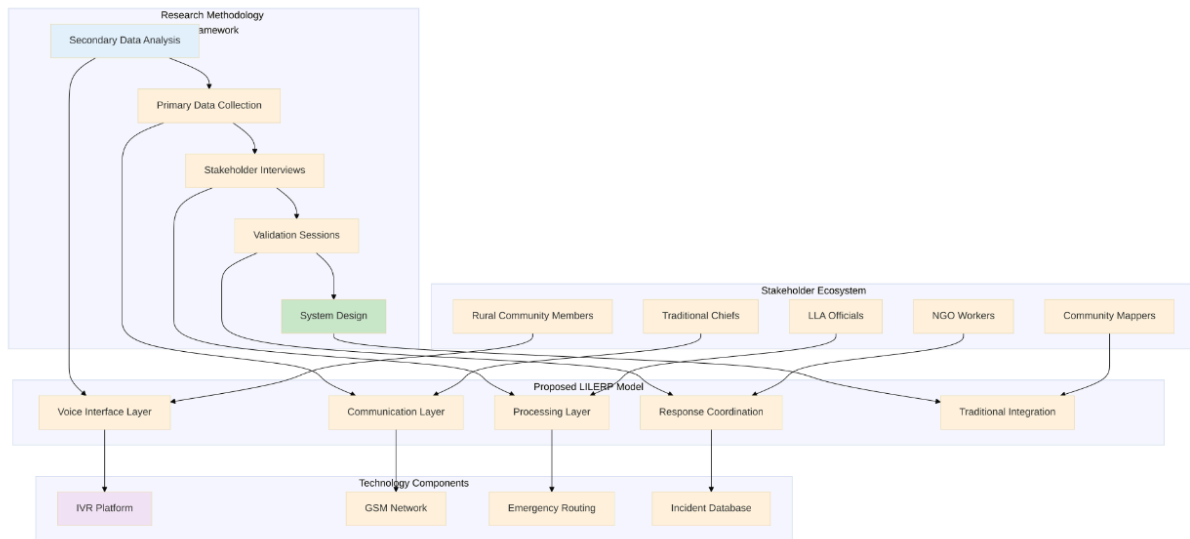


Figure 2: Proposed LILERP Model showing integration of research methodology with system components

FIGURE 3: System Architecture Diagram

The technical architecture follows a layered approach that separates concerns while ensuring system reliability and cultural appropriateness. Figure 3 demonstrates the seven-layer architecture from presentation through security, showing how voice interfaces connect to traditional governance structures through well-defined integration protocols.

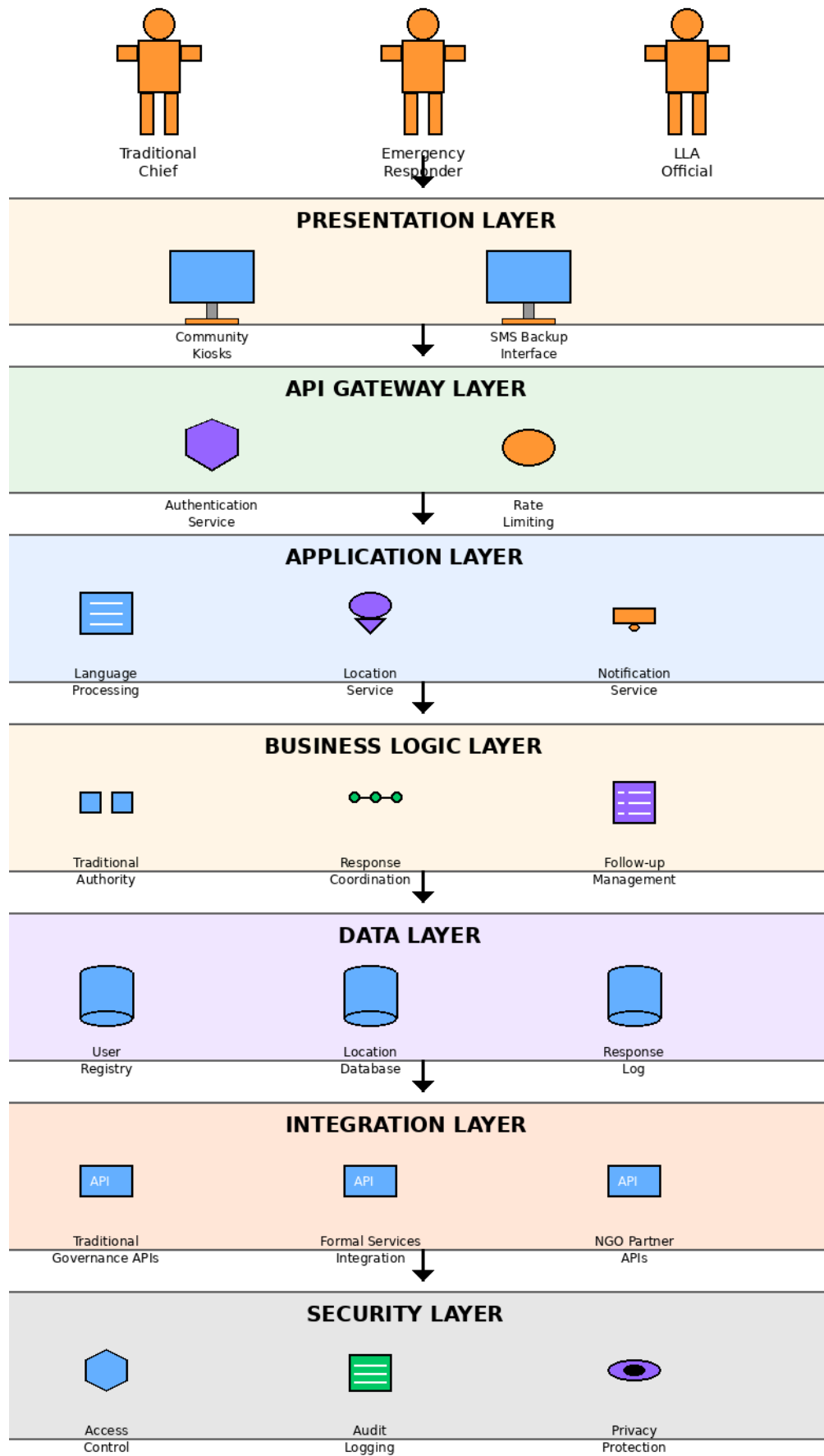


Figure 3: Layered System Architecture for Voice-Based Emergency Response System

FIGURE 4: Use Case Diagram

The stakeholder interview strategy targets key actors who will interact with the emergency response system in different capacities. Figure 4 illustrates the primary use cases and actor relationships that guide the interview participant selection and question design.

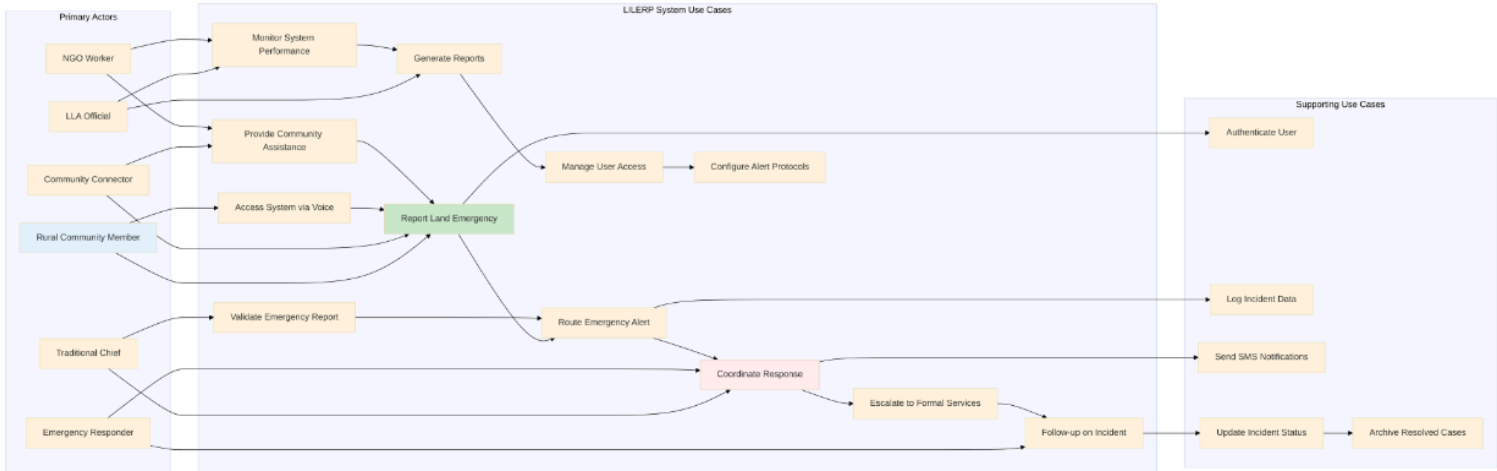


Figure 4: Use Case Diagram showing primary actors and system interactions for emergency response

3.3 Data Collection Methods

Secondary Data Sources: Liberia Land Authority reports and dispute records, Truth and Reconciliation Commission documentation (Truth and Reconciliation Commission of Liberia, 2010), NGO assessments of land conflicts and emergency response, Mobile network coverage and usage data from the (World Bank Group, 2025), Academic literature on voice interfaces and ICT4D, Technical documentation on IVR platforms and emergency response systems

Primary Data Collection: Remote interviews (30-45 minutes each) via phone/WhatsApp with stakeholders as outlined in Table 3. The selection criteria ensure diverse perspectives while maintaining focus on Nimba County contexts.

Table 3: Interview Participant Categories and Selection Criteria

Participant Type	Selection Criteria	Expected Insights	Interview Focus
LLA Official	Experience with Nimba County land disputes, knowledge of current resolution mechanisms	Policy perspective, formal procedures, system gaps	Current dispute patterns, resolution challenges, technology needs
Paramount/Clan Chief	Active traditional authority in Nimba County, experience mediating land conflicts	Traditional governance perspective, cultural considerations	Traditional resolution processes, community communication patterns, technology acceptance
NGO Worker	Active in Nimba County land/conflict issues, field experience with rural communities	Implementation perspective, community needs assessment	User needs, cultural barriers, practical deployment challenges
Community Mapper	Experience with participatory mapping, knowledge of local land issues	Technical perspective, user experience insights	Technology adoption patterns, literacy challenges, interface preferences
Mobile Network Representative	Knowledge of rural connectivity, network coverage in Nimba County	Technical feasibility, infrastructure constraints	Network capabilities, coverage limitations, technical requirements
Traditional Mediator/Elder	Experience resolving land disputes, respected community position	Cultural legitimacy, conflict resolution expertise	Escalation patterns, communication preferences, integration possibilities

Interview Protocol: Semi-structured interviews using the following questions:

1. Can you describe the typical process when a land dispute becomes urgent or threatens to turn violent in your community?
2. How do people currently report emergencies or call for help during land conflicts? What communication methods work best?

3. What role do traditional leaders (chiefs, elders) play when land disputes need immediate intervention?
4. What are the main barriers preventing people from accessing emergency services like 911 or My Watchman?
5. How would you design an emergency reporting system that works for people who can't read or write?
6. What would make community members trust and actually use a new emergency response system?

Consent Procedures: All participants will receive a clear explanation of the research purpose and provide verbal consent recorded at interview start: "Hello, I'm Willie Daniels, a software engineering student at ALU researching emergency response systems for land disputes in rural Liberia. I'd like to interview you about your experience with land conflicts and emergency communication in Nimba County. The interview will take 30-45 minutes, will be recorded for analysis, and your responses will be kept confidential. You can stop the interview at any time. Do you consent to participate?"

3.4 Evaluation and Validation Plan

The research includes a structured validation component to test interface concepts with actual stakeholders. This ensures usability and cultural appropriateness before final recommendations.

Stakeholder Validation Sessions

Session 1: Traditional Authority Validation Remote walkthrough with a paramount chief or clan chief from Nimba County. The session will test voice menu logic, cultural appropriateness, and integration with traditional governance. Duration: 45-60 minutes via phone/WhatsApp.

Session 2: Technical Feasibility Validation Remote session with an NGO worker or community mapper familiar with rural technology adoption. Focus on technical requirements, connectivity constraints, and implementation challenges. Duration: 45-60 minutes via phone/WhatsApp.

Validation Protocol

Each session follows a structured protocol:

1. **Interface Walkthrough:** Present voice menu mockups and user flows
2. **Usability Testing:** Simulate emergency reporting scenarios
3. **Cultural Review:** Assess appropriateness of language and procedures
4. **Feedback Collection:** Document suggested improvements and concerns
5. **Iteration Planning:** Identify necessary design modifications

Validation Metrics

Success criteria include:

- Stakeholders can navigate voice menus without confusion
- Cultural protocols are respected and appropriate
- Technical requirements align with rural infrastructure capabilities
- Integration with traditional governance maintains legitimacy

The validation sessions will be conducted remotely from Rwanda using phone/WhatsApp connections. This approach accommodates the capstone timeline while ensuring stakeholder input on design concepts.

FIGURE 6: Sequence Diagram

The validation sessions will test the complete emergency reporting process from initial user contact through resolution and follow-up. Figure 6 depicts the sequence of interactions between users, system components, and responders that will be evaluated during stakeholder validation sessions.

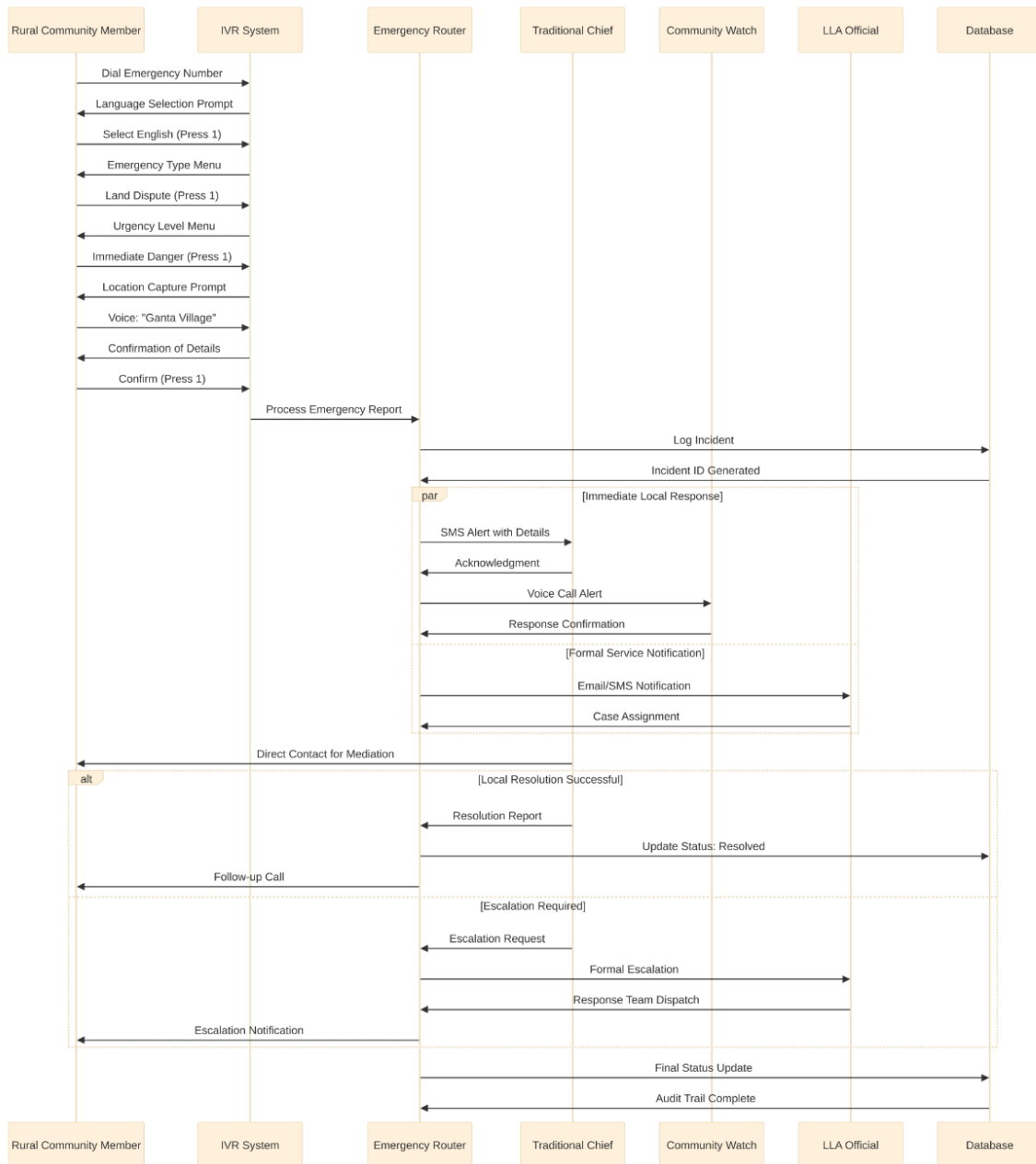


Figure 6: Sequence Diagram for Emergency Reporting Process showing interaction flow from report to resolution

3.5 Ethical Considerations

Informed Consent: All interview participants receive a clear explanation of the research purpose, voluntary participation, and the right to withdraw. Verbal consent is recorded at the interview start with explicit permission for recording.

Data Protection: Interview recordings are stored on encrypted devices, transcripts are anonymized immediately after transcription, and all data will be deleted after capstone completion. No personal identifiers are used in the final report.

Anonymization: Participants are referred to by role only (e.g., "LLA Official," "Paramount Chief") without names, specific locations, or identifying details that could compromise confidentiality.

Risk Mitigation: Given the sensitive nature of land disputes, interview questions avoid specific ongoing conflicts and focus on general patterns and system design needs. Participants are informed they can skip any questions that make them uncomfortable.

Cultural Sensitivity: Interview protocols respect traditional authority structures and local customs around discussing land issues. Questions are framed to acknowledge the legitimacy of traditional governance while exploring how technology might support rather than replace existing systems.

Approvals: Research is conducted under ALU's academic research guidelines. While formal IRB approval is not required for this scope, supervisor approval is obtained before conducting interviews, and all procedures follow university ethical standards.

Validation Session Ethics: Stakeholder validation sessions follow the same ethical protocols as interviews, with clear consent procedures and confidentiality protections.

3.6 Data Analysis Framework

Secondary Data Analysis: Thematic analysis of government reports, NGO assessments, and academic literature to identify patterns in land dispute escalation, communication preferences, and emergency response gaps. Content analysis of technical documentation to establish design requirements and implementation constraints.

Primary Data Analysis: Thematic coding of interview transcripts using both deductive codes derived from the literature review and inductive codes emerging from the data. Analysis focuses on identifying communication patterns, user needs, cultural considerations, and design requirements for voice-based emergency systems.

Validation Data Analysis: Structured analysis of validation session feedback focusing on usability issues, cultural appropriateness, and technical feasibility. Feedback will be categorized and prioritized for design iteration.

Triangulation: Validation of findings through comparison of secondary data sources, cross-checking interview responses, and assessment of design recommendations against documented best practices from similar contexts.

Design Synthesis: Integration of research findings into concrete system design recommendations, including technical specifications, user interface mockups, and implementation guidelines suitable for rural deployment.

The analysis framework ensures that design recommendations are grounded in empirical evidence while remaining practical and culturally appropriate for the target context.

FIGURE 5: Entity Relationship Diagram (ERD)

The data analysis framework will inform the database design that supports emergency response coordination and audit trail requirements. Figure 5 presents the entity relationship model that captures incident reporting, response coordination, and traditional authority integration while maintaining data privacy and security standards.

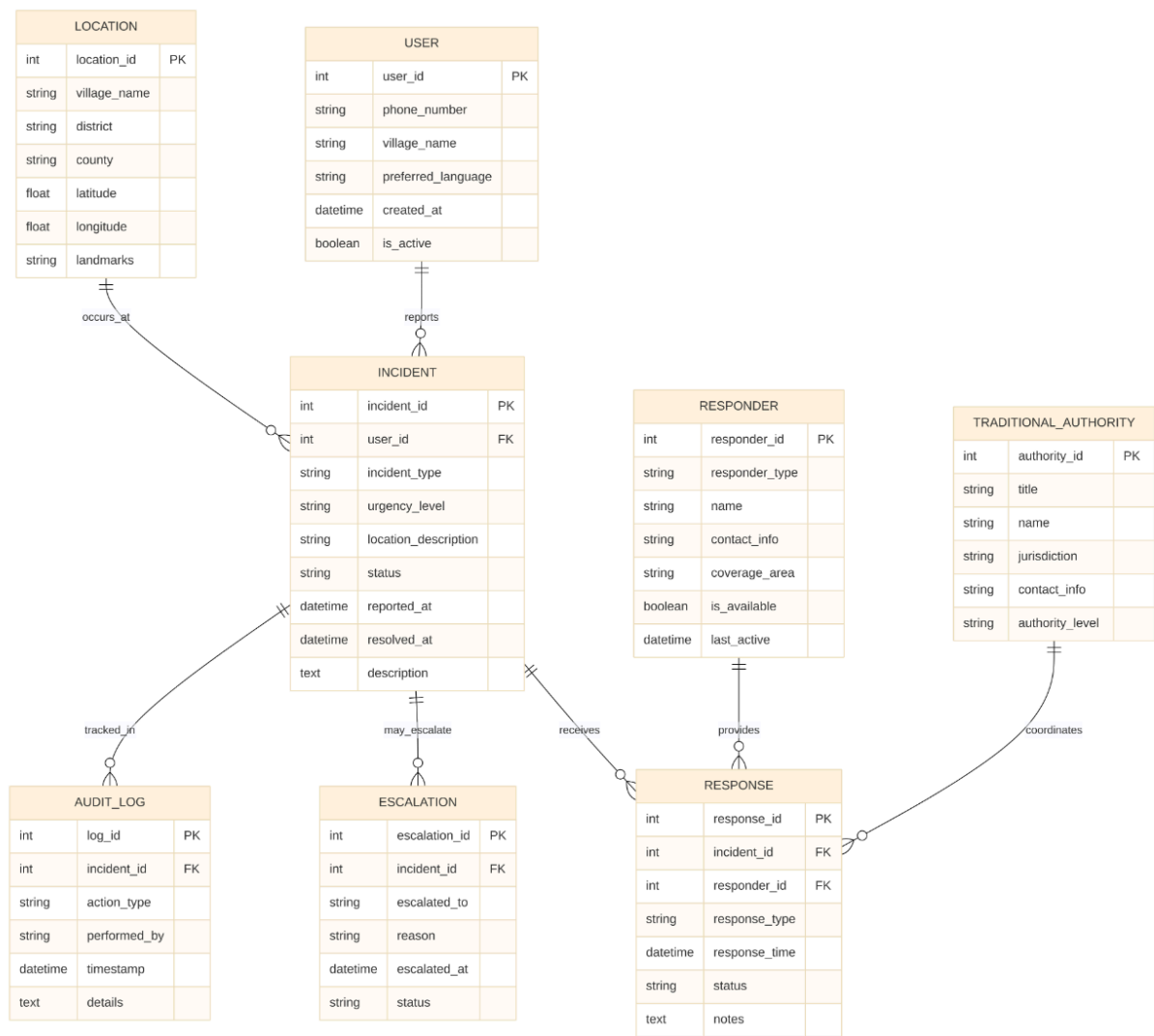


Figure 5: Entity Relationship Diagram for Emergency Response System Database

3.7 Risk and Limitations

Several foreseeable challenges may impact research execution and findings. Connectivity issues in rural Nimba County could affect remote interview quality and stakeholder validation sessions. Scheduling conflicts with traditional authorities may delay primary data collection, given their community responsibilities and limited availability.

Capturing accurate location data through voice input presents technical challenges. Rural users may provide imprecise village names or landmarks unfamiliar to external responders. Language barriers could complicate interviews, despite using local interpreters when necessary.

The 7-week capstone timeline limits prototype development to English-language interfaces only. Mano and Gio language versions require additional time and native speaker involvement. Remote research from Rwanda restricts direct observation of user interactions and community dynamics.

Stakeholder availability for validation sessions depends on phone access and willingness to participate. Traditional authorities may be skeptical of technology interventions, potentially affecting feedback quality. Technical validation relies on stakeholders' understanding of rural infrastructure constraints.

These limitations are acknowledged and addressed through flexible research protocols, backup communication methods, and realistic scope management within capstone constraints. The research design accounts for these challenges while maintaining methodological rigor.

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