Technical Report

for

MAMASAVE

Prepared by

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Abstract

This report provides an overview of MamaSave, an embedded system-based wearable solution designed to address the critical challenges of high maternal and infant mortality rates in Uganda, particularly in rural and underserved areas. The project aims to develop a low-cost, real-time, and location-aware system that monitors the health parameters of expectant mothers, detects emergencies and triggers timely alerts to nearby health workers, midwives, and family members via mobile GPS networks. This solution is envisioned to significantly improve survival rates by enabling rapid response to health complications as well as health monitoring ensure a healthy environment for the baby.

1 Introduction

This document outlines the development and current status of MamaSave, a smart maternal health monitoring and emergency alert system. It details the problems MamaSave seeks to solve, its core objectives, functional requirements, and the technical approach taken in its design and implementation. This report serves as a comprehensive overview of the project's progress and future direction.

1.1 User Challenge

Uganda faces a high maternal and infant mortality rate, especially in rural areas where access to prenatal care and emergency health services is limited. Delays in detecting health complications, inadequate monitoring during pregnancy and lack of timely transport to health facilities result in preventable deaths of both mothers and newborns. This critical situation highlights an urgent need for an accessible, low-cost, real-time and location-aware solution that can effectively monitor the health of expectant mothers and newborns and trigger timely emergency interventions. The lack of immediate information and response mechanisms in remote settings contributes significantly to these preventable deaths, making a proactive monitoring system indispensable.

1.2 Project Goals

MamaSave is an innovative, embedded system-based wearable and alert solution with the primary objective of monitoring maternal and newborn health parameters, detecting emergencies, and sending alerts with GPS location to nearby health workers, midwives, and family members via GSM network. Its purpose is to ensure rapid response and improved survival rates for mothers and babies in rural and underserved areas of Uganda. The innovativeness of MamaSave lies in its low-cost, low-power, and offline fast processing approach. By providing continuous, real-time health data and automated emergency alerts, MamaSave directly addresses the user challenges by bridging the information gap, enabling early detection of complications, and facilitating prompt medical intervention, thereby reducing preventable maternal and infant deaths. The project also pivots towards ensuring the mother's comfort and the baby's well-being as a primary focus, alongside the critical emergency alert functionality.

1.3 Functional Requirements

MamaSave is designed to perform several key functions to achieve its objectives. These functions are categorized into distinct areas to provide a detailed understanding of the system's intended behavior.

1.3.1 Wearable Health Monitoring

- **Continuous Vital Sign Monitoring:** The system shall continuously monitor maternal heart rate, blood oxygen levels and body temperature.
- **Uterine Contraction Detection:** The system shall detect uterine contractions to identify the onset of labor.
- **Heart Rate Monitoring:** The system will mother’s fetal heart rate

- **Blood Oxygen monitoring:** The system will monitor the mother’s blood Oxygen.
- **Comfortable Design:** The device shall be designed as a comfortable belly band for pregnant mothers.

1.3.2 Real-time Emergency Detection

- **Sensor Data Analysis:** The system shall continuously analyze sensor data for dangerous patterns, such as low blood Oxygen levels, abnormal heart rate or abnormal contraction patterns/ baby movements.
- **Threshold-Based Alert Triggering:** The system shall automatically trigger an emergency alert when predefined health thresholds are exceeded.

1.3.3 Alert System

- **Emergency Message Transmission:** The system shall send emergency messages containing the mother's condition and GPS location.
- **Recipient Notification:** The system shall notify pre-configured contacts, including local midwives, health centers, family members, or ambulance drivers.

1.3.4 GPS-Based Location Sharing

- **Location Pinpointing:** The mobile device’s GPS module shall pinpoint the mother’s precise location during an emergency.
- **Responder Assistance:** The location data shall help responders quickly locate the individual, especially in remote or unfamiliar areas.

1.3.5 Postnatal Baby adaption

- **Newborn Monitoring:** Components of the belt can still be used at home to monitor the newborn’s temperature, blood oxygen levels as well as heart rate.

2 Project Results

2.1 Product Design

The MamaSave system is designed around a central microcontroller, the ESP32 WROOM-32, which serves as the brain for data processing and communication. The core hardware components are integrated onto a perforated board for a robust and permanent circuit, transitioning from the initial breadboard prototyping phase.

System Architecture:

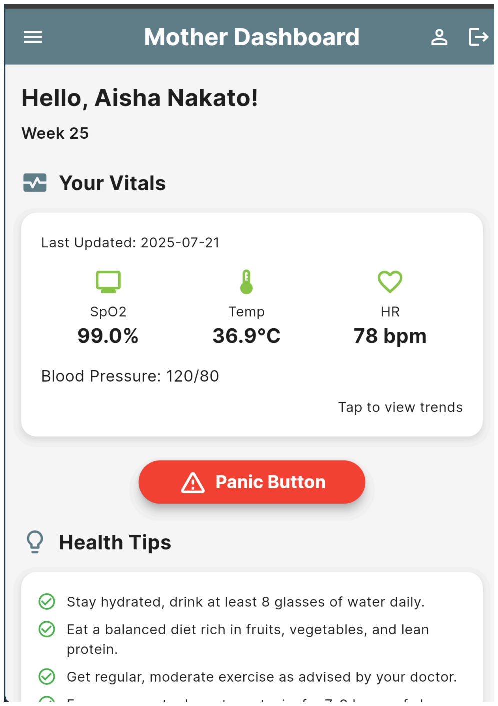
- **Microcontroller:** ESP32 WROOM-32, chosen for its Wi-Fi/Bluetooth capabilities (for future app integration) and low-power modes.
- **Sensors:**
  - **DS18B20 Temperature Sensor**: Used for body temperature monitoring, intended to be placed in the axillary region with a flexible wire extension**.**
  - **MAX30100 Heart Rate & SpO2 Sensor**: For maternal heart rate and blood oxygen saturation. This is designed as a finger-based sensor, connecting to the main unit via a flexible cable.
  - **DF9-40 Pressure Sensor**: For detecting uterine contractions and fetus movements, integrated into the belt with a soft compressible pad and encapsulated for protection. This sensor was made with careful calibration.
- **Communication Modules:**
  - Mobile phone inbuilt GPS module for locating where the expecting mother is
  - Mobile phone GSM module to allow communication between the mothers mobile device to the emergency services
  - ESP Bluetooth to allow the transfer of data from the sensors to the mobile application.
- **Power Management:** A Lithium-ion battery provides power to the hardware. A Low-Dropout (LDO) regulator steps down the battery voltage to a stable 3.3V for the ESP32 and sensors, ensuring voltage sensitivity is managed. The battery is placed on a separate lace on the thigh to reduce bulk on the main belt.
- **Physical Integration:** The ESP32 and core sensors are planned for integration onto the pregnancy belt. The perforated board will house the main circuit, with careful consideration for wire lengths. We have included a 3D printed casing for the main electronics and direct integration into the belt fabric for modules such as the temperature sensor**.**

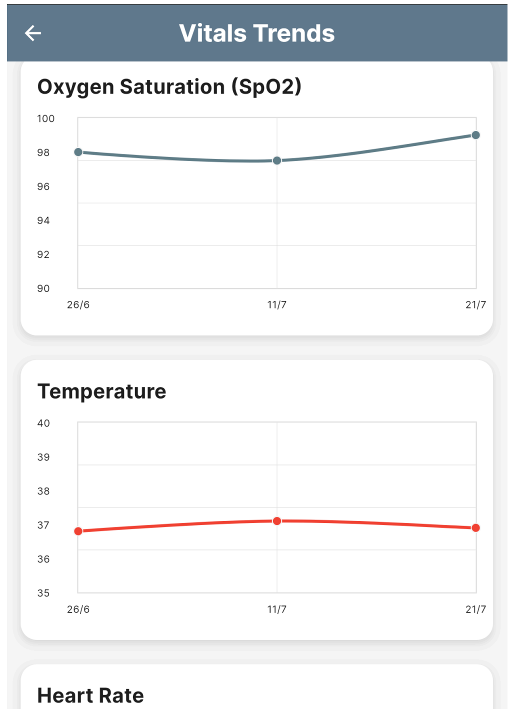
Product Functionality and Screenshots

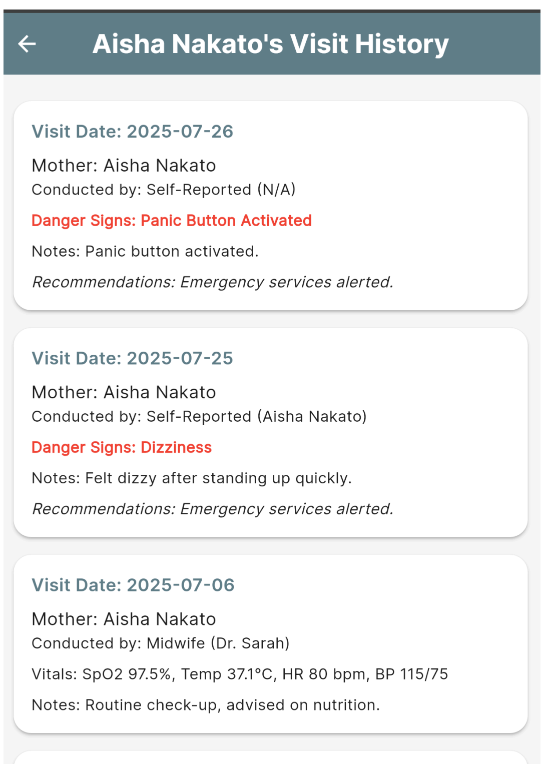
The current prototype successfully integrates and reads data from the DS18B20 temperature sensor and the MAX30100 heart rate/SpO2 sensor. The team has successfully run individual code for each sensor, verifying their functionality. The combined code allows for simultaneous operation and data acquisition from both sensors, with periodic reporting to the serial monitor. The DF9-40 pressure sensor has also been successfully tested for its ability to detect pressure changes, which will be calibrated to deduce contractions and fetus movements.

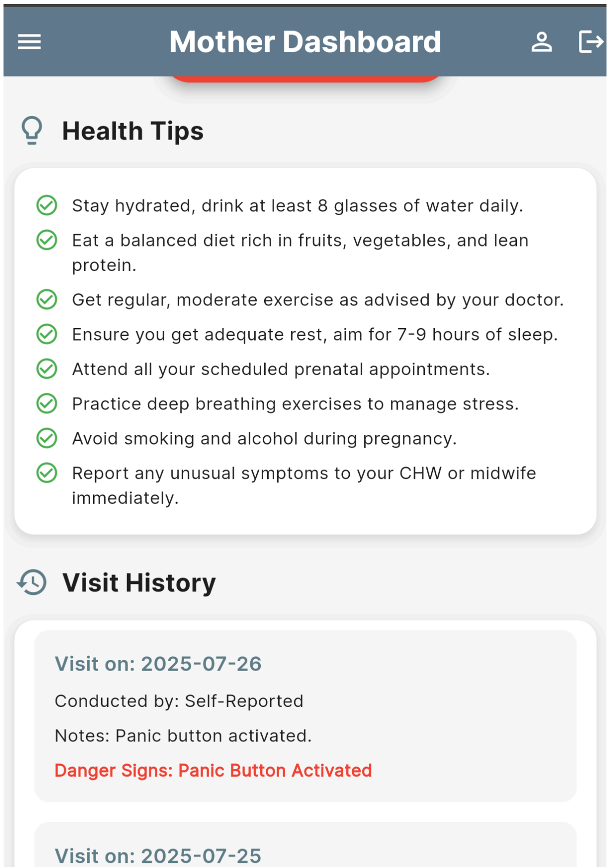
Implemented Functionality:

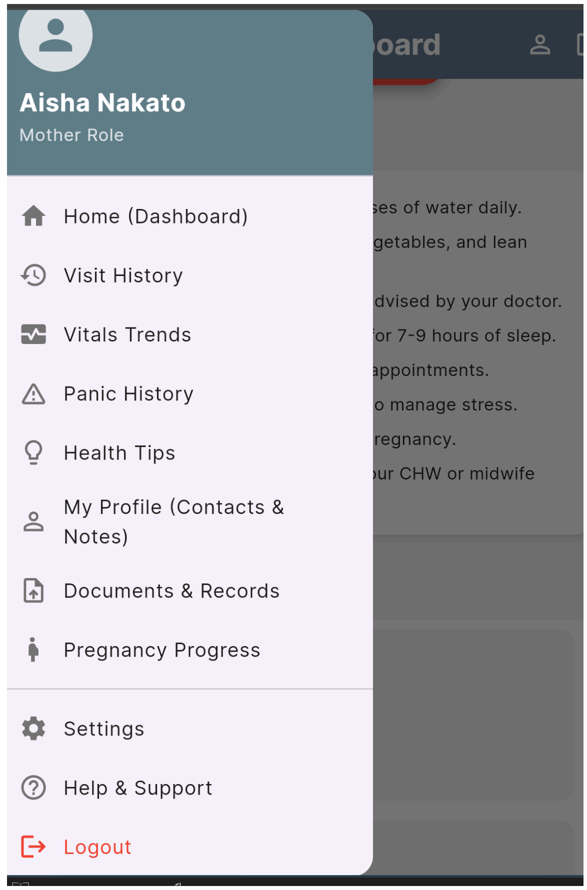
- ***Temperature Monitoring:*** *Reads and displays temperature values from the DS18B20 sensor.*
- **Heart Rate and SpO2 Monitoring:** Reads raw values from the MAX30100. The integrated library provides calculated Heart Rate and SpO2 values.
- **Sensor Data Acquisition:** Both temperature and heart rate data are acquired simultaneously in a non-blocking manner, ensuring continuous monitoring.


Mother Dashboard
Hello, Aisha Nakato!
Week 25
Your Vitals
Last Updated: 2025-07-21
SpO2
99.0%
Temp
36.9°C
HR
78 bpm
Blood Pressure: 120/80
Tap to view trends
Panic Button
Health Tips
Stay hydrated, drink at least 8 glasses of water daily.
Eat a balanced diet rich in fruits, vegetables, and lean protein.
Get regular, moderate exercise as advised by your doctor.


Vitals Trends
Oxygen Saturation (SpO2)
100
98
96
94
92
90
26/6
11/7
21/7
Temperature
40
39
38
37
36
35
26/6
11/7
21/7
Heart Rate


Aisha Nakato's Visit History
Visit Date: 2025-07-26
Mother: Aisha Nakato
Conducted by: Self-Reported (N/A)
Danger Signs: Panic Button Activated
Notes: Panic button activated.
Recommendations: Emergency services alerted.
Visit Date: 2025-07-25
Mother: Aisha Nakato
Conducted by: Self-Reported (Aisha Nakato)
Danger Signs: Dizziness
Notes: Felt dizzy after standing up quickly.
Recommendations: Emergency services alerted.
Visit Date: 2025-07-06
Mother: Aisha Nakato
Conducted by: Midwife (Dr. Sarah)
Vitals: SpO2 97.5%, Temp 37.1°C, HR 80 bpm, BP 115/75
Notes: Routine check-up, advised on nutrition.


Mother Dashboard
Health Tips
Stay hydrated, drink at least 8 glasses of water daily.
Eat a balanced diet rich in fruits, vegetables, and lean protein.
Get regular, moderate exercise as advised by your doctor.
Ensure you get adequate rest, aim for 7-9 hours of sleep.
Attend all your scheduled prenatal appointments.
Practice deep breathing exercises to manage stress.
Avoid smoking and alcohol during pregnancy.
Report any unusual symptoms to your CHW or midwife immediately.
Visit History
Visit on: 2025-07-26
Conducted by: Self-Reported
Notes: Panic button activated.
Danger Signs: Panic Button Activated
Visit on: 2025-07-25


Aisha Nakato
Mother Role
Home (Dashboard)
Visit History
Vitals Trends
Panic History
Health Tips
My Profile (Contacts & Notes)
Documents & Records
Pregnancy Progress
Settings
Help & Support
Logout

Project website and repository

https://joy-git199.github.io/mamasave-web/
https://github.com/Joy-git199/mamasave-web

3 Limitations and Next Steps

3.1 Limitations

Despite significant progress, the current MamaSave prototype has several limitations:

- **DF9-40 Integration and Calibration:** The DF9-40 pressure sensor is small and fragile, posing challenges for robust integration into the pregnancy belt and requiring precise calibration to accurately deduce uterine contractions.
- **MAX30100 Physical Integration:** Integrating the finger-based MAX30100 heart rate sensor into the belt in a way that allows for easy and consistent finger placement for accurate measurements remains a design challenge.
- **Perforated Board Assembly Complexity:** The transition from breadboard to a permanent PCB requires meticulous soldering and wiring, with concerns regarding wire length management, resistor placement, and potential EMI/EMF reduction.
- **Battery Connection Safety:** The ESP32's voltage sensitivity necessitates careful handling of battery connections and power management circuitry to prevent damage.
- **Enclosure Design:** A robust and comfortable physical casing for the electronics is still under consideration, with options between 3D printing or direct integration into the belt fabric.
- **Full System Integration Testing:** While individual sensors and the combined temperature/heart rate code work, full system integration testing with all components and power management on the perfboard is yet to be completed.
- **Software Backend:** The mobile application's front-end has been developed, but the backend infrastructure for data storage, alert management, and potential integration with health databases works but improvements can be done.

3.2 Next Steps

Building upon the current progress, the following steps are planned for the MamaSave project beyond the recess term:

- **Complete Physical Assembly:** Finalize the portable PCB assembly, ensuring all components are securely soldered and wired according to the planned layout, including the DF9-40 and its voltage divider.
- **Power System Implementation:** Securely integrating the LiPo battery, TP4056 charging module, and LDO regulator onto the thigh strap, ensuring safe and stable power delivery to the main unit.
- **Comprehensive System Testing:** Conduct thorough testing of the fully integrated hardware system, including all sensors, GSM, GPS, and power management, under various operational conditions.
- **Firmware Development & Optimization:** Further developing the ESP32 firmware to incorporate data processing for all sensors, implementing the emergency detection logic, and optimizing power consumption using deep sleep modes.

- **Mobile Application Backend Development:** Developing the backend infrastructure for the mobile application to handle data from the device, manage alerts, and potentially store health records.
- **Future Extensions:** Exploring and implementing the planned future extensions, including:
  - Bluetooth/mobile app interface for comprehensive health record storage and visualization.
  - Integration with national health databases for broader impact.
  - Development of a community-level dashboard for NGOs and health workers.
  - Research into AI-based prediction models for high-risk pregnancies.

References

- Anika Alim and Masudul H Imtiaz, "Wearable Sensors for the Monitoring of Maternal Health." Available: LINK
- L. Liu et al., "Wearable Sensors, Data Processing, and Artificial Intelligence in Pregnancy Monitoring. Available *LINK*
- *M. Qin et al., "A wearable fetal movement detection system for pregnant women,"* Available: LINK
- *H. Vyas, H. Shukla, and M. N. Jivani, "A Portable IoTBased Health Monitoring Framework Using ESP32 for Isolated and HomeBased Patient Care,". Available: LINK*
- *B. Boatin et al., "Wireless Monitor Aims to Reduce Maternal Mortality in Uganda," Available: LINK*

4 Appendix A – Project Work plan

<Provide project work plan that was followed. Gannt chart format is strongly recommended see https://en.wikipedia.org/wiki/Gantt_chart >

Appendix B – Contribution by Team Members

No.	Team Member	Contribution
1.	AGABA JOEL MUHANGUZI	Assembled sensor and microprocessor hardware both on testing and development of the final PCB and 3D casing. Programmed all modules to function as well as linking module and sensor output to the application via a Bluetooth relay. Battery configuration and voltage regulation with the ESP to prevent component failure. Website creation. Appllication backend flow Application backend processing for received sensor data Poster and Report design Repository creation
2.	SSEMPALA HARRISON SOLOMON	Machine learning and also backend with machine learning Website bankend programming
3	*MUHINDO JULIANAH ALINETHU*	UI/UX Design & Setup Main Contributions: Designed all screens using Figma (onboarding, role selection, dashboards, etc.) Chose the color scheme, fonts, and icon styles Set up the Flutter project structure and added required packages in pubspec.yaml Created assets folder and added logos/images Application backend flow contribution
4	SHENAZ IBRAHIM ADAM	Navigation & Screens Implementation Main Contributions: Implemented navigation flow for all user roles using named routes Built core UI screens: Login Role Selection Onboarding

		Coded reusable widgets like buttons and input fields Handled conditional screen loading based on role (Mother, Midwife, CHW) Sensor Programming
5	MUYAMA JOYCE JUDITH	Theming & Role-Based Dashboards Main Contributions: Implemented Light/Dark theme switch and AppColors/AppStyles setup Built Mother Dashboard, Midwife Profile screen, and CHW Visit UI Created Visit Logging Form and Calendar UI Connected all dashboards to their respective frontend components Git hub repository organization Website front end design