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A COMPREHENSIVE EVALUATION OF THE "E-ALERT" MHEALTH SYSTEM FOR EARLY OUTBREAK DETECTION IN RURAL GHANA: A MIXED-METHODS IMPLEMENTATION STUDY

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Abstract

Background: Timely detection of infectious disease outbreaks remains a major challenge in resource-limited settings, particularly in rural Sub-Saharan Africa, where surveillance systems are hindered by delays in reporting and limited infrastructure. In Ghana, the Integrated Disease Surveillance and Response (IDSR) system often requires 7–14 days for outbreak data transmission, creating critical delays in public health response. Mobile health (mHealth) technologies present an opportunity to improve real-time surveillance; however, evidence on their effectiveness in routine health system contexts remains limited. This study aimed to evaluate the impact of the "e-ALERT" mHealth system on outbreak detection timelines and its implementation dynamics in rural Ghana.

Methods and Materials: A sequential explanatory mixed-methods design was employed, combining a quasi-experimental nonrandomized controlled before-and-after study with qualitative inquiry. Six intervention districts implementing the e-ALERT system were compared with six matched control districts using standard IDSR processes over a 12-month period. Quantitative outcomes included time-to-detection, reporting completeness, and system performance metrics, analyzed using survival analysis and comparative statistics. Qualitative data were collected through 35 in-depth interviews and 6 focus group discussions with stakeholders and analyzed using the Consolidated Framework for Implementation Research (CFIR) to explore implementation barriers and facilitators.

Results: The e-ALERT system significantly reduced the mean time-to-detection from 11.7 days in control districts to 2.3 days in intervention districts, representing an 80% improvement ($p < 0.001$). Reporting completeness reached 98% in intervention areas compared to 67% in controls. The system successfully generated early alerts for cholera and measles outbreaks, providing 7–9 days of additional response time. Qualitative findings revealed increased motivation and

empowerment among community health workers, alongside challenges such as parallel reporting systems and infrastructure limitations, including unreliable electricity and network connectivity.

Conclusion: The e-ALERT mHealth system demonstrated substantial effectiveness in improving outbreak detection timeliness and reporting performance in rural Ghana. However, sustainable implementation requires addressing broader socio-technical challenges, including infrastructure development, workflow integration, and policy alignment. mHealth surveillance systems have significant potential to strengthen early warning systems and enhance global health security when supported by comprehensive system-level investments.

Keywords: *mHealth, Disease Surveillance, Outbreak Detection, Implementation Science, Rural Health Systems*

Background

In global public health, timely detection of infectious disease outbreaks remains a critical challenge, especially in resource-limited settings, where health infrastructure is often fragmented, and surveillance systems face significant operational bottlenecks. This challenge is felt very strongly in rural parts of Sub-Saharan Africa, where geographical barriers, coupled with other limiting factors, such as a lack of technological infrastructure and human resources, create dangerous delays in disease reporting and response. The Northern Region of Ghana typifies these challenges; local paper-based surveillance under the IDSR framework takes 7-14 days for disease reports to travel from remote communities to district health authorities. This temporal gap creates a critical vulnerability to national and global health security, as recurrent outbreaks of cholera, measles, and meningitis overwhelm local response capacities due to delays in detection.

The emergence of mHealth technologies thus offers a promising avenue for overcoming systemic delays. Indeed, the proliferation of mobile cellular networks, even in the most remote areas of developing countries, opens up new opportunities for real-time data transmission that can theoretically revolutionize disease surveillance practices. Although many pilot projects have demonstrated the technical feasibility of applying mHealth technologies to healthcare delivery, there remains a significant evidence gap regarding their operational effectiveness in improving concrete public health outcomes at scale under routine health system functioning. Most of these studies focus on endpoint metrics, such as completeness of reporting, whereas very few have assessed how these technologies actually influence time-critical public health decision-making and outbreak response.

Accordingly, this research study aimed to develop, implement, and rigorously evaluate a community-based mHealth syndromic surveillance system ("e-ALERT") designed to specifically address the critical challenge of delayed outbreak detection in rural Ghana. Unlike previous investigations that have assessed mainly technical feasibility, this study aimed to assess the actual impact of digital surveillance on time-to-detection metrics and to understand the complex implementation dynamics that determine success or failure in real-world settings. This study sought to move beyond the question of whether such systems can work technically to investigate

how they actually operate, for whom, and under what conditions they can be integrated sustainably into existing health system architectures.

Methods

The study used a sequential explanatory mixed-methods design, combining quantitative and qualitative approaches to assess the intervention's effects and the experience of implementation. The quantitative approach used a quasi-experimental design with a nonrandomized controlled before-and-after approach, comparing six intervention districts implementing the e-ALERT system with six carefully matched control districts continuing with standard IDSR procedures. This design enabled robust measurement of the intervention effect on primary outcomes while accounting for contextual factors that may influence implementation success.

The analysis framework was informed by the Consolidated Framework for Implementation Research, which provided a systematic structure for assessing implementation determinants across multiple domains: intervention characteristics, outer setting, inner setting, individual characteristics, and implementation process. Such a theoretical underpinning ensured that the investigation captured not only whether the intervention worked, but also why it worked or failed in specific contexts, and what factors influenced its adoption and integration.

Quantitative analysis focused on time-to-detection as the primary outcome, measured as the number of days from the first symptomatic case in a cluster to the date the health district officially logged an alert. Survival analysis using Kaplan-Meier curves and Cox proportional hazards models compared detection timelines between intervention and control districts, adjusting for potential confounders, including district population density and baseline reporting rates. Secondary quantitative metrics included weekly reporting completeness, system reliability statistics, and user engagement metrics, analyzed using descriptive statistics and comparative tests.

Qualitative data collection included 35 in-depth interviews and 6 focus group discussions with key stakeholders, including community health workers, district surveillance officers, facility-based clinicians, and health managers. The directed content analysis approach used CFIR constructs as an initial coding framework, allowing emergent themes to surface. The qualitative analysis aimed to explain the quantitative findings by exploring the lived experiences of

implementation, identifying the barriers and facilitators to adoption, and understanding the contextual factors that drive system use and effectiveness.

Integration was based on the principle of complementarity, whereby qualitative findings provided context to explain the quantitative patterns, while quantitative results triangulated qualitative observations. Such mixed-methods integration allowed for nuance in both the outcomes achieved and the processes through which they were realized.

Results and Conclusions

The study produced compelling evidence about both the effectiveness and implementation dynamics of the mHealth surveillance system. Quantitatively, the e-ALERT system showed a significant reduction in time-to-detection, with a mean of 2.3 days in intervention districts compared to 11.7 days in control districts, an 80% improvement that was statistically significant, $p<0.001$. During the 12 months of the study, the system generated early alerts for two confirmed cholera outbreaks and one confirmed measles outbreak, yielding 7-day and 9-day lead times over the standard surveillance system, respectively. The intervention also achieved remarkable reporting completeness, with community health workers submitting 98% of expected weekly reports, compared with 67% in control districts. Qualitatively, the analysis identified several key findings that explained both the successes and challenges of implementation. Community health workers reported feeling empowered in their role as "digital sentinels," including increased professional identity and motivation through their connection to the real-time surveillance system. However, the study also identified significant implementation barriers, most prominently the burden of maintaining parallel digital and paper-based reporting systems, contributing to workflow inefficiencies and contributor fatigue. Infrastructure issues, particularly unreliable electricity and network connectivity, were common and persistent barriers that limited the system's reliability in the most remote communities. Taken together, the integrated findings suggest that mHealth-based syndromic surveillance systems have tremendous potential to strengthen early warning capacities in resource-limited settings, yet realizing this potential will involve not just technical considerations but also complex socio-technical ecosystem issues. While the technology was highly effective in accelerating detection, its sustainable integration requires complementary investments in infrastructure, workflow redesign, and policy alignment. The present study emphasizes that digital health innovations are not isolated technical fixes but

should instead be framed as complex interventions that need co-evolution with health worker practices, managerial systems, and policy frameworks.

The key messages from this research, therefore, point to the importance of future scale-up and sustainability by developing national digital health standards that enable integration rather than parallel operation; investing in the foundational infrastructure of electricity and connectivity that underpins digital system functionality; and creating implementation strategies that address the human and organizational dimensions of technological change. It is apparent that such complementary conditions create the potential for mHealth surveillance systems to transform disease detection from an essentially retrospective activity to a proactive process of vigilance, thereby strengthening health security and improving population health outcomes in some of the world's most vulnerable communities.

1. Project definition

1.1. Problem Statement

The persistent challenge of delayed outbreak detection is a critical vulnerability in global health security, particularly in rural Sub-Saharan Africa. Ghana's health system remains committed to the IDSR framework but faces formidable reporting delays from remote communities through district health directorates. These delays, typically 7-14 days, primarily undermine the effectiveness of public health responses to infectious disease outbreaks such as cholera, measles, and meningitis. This "last mile" problem-the final stage of data transmission from community to formal health systems-represents a critical break in the surveillance chain, creating dangerous windows of opportunity for disease transmission before containment measures can be initiated.

1.2. Main Objective

Develop, implement, and rigorously evaluate the impact of a community-based mHealth syndromic surveillance system, "e-ALERT", on early outbreak detection timelines and response coordination in the Northern Region of Ghana, as compared to the standard IDSR system.

1.3. SMART Objectives

1. Specific: To implement the e-ALERT mHealth system in six intervention districts and compare its performance against six matched control districts using standard IDSR over a period of 12 months.

2. Measurable: To achieve at least 90% weekly reporting completeness from Community Health Workers using the e-ALERT system, with a reduction in the mean time to detection of suspected outbreaks by at least 50%, as compared to control districts.
3. Achievable: To train 120 CHWs and 12 district surveillance officers on the use of e-ALERT, establish a functioning dashboard system for district health directorates, and maintain functionality of the system for the full study period.
4. Relevant: To generate evidence for the Ghana Health Service on the feasibility and effectiveness of mHealth-enabled syndromic surveillance for strengthening national disease surveillance capabilities.
5. Time-Bound: All research activities, including implementation, collection of data, analysis, and reporting, have to be performed within the 15-month project timeframe.

1.4. Key Terminology

1. Digital Health Technologies: Refers in this project to mHealth applications for the collection of syndromic data and Web-based dashboards for the display of data in real time, with alert generation.
2. Disease Surveillance: The continuous, systematic collection, analysis, interpretation, and dissemination of health data in accordance with public health action, emphasizing IDSR.
3. Syndromic Surveillance: The monitoring of clinical case features, probable precursors to confirmed diagnoses, for early warning in advance of laboratory confirmation.
4. Time-to-Detection: This is the primary outcome measure, which is defined as days from the first symptomatic case in a cluster to the date the health district officially logs an alert.
5. Implementation Science: The scientific study of methods to promote the systematic uptake of research findings and evidence-based practices into routine care.

2. Final Project Overview

The "e-ALERT" project implemented and assessed a community-based mHealth syndromic surveillance system in six districts of Northern Ghana. Overall, the intervention demonstrated great improvements in early outbreak detection capacity and critical lessons learned in low-resource settings.

Key Accomplishments:

1. System Deployment: Successfully deployed the e-ALERT mHealth system to 118 CHWs across six intervention districts, reaching a 98% weekly reporting rate throughout the study period.
2. Performance Improvement: Reduced mean time-to-detection from 11.7 days in control districts to 2.3 days in intervention districts, representing an 80% reduction in detection time.
3. Outbreak Alerts: Generated early warnings for two confirmed cholera outbreaks and one measles outbreak, providing 7-day and 9-day lead times, respectively, over the standard IDSR system.
4. Engagement with Stakeholders: Ensured participation and collaboration from all levels of the health system, from the grassroots community health workers to the regional health directorates. Unforeseen Consequences: • CHW Empowerment: This was a significant qualitative finding wherein CHWs reported increased professional identity and motivation through their role as "digital sentinels."
5. Burden on Parallel System: Highlighted the key challenge of running a parallel system for both digitized and paper-based reporting systems, which created an inefficiency in workflows.
6. Infrastructure Limitations: Despite the preparations, persistent issues with electricity and network connectivity necessitated adaptive implementation strategies. The study not only demonstrated the technical feasibility of mHealth surveillance but also provided valuable insights into the socio-technical factors that govern its successful implementation in real-world, resource-limited settings.

Project Relevance and Rationale

This research project addresses a major challenge in Nigerian public health: strengthening disease surveillance and monitoring systems to improve population health outcomes. Traditional disease surveillance methods in Nigeria often face limitations in timeliness, accuracy, completeness, and accessibility, hindering effective outbreak detection, response, and prevention efforts. The emergence of modern digital health technologies offers a promising avenue to overcome these limitations and revolutionize disease surveillance in the country. However, the

actual impact of these technologies on surveillance effectiveness remains poorly understood, particularly within the specific context of the Nigerian healthcare system.

The rationale for this project is rooted in several key factors:

1. **Addressing Surveillance Gaps:** Nigeria continues to grapple with significant challenges in disease surveillance, as evidenced by ongoing outbreaks of infectious diseases such as Lassa fever, cholera, and measles in recent years. Digital health technologies have the potential to enhance the speed, accuracy, and completeness of data collection, reporting, and analysis, thereby enabling more timely and effective responses to public health threats.
2. **Informing Policy and Investment Decisions:** Limited evidence exists on the actual impact and cost-effectiveness of digital health interventions for disease surveillance in Nigeria. This research will provide policymakers and healthcare administrators with data-driven insights to inform strategic investments in digital health technologies and optimize their implementation for maximum impact.
3. **Contributing to Global Health Security:** Strengthening disease surveillance systems in Nigeria is essential for national and global health security, as infectious disease outbreaks can rapidly spread across borders. This project aligns with global efforts to improve disease surveillance capacity and prevent pandemics, as outlined in the Global Health Security Agenda and the International Health Regulations.
4. **Alignment with National Health Priorities:** The Federal Ministry of Health in Nigeria has prioritized the use of digital health technologies to improve healthcare delivery and improve health outcomes, as reflected in the National eHealth Strategy and other policy documents. This research will directly support the achievement of these national health goals. This study will not only generate evidence on the impact of digital health technologies on disease surveillance in Nigeria but also provide valuable insights into the factors that influence their successful implementation and sustainability. By informing evidence-based policy and practice, this project has the potential to contribute to a more robust and effective disease surveillance system, leading to improved public health outcomes and enhanced health security for the Nigerian population.

3. Updated Research Summary

3.1. Foundational Research

The project proposal was based on an extensive review of existing literature on mHealth applications in low-resource settings.

Key foundational research included:

- Systematic reviews by Blake et al. (2021) show overall positive impacts of mHealth on data timeliness and completeness
- WHO guidelines on digital interventions for health system strengthening, WHO, 2021
- Research into the effectiveness of CHW programs in Ghana and comparable settings - Asante & Price, 2020

3.2. Implementation Period Research Activities

Throughout project implementation, numerous focused research tasks were carried out to support implementation and put findings into context:

3.2.1. Baseline Infrastructure Assessment

Conducted detailed mapping of network coverage, electricity access, and digital literacy levels across all 12 study districts. This assessment revealed:

- Only 45% of the intervention communities had reliable daily electricity access
- 68% had 2G network coverage sufficient for basic data transmission
- Huge difference in familiarity with smartphones for CHWs across districts: from 15% to 70%

3.2.2. Stakeholder Analysis

Comprehensive engagement with key stakeholders, both through formal and informal channels:

- Policy Level: Consultations with the leadership of the Ghana Health Service showed interest in the area of digital health, but the challenge of sustainability and scalability was raised.
- Management Level: The integration with existing systems and minimum disturbance of workflows were highlighted by district health directors.
- Frontline Level: CHWs showed enthusiasm for technology but were concerned about increased workload and technical support

3.2.3. Adaptive Literature Review

Ongoing monitoring of emerging evidence during implementation included:

- Recent studies on the sustainability of digital health interventions in LMICs include Soutongnoma et al. (2022)
- New WHO guidelines on community-based surveillance
- Lessons learned from similar mHealth implementations in neighbouring countries

3.2.4. Contextual Barrier Analysis

Detailed exploration of implementation barriers specific to the Northern Region context:

- Seasonal patterns of network reliability during the rainy season
- Cultural and linguistic variables in interface design
- Logistics of device maintenance and support in remote areas
- This specifically informed implementation strategies, such as developing contingency plans for infrastructure challenges and contextually appropriate training materials.
- This is considered an example of a PIP.

4. Project Implementation Summary

Phase 1: Preparation and Planning (Months 1-3)

Month 1: System Development and Stakeholder Engagement

- Conducted requirements gathering workshops with district health directors and CHW supervisors
- Finalized the technical specifications for the e-ALERT application
- Established project governance structure and advisory committee
- Developed a detailed implementation framework based on the CFIR constructs

Month 2: Ethical Approvals and Protocol Finalization

- Submitted and obtained approval from the Ghana Health Service Ethics Review Committee
- Secured permissions from regional and district health directorates
- Finalized all data collection tools and standard operating procedures
- Conducted preliminary community engagement and sensitization

Month 3: Training Curriculum Development and Pilot Testing

- Developed comprehensive training materials both in English and local languages.

- Provided pilot training to 12 CHWs from non-study districts
- Refined application interface based on pilot user feedback
- Established data management and security protocols

Phase 2: System Deployment and Capacity Building (Months 4-6)

Month 4: Procurement and Distribution of Devices

- Procured 130 smartphones and solar chargers
- Established device management and accountability system
- Configured all devices with the e-ALERT application and the necessary software
- Device maintenance and troubleshooting guide developed

Month 5: Cascade Training Program

- Conducted master trainer session for district surveillance officers
- Provided district-level training for all 118 CHWs in the intervention districts
- Established a network of peer support among CHWs
- Competency assessments were conducted, and refresher training was provided when necessary.

Month 6: System Go-Live and Initial Support

- E-ALERT system activated at all intervention districts
- Established real-time monitoring of system performance
- Implemented intensive first-month support system.
- Conducted initial user experience feedback sessions

Phase 3: Operations and Monitoring Months 7-12

Months 7-9: Routine System Operations

- Monitored daily reporting rate and system performance
- Conducted supervisory visits to all intervention districts
- Continuous quality improvement based on user feedback
- Maintained detailed logs of the technical issues and resolutions

Months 10-12: Intensified Monitoring and Data Collection

- Enhanced data collection for outcome measurement
- Conducted a mid-term implementation review with stakeholders

- Commenced preliminary analysis of quantitative performance data
- Documented adaptation and evolution of implementation strategies

Phase 4: Evaluation and Analysis (Months 13-15)

Month 13: Quantitative Data Analysis

- Data cleaning and validation completed.
- Performed statistical analysis on time-to-detection results
- Analyzed reporting completeness and system reliability metrics
- Prepared preliminary quantitative findings report

Month 14: Qualitative Data Collection and Analysis

- Conducted 35 in-depth interviews with stakeholders
- Facilitated 6 focus group discussions with CHWs
- Transcribed and translated qualitative data
- Conducted thematic analysis through the CFIR framework.

Month 15: Integration and Reporting

- Integrated quantitative and qualitative findings
- Developed evidence-based recommendations
- Prepared final project report and dissemination materials
- Conducted stakeholder validation workshop

5. Project Analysis, Evaluation, and Recommendations

5.1. Objective Achievement Analysis

Objective 1: System Implementation

- Target: Implement e-ALERT across six intervention districts
- Achievement: Successfully deployed to 118 CHWs in six districts
- Performance rating: 100% achieved
- Key Success Factors: Robust stakeholder engagement, adaptable strategy of implementation, full training program

Objective 2: Reporting Completeness

- Target: ≥90% weekly reporting rate
- Achievement: 98% average weekly reporting rate

- Performance Rating: 109% of target

Key Success Factors: User-friendly interface; strong peer support network; consistent supervisory follow-up

Objective 3: Reduce Time-to-Detection

- Target: ≥50% reduction in mean time-to-detection
- Achievement: 80% reduction from 11.7 days to 2.3 days
- Performance Rating: 160% of target

Key Success Factors: real-time data transfer, automated alerting system, and immediate visibility on the dashboard

5.2. Implementation Successes

5.2.1. Technical Performance

The e-ALERT system showed robust technical performance during the period of the study:

- Application stability: 99.2% uptime
- Data transmission success rate: 96.8%
- Average data submission time: <2 minutes per day per CHW

5.2.2. User Engagement and Acceptance

- CHW satisfaction score: 4.3/5.0
- District manager satisfaction: 4.1/5.0
- Features adopted above minimum requirements: 78% of users

5.2.3. Public Health Impact

• Early detection of 3 confirmed outbreaks

• Lead time for public health action: 7-9 days

• Estimated cases averted through early response: 45-60 (projected)

5.3. Implementation Challenges

5.3.1. Infrastructure Limitations

- Network Connectivity: 32% of CHWs needed to travel to submit reports at least once a week
- Power Availability: 28% of devices required alternative charging at least weekly
- Device Durability: Device failure rate at 8%, requiring replacement

5.3.2. Workflow Integration

- Parallel Reporting: 100% of CHWs maintained paper-based reporting alongside the digital system
- Time Burden: Average 15 minutes additional daily work per CHW
- System Integration: No direct integration with the national HMIS

5.3.3. Sustainability Concerns

- Cost Projections: Estimated annual cost of $127 per CHW for system maintenance • Technical Support: Limited local capacity for application maintenance
- Alignment of Policy: No formal policy for digital data recognition

5.4. Evaluation Against Theoretical Framework

The CFIR framework provided insight into the following determinants of implementation:

Intervention Characteristics

- Strength: High relative advantage demonstrated
- Challenge: Limited adaptability for local customization Inner Setting • Strength: Strong implementation climate in engaged districts Challenge: Structural characteristics requiring parallel systems Exterior Environment
- Strength: High patient needs driving motivation • Challenge: Limited infrastructure and cosmopolitanism Traits of Individuals
- Strengths: High self-efficacy and positive attitude
- Challenge: Variable innovation readiness Process
- Strength: Quality planning and engaging • Challenge: Inconsistent implementation at the district level

5.5. Recommendations

5.5.1. For Scale-Up (Short-term: 0-12 months)

1. Develop Phased Scale-Up Strategy: Start in districts showing the most readiness for implementation
2. Establishment of National Digital Health Standards: Technical standards on interoperability
3. Hybrid reporting: Develop the policy for a gradual transition from paper to digital.

4. Build Technical Support Capacity: Train district-level technology champions

5.5.2. For System Integration (Medium-term: 12-24 months)

1. Pursue HMIS Integration: develop APIs for automatic data transfer to national systems
2. Establish Sustainable Financing: Integrate costs in core health budgets
3. Infrastructure Development: Engage with Telecom Providers for Health-Specific Solutions
4. Develop Advanced Analytics: Include predictive modelling and machine learning capabilities.

5.5.3. For Policy Development Long-term: 24+ months

1. Legislate Digital Data Identification: Develop a legal framework for digital health data
2. Create Digital Health Workforce Strategy: Develop career pathways for digital health roles
3. Establish National Digital Health Governance: Oversight body for digital health initiatives
4. Public-Private Partnerships: Engaging the technology sector in sustainable solutions

5.5.4. Future Research Directions

1. Cost-Effectiveness Analysis: Detailed study of economic benefits
2. Longitudinal Implementation Study: Track sustainability over a 3-5 year period
3. Comparative Effectiveness Research: Compare various digital health approaches
4. Implementation Strategy Trials: Testing various support interventions.

6. Materials Delivered

6.1. Technical Deliverables

6.1.1. e-ALERT Application Suite

- Mobile application for Android devices (APK file and source code)
- Web-based dashboard for health managers - login credentials and admin manual
- System administration guide and troubleshooting manual
- Data backup and recovery protocol documentation

6.1.2. System Documentation

- Technical Requirements Specification Document

- System architecture and design documentation
- Data dictionary and database schema
- Security and privacy compliance documentation

6.2. Training and Capacity Building Materials

6.2.1. Training Curriculum

- CHW training manual (English and Dagbani versions)
- District supervisor facilitation guide
- Training Presentation Slides and Visual Aids
- Competency assessment checklist

6.2.2. Job Aids and Reference Materials

- Quick reference guide for CHWs
- Troubleshooting flowchart for common issues
- Poster-sized system overview for health facilities
- Digital literacy primer for novice users

6.3. Research and Evaluation Materials

6.3.1. Data Collection Instruments

- Baseline assessment questionnaire
- Time-to-detection tracking forms
- CHW satisfaction survey
- In-depth interview guides for all stakeholder groups
- Focus group discussion guides

6.3.2. Analysis and Reporting Documents

- Quantitative dataset with a codebook
- Qualitative data transcripts anonymized
- Syntax and output of statistical analysis
- Thematic analysis codebook and memos

6.3.3. Research Documentation

- Study protocol and its amendments

- Ethical approval certificates
- Data management plan
- Quality assurance reports

6.4. Policy and Implementation Guides

6.4.1. Implementation Toolkit

- New districts' readiness assessment tool
- Implementation timeline and milestone tracker
- Stakeholder engagement strategy template
- Risk management and contingency planning guide

6.4.2. Policy Briefs and Recommendations

- Cost-benefit analysis brief for policy makers
- Scale-up strategy document
- Integration roadmap for national HMIS
- Sustainability planning framework

6.5. Knowledge Products

6.5.1. Academic Publications

- Study protocol manuscript Primary outcomes paper
- Qualitative implementation analysis Paper integrating a mixed-methods approach.

6.5.2.

- Dissemination Materials Executive summary for health officials
- Community feedback presentation, Conference presentation slides
- Project infographic and fact sheet

All materials have been archived, both digitally and physically, and are always available for review by stakeholders. Digital materials will be stored on encrypted servers with access controls, while physical materials will be kept in secure storage at the regional health directorate.

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