MZUMBE UNIVERSITY

FACULTY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF COMPUTING SCIENCE STUDIES

A PROJECT REPORT

ON

OXEN HEALTH MONITORING AND WORKLOAD ESTIMATION SYSTEM

THE CASE OF SHINYANGA REGION FARMERS

BY

JUMANNE L. NDAKI

REG. NO: 14320074/T.22

PROGRAMME: BSc ICTM

SUPERVISED
BY
DR. ENG. MORRICE

A project report submitted to the Faculty of Science and Technology as part of the requirements for a project partial fulfillment for the Award of the Degree of the Bachelor of Science in Information and Communication Technology with Management (BSc ICT-M) at Mzumbe University

2025

DECLARATION:

I, **JUMANNE L. NDAKI**, hereby declare that this project report titled **"Development of Oxen Health Monitoring and Workload Estimation System** (OHMWES) **"** is my original work and has not been submitted for any degree or other academic purposes at any institution of learning.

Signature: ______________________________

Date: ___________________________________

CERTIFICATION:

This is to certify that this project report titled "Development of Oxen Health Monitoring and Workload Estimation System (OHMWES) " was completed and submitted by JUMANNE L. NDAKI under my supervision and guidance as part of the final year project requirements.

Signature: .... Date: ....

Supervisor name: ....

ACKNOWLEDGMENT:

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DEDICATION:

I dedicate this project to my family, especially my beloved parents, for their unwavering support, love, and encouragement throughout my academic journey. Their sacrifices, prayers, and belief in my potential have been the foundation of my success. To my siblings, thank you for always standing by my side and motivating me to keep going, even in difficult times. Your words of encouragement and constant support have meant the world to me. This project is also dedicated to all those who have inspired me along the way my mentors, teachers, and friends whose guidance and belief in me played a vital role in bringing this work to life. This is for everyone who never stopped believing in me.

ABBREVIATIONS AND ACRONMYS:

OHMWES: Oxen Health Monitoring and Workload Estimation System

USSD: Unstructured Supplementary Service Data

SMS: Short Messaging Service

FAO: Food and Agriculture Organization

ICT: Information and Communication Technology

DHT11: Digital Humidity and Temperature Sensor

IoT: Internet of Things

GSM: Global System for Mobile communication

ER Diagram: Entity Relationship Diagram

API: Application Programming Interface

SDLC: Software Development Life Cycle

UI: User Interface

SQL: Structured Query Language

DBMS: Database Management System

LED: Light Emitting Diode

C++: C Plus (Programming Language)

HTML: HyperText Markup Language

POSTGRES: PostgreSQL Database

ABSTRACT:

The Oxen Health Monitoring and Workload Estimation System (OHMWES) is designed to address the challenges faced by farmers in the Shinyanga region of Tanzania, where oxen play a vital role in agricultural activities. Many farmers in this region experience reduced agricultural productivity due to poor management practices such as overworking oxen and the lack of proper health monitoring systems. These issues often result in exhaustion, injury, or death of oxen, ultimately affecting farm output and income. This project introduces a comprehensive digital solution that leverages Internet of Things (IoT) technology alongside SMS and USSD services to help farmers monitor the health and workload of their oxen in real time. The IoT system includes sensors that collect vital data such as temperature, pulse rate, and workload levels, which are then analysed and transmitted to farmers using mobile technologies. This ensures that even those in remote rural areas with limited internet access can receive timely alerts and updates about their animals through basic mobile phones. The system empowers farmers with actionable insights to prevent overworking their oxen, schedule appropriate rest times, and detect early signs of illness. By combining IoT with low-bandwidth communication tools, the project bridges the digital gap and supports data-driven decision-making in traditional farming communities. The report outlines the background of the problem, a literature review of existing technologies, system design and architecture, and detailed functional and non-functional requirements. It emphasizes creating an inclusive, accessible, and sustainable solution tailored to the needs of rural farmers, aiming to enhance animal welfare and agricultural productivity.

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CHAPTER ONE:

INTRODUCTION AND PROBLEM DESCRIPTION

1.1Introduction

Agriculture remains the backbone of rural economies in Tanzania, and oxen are essential to smallholder farmers for pillowing fields and land preparation. In regions like Shinyanga, oxen play a critical role in ensuring food security, income generation, and agricultural productivity. However, challenges such as inefficient oxen management, overworking, and lack of proper health monitoring hinder the full potential of these animals. The absence of tools for estimating workloads and tracking health has resulted in premature death of oxen and reduced agricultural productivity (Mwaijage, 2018).

The Oxen Health Monitoring and Workload Estimation System (OHMWES) aims to address these issues by providing an integrated platform for oxen health and workload monitoring. Using simple mobile technologies like USSD and SMS, the platform allows farmers and ox owners to receive critical information on oxen health, workload capacity, and overall well-being. This project intends to increase oxen management, productivity, and oxen's long-term health without requiring the employment of internet connectivity (Gartaula et al., 2012).

1.2 Background of the Study

Oxen form a very crucial element in agriculture, especially rural land preparation in Tanzania. Oxen owners and farmers lack effective tools to monitor oxen workload and health and hence inefficiency in farm production. Because oxen play a critical role to Plow large fields of land, their inability to be managed well leads to overworking, injuries, and low levels of production. Moreover, most farmers in Tanzania lack or have limited access to internet services, and hence they cannot access modern farm equipment (Mdegela et al., 2020). Hence, a system that integrates both health monitoring and workload estimation based on mobile phones is greatly required.

Current Challenges:

- Overworked Oxen: With no tools to estimate the workload, oxen get overworked and experience fatigue and injury.
- Limited Monitoring Tools: Farmers have no tools for estimating the workload or health of oxen, leading to overwork and low animal welfare (Hassan et al., 2018).

- Health Neglect: Lack of organized health monitoring leads to disease, death rates, and financial losses to farmers.
- Technological Barriers: Rural farmers lack access to advanced technologies, limiting the scope for improving farming.

Consequences of Poor Management:

- ✓ Reduced Agricultural Productivity: Poor ox health and delayed pillowing reduce crop yields.
- ✓ Economic Losses: Overloading oxen raises replacement costs and imposes economic burdens on farmers.
- ✓ Social Inequalities: Limited ox access exacerbates inequalities among smallholder farmers.

The OHMWES attempts to bridge this gap, providing easy-to-use tools for farmers and ox owners to monitor oxen workload and health utilizing easy mobile phones via USSD and SMS technology (Dube et al., 2017).

1.3 Problem Statement

Utilization of conventional and ineffective oxen management systems has been a major hindrance to agricultural productivity in Shinyanga district. The farmers are faced with several issues like the unavailability of oxen during the time of critical need for agricultural operations, delayed land preparation, and lack of workload control mechanisms. Overload on oxen without supervision results in fatigue, injury, and low productivity, whereas ineffective health management causes premature death of oxen, impacting agricultural performance negatively. Moreover, poor availability of internet-based services demotivates farmers towards modern management approaches, adding to inefficiencies (Hassan et al., 2018).

In line with these constraints, the Oxen Health Monitoring and Workload Estimation (OHMWES) will be developed with the goal of facilitating better oxen management practices. The platform will deliver workload estimation tools, oxen health monitoring, and decision support with simple mobile technologies without the requirement of internet connectivity. By facilitating the monitoring of oxen health and workload among farmers, the platform will expand productivity, animal welfare, and minimize inefficiencies associated with conventional methods.

1.4 Project Objectives

This section outlines the general objective of the project and the specific objects.

1.4.1GeneralOjective

To develop a centralized system that enhances oxen management practice through the provision of workload estimation and health monitoring tools, which can be accessed using USSD and SMS technologies.

1.4.2 Specific Objectives

1. To analyse the challenges of existing oxen workload estimation and health monitoring systems.

2. To determine user requirements for an oxen workload and health monitoring system.

3. To design conceptual and physical architecture for the proposed system.

4. To develop an oxen workload estimation and health monitoring system with SMS and USSD functionality.

5.To conduct system testing to ensure reliability, accuracy, and usability for farmers.

1.5 Significance and Scope

1.5.1 Project Scope

The OHMWES is to enhance ox management and productivity within rural communities, starting with the Shinyanga region of Tanzania. The system will provide health monitoring and workload estimation capabilities to ox owners and farmers using mobile phones with USSD and SMS technologies. The system will be scalable and could be replicated anywhere else where the same agricultural problems dominate (Gartaula et al., 2012).

Geographical Coverage:

• Begin with Shinyanga, scale the system to other farming areas in Tanzania.

Technological Implementation:

• USSD and SMS Integration: Utilize basic mobile technologies to enable access to farmers not connected to the internet, an affordable and inclusive platform for rural areas.

• Offline Access: Catering to lower digital literacy by offering key functionalities through text-based mobile interfaces.

Core Functionalities:

• Workload Estimation: Calculators for determining pillowing capacity in terms of land and oxen endurance, to avoid overwork.

• Health Monitoring: Functionality to monitor the health of oxen, including alerts for vaccinations and workload balance.

1.5.2 Significance of the Proposed project

The OHMWES shall be of utmost significance to farmers, oxen owners, and the agricultural industry through the resolution of essential challenges in oxen management:

1.For Farmers: The system will ensure timely provision of oxen management facilities, increasing agricultural productivity and the health of animals.

2.For Oxen Owners: Oxen owners shall benefit from enhanced management facilities that increase the health and longevity of their oxen, reducing replacement costs.

3. For Agriculture: Better oxen management will lead to improved land preparation, and hence higher crops yields and overall agricultural productivity.

Key Benefits:

1. Decreased Animal Mortality: Monitoring systems prevent overloading, leading to increased oxen welfare and lifespan.

2. Increased Accessibility: Farmers can obtain access to trustworthy oxen rental services through mobile platforms, guaranteeing availability during critical farming seasons.

3. Increased Agricultural Productivity: With optimized oxen workload and plowing power, the system assists in achieving maximum farming yields.

4. Economic Growth: The greater agricultural productivity increases the incomes of smallholder farmers, resulting in rural economic development.

CHAPTER TWO

LITERATURE REVIEW

2.Introduction

This chapter gives an overview of what is known about oxen management in agriculture, problems, research findings, and potential solutions. A critical literature review ensures the project is built on what has been done and addresses gaps that are known to exist. The review has four parts: an overview of the subject, related research and systems, field review, and a conclusion outlining major findings and their relevance to the project.

Oxen Health Monitoring and Workload Estimation System (OHMWES) draws from local and international research, citing the key vulnerabilities of current systems and points where there is a potential for improvement. Literature review here is on oxen-related subjects, technology application in agriculture, and the lessons from similar platforms (FAO, 2020; GSMA, 2019; Hello Tractor, 2020).

2.1 Review of the Topic

The application of oxen in farming in the rural areas of Shinyanga is both a weakness and a strength. Although they are an asset, the lack of organized management tools has resulted in inefficiencies in agricultural productivity. In this case, we examine existing practices and potential for digital solutions to these issues (FAO, 2020).

2.1.1 Existing Oxen Management Challenges

1. Ineffective Workload Monitoring:

Farmers lack equipment to estimate the workload that their oxen can handle, leading to overloading, injury, and stress (Hassan et al., 2018).

2. Inadequate Health Monitoring:

Because there are no health records and monitoring systems, oxen are prone to disease and premature death, rendering them less productive in agriculture (FAO, 2020).

3. Technological Barriers:

The farmers in rural areas have few avenues to new agricultural technologies, and traditional hand-Labor techniques are used (Digital Green, 2018).

2.2 Related Research and Systems

There have been several systems and studies that address inefficiencies of farming using digital mechanisms. While most do it with mechanized farming, fewer exist for oxen management.

- Hello Tractor (Kenya)

A platform connecting farmers to tractor services. Efficient but not targeting ox-related problems or workload quantification (Hello Tractor, 2020).

- Digital Green (India)

Provides SMS farm advice but no leasing or health monitoring services for animals (GSMA, 2019).

- Land Information Systems (LIS)

These systems, as in Rwanda and Ethiopia, highlight the importance of good records and transparent resource allocation.

2.2.1 Benefits of Digital Platforms for Agriculture

1. Enhanced Efficiency: Web-based systems save time and effort in resource allocation.
2. Enhanced Accessibility: Farmers are given access to major services, e.g., oxen rental, through mobile channels like USSD and SMS.
3. Effective Resource Management: Workload estimation tools prevent overuse of oxen and enhance their welfare.

2.3 Domain Review

Current agriculture platforms, like Hello Tractor, have shown the potential of technology to transform but are restricted in that they deal with mechanized equipment and not animals. OHMWES hopes to fill this gap by developing a platform specifically designed for oxen management.

Key findings from similar platforms are:

The need for user-friendly interfaces, especially for farmers with low technology literacy. The need for offline capability where internet access is limited.

Example:

Hello Tractor addresses large-scale mechanization with useful insights into rental management systems but ignoring the special challenges of operating with oxen.

2.3.1 Comparative Analysis

Several ox monitoring systems exist globally, particularly within precision livestock farming, where IoT is used to track cattle health and productivity. Research into such technologies, particularly in countries utilizing smart agricultural solutions, can offer valuable insights. For instance, Kenya's Hello Tractor initiative successfully connects farmers to mechanized plowing services. Adapting similar IoT-driven methodologies to oxen workload estimation can significantly enhance system effectiveness.

2.4 Problem Conclusion

The review also determines the greatest oxen management system gaps, including the absence of rental service equipment, workload calculation, and health monitoring. Some beneficial platforms exist but are not tailored to the needs of smallholder farmers employing oxen (FAO, 2020; GSMA, 2019).

Oxen Health Monitoring and Workload Estimation System leverages these to develop a solution that consolidates rental services, health monitoring, and workload tools into a USSD and SMS-based platform.

By filling these gaps, OHMWES can:

- Increase farm productivity through efficient oxen management.
- Increase access among rural farmers with minimal technological capabilities.
- Promote sustainable agriculture through improved animal welfare (Hassan et al., 2018).

CHAPTER THREE:

REQUIREMENT ELICITATION AND SYSTEM ANALYSIS

3.1 Introduction to Requirement Elicitation

Requirement elicitation, also known as requirement gathering, is the process of determining the specific needs and functions required from a system by consulting with stakeholders (Somerville, 2011). This phase is critical as it sets the foundation for the entire system's design and development. The process involves engaging actively with customers and end users to understand the domain's needs and identify constraints. By gathering detailed system requirements, both functional and non-functional, the team can proceed with building a system that meets user expectations and project goals (FAO, 2020).

This chapter presents the analysis of the Oxen Health Monitoring and Workload Estimation System. It outlines the functional requirements, the non-functional requirements, and the analysis of the system's domain. Furthermore, this chapter discusses the methodologies that have been used in capturing the system's requirements to ensure the system is able to meet the needs of the users and fill the gaps in the existing systems.

3.1.1 Techniques Used in Collecting the Requirements

Several techniques were used in collecting the information needed to define the requirements of the system. These techniques will go a long way to explain how the system should work, the data to be collected, and how it should operate within its intended environment. The methods used to collect the requirements for the proposed system are thus:

1. Literature Review

A review of the available literature on oxen management and agricultural technology systems helps in the identifications of the problems faced by farmers and the shortcomings of the available solutions. The background information helps understand what the proposed system requires and aids in pointing out areas that require improvement.

2. Questionnaires

Structured questionnaires to stakeholders allow comprehensive input from several users simultaneously. It finds very useful applications in garnering opinions regarding desired parameters of features and functionalities of a system. These questionnaires are especially good when a large population needs to be tapped comprising farmers, oxen owners, and local agricultural experts.

3.Observation

It gives an idea about how stakeholders interact with the prevailing practices and systems in place. Observation can be active, where one interacts directly with the stakeholders, or passive, where one observes interactions with a system without interference. The direct observation will play a significant role in understanding user behaviour and any inefficiencies of the system.

4.Review of Documents

It helps review existing documentation, such as surveys, books, and scholarly articles, to summarize and analyse prior research related to oxen management systems. This approach helps in understanding the shortcomings of the previous solutions and further refines the system requirements for the new platform.

3.2 System Functionalities

The Oxen Health Monitoring and Workload Estimation System is designed to meet specific user needs through a set of basic features and operations. They ensure that the system works not only effectively but also efficiently. They can be divided into two major groups: functional requirements and non-functional requirements. The functional requirements outline what the system must do in the accomplishment of user expectations, while the non-functional requirements outline performance and infrastructure requirements.

Thus, below is an explanation of the main functional requirements of the OHMWES: each focused-on oxen management with input from Digital Green in 2018 & Hello Tractor in 2020.

3.2.1 Functional Requirements

Functional requirements define

the functions and services that must be delivered from the system. These are very crucial as they ensure that the system works within the expected framework and satisfies the users of the system. The key functional requirements of OHMWES are highlighted below:

1. Compute Optimal Work Duration for Oxen

In this regard, to avoid overworking oxen, the system is designed for continuous workload monitoring and will give recommendations on safe working hours. This ensures that the oxen do not exceed their capacity and hence avoids fatigue and injuries. Through workload data capture, the platform will be ensuring that oxen work within their physical limits for better welfare and productivity at work.

2. Sizing of Land an Ox Can Cultivate

The system shall calculate the optimum area of land that an ox can efficiently Plow, considering its health conditions, breed, and workload capacity. Based on all these considerations, the system will define the right land size for the given number of oxen. In this way, it may ensure that the whole farming activities are done smoothly without giving extra stress to the animals. Using this, farmers can plan accordingly and prepare land accordingly to achieve maximum agricultural productivity.

3. Monitoring the Health Status of Oxen

Health monitoring is a vital part of the OHMWES. The system shall continuously monitor and update information on individual health status, thus providing real-time reports with timely alerts if there will be some health concerns. In this respect, this feature will enable farmers to act regarding health problems before they escalate to more serious conditions that could shorten the lives of the oxen and eventually impact farming tasks where the animals are used. The system will also provide recommendations for periodic health check-ups and necessary treatments.

3.2.2 Non-Functional Requirements

Non-functional requirements are the qualities or attributes the system should possess in terms of performance, security, usability, and other aspects. These ensure that the system is reliable and usable to a high standard.

1. Performance

The system should support many users and transactions and provide fast and responsive user experiences. It should efficiently process data at peak usage times.

2.Security

The system should ensure that the data regarding users and their transactions is kept confidential and secure from unauthorized access and data breaches. Strong security is paramount to protect sensitive information about land ownership.

3. User Experience

The system should be friendly to use and navigate through it, so that the users interact in the best possible way. A user-friendly interface will go a long way in ensuring ease of use for farmers, owners of the oxen, and buyers in general.

4. Compatibility

The system should be accessible through mobile phones, tablets, and desktop computers and be supported by different operating systems. This ensures that the platform can reach as many users as possible regardless of device preference.

5.Localization

The system should be able to support many languages and many types of currency. This makes access easy for a wide range of users. In Tanzania alone, this system would support Swahili and English.

6.Data Management

It needs to offer appropriate, effective data storage management and, more so, facility for backup and recovery. In the event of a system crash, this means the assurance of preserved and retrievable user data.

3.3 System Analysis

System analysis is the study of the present system if it exists and identifies the problems that need to be solved. System analysis can be defined as understanding the operations already present, detecting inefficiency, and recommending enhancements on them Somerville, 2011.

3.3.1Analysis of Current System

Nature of Present System:

The current system of managing oxen is mostly manual, based on traditional means of managing, such as paper records, word of mouth, and gentlemen's agreements. Farmers usually track the availability and health of oxen using some very rudimentary tracking methods that are not organized or reliable. These outdated practices result in mismanagement and inefficiencies, including inconsistent tracking of key metrics such as workload and health status. Besides, there is no central platform to organize oxen rentals or monitor their usage effectively.

During this analysis phase, the team also investigates how users interact with current systems and where improvements can be made to streamline operations. By system analysis, a new platform is proposed that embeds features inclusive of health monitoring and workload estimation tools. These will help in eliminating the problems of the existing systems so that farmers can better their efficiency and productivity.

The system will integrate state-of-the-art technologies that ensure more integration and automation, hence more reliable and friendlier to the users. In doing so will fill the gaps in the present management of oxen, improving agricultural productivity and animal welfare.

Short Comings of the Present System:

1.Inaccessibility of Oxen in Peak Seasons

Farmers are highly inconvenienced by delays in accessing oxen in peak seasons, like pillowing seasons, negatively affecting the undertaking of farming operations in time.

2.No Workload Estimation Tools

Overworking due to lack of estimation tools results in fatigue and injuries among oxen.

3.Lack of Health Monitoring Systems

Due to the lack of health monitoring, most illnesses or injuries are detected when the case is worse, hence lowering productivity and compromising welfare.

Impact of the Current System:

1. Decreased Agricultural Productivity

Lack of proper access to the oxen and mismanagement of the workload meant farming activities were delayed, therefore directly impacting crop yields.

2. Increased Operational Costs

Poor management, breakdowns of the oxen, and inefficiencies in scheduling add to the farmer's costs.

3. Reduced Welfare of the Oxen

Overworking, without workload management tools, reduces the life spans and lowers their ability to perform effectively.

3.3.2 Technical Feasibility

The workload estimation feature requires a well-defined formula or model to accurately assess the oxen's workload. Several parameters should be considered, including the number of steps taken by the oxen, duration of plowing, weight of the Plow, and land size covered. To enhance precision, integrating IoT-based sensors on the Plow or ox harness can provide real-time workload data. These sensors can measure factors such as movement, force exerted, and working duration, ensuring oxen are not overworked and maintaining their welfare.

Hardware Interfaces:

The system will be interfaced with wearable sensors placed on oxen to retrieve real-time health and workload information. The sensors will track:

✓ Movement patterns (to identify illness or fatigue).

✓ Normal Body Temperature (37.5°C to 39.5°C (99.5°F to 103.1°F).

✓ Appetite levels (to measure energy levels and workload capacity).

✓ Respiratory rates (to identify respiratory infections).

✓ Heart rates (for stress and possible health risks monitoring).

✓ Posture and stability (for determining the overall physical condition).

Disease detection for the following:

• Babesiosis

• Contagious Bovine Pleuropneumonia (CBPP)

• Foot and Mouth Disease (FMD)

• Lumpy Skin Disease

• Respiratory Infections

These sensors will send data to a central server for analysis and processing. The hardware interfaces will also support communication through GSM modules for areas with no internet connection.

3.3.3 User Testing Strategy

Given that the primary users of the Oxen Health Monitoring and Workload Estimation System (OHMWES) are rural farmers with limited digital literacy, usability testing must be conducted in real-world farming environments. A pilot phase should be launched in select villages, where a small group of farmers tests the system over a farming season. Their feedback will be collected through surveys and interviews, refining the user interface, SMS/USSD accessibility, and alert mechanisms. This iterative testing approach ensures the system remains user-friendly and meets the farmers' practical needs.

3.3.4 Security and Privacy Considerations

Since the system will collect sensitive data regarding farmers' livestock and business operations, robust security measures must be implemented. Data encryption should be employed to secure transmitted and stored data, ensuring that unauthorized access is prevented. Access control policies must be established to restrict data retrieval to authorized users only. Additionally, the system should comply with data protection regulations to safeguard farmers' information while maintaining transparency on how their data is used. Providing farmers with the option to opt into or out of data collection ensures ethical technology practices.

3.3.5 Proposed System Analysis

Core Features of the Proposed System

The proposed system, the Oxen Health Monitoring and Workload Estimation System, is designed to address the limitations identified in the current system through the integration of modern digital tools and automation. The platform shall ensure accessibility to farmers by ensuring that all the main functionalities are availed to them through USSD menus that do not require access to the internet or the website login. To this end, the platform shall be all-inclusive and ideal for farmers in rural settings with limited digital literacy and connectivity.

Proposed Features:

1.Workload Estimation Tools

Based on the breed, health, and workload capability, the system will estimate how much land an ox can Plow without being overworked or underutilized.

2.Real-Time Health Monitoring

It shall monitor various vital health variables such as body temperature and workload, with a warning system on potential health hazards. This assures timely interventions with improved animal welfare.

Benefits of the Proposed System:

1.Increased Efficiency and Productivity

The automation of rental services in workload management will smoothen the operations and guarantee timely access to oxen with their best utilization.

2.Improved Welfare of Oxen

The system will prevent overworking and undetected health issues, hence prolonging the productive life of oxen, by means of real-time health monitoring and workload estimation tools.

4.User Experience Enhanced

The user interface, integrated with SMS and USSD support, will ensure accessibility even in rural areas where internet access is limited, thus inclusive for all farmers.

USE CASE DIAGRAM

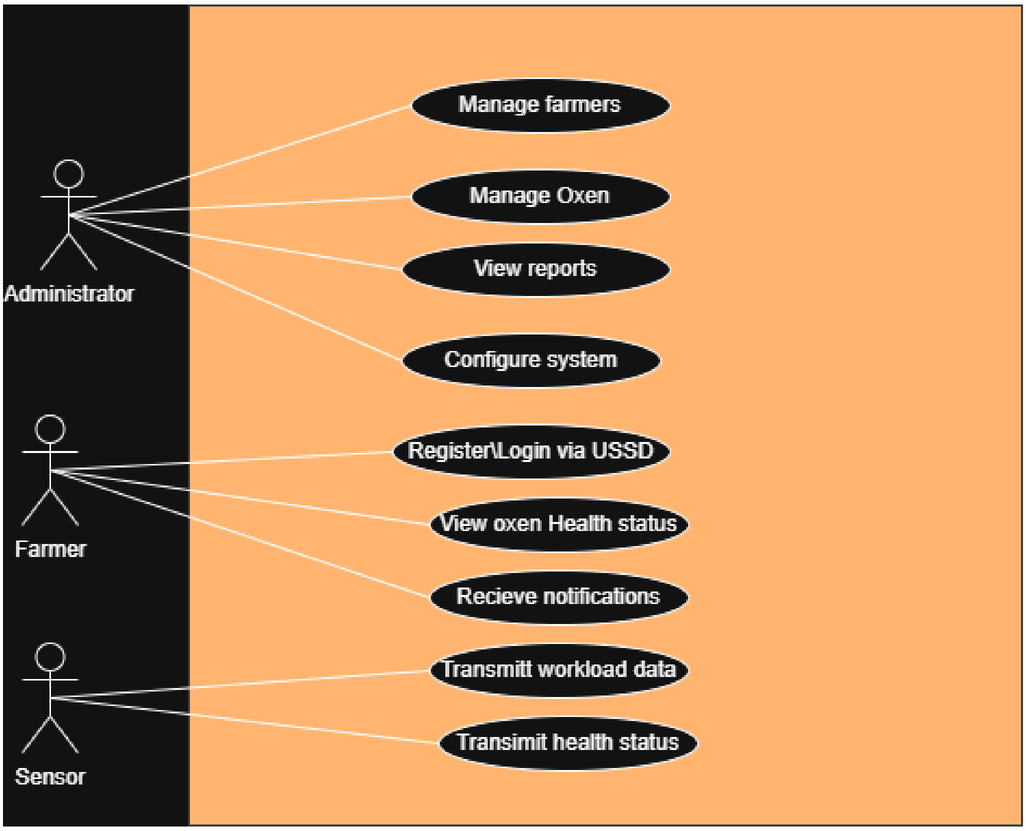


Figure 1:Use case diagram

CHAPTER FOUR: SYSTEM DESIGN

4.1 Introduction to System Design

The design of the Oxen Health Monitoring and Workload Estimation System (OHMWES) provides a complete solution for rural livestock management by combining hardware sensors, IoT devices, and a mobile-accessible interface. This design serves as a blueprint for building the solution and enables real-time data flow from the field (oxen health sensors) to the end users (farmers and administrators). System processes are functionally modular divided into sensing, data transmission, storage, analysis, and notification.

OHMWES employs web-based dashboards for administrators and USSD/SMS-based access for local farmers with feature phones. The system transforms raw input from sensors (e.g., heart rate, temperature, movement) into useful information such as workload metrics, stress alerts, and recommendations.

4.2 System design methodology and technologies

This section outlines the step-by-step development approach (Waterfall model) and the key technologies used to build the OHMWES system, integrating software, hardware, and communication tools.

4.2.1 System design methodology

The system follows the Waterfall Model a linear software development life cycle (SDLC) that suits the hardware-software integration nature of OHMWES. Each stage (requirements, design, implementation, testing, deployment) is completed before moving to the next.

The Waterfall model ensures a clear understanding of the challenges before physical implementation, allowing efficient resource allocation and risk minimization.

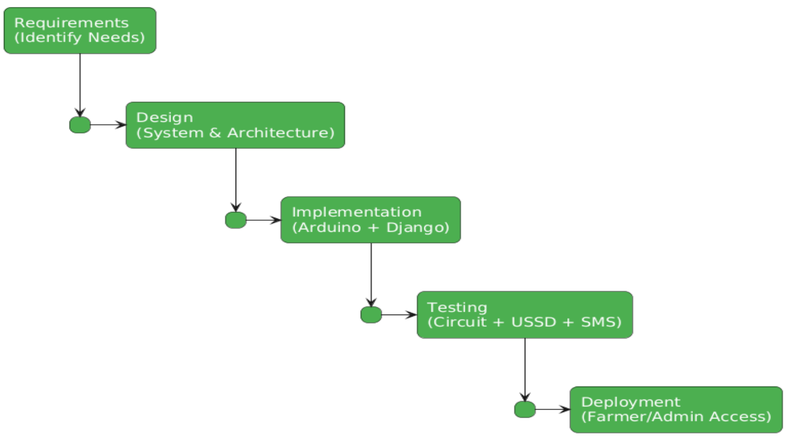


Figure 2:Waterfall SDLC model with five phases applied to OHMWES.

4.2.2 Solution Capability Envisioning

The system is envisioned to empower farmers by transforming local knowledge with technology:

- ✓ Admin registers oxen and assigns to a farmer
- ✓ IoT sensors attached to oxen monitor heart rate, temperature, and effort
- ✓ Farmers query this data via USSD codes like *384#
- ✓ The backend interprets and responds via SMS with alerts or insights

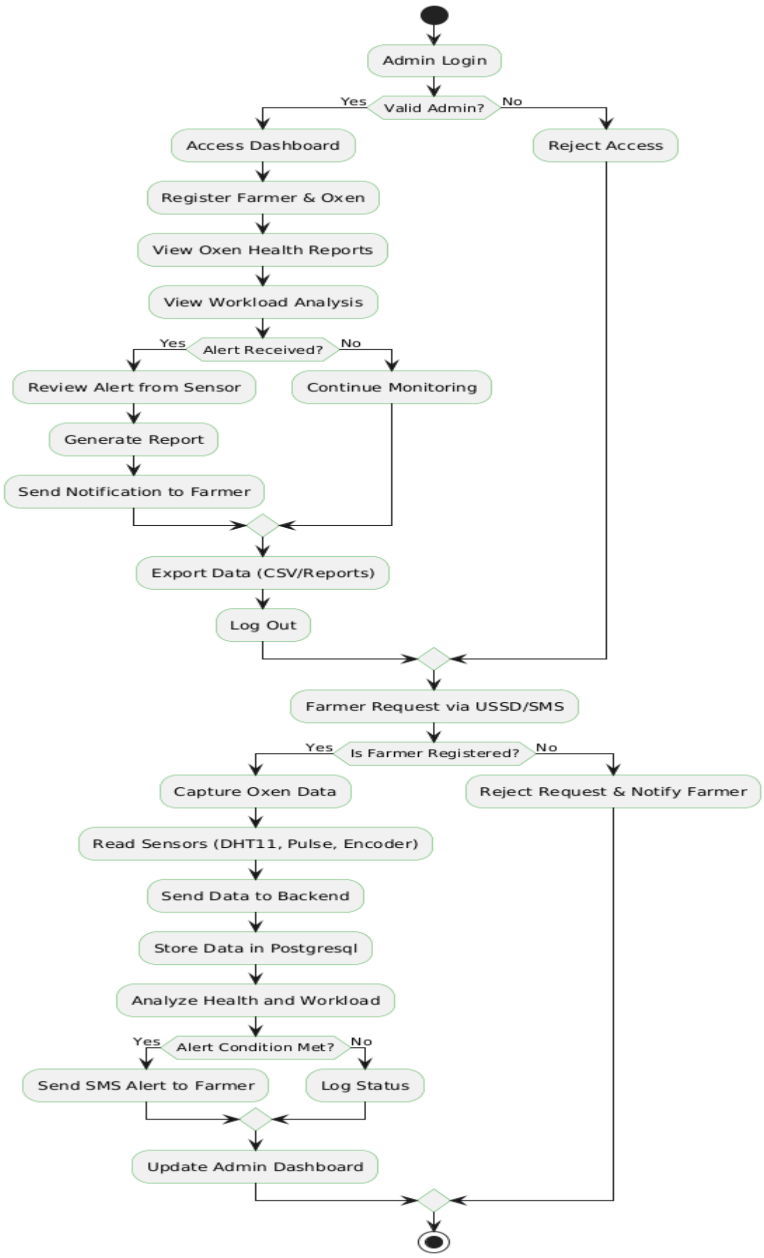


Figure 3: Data Flow Chart Diagram

4.2.3Adopted Architectural and Design Orientation

The OHMWES system adopts a Three-Tier Architecture to ensure separation of concerns and smooth integration of its components.

The Presentation Layer: includes the USSD interface for farmers and a web-based dashboard for administrators to interact with the system. The Logic Layer is managed using the Django framework, which handles processing of sensor inputs, analysis of data, and generation of alerts. Finally, the Data Layer uses PostgreSQL to store all essential records such as health metrics, oxen profiles, farmer details, and alert history, supporting efficient data retrieval and long-term storage.

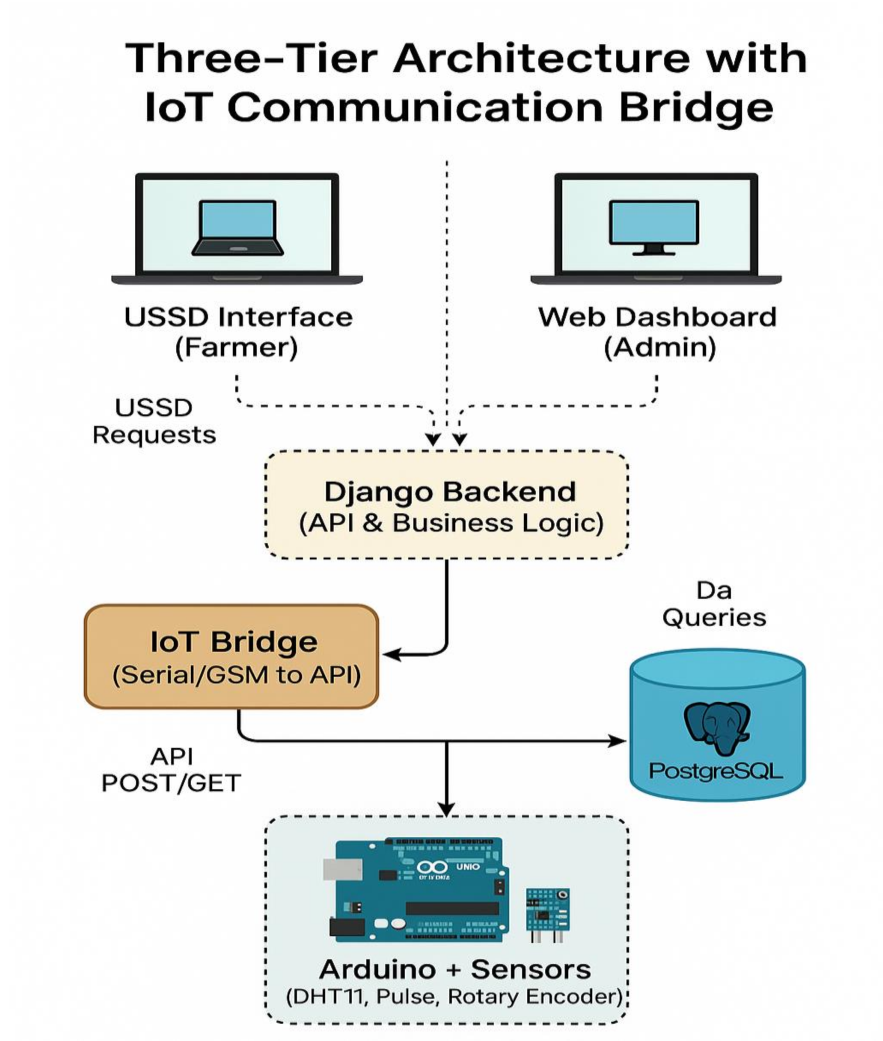


Figure 4: Three-tier architecture for OHMWES

4.2.4 Technologies used

The Oxen Health Monitoring and Workload Estimation System (OHMWES) was built using a combination of software, hardware, and communication technologies.

Python (Django): Used to build the backend logic, APIs, and manage database operations securely and efficiently.

PostgreSQL: A powerful open-source relational database system used to store health records, oxen data, and farmer information.

Arduino (C++): Microcontroller platform programmed in C++ to read sensor data (temperature, heart rate, rotation) and send it to the backend.

Bootstrap: A frontend framework used to create responsive and user-friendly web interfaces for the admin dashboard.

Africa's Talking USSD & SMS API: Enables SMS alerts and USSD-based communication with farmers, especially in low-internet areas.

4.2.5 IoT Devices and Sensors Used

The system employs various IoT components that form the backbone of oxen monitoring:

- ✓ Rotary Encoder (Simulated via Potentiometer)
  Used to measure rotational movement simulating oxen pulling loads.
- ✓ DHT11 Sensor (Temperature sensor)
  Monitors oxen body environment: temperature and humidity.
- ✓ Pulse Sensor (Heartbeat sensor)
  Detects oxen's heart rate, indicating stress or exhaustion.
- ✓ LCD Display

  Used to display the collected data temperature readings, heartbeat readings

- ✓ Relay Module + LEDs
  Simulates real-time alerts or load indicators.
- ✓ GSM Module (SIM800L or similar)
  Sends SMS alerts and interacts with USSD sessions.
- ✓ Arduino Uno
  Central processing unit that reads sensor data and communicates with the backend.

4.2.6 Circuit Design and Component Placement

The Arduino-based hardware is built on a breadboard or PCB using the above components.

- ✓ All sensors are connected to analog/digital pins
- ✓ Data is transmitted via Serial USB to backend or GSM module

✓ LEDs simulate workload visualization

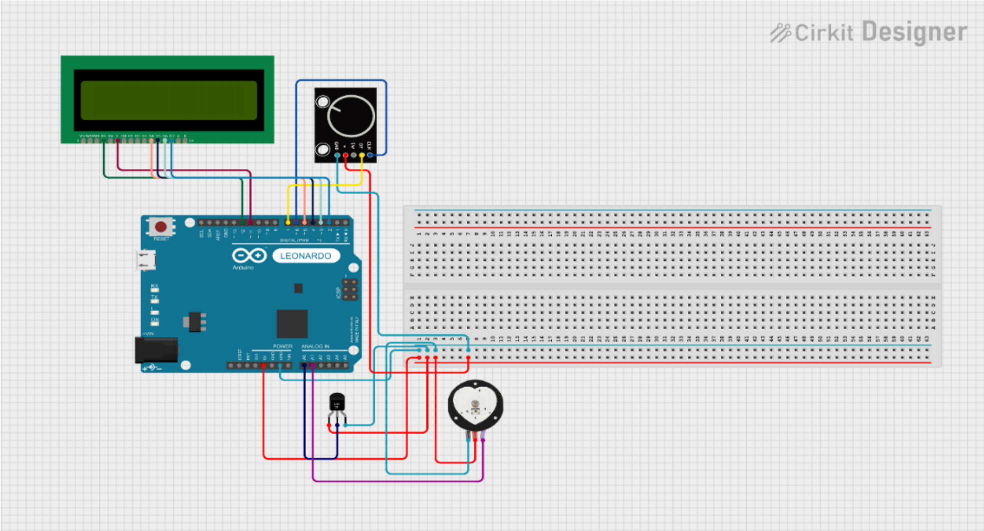


Figure 5: IoT Circuit Diagram

4.2.7 Overall System Design and Integration Approach

This system combines the following domains:

✓ IoT sensing for physical condition tracking
✓ USSD/SMS communication for accessibility in low-bandwidth environments
✓ Web dashboards for centralized decision-making

Data flows in real time from oxen sensors to farmers/admins through a secure backend. This hybrid approach ensures scalability, usability, and reliability.

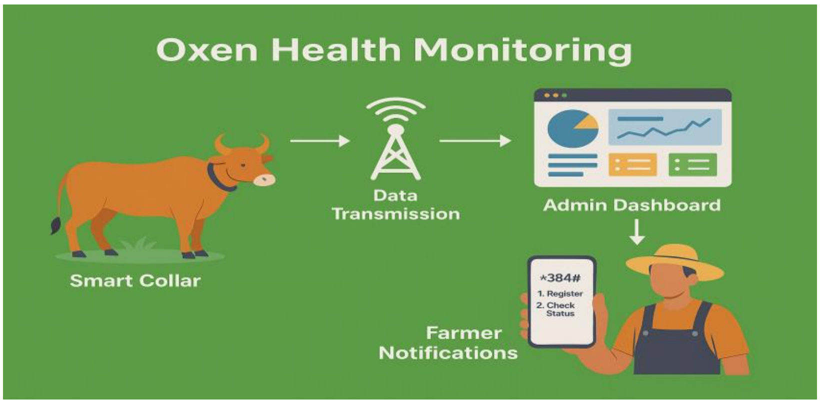


Figure 6: System Approach

4.3 Database Design

The OHMWES database was designed to manage all system data efficiently, including farmer profiles, oxen records, health readings, workload tracking, and alert notifications. It consists of well-structured relational tables such as:

Farmer: Stores farmer details (e.g., ID, Name, Phone, PIN).

Oxen: Links each ox to a farmer and records breed and registration info.

Health: Logs vital signs like heart rate and temperature for each ox.

Workload: Tracks oxen workload based on farm activity data.

Notification: Manages alert messages sent to farmers about oxen health or workload.

The design supports real-time updates and integration with sensor data and is represented through an ER diagram and table creation SQL statements.

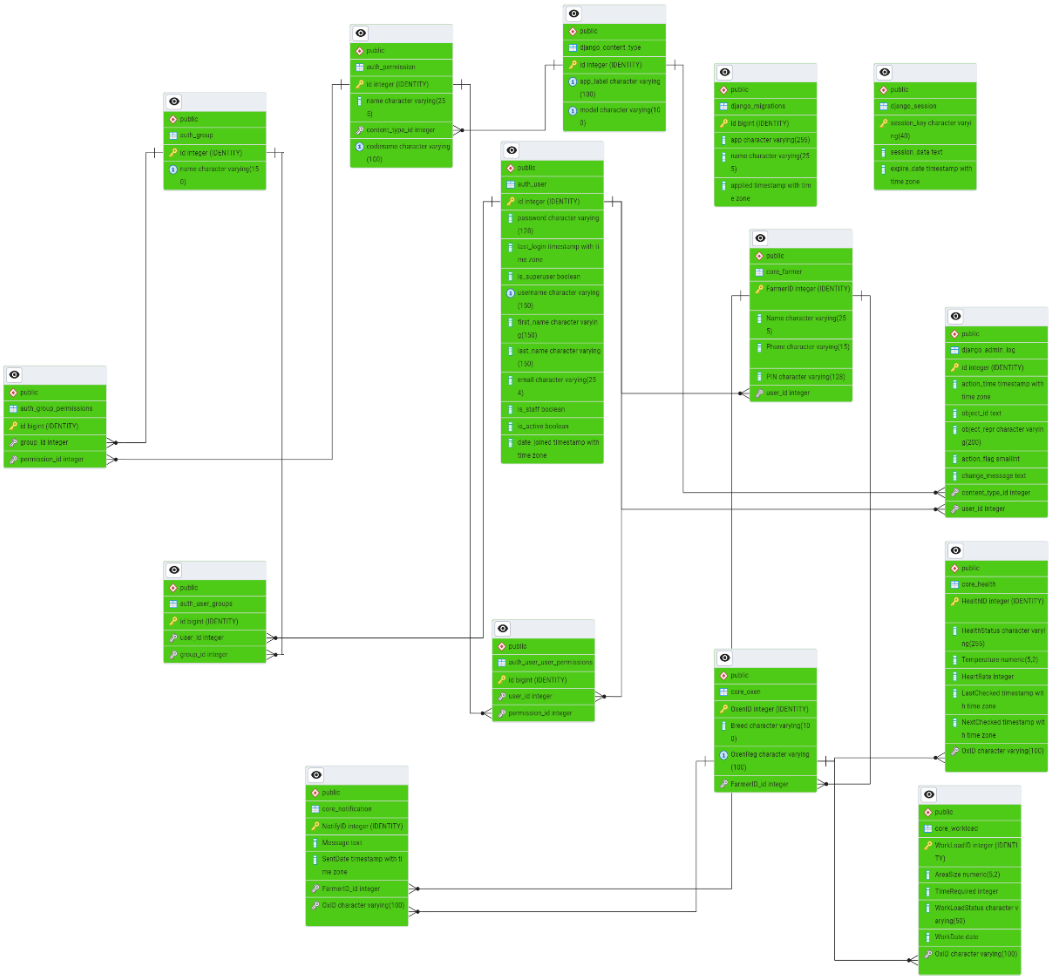


Figure 7: Entity-Relationship (ER) Diagram

The relationships illustrated in the above Entity-Relationship (ER) diagram were implemented using SQL queries within the PostgreSQL database server. During the design and development process, the database schema was carefully structured and normalized up to the Third Normal Form (3NF). This normalization process was applied to eliminate data redundancy and ensure logical data grouping, thereby enhancing data consistency, integrity, and efficiency in query execution. By adhering to 3NF principles, each table is focused on a single subject, and dependencies are properly maintained between primary and foreign keys, allowing for reliable data storage and accurate relationships among entities such as farmers, oxen, health logs, workloads, and notifications.

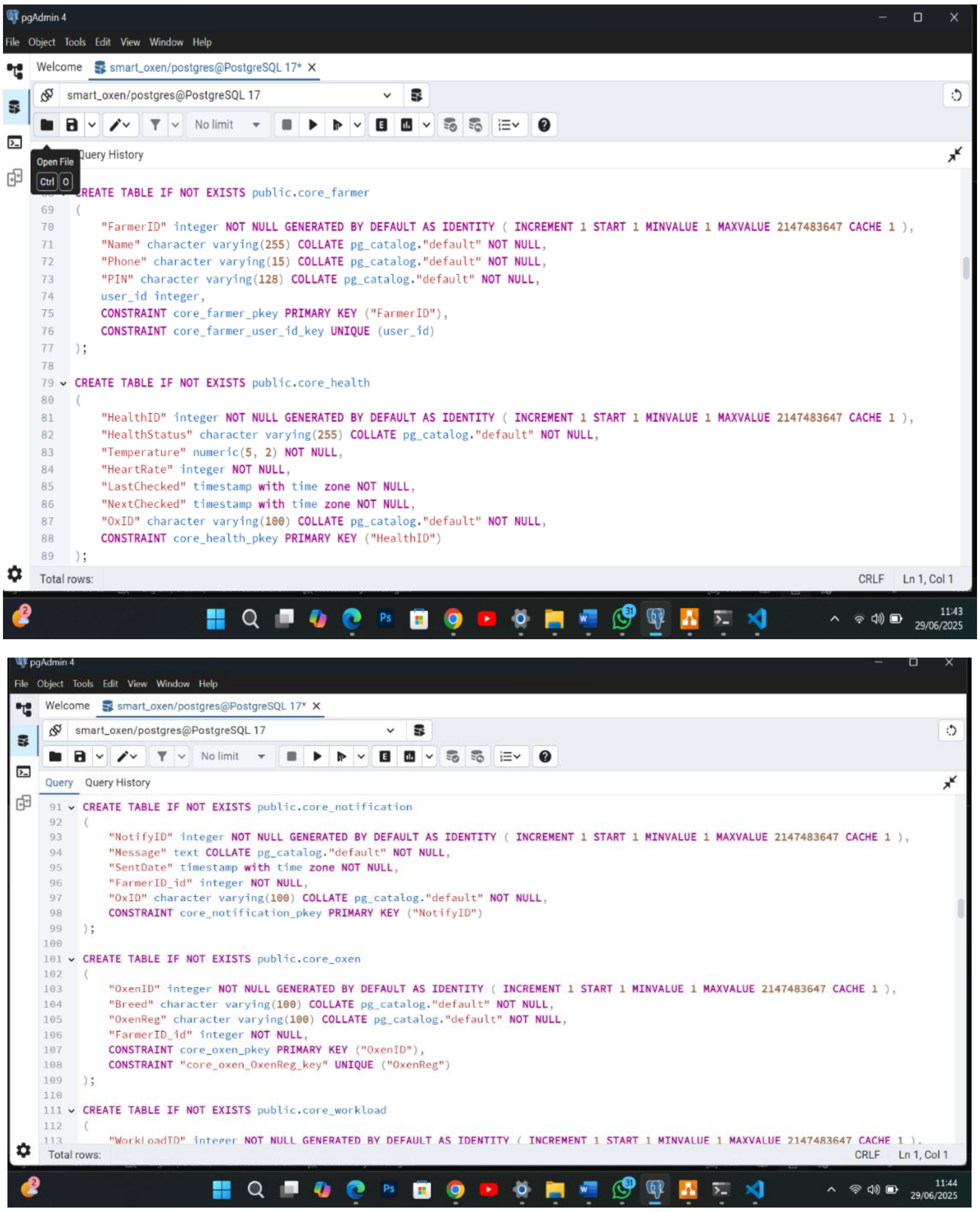


Figure 8: SQL Statement of Database Relations

4.4 User Interface Design Sketch

The user interface is designed to be simple, responsive, and accessible to both farmers and administrators. Admins access the system through a secure web dashboard to manage data and monitor oxen health, while farmers interact using USSD codes and receive SMS alerts. Key interfaces include the admin login screen, dashboard with health summaries, and a USSD menu for farmers with basic mobile phones.

The UI is tailored for two main user roles:

Administrators, who use a web-based dashboard.

Farmers, who interact with the system via USSD codes and receive responses through SMS ideal for areas with limited internet connectivity.

Below are the core components of the UI and the key design principles implemented:

Layout and Navigation:

The admin interface features a well-organized layout with:

- ✓ A sidebar menu for navigation between key modules (e.g., Dashboard, Farmer Registration, Oxen Monitoring, Reports).
- ✓ A top navigation bar showing system status and notifications.
- ✓ Dashboard cards and tables summarizing real-time oxen health, workload data, and recent activity logs.

Navigation is consistent and user-friendly, ensuring minimal learning curve for new users.

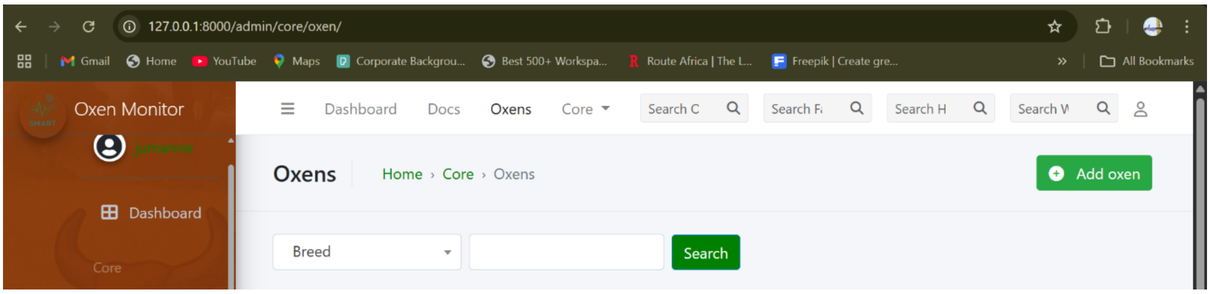


Figure 9: Admin Navigation Layout

Responsive Design:

The admin dashboard is designed using **Bootstrap**, which makes it responsive across various devices and screen sizes. Whether accessed from a laptop, desktop, or tablet, the interface adjusts smoothly without compromising functionality.

Farmers, who primarily use basic phones, interact through USSD codes (e.g., *384#). The USSD menus are designed for fast loading and efficient input, providing a responsive experience even on 2G networks.

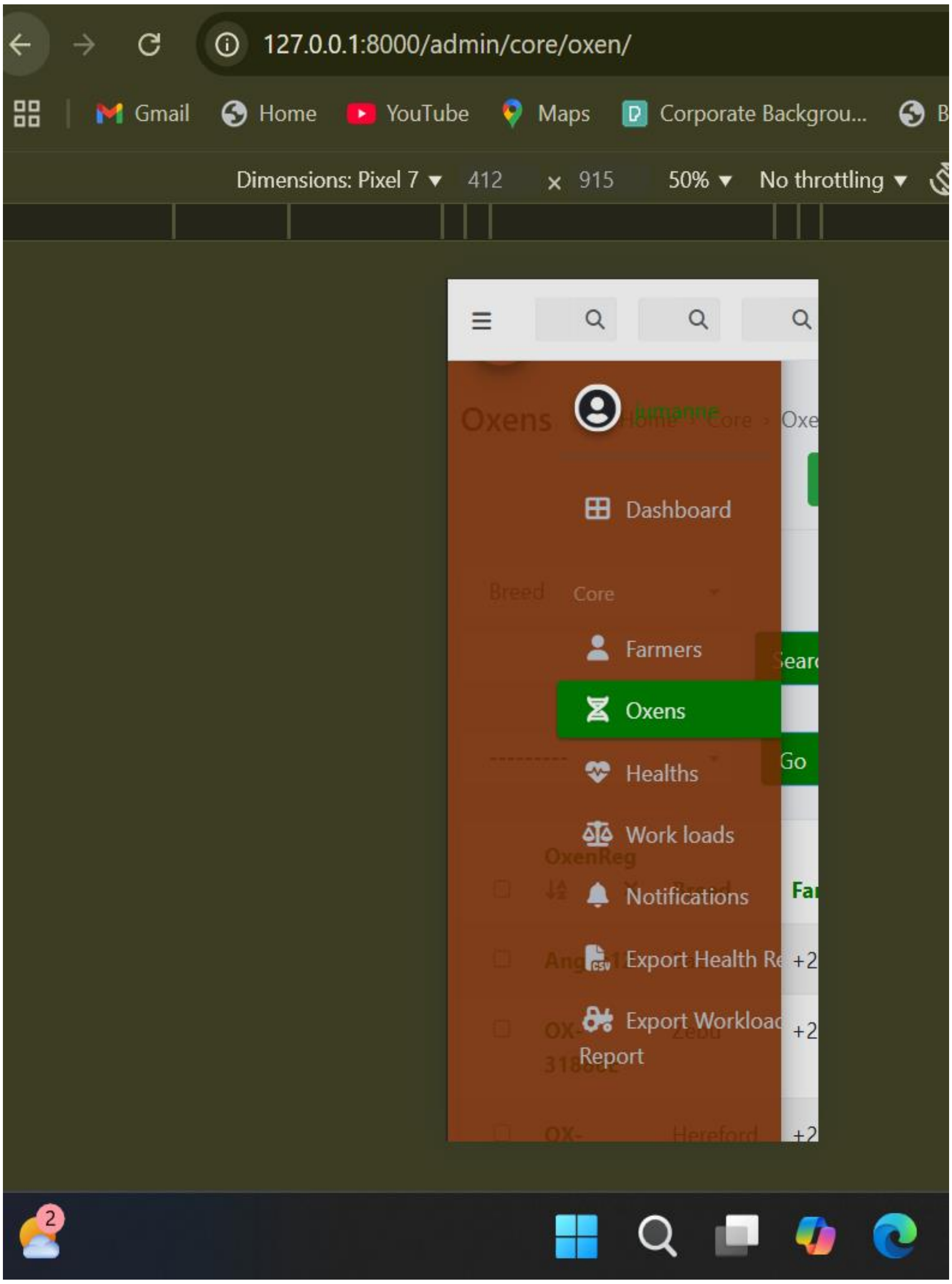


Figure 10: Admin Dashboard on Mobile phones responsive

Forms and Input Validation:

The admin dashboard includes several interactive forms with client-side and backend validation:

- ✓ Farmer registration forms with required field checks.
- ✓ Oxen assignment and data input forms to ensure accurate entry of breed, health stats, and workload parameters.
- ✓ Sensor threshold setting forms with validation to avoid extreme input values.

The forms help prevent errors and improve data integrity.

CHAPTER FIVE: SYSTEM IMPLEMENTATION

5.1 Introduction

This chapter outlines the implementation process of the Oxen Health Monitoring and Workload Estimation System (OHMWES). It explains how the users interact with the system, the backend logic, the IoT sensor integration, and the interfaces involved. It also provides a step-by-step account of how data flows from the sensors on the oxen to the backend and finally reaches farmers via USSD or SMS, or the admin via a web dashboard.

5.2 Functionalities and Services Implementation

The system was implemented using a combination of web, IoT, and mobile technologies. The web-based dashboard was developed using Django (Python) and styled using Bootstrap. The backend integrates with the Arduino-based hardware that reads oxen physiological data and transmits it either via USB (for prototyping) or GSM module (for deployment). Farmers access system services using USSD codes and receive feedback via SMS.

5.21 Farmer Registration and Oxen Assignment

Admins register each farmer's details and assign unique oxen to them through the dashboard. This relationship is stored in the database and used to filter and retrieve health data relevant to specific farmers.

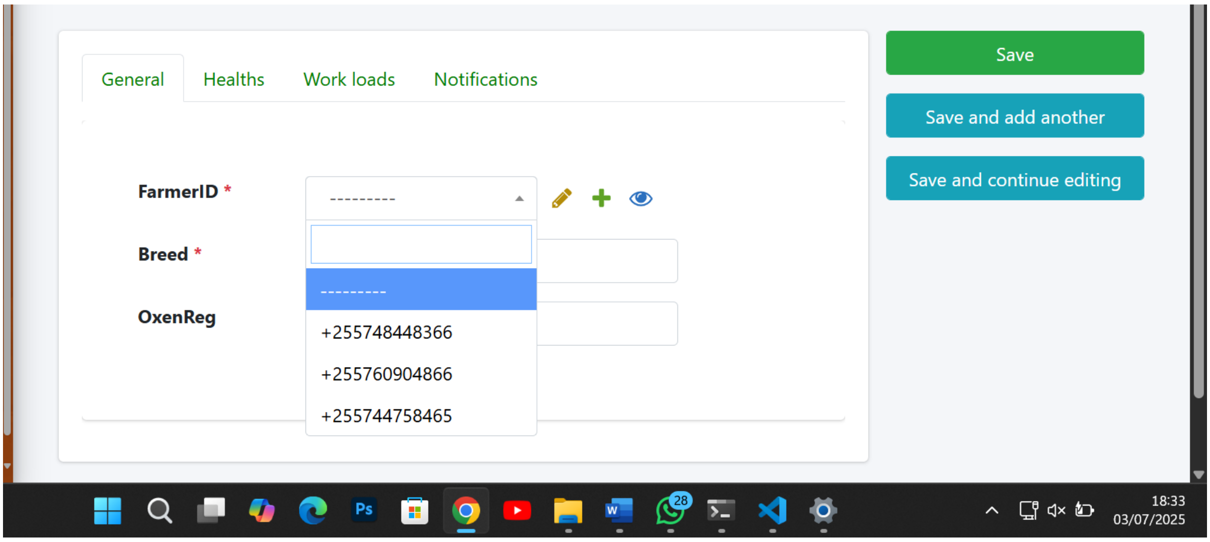


Figure 11: Admin Manage Famer registrations

5.2.2 Oxen Health Monitoring

Sensors like DHT11 (temperature) and a pulse sensor collect real-time physiological data from each ox. This data is processed and analysed to determine oxen stress levels or abnormal conditions.

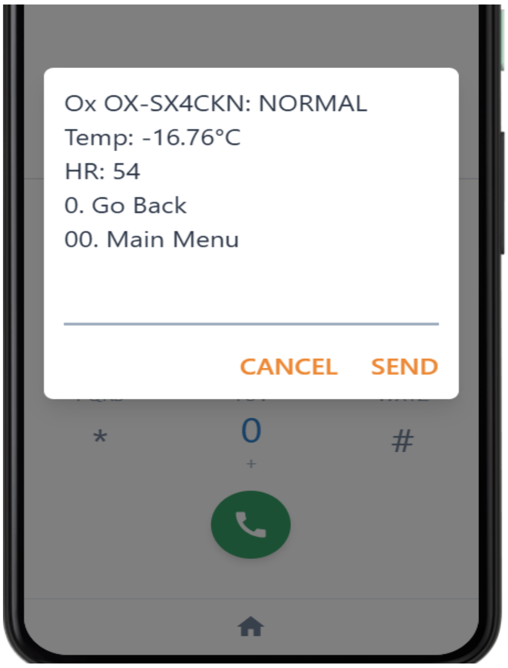


Figure 12: Farmer Monitor oxen health

5.2.3 Workload Estimation using a Rotary Encoder

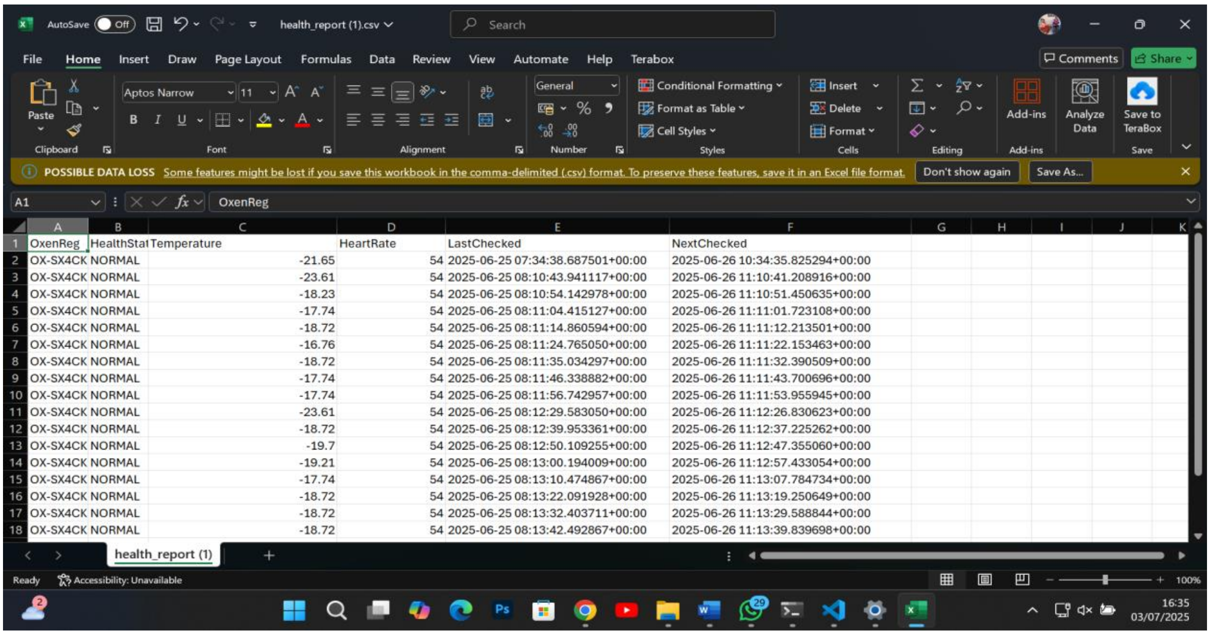
The rotary encoder measures movement and simulates the effort an ox exerts during plowing or load pulling. The system translates this data into workload metrics to identify overworked or underutilized animals

5.2.4 Real-time Alerts via SMS

When a sensor detects an abnormal value (when heart rate > 89 bpm), the backend instantly sends an SMS to the assigned farmer, notifying them of the issue. Alerts are stored for reporting and audit.

5.2.5 Admin Reports and Data Exports

Admins can download CSV or PDF reports on oxen health and workload trends via the dashboard. These reports support veterinary intervention or planning.



	A	B	C	D	E	F
1	OxenReg	HealthStat	Temperature	HeartRate	LastChecked	NextChecked
2	OX-SX4CK	NORMAL	-21.65	54	2025-06-25 07:34:38.687501+00:00	2025-06-26 10:34:35.825294+00:00
3	OX-SX4CK	NORMAL	-23.61	54	2025-06-25 08:10:43.941117+00:00	2025-06-26 11:10:41.208916+00:00
4	OX-SX4CK	NORMAL	-18.23	54	2025-06-25 08:10:54.142978+00:00	2025-06-26 11:10:51.450635+00:00
5	OX-SX4CK	NORMAL	-17.74	54	2025-06-25 08:11:04.415127+00:00	2025-06-26 11:11:01.723108+00:00
6	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:11:14.860594+00:00	2025-06-26 11:11:12.213501+00:00
7	OX-SX4CK	NORMAL	-16.76	54	2025-06-25 08:11:24.765050+00:00	2025-06-26 11:11:22.153463+00:00
8	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:11:35.034297+00:00	2025-06-26 11:11:32.390509+00:00
9	OX-SX4CK	NORMAL	-17.74	54	2025-06-25 08:11:46.338882+00:00	2025-06-26 11:11:43.700696+00:00
10	OX-SX4CK	NORMAL	-17.74	54	2025-06-25 08:11:56.742957+00:00	2025-06-26 11:11:53.955945+00:00
11	OX-SX4CK	NORMAL	-23.61	54	2025-06-25 08:12:29.583050+00:00	2025-06-26 11:12:26.830623+00:00
12	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:12:39.953361+00:00	2025-06-26 11:12:37.225262+00:00
13	OX-SX4CK	NORMAL	-19.7	54	2025-06-25 08:12:50.109255+00:00	2025-06-26 11:12:47.355060+00:00
14	OX-SX4CK	NORMAL	-19.21	54	2025-06-25 08:13:00.194009+00:00	2025-06-26 11:12:57.433054+00:00
15	OX-SX4CK	NORMAL	-17.74	54	2025-06-25 08:13:10.474867+00:00	2025-06-26 11:13:07.784734+00:00
16	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:13:22.091928+00:00	2025-06-26 11:13:19.250649+00:00
17	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:13:32.403711+00:00	2025-06-26 11:13:29.588844+00:00
18	OX-SX4CK	NORMAL	-18.72	54	2025-06-25 08:13:42.492867+00:00	2025-06-26 11:13:39.839698+00:00

Figure 13: Report of oxen data

5.3 Backend and Database Implementation

In the Oxen Health Monitoring and Workload Estimation System (OHMWES), the backend was implemented using the Django (Python) framework, and the database layer is powered by PostgreSQL for production deployment. During the initial development phase, MySQL was used for prototyping and schema testing, but PostgreSQL was later adopted for its reliability, scalability, and better support for advanced queries and GIS features.

The database configuration is defined in the DATABASES setting in Django's settings.py file:

ENGINE: Specifies the backend database engine used by Django. In our case, it is set to 'django.db. backends.postgresql' indicating PostgreSQL as the database engine.

NAME: This defines the name of the production database. For this project, it is set to 'smart_oxen'.

USER and PASSWORD: These specify the login credentials for connecting to the PostgreSQL server. For example, USER='postgres' and PASSWORD='jumanne1234.

HOST and PORT: Define where the PostgreSQL server is running. Commonly, HOST='localhost' and PORT='5432', which is the default port for PostgreSQL.

OPTIONS: PostgreSQL-specific connection options can be defined here if needed, such as SSL mode or time zone settings.

The backend is responsible for processing sensor data received through either serial connections (USB during prototyping) or GSM modules. Data from sensors—such as temperature, heart rate, and rotation is posted to Django endpoints. The logic compares the received values against preset thresholds. If abnormal values are detected (e.g., high heart rate), SMS alerts are triggered using the Africa's Talking SMS API.

```
smart_oxen > settings.py > ...
# Database configuration
DATABASES = {
    'default': {
        'ENGINE': 'django.db.backends.postgresql',
        'NAME': 'smart_oxen',
        'USER': 'postgres',
        'PASSWORD': 'jumanne1234',
        'HOST': 'localhost',
        'PORT': '8080',
    }
}
```

Figure 14: OHMWES Backend and PostgreSQL Database Configuration Diagram

5.4 Frontend and User Interface Implementation

The frontend was developed using HTML, CSS (Bootstrap), and integrated with Django templates for dynamic rendering. The admin interface provides functionalities like farmer registration, real-time oxen health monitoring, report downloads, and alert management. Farmers use a USSD menu to access oxen health data, and receive SMS summaries, ensuring accessibility for users without internet-enabled devices.

Admin Login and Dashboard Access:

The admin interface features a secure login system built with Django's authentication module. Admins authenticate using their username and password to gain access to the dashboard. Once logged in, administrators can manage farmers, register oxen, view real-time health readings, and export performance reports. The interface leverages the **Jazzmin theme** for a clean, modern appearance and improved user experience.

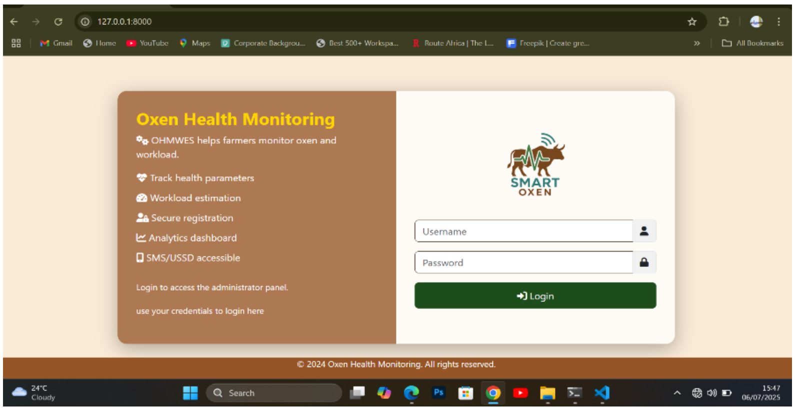


Figure 15: Admin login page

Admin Dashboard Overview:

Upon successful login, the administrator is redirected to the dashboard, which provides a comprehensive overview of system operations. This includes visual summaries of active oxen, their health metrics (temperature, heartbeat), workload history, and alert status. Admins can also download PDF/CSV reports, edit profiles, and register new oxen.

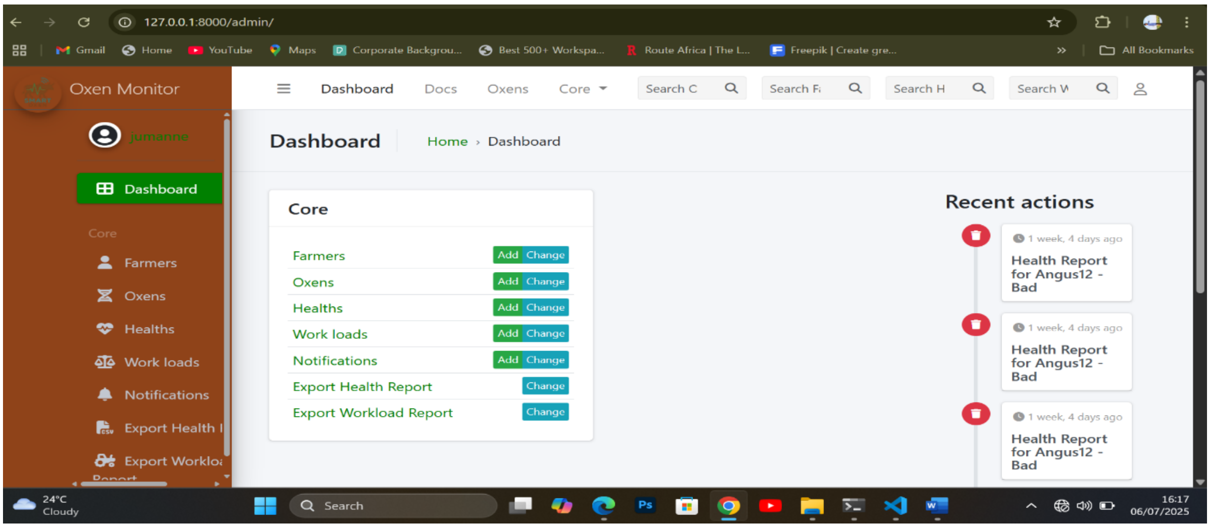


Figure 16: Admin dashboard

Farmer USSD Menu Interaction:

The system is designed to ensure inclusivity by supporting feature phones through USSD interaction. Farmers interact with the system via short codes like *384# using Africa's Talking sandbox integration. They receive SMS summaries containing oxen health updates and workload recommendations, all without needing internet connectivity.

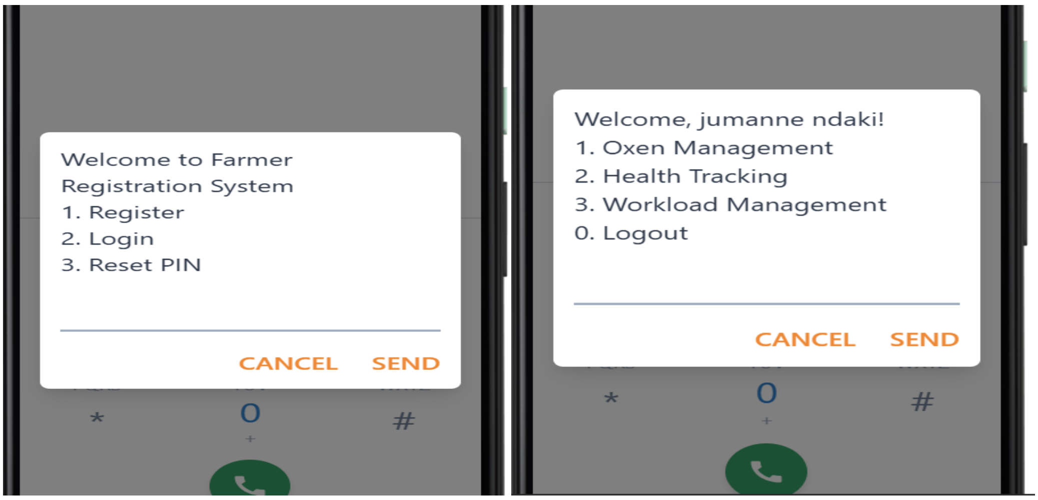


Figure 17: USSD Menu Flow

5.5 System Testing and Evaluation

Thorough testing was conducted to ensure the reliability, accuracy, and performance of the Oxen Health Monitoring and Workload Estimation System (OHMWES). The testing phase focused on both software and hardware components to verify that data transmission, sensor readings, alerts, and user interactions functioned as expected under various conditions.

Software Testing:

The Django backend was unit-tested using Django's built-in testing framework. This involved:

- ✓ Validating API endpoints for processing sensor inputs and sending SMS alerts.
- ✓ Testing the authentication system for admin login and user session handling.
- ✓ Form validation for farmer registration, oxen assignment, and report generation.

Additionally, manual functional testing was conducted on:

- Serial data input from the Arduino board.
- SMS delivery success via Africa's Talking API.
- USSD session timeout handling and user navigation.
- Web interface responsiveness across devices and screen sizes.

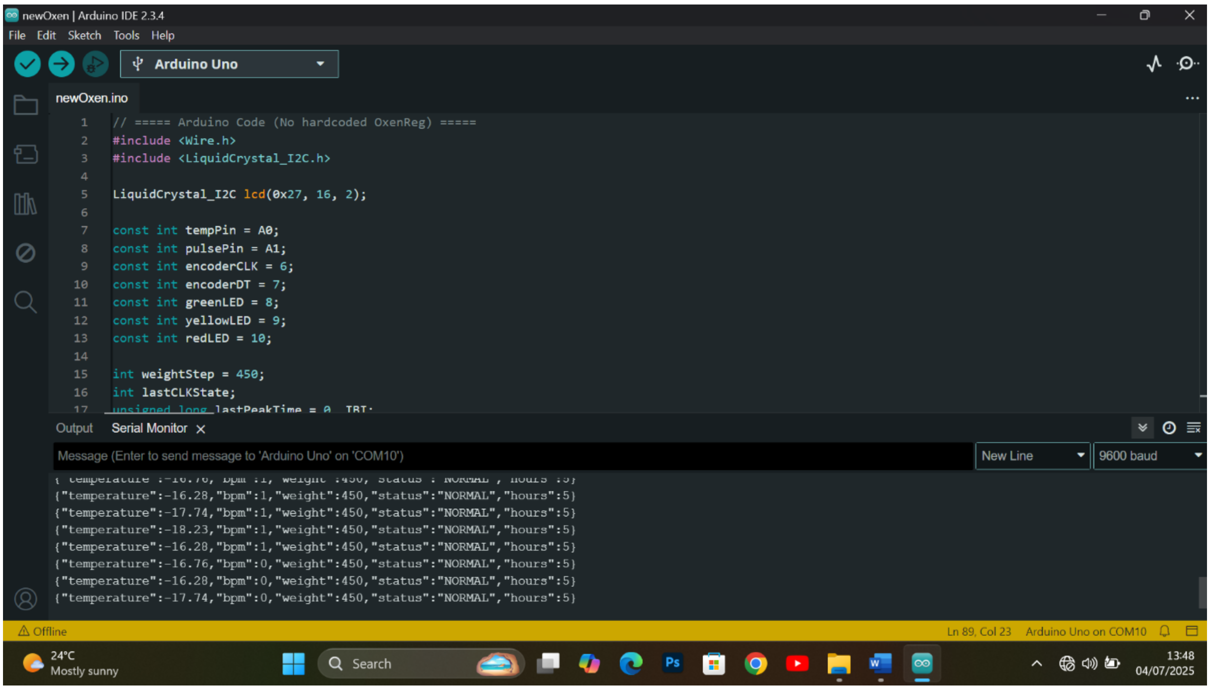


Figure 18: Software Flow of data

Hardware Testing:

Hardware testing ensured that the IoT devices were functioning correctly and consistently. The following were performed:

- ✓ Simulation on Tinkercad: Arduino Uno, sensors (pulse, DHT11), GSM module, and LEDs were virtually tested for logic and flow verification.
- ✓ Physical Testing using Arduino Kit: Real sensors (e.g., pulse and temperature) were connected to Arduino and tested for accuracy and consistent data logging.
- ✓ Live Deployment Testing: The setup was tested in rural environments using GSM-enabled SIM cards and feature phones to validate USSD and SMS delivery.

Test conditions included:

- Intermittent network scenarios.
- Power fluctuations.
- Varying environmental temperatures to simulate realistic oxen working conditions.

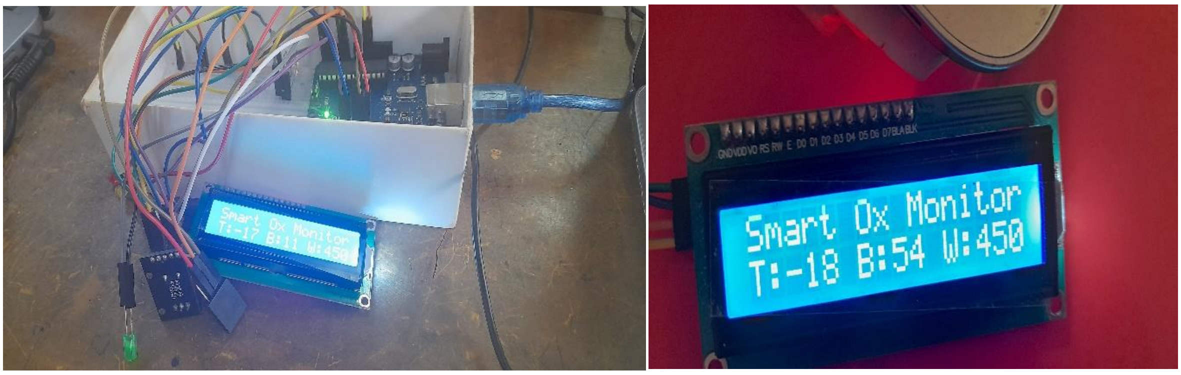


Figure 19: Hardware Testing

Devices Used for Testing:

To ensure device compatibility and reliability, multiple testing environments were used:

- Laptops (2.4 GHz CPU, 8GB RAM) for backend and web dashboard validation.
- Arduino Uno + Breadboard with actual sensors for physical tests.
- Android phones and Feature Phones for USSD and SMS feedback.

Outcome of Testing:

The testing process confirmed:

- High data accuracy from sensors when calibrated.
- Reliable SMS alerts under stable GSM conditions.
- Fast USSD response in low-bandwidth environments.
- Responsive admin interface across laptop and mobile screens.
- System stability in both prototyped and live test scenarios.

Minor issues such as GSM signal loss and inconsistent sensor calibration were documented and solutions proposed in the conclusion and future work section.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Summary of achieved objectives

The Oxen Health Monitoring and Workload Estimation System (OHMWES) was developed using Python (Django), C++ for Arduino microcontroller logic, and PostgreSQL for data management. The integration of USSD, SMS, and IoT sensors ensures farmers especially those in rural areas can receive vital oxen health information even without internet access.

The system meets its core objectives: continuous health monitoring, workload estimation using a rotary encoder, real-time alerts via SMS, and remote farmer access through feature phones. The design ensures simplicity, scalability, and user-friendly interaction through both the web-based admin interface and mobile communication channels.

The project introduces an innovative way to bridge digital farming and traditional livestock practices. The architecture and components of the system were well-documented and effectively integrated, enabling future extension for more complex features.

6.1.1 Achievement of Research Objectives

The main objectives of this research and system development were:

- ✓ To monitor oxen vital signs (temperature, heart rate) and detect abnormal health conditions.
- ✓ To estimate workload using rotary encoders to simulate movement/load during oxen work.
- ✓ To deliver health alerts and summaries to farmers via SMS.
- ✓ To provide an admin dashboard for monitoring all oxen, their health records, and workload data.
- ✓ To implement a USSD-based interface allowing farmers to query oxen health without internet.
- ✓ To design and simulate a working prototype of sensor and GSM module integration.

All the objectives were fully achieved through the prototype simulation, real hardware integration via Arduino, and backend implementation using Django. The results are presented through the dashboard, SMS alerts, and stored securely in the database.

6.1.2 Future Work

This project lays the foundation for future innovations in digital livestock management. Based on our results and farmer interactions, the following future improvements are proposed:

- ✓ Integrating a weight sensor to calculate exact body mass and detect health loss patterns.
- ✓ Adding a GPS module for oxen movement and location tracking in large farms.
- ✓ Creating mobile applications (Android/iOS) for semi-literate users or caregivers.
- ✓ Building solar-powered IoT versions for use in off-grid locations.
- ✓ Extending monitoring to cows and bulls, including pregnancy detection modules.
- ✓ Using machine learning models to predict disease trends or detect stress based on collected sensor data.

These advancements will enhance animal welfare, increase agricultural productivity, and empower rural farmers with real-time, accessible tools.

6.1.3 Shortcomings with the System

Although the system works reliably, there are a few limitations encountered during implementation:

Connectivity issues: GSM network fluctuations affected SMS delivery.

Sensor accuracy: Rotary encoder and pulse sensors need calibration based on oxen species and motion dynamics.

Limited Funding: Prevented large-scale deployment or cloud hosting.

Security: If a farmer’s phone is stolen, there's no biometric or second factor to verify USSD access.

Future upgrades may address these issues using GPS modules, encrypted USSD tokens, and solar-powered devices for rural usage.

6.2 Conclusion and Recommendations

The OHMWES project successfully integrates IoT technology with mobile communication to support rural livestock management. The system enables farmers to monitor oxen health and workload in real time using USSD/SMS and a web dashboard. It is recommended that local language support, secure data handling, farmer training, and partnerships with agricultural stakeholders be adopted to ensure successful system deployment and scaling.

6.2.1 Conclusion

People are constantly seeking innovative ways to improve traditional practices through technology. Just like how online banking revolutionized financial services, OHMWES offers an innovative transformation in livestock management by combining hardware sensing with mobile accessibility.

Through simple interfaces and real-time feedback, farmers can now monitor their oxen's health, reduce mortality, and increase farming efficiency—regardless of internet access. This system serves as a model that technology can be inclusive, practical, and rooted in solving real-world problems in African agriculture.

6.2.2 Recommendations

The adoption of OHMWES at a larger scale can benefit agricultural extension officers, NGOs, and farmers alike. The project proves that IoT technology combined with SMS/USSD services can bridge the digital divide in livestock health monitoring.

We recommend the following actions for effective implementation and scaling:

Accessibility: Ensure the USSD codes and SMS messages are provided in local languages.

Participation: Train farmers and caregivers on interpreting sensor data and responding to alerts.

Security: Secure the backend with strong authentication and encrypted communication for data privacy.

Integration: Partner with government or veterinary NGOs to supply affordable sensor kits to farmers.

Evaluation and Testing: Conduct pilot programs in at least two rural wards before large-scale deployment.

Dashboard Training: Admins and livestock officers should be trained on how to monitor health metrics and intervene when alerts are triggered.

By adopting these principles, OHMWES can be scaled into a national ox monitoring network that supports food security and sustainable agriculture.

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