Malnutrition management mobile application

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Declaration

I declare that this work has not been previously submitted and approved for the award of a Bachelor’s degree by this or any other University. To the best of my knowledge and belief, the documentation contains no material previously published or written by another person except where due reference is made in the documentation itself.

Abstract

It has been observed that most people living within urban areas have unhealthy diets and are at higher risk of developing health complications related to malnutrition as a result; particularly amongst children in low income earning families who have limited access to health services that help identify and manage said complications. Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and nutrients resulting from eating a diet in which one or more nutrients are either in excess or minimal amounts thus affecting the overall health of an individual. It is a universal issue holding back human development with millions of children worldwide being affected by stunting, wasting and even obesity. The aim is to develop a mobile application that enables health workers to manage malnutrition within low-income urban communities by providing a simple, step-by-step guidance to help them assess, treat or refer individuals suffering from malnutrition as well as to aid in educating the public on malnutrition and nutrition practices. The system was developed using an object-oriented approach through the dynamic system development methodology. It was developed using the android studio development environment and firebase technology for the database. Java will be the main programming language with HTML 5 and CSS for the mark-up and styling respectively.

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List of Abbreviations

1. **CMAM –** Community based management of acute malnutrition.
2. **CHMT –** County health management team.
3. **GODAN –** Global Open Data for Agriculture and Nutrition.
4. **GAM –** Global Acute malnutrition.
5. **HCI –** Human Computer interaction.
6. **MAM –** Moderate Acute Malnutrition.
7. **MOH –** Ministry of Health.
8. **MoSCoW –** Must have, should have, could have and want to have.
9. **OTP -** Outpatient Therapeutic Program.
10. **RUTF –** Ready to use therapeutic foods.
11. **SAM –** Severe Acute malnutrition.
12. **SC –** Stabilization centre.
13. **SCHMT –** Sub-county health management team.
14. **TSFP –** Targeted Supplementary Feeding Program.
15. **UNICEF –** United Nations Children's Fund.
16. **WHO –** World Health Organisation.

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Chapter 1: Introduction

1.1 Background

According to WHO (2017), Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and nutrients. This results from eating a diet in which one or more nutrients are either in excess or minimal amounts thus affecting the overall health of an individual. It may involve calories, protein, carbohydrates, fat, vitamins or minerals. Malnutrition covers two broad groups of conditions. One is 'undernutrition', which includes stunting, wasting, acute malnutrition, underweight and micronutrient deficiencies. The other is 'overweight', which refers to obesity and diet-related non-communicable diseases such as heart disease, stroke, diabetes, and cancer.

Malnutrition is a universal issue holding back human development with unacceptable human consequence. WHO (2017) "In 2016, 155 million children were affected by stunting and 52 million children were wasted while 41 million children were overweight." This not only affects children but adults as well. A report conducted by Kimani – Murage et al. (2015) demonstrated a rise in adult obesity prevalence in Africa, particularly in Northern African countries, and especially among women. Further, in a study on the trends of overweight and obesity among urban women in seven African countries which include Burkina Faso, Ghana, Kenya, Malawi, Niger, Senegal and Tanzania, shows that the prevalence of overweight and obesity increased by approximately 35% between 1992 and 2006, with most of the increase being among the poorest women.

World Health Organisation (2009). "Despite the known benefits of maintaining healthy body weights and an active lifestyle, obesity is classified as the fifth leading cause of global mortality, and an important predictor of various non-communicable diseases." Obesity is also associated with impaired social and economic productivity in adulthood and results in psychological problems such as low self-esteem and depression. Consequently, the concern for a growing prevalence of non-communicable diseases in Sub Saharan Africa is concerning.

The persistence of undernutrition and rising prevalence of obesity in the slum areas in urban settings in Kenya may also reflect poor prioritisation and commitment to nutrition by the government, hence low budgetary allocation. According to UNICEF (2011) "the government allocated only 0.5% of its limited health budget to nutrition in the 2010/2011 financial year" showing that current practices are failing to accommodate the growing need for quality, nutritious food and increasing demand for food in the previous decade.

However, with reference to Vision 2030, achievement of national food security is to be a key objective of the Government of Kenya. According to Kenya Food Security Steering Group (2008) "Food security refers to the situation in which all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life". This aims at reducing malnutrition rates within the country and has led to the rise in use of technology to help curb the situation. Technological approaches to curb malnutrition include systems such as Community-based management of acute malnutrition (CMAM). It is a proven high-impact and cost-effective approach in the treatment of acute malnutrition and treatment at an early age also helps prevent complications experienced in adulthood. However, its success was limited by a number of factors, including lack of protocol adherence by health workers and inaccurate record keeping.

1.2 Problem Statement

It has been observed that most people living within urban areas have unhealthy diets and are at higher risk of developing health complications related to malnutrition as a result; particularly amongst children in low income earning families who have limited access to health services that help identify and manage said complications.

Currently, the majority of frontline health workers supporting CMAM programmes are trained in standardised protocols to manage and educating the public on malnutrition but do not have frequent onsite supportive supervision, or job aids, to support protocol adherence and accurate treatment. All tracking and site monitoring systems are paper-based and subject to error and misreporting. The system will aid health workers by guiding them through the necessary steps of the CMAM protocols; it will provide accurate and timely data for them to keep track and monitor the people in the community subscribed to the programme. It will also aid in managing inventory such as medication and RUTF packages administered to people suffering from malnutrition in the community.

1.3 Aim

The aim is developing a mobile application that enables health workers to manage malnutrition within low-income urban communities by providing a simple, step-by-step guidance to help them assess, treat or refer individuals visiting the CMAM programme. It solves the problem of tracking and monitoring individuals suffering from malnutrition with regards to dosage of medication, administering of RUTFs and various test results during the treatment process as well as managing inventory.

1.4 Specific Objectives

i. To identify and review existing malnutrition management systems.
ii. To identify needs and challenges experienced by health workers in identifying and managing malnutrition within the community.
iii. To develop an application to manage malnutrition and curb poor nutrition practices.
iv. To test the developed system.

1.5 Justification

This project is important because it will create a platform that enables health workers to accurately assess, treat or refer children visiting the CMAM programme. It will take the health workers through the steps, remind them of the treatment protocol and calculate z-scores (standard deviation method used in classifying malnutrition based on weight, height and age), when to administer ready-to-use therapeutic foods (RUTF) sachets and routine medications.

It also aids in record keeping, making follow up easier and providing live, accurate and comparable data for higher level decision making and management to stakeholders such as open data forums and organisations that run programmes aimed at curbing malnutrition through a data driven decision-making process that informs their approach to implementing solutions. According to GODAN, lack of comparable data on malnutrition rates has slowed down the decision process of organisations when it comes to implementing solutions.

1.6 Scope and Limitations

1.6.1 Scope

The project is set to cover all the bases of the specific objectives. Issues being addressed mainly being, to accurately assess, treat or refer children visiting the CMAM programme by taking the health workers through the CMAM steps.

It will have modules for recording data on tests such as the appetite test, rapid diagnosis tests (RDT) for complications related to malnutrition and respiratory rate information. RDTs are quick and simple to perform and are used in preliminary or emergency medical screening usually with access to minimal resources and helps in identifying underlying conditions before proceeding with treatment.

It will also be able to calculate the following z – scores: weight for age, weight for height, weight for length, MUAC score and height for age. These metrics will be specifically for children between the age of 0 months to 2 years and 4 months, as well as for pregnant and lactating considered high risk (below 21 years of age). They are used to determine whether a child is experiencing SAM (severe acute malnutrition) or MAM (moderate acute malnutrition).

The system will allow for managing inventory such as RUTF sachets, medication available and rapid test kits. The system will also analyse and visualize the data recorded to give insight on malnutrition rates and its distribution in the community based on age, gender and location.

The system will also have modules used to aid health workers to follow treatment guidelines, teach good nutrition and health practises while counselling and advising those affected by malnutrition while administering treatment.

1.6.2 Limitations

The project is set to cover all the bases of the specific objectives hence will be implemented within the boundaries of the scope. The system will not utilize advanced technology such as IOT devices within its implementations and will limit its application in terms of location to the Nairobi area.

Chapter 2: Literature Review

2.1 Introduction

This chapter focused on the work done in reference to managing malnutrition. The main rational of the study will be investigating how mobile device based apps can improve frontline health workers' ability to manage malnutrition more effectively. Later in this chapter, we shall discuss malnutrition management systems deployed in the community and challenges faced.

2.2 Existing malnutrition management systems

2.2.1 *Manual malnutrition management systems*

Many health workers and institutions use paper based methods for tracking and monitoring cases of malnutrition which is prone to error and misreporting. The health workers also have limited access to guidelines used in CMAM while on the field. Although they are trained in standardised protocols, they do not have frequent onsite supportive supervision, or job aids, to support protocol adherence and accurate treatment methods. As a result of this, the availability of these guidelines is important.

2.2.2 *Mobile malnutrition management systems*

2.2.2.1 Mhealth by Transform nutrition

The MHealth app provides health workers with guidance on treating children visiting the CMAM programme, similarly with what my project aims to achieve and improve. The app is built on the CommCare platform. Frank (2017). "It uses a touch swiping function to take health workers through the steps, remind them of the treatment protocol and counselling messages and calculate z-scores and numbers of ready-to-use therapeutic foods (RUTF) sachets and routine medications." More so, "It also records the child's information, making child follow up easier and uploads the data to the 'cloud' providing live and accurate data for district and national level decision making and management."

The app prompts the health worker to conduct the appetite test and provides a reminder for the criteria to 'pass or fail'. It has an integrated respiratory rate timer, which automatically calculates if the child has a high respiratory rate for their age, and prompts the health worker if they need referral for pneumonia. The app prompts the health worker to test the child for conditions such as malaria using a rapid diagnostic test before moving on to treatment. However, it doesn't allow the health worker to proceed to the next stage of treatment without providing a response.

According to Frank (2017), The overall objective of the project was to improve CMAM treatment, reporting, monitoring, and supply management for improved quality of care for children suffering from acute malnutrition, ensuring more prompt treatment; adherence to recommended treatment protocols; and improved healthcare behaviours to prevent malnutrition.

2.2.2.2 Malnutrition checker by Deshpande foundation

This app helps checking if a child is undernourished, based on the input parameters. All parameters are WHO standards based on calculating the following z – scores: SAM, MAM and MUAC levels. The application helps check if a child is undernourished based on the input parameters. The application was launched in North Karnataka, India.

Field facilitators of Magu Nee Nagu, a malnutrition eradication programme, conducted a door-to-door survey in the slum. They took a boy by the name of Anandappa under their care and started providing him nutritional supplements and food and hygiene advice to his parents, all through an app. Today, Anandappa is on his way to recovery. The programme is run by the Hubbali-based Deshpande Foundation, which promotes social entrepreneurship.

The app, SAM Check, enables doctors and healthcare workers to keep track of children's health and nutritional status on a regular basis. It provides expert medical and dietary advice, and if required, prescribes medication and nutritional supplements. It recommends daily nutritional values for the children, based on which the field facilitators provide them with ready-to-use therapeutic food (RUTF) such as spirulina, and eeZeepaste, dry banana, ragi and peanut paste to supplement regular home-cooked food. It also suggests follow-up nutritional measures. The app, SAM Check, enables doctors and healthcare workers to keep track of children's health and nutritional status on a regular basis.

2.3 Needs and challenges faced in identifying and managing malnutrition

The needs and challenges faced by health workers are largely determined by whether the approach used to treat and manage malnutrition utilizes a manual paper based system or an automated system such a mobile application or web application.

2.3.1 *Manual malnutrition management systems*

There was poor management and comparability of data since it was recorded on paper based systems leading to inaccuracies and compilation errors. It was also expensive to send data from remote locations to data centres due to the cost of paying couriers to deliver records.

Data was not delivered in a timely manner; for example, request for new supplies from the head office took a long time to be processed hence patients and health workers had to wait for a long time before the request could be satisfied in which case some people suffering from malnutrition may succumb.

2.3.2 *Mobile malnutrition management systems*

The decentralised health system in Kenya requires strong local engagement in order to implement a project and to scale its operational use. This proved to be a challenge in the pilot phase of the Mhealth application. It took a period of 5 months before the Kenya MOH (Ministry of Health) bought into the project. The project eventually succeeded in securing their full support, and the MOH has been a particularly strong partner in the project.

With reference to the Mhealth application, Frank (2017) “it was assumed that tablets would be more user friendly, with the bigger screens making navigating and data entry easier. This proved to be correct. However, when considering using tablets or cell phones, factors such as shelf life, battery life and cost should also be considered.” This showed that the cost effectiveness of implementing such an application needs to be considered in terms of the devices to be used.

Frank (2017) “Many health workers were initially resistant to using the apps because of bug, connectivity issues or because it meant changing habitual treatment practice” e.g. they were no longer able to take short cuts when assessing and treating a child, or because they did not trust data being uploaded to the ‘cloud’. It is recommended that significant time and resources are allocated to thoroughly explain the potential benefits and the concept of automated reporting, and to be upfront about the nature of technological programmes, where bugs and troubleshooting are inevitable.

With reference to the Mhealth application, Kenya having a very high rate of staff rotation, and experiencing difficulties in filling positions in remote locations proved to be a challenge for the project. This meant a constant wave of trainings on using the application needed to be organised however the resources were not available.

2.3.3 *Gaps in existing nutrition management systems*

The existing systems discussed above do not give health workers have some limitations. With reference to the Malnutrition checker, it has testing capabilities but does not have a data storage services to help store patient records and keep track of their progress. Although this has been provided in the Mhealth app, with reference to reporting, the data is not analysed to provide insight onto malnutrition and how it affects the community on a more strategic level.

2.4 Developing a malnutrition management application

As discussed in previous chapters, development of a malnutrition management application is essential in providing health workers with step-by-step guidance to help them assess, treat or refer children suffering from malnutrition. In order to develop an effective solution, it is important to offer a solution that helps cater for the challenges discussed.

The system aims to solve the following issues; data management challenges, monitoring and analysing health worker performance and applying data science techniques to extract meaningful information from the data collected. It will also have modules that can be used to provide health workers with on-site guidance on treatment protocols and teach good nutrition practises.

2.4.1 *Data management and data science techniques*

Improving and optimizing data management within the system is one of the key aspects that will help ensure success of the system. In order to ensure this, these are the key steps that will be followed in terms of implementing data management approach is efficient:

i. Simplify access to data via defining input types form users through use of dynamic forms as well as specified data types. This will enable the application to have access to data for recording and analysis.

ii. Scrub data to build quality into existing processes. This will aid in cleaning up the data and pre-processing it for more detailed analysis.

iii. Strengthen the analytic process by applying data science techniques such as linear regression to help identify causal relationships in cases of malnutrition and whether treatment is beneficial as well as use of cluster analysis in order to group observations together. Time series analysis may also be implemented as a technique to track the development of certain variables and trend over time.

iv. Shape data using flexible manipulation techniques in order to visualize results.

v. Share metadata across data management and analytics domains.

2.4.2 *Monitoring and analysis techniques*

Monitoring and analysis within the system will be approached from two distinct perspectives: treatment of the patient and performance of health workers.

Firstly, it would be in line with monitoring patients from initial testing to the end of treatment. This would include measuring key indicators such as body weight, temperature, respiratory rate and MUAC levels at specific intervals as well as medication administered, and supplements provided. This will aid in providing data for analysis as well as presenting key findings on how treatment is benefiting the patients. It also proposes to optimise the use of resources in each specific case and present data to support future allocation of resources.

Second, the focus would be on ensuring health workers are following treatment protocols appropriately and timely. This will be monitored through use of logs that record when health works have assessed patients, what stage of treatment is currently being conducted and what medication and supplements have been administered. It will also keep a record of how many patients a health worker has seen and attribute their progress to the specific health work in see how well the assigned patients are responding to treatment.

2.5 Testing

Functional testing is the testing approach that will be used in development. This is whereby the system is tested against its functional requirements. It is performed in the level of system and acceptance testing. It involves identifying functions the system is expected to perform, create input data and determine the output based on the function's specifications, execute test and compare the expectations against the results. Functional testing is more effective when the test conditions are defined from user requirements.

Chapter 3: System Development Methodology

3.1 Introduction

A methodology refers to a comprehensive guideline to follow to complete the development of a system. It encompasses the system development lifecycle including models, tools and techniques to be used. It will be OOAD based because the methodology selected follows an incremental and repetitive approach to developing the system. This allows the problem to be decomposed into separate parts and involves going through several iterations.

The project will apply Dynamic system development methodology. This is a methodology that was derived from rapid application development methodology and allows for easy access to end users by the developers for requirements gathering. It also enables quick delivery of functionalities during development of the system and allows user to be involved in the software development process.

3.2 Dynamic Systems Development Methodology

It is an agile project delivery framework, primarily used as a software development method. It focuses on the business needs, delivery time, quality, collaboration, incremental and iterative development, and continuous communication with clients. This methodology utilizes various practices which include time boxing, MoSCoW prioritization, modelling and iterative development as well as prototyping.

Time boxing is whereby specific tasks are given a duration of no more than two weeks to be completed and tasks to be completed are subject to change within the time box. MoSCoW4 prioritization is a technique used to weigh the importance of requirements within the system. It consists of the following statements: must have, should have, could have, and want to have.

Must have: these are functionalities and requirements the system that need to be implemented in order to function as expected and if they are not implemented, the system is considered a failure. Should have: refers to the features that are important to the system however they can be omitted if the time constraint is too great.

Can have: these are beneficial functionalities the system may implement however they can be pushed forward to later stages of development or simply omitted. Want to have: these are features of limited value to the system.

Prototyping, as mentioned previously, is a key element of this methodology and is used in this methodology to enable frequent delivery and incremental development.

According to Pledger (2010), "prototyping is building a small version of a system, usually limited with functionality that can be used to help users identify key requirements within the system and demonstrate the feasibility of a design or approach." There are throwaway and evolutionary prototypes. This methodology implements the Evolutionary prototypes which are developed not only to investigate problems and various solutions however it will be incorporated into the final product.

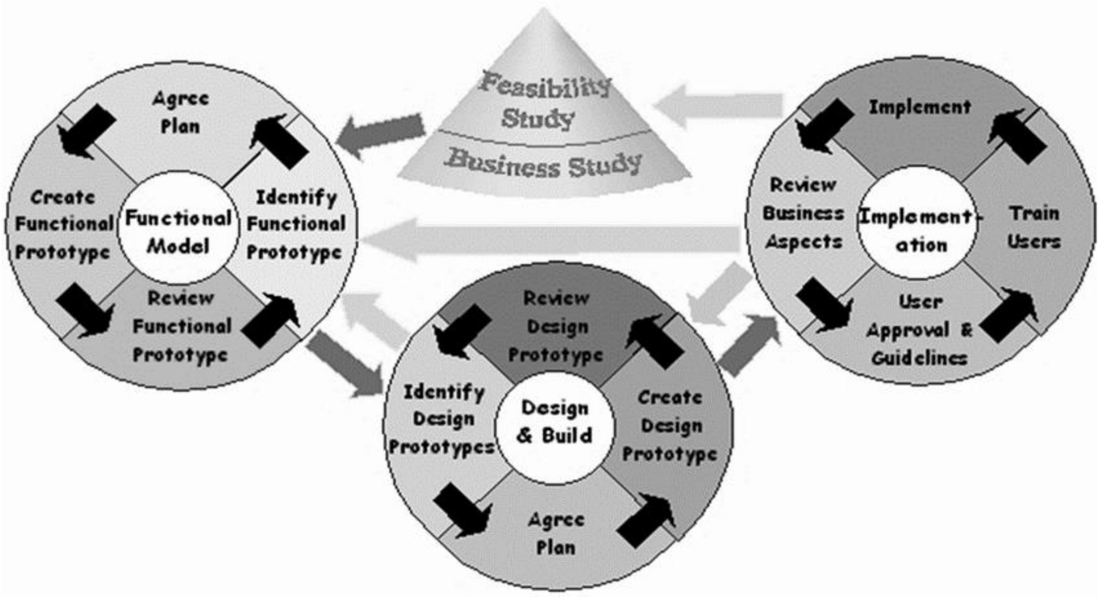


Figure 3.1 Dynamic systems development methodology

3.2.1 *Feasibility study*

This is the first step in development using this methodology. It involves examination of the intended requirements within the system, identifying problems, identifying new requirements, cost/benefit analysis, alternative solutions and recommended solutions. This includes economic, operational, scheduled, legal and political feasibility.

3.2.2 *Functional model/Prototyping iteration*

Evolutionary prototyping is used in iterative development in order to build on and improve the existing prototype during the development lifecycle. Pfleeger (2010) "The purpose of such a prototype is to test the design and is a partial solution that is built to help us understand the requirements or to evaluate design alternatives" (p. 219).

3.2.3 *Design and Build*

This phase applies practices such as Iterative Development, time boxing, and MoSCoW prioritisation, together with Modelling to converge over time on an accurate solution that meets the business need. The design stage is concerned with how the system works. The outputs include programs, inputs and outputs. It also includes file organization in terms of database design, procedures and hardware specifications.

3.2.4 *Implementation*

The final solution is implemented and presented as the final prototype or product. After the product is cleared and launched is when it can be reviewed, however this cannot be done before testing the product.

3.3 Requirements Analysis

Pfleeger (2010) “Requirements definition is a record of the requirements expressed in the customer’s terms” (p. 219). Software Requirements analysis involves those tasks and activities that go into determining the needs or the conditions to meet for the development of a system. (Kendall, 2006) “It outlines the general purpose and scope of the system including relevance, benefits, objectives and goals of the system. This requirements analysis takes into consideration the needs of the various stakeholders e.g. the users/ beneficiaries”.

3.3.1 *Functional requirements*

The functional requirements include:

i. **Authentication**. User roles define login capability (admin, healthcare provider, patient).

ii. **Administrative functions.** Only the administrator can CRUD the organisations and health workers while the health workers can create and update patient information.

iii. **Performing tests on patients and input results.** The system should have functions that calculate z-scores (SAM, MAM and MUAC levels) based on inputs from the health worker. It should also allow input of body measurements such as weight and height. It should also record results on oedema tests and appetite tests.

iv. **Monitoring and tracking patient malnutrition rate and treatment progress.** After initial testing, the system should store patient data and enable the health worker to monitor patient**’s** progress during each visit as well as track prescribed medication and nutrition supplements administered.

v. **Monitor health worker performance.** It will be done through use of logs and statistics related to the number of patients seen and the progress of their treatment in accordance with the CMAM protocols.

vi. **Managing patient records and data.** Managing patient, organisation, and health worker records. Managing inputs from health workers and resources used.

vii. **Analysing, visualizing and reporting based on data input into the system.** The system should be able to generate reports based on different criteria specified. Applying data science techniques such as supervised learning to train a model and input data from the system to provide insights on malnutrition rates, and map areas of occurrence.

viii. Modules used for giving step by step treatment guidelines for health workers to follow and displaying material necessary for educating the public on good nutritional practices.

3.3.2 *Non-Functional requirements*

i. **Data accuracy.** The data collected should be collected accurately to give correct results thus promoting efficiency.

ii. **Performance.** The system should be able to perform the tasks at a certain speed to ensure tasks are completed efficiently.

iii. **Usability.** The system should be user friendly and simple to navigate.

iv. **Security.** Ensuring that access to specific modules is user restricted and sessions within the application are managed.

3.4 List of Design Diagrams that will be drawn in Chapter 4

The design diagrams to be used are use case diagrams, data base schemas, GUI design mock-up and sequence diagrams.

Use case diagrams helps represent users' interaction with the system in order to perform specific tasks. Database schemas represents the organization of data to be stored within the database. There are logical and conceptual schemas which show structure and constraints of the database and the information needs of the system, respectively. Sequence diagrams will show the event scenarios and expected responses within the systems while mock-ups will help represent the systems graphical design. The mock-ups will be used to present the graphical design of the system.

3.5 Development Tools that will be used

The development environment that will be used to develop the system is Android studio. This because it supports debugging, task running, highlights syntax of the coding language and has a community of developers where I can get assistance from during the development process.

The programming languages to be used will be Java. It is free to use and has a fully supported development community.

Firebase is the tool that will be used to satisfy the database requirements. It provides the capability of running the database on a cloud server rather than locally.

3.6 Method to be used to test the developed system

As describe in chapter two, the method of testing that will be employed is functional testing in form of System testing the third level of testing after integration testing and before acceptance testing. System testing is used to determine whether the system has satisfied the given requirements.

The method used is black box testing. This is a method whereby the system is viewed as closed box, meaning that it is assumed that there is no knowledge of what processes occur within the system. Pfleeger (2014) “the test’s goal is to ensure that every kind of input is submitted and that the output observed matches the output expected” (p. 236). The advantage is that the test is not limited by the constraints of imposed by the internal structure of the system. Considering that it is an object-oriented system, it is important to check the objects and classes for problem areas and possible limitations that need to be addressed, such as missing objects and unnecessary classes.

3.7 Domain of Execution

The domain of execution is mobile based. This is because the system developed is a mobile application to increase portability. It is also because the Internet is flexible, and users can access the system from anywhere with access to the Internet. This also allows for support during the development life cycle considering there are communities of mobile application developers on the internet.

Chapter 4: System Analysis and Design Description

4.1 Introduction

In this chapter we are going to cover more on the system itself and what the system seeks to achieve with reference to the system's functional and non-functional requirements. This chapter will also highlight the approaches that were employed in the process of gathering the functional and non-functional requirements during the system analysis stage and how the system will operate and the arrangement of the different modules within the system. It also includes the design diagrams based on the object-oriented design. The design diagrams to be used are use case diagrams, database schemas, GUI design mock-up and sequence diagrams. In addition to that, the system architecture, that entails the: mobile-based application accessed by both the admins and health workers, has been illustrated.

4.2 Requirements Gathering

This refers to the collection and identification of the different requirements that the system was able to satisfy either functional or non-functional and involved analysing and interaction with the different users of the system. There are different methods used to gather and understand the given requirement and some of these methods include use of questionnaires, observation, documentation review, interviews, brainstorming, personal experience and among others.

The main method used to gather requirements were observation documents review and interviewing of users of the system to identify action necessary for actors to ensure successful implementation of the system. This made it possible to obtain detailed first-hand information and get an understanding of the policy structures that govern the medical extension services system in Kenya.

4.3 System Requirements

Pfleeger (2010) "A requirement is an expression of desired behaviour" (p. 169). It deals with objects within a system and their functions, state, and characteristics. The system analysis aids in the identification of these requirements.

4.3.1 *Functional requirements*

These are the requirements that specify the systems behaviour and required activities. The functional requirements for the web-based sales and marketing system includes.

Table 1 Functional Requirements

ID	Description
FRQ1	Authentication.
FRQ2	Administrative and CRUD functions.
FRQ3	Performing tests on patients and input results.
FRQ4	Monitoring and tracking patient malnutrition rate and treatment progress.
FRQ5	Monitor health worker performance.
FRQ6	Managing patient records and data.
FRQ7	Analysing, visualization and reporting based on data input into the system.
FRQ8	Modules used for giving step by step treatment guidelines for health workers to follow.
FRQ9	Displaying material necessary for educating the public on good nutritional practices.

4.3.2 *Non-functional requirements*

These are constraints that apply to the system as a whole and are not related to its execution. These requirements promote the system's operations and overall efficiency. These requirements include.

ID	Description
NFRQ1	**Data accuracy.** The data collected should be collected accurately to give correct results thus promoting efficiency.
NFRQ2	**Performance.** The system should be able to perform the tasks at a certain speed to ensure tasks are completed efficiently.

NFRQ3	**Usability.** The system should be user friendly and simple to navigate.
NFRQ4	**Security.** Ensuring that access to specific modules is user restricted and sessions within the application are managed.
NFRQ5	**The system should be reliable.** It should accurately perform tasks with limited risk of failure.

Table 2 Non-functional requirements

4.4 System Architecture

The system architecture illustrates the interaction between the system components is as shown in figure 3.1 below.

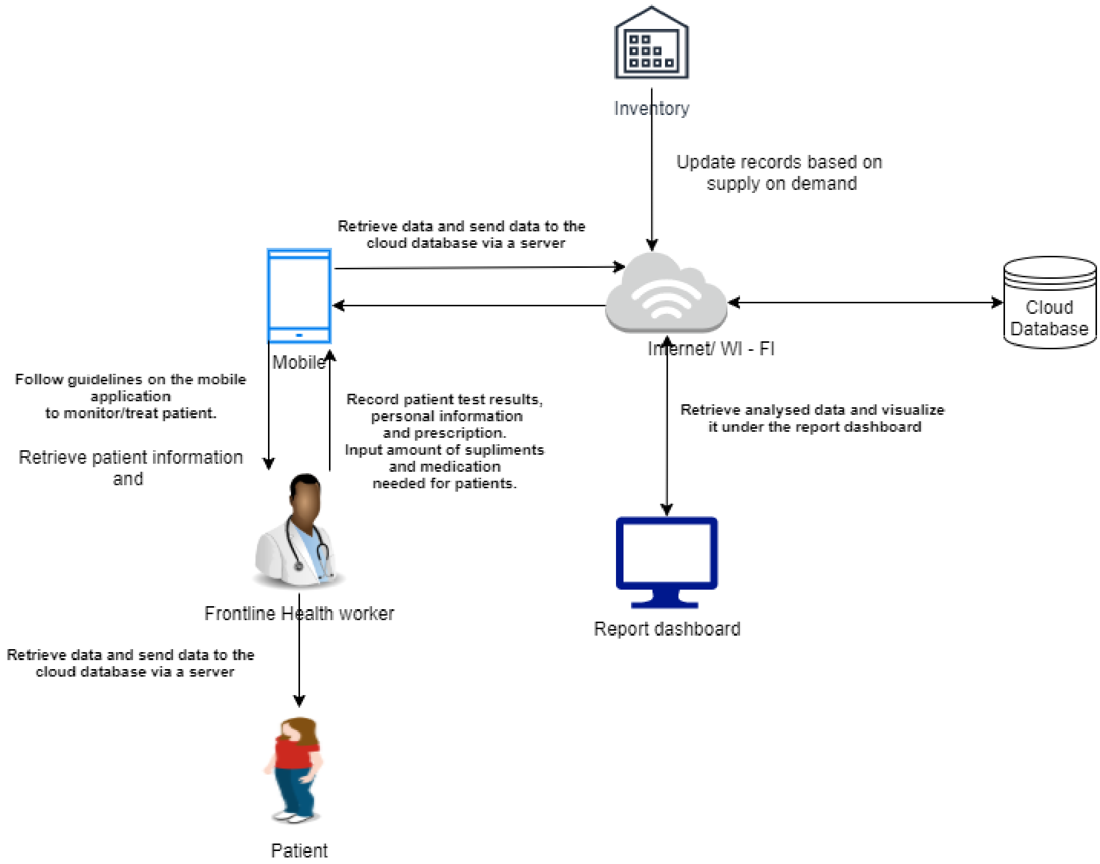


Figure 4.1 System architecture

The app will be run using an android device whilst in the field and utilize cloud services for data storage on firebase. The actors who define the modules in the system include the health workers, patients, organisation, and administrator of the system. A module is a specified component that contains a subset of routines and events within the system, while an architecture is the structure of the system.

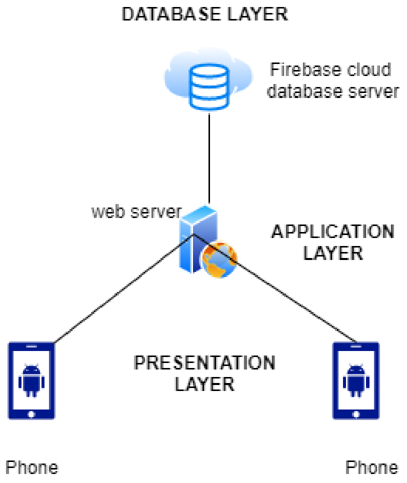


Figure 4.2 System architecture 2

The presentation layer contains the user interface and will be responsible for all the human – computer interactions (HCI). The cloud database and application servers comprise the server-side architecture and deals with the management of data and applications stored. They will be responsible for the business logic of the application and data utilities, access and storage components. They will also facilitate the security of the application though use of firewalls and securing HTTP requests.

4.5 Analysis

4.5.1 *Use case*

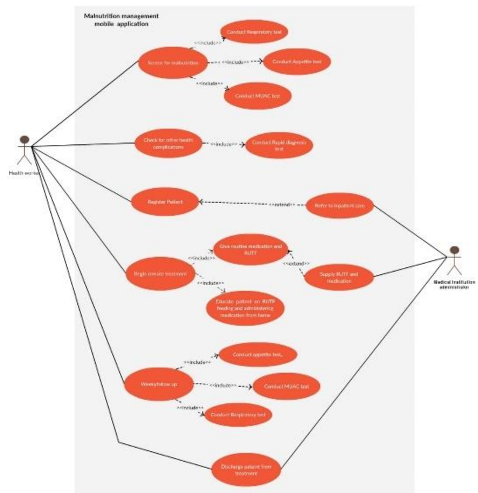


Figure 4.3 Malnutrition assessment and treatment use case

4.6 Design

System diagrams aid in illustrating the visual model of a system's components and their interactions (Salustri, 2018). Below are the system diagrams that are to illustrate the visual model of the mobile malnutrition management system's components and their interactions. They include a use-case diagram, a sequence diagram, a class diagram, an entity relationship diagram, and a database schema, as previously mentioned in chapter 3.

4.6.1 *Sequence diagram*

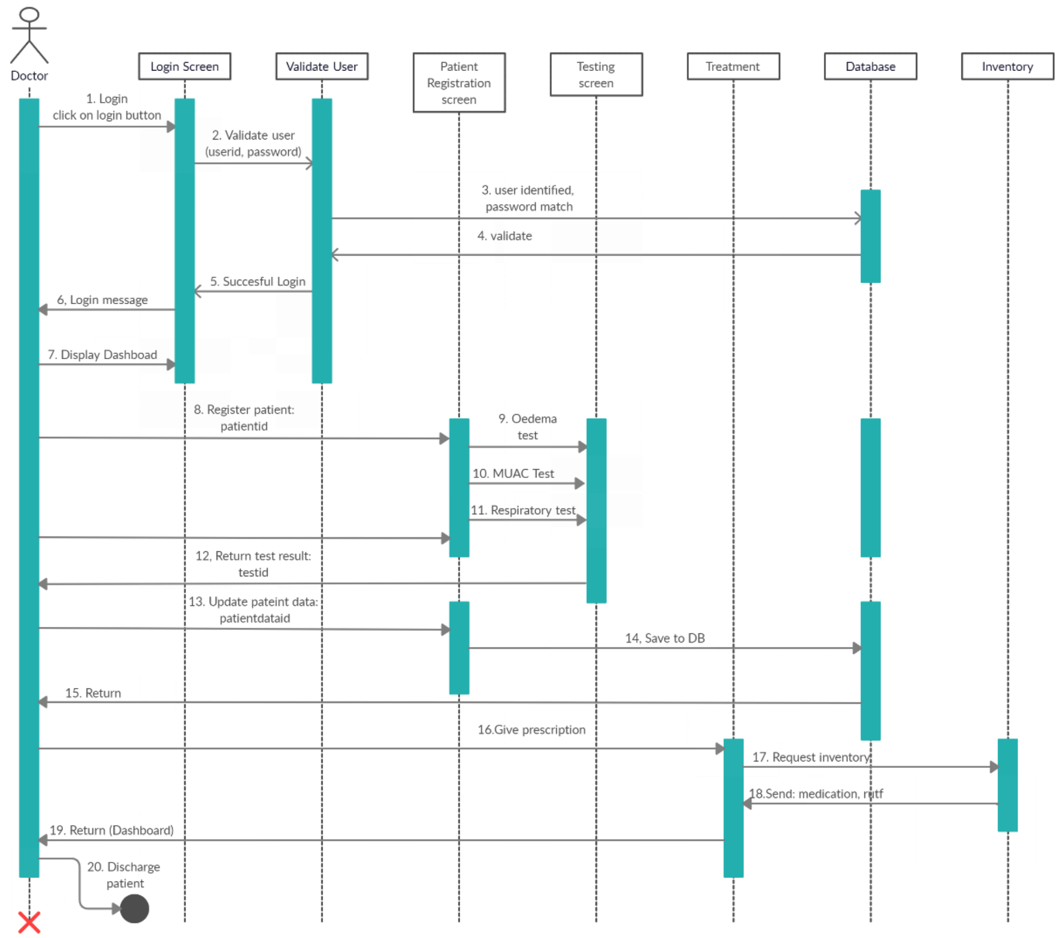


Figure 4.4 Sequence diagram

4.6.2 *Entity relationship diagram*

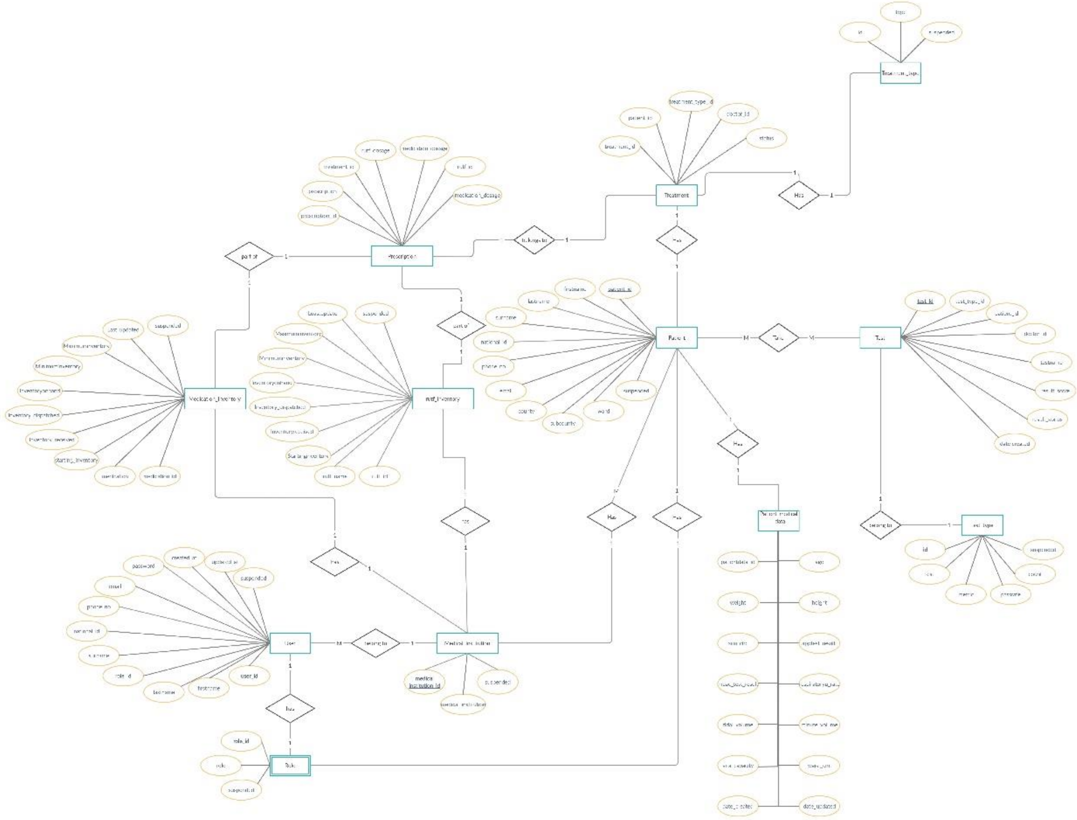


Figure 4.5 ERD

4.6.3 *Class Diagram*

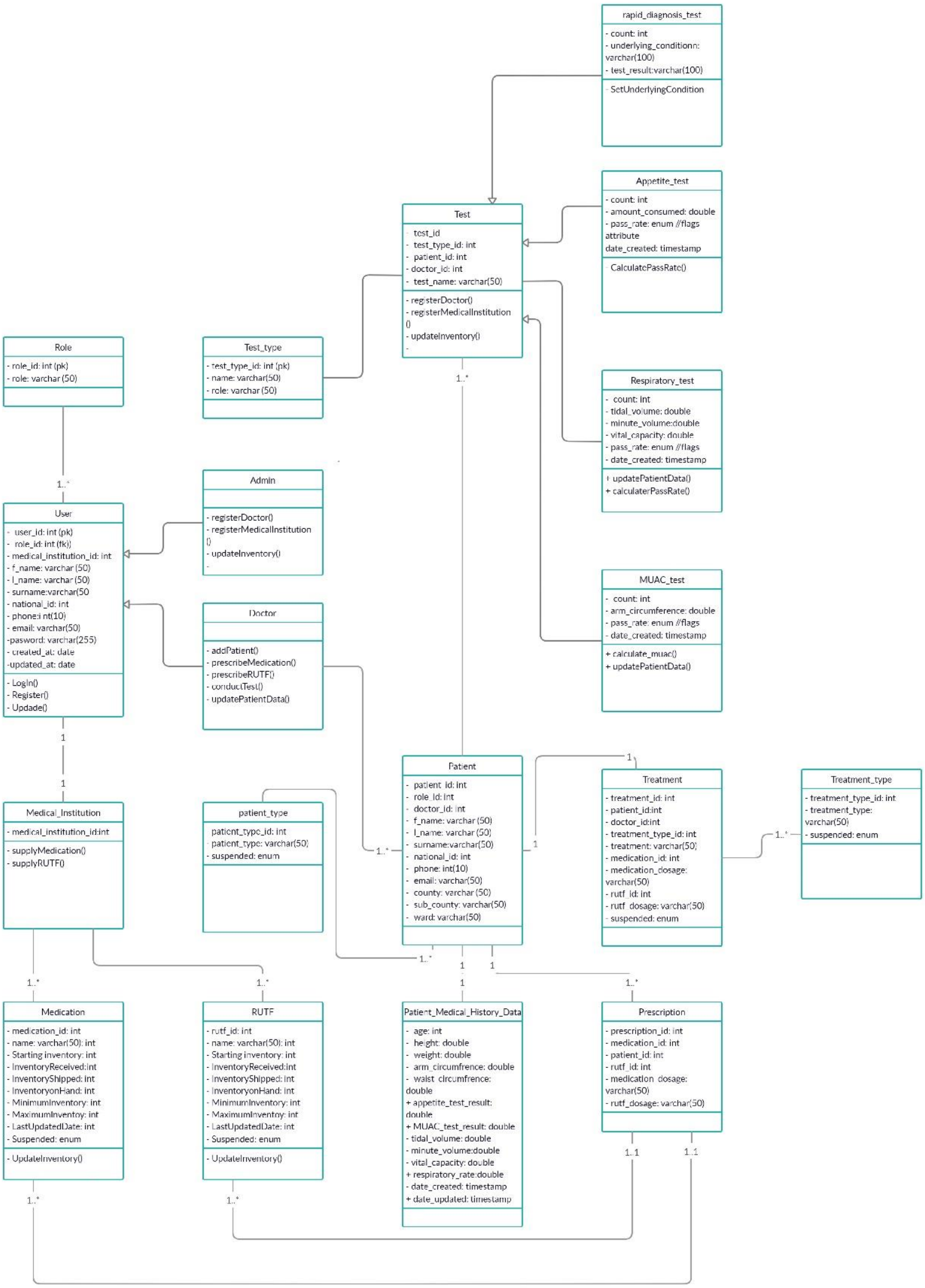


Figure 4.6 Class diagram

4.6.4 *Database Schema*

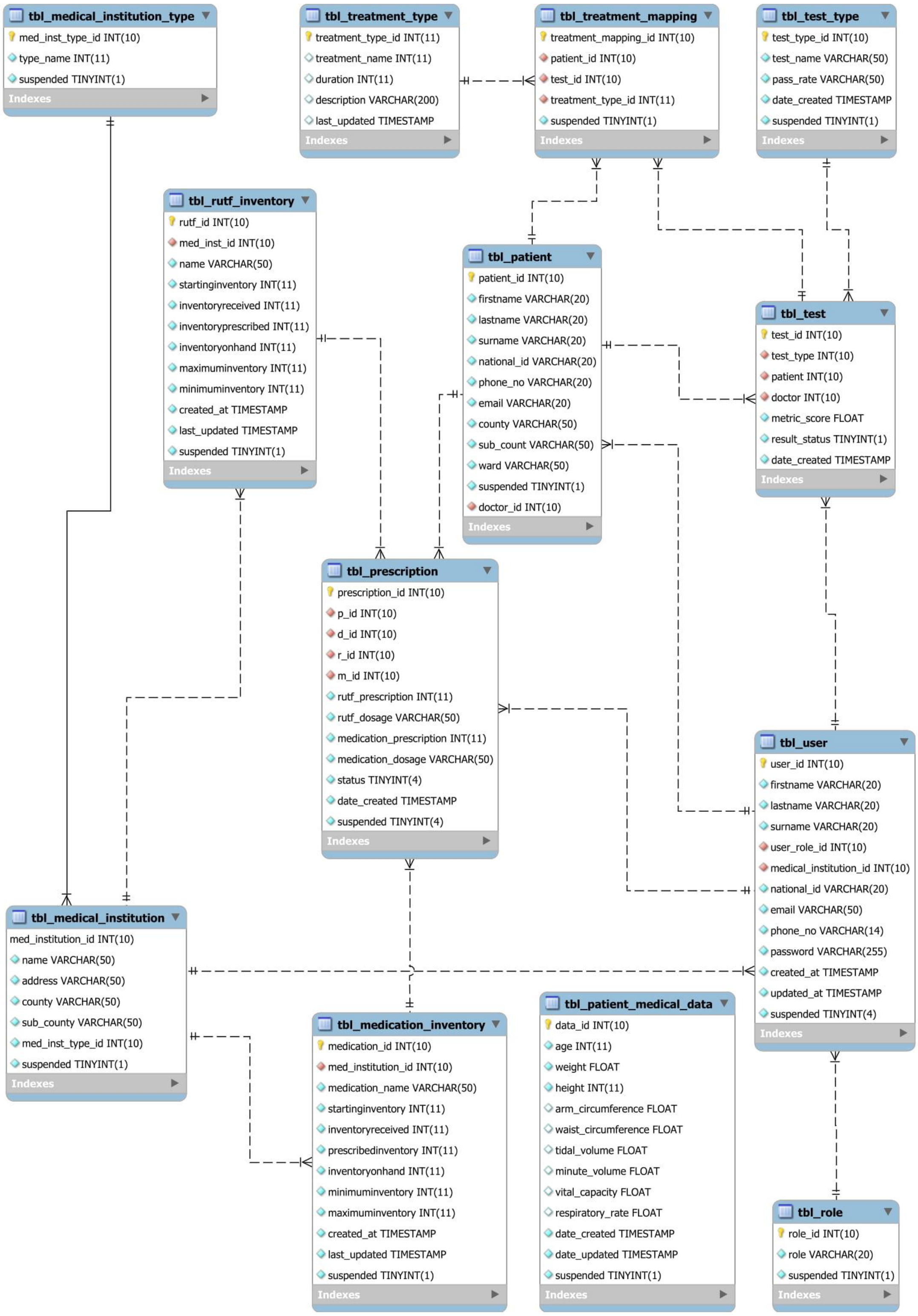


Figure 4.7Database schema

4.7 Graphical User Interface Mock-ups

4.7.1 *Login, password rest and User registration*

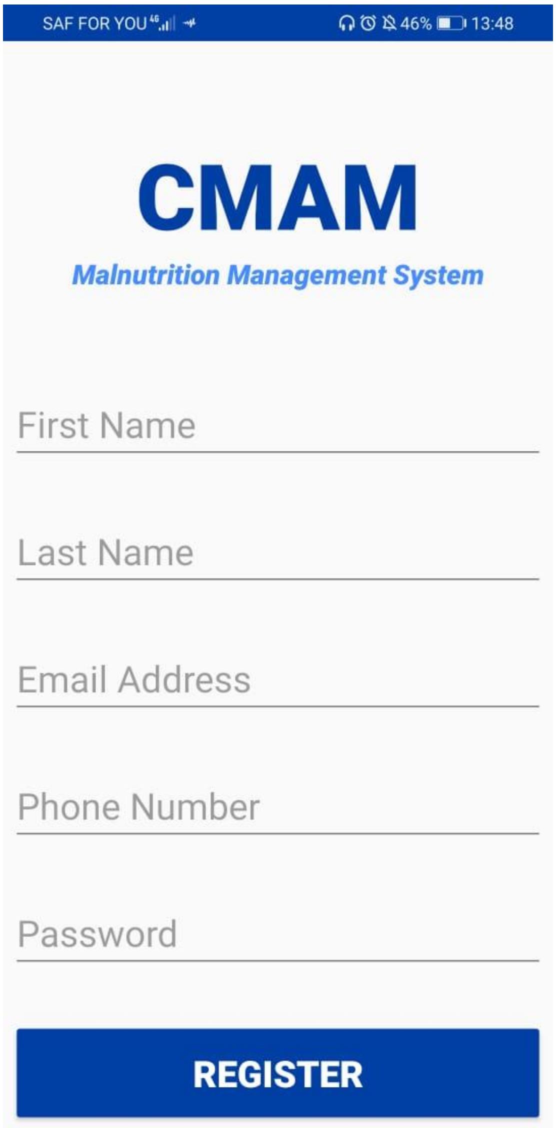


Figure 4.8 Registration

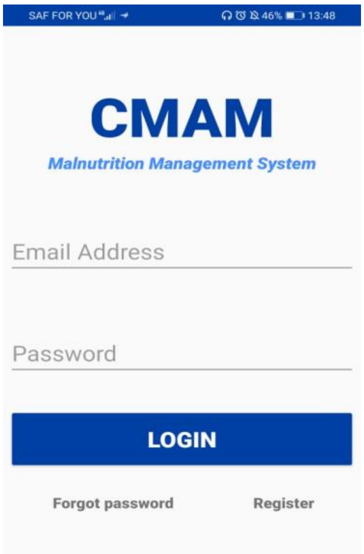
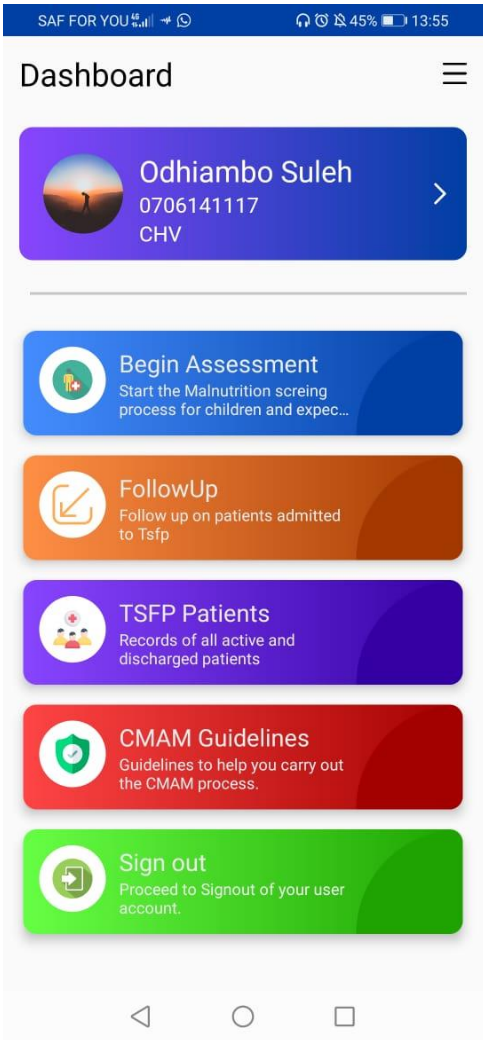


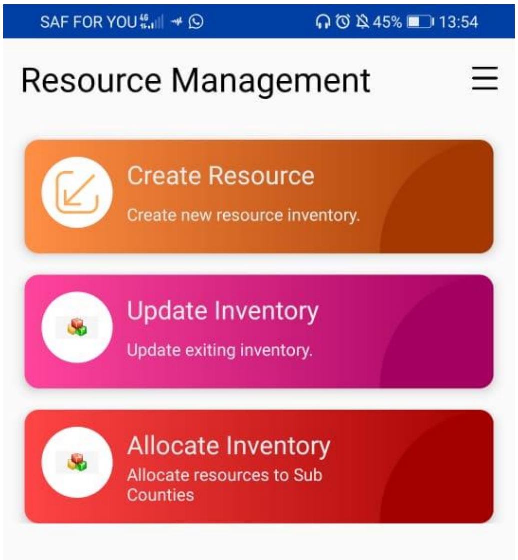
Figure 4.9 Login

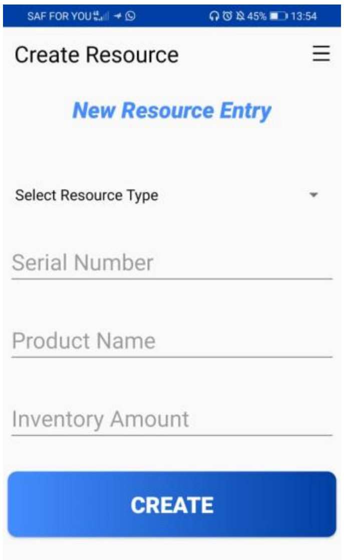
Figure 4.10 Password reset

4.7.2 *Admin and User Dashboards*

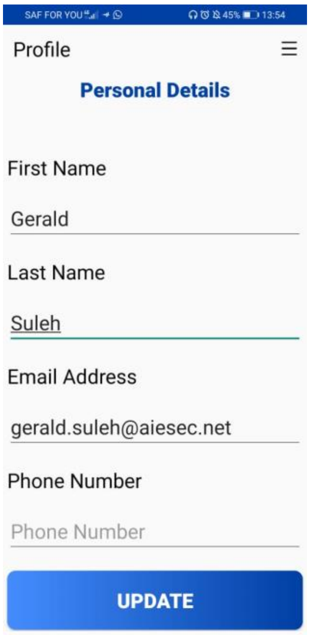


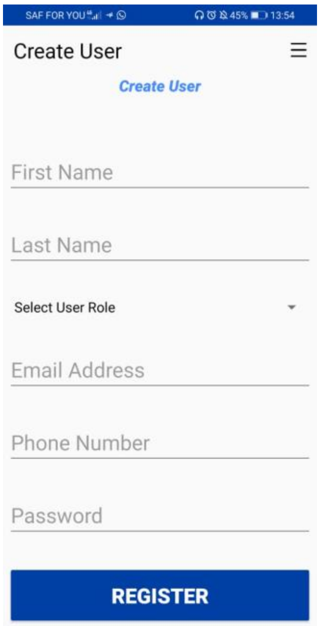
4.7.3 *Resource management*

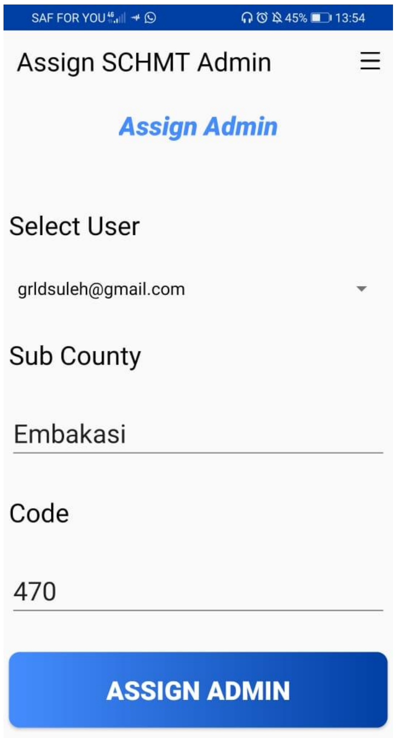


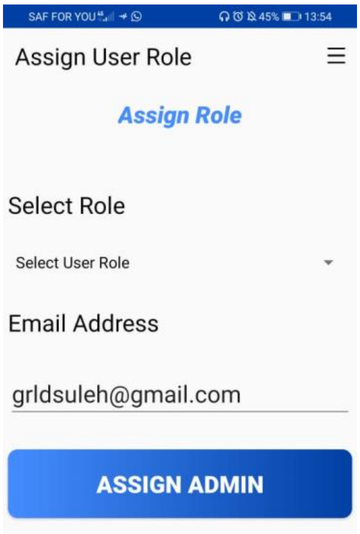


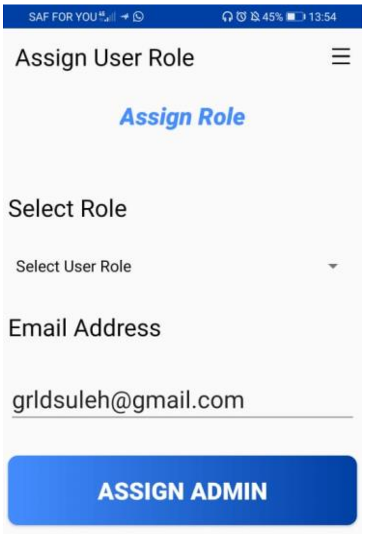
4.7.4 *User Management*





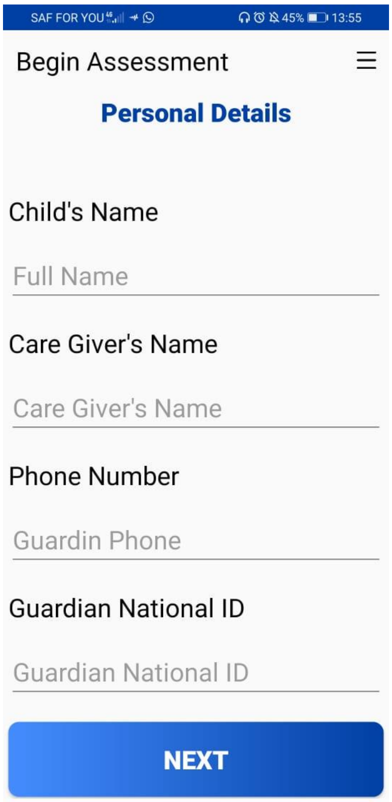


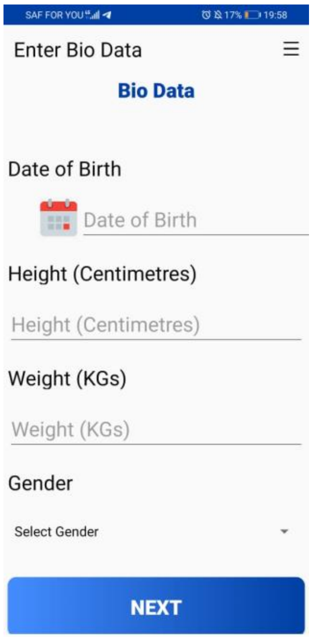


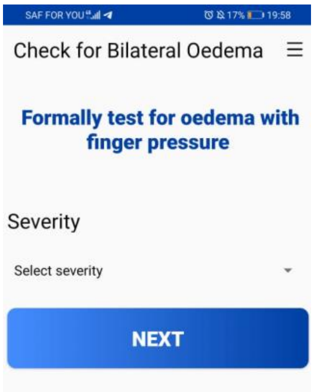


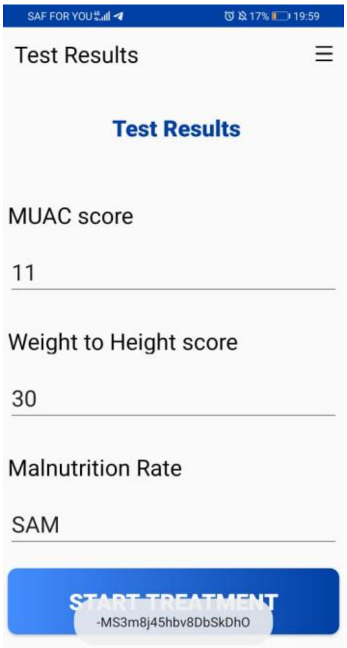
4.7.5 *Malnutrition assessment*

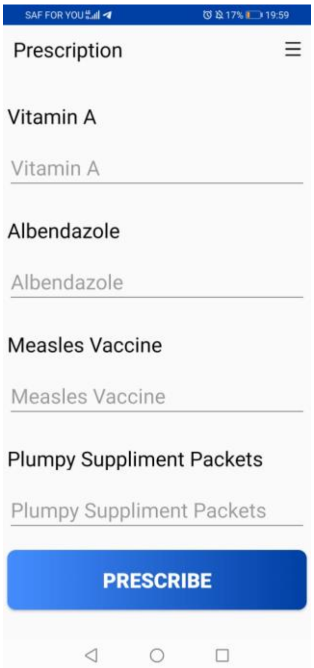

Assessment Group
Children 0-59 months
Begin assessment for children between the ages of 0 - 59 mo...
Pregnant and
Begin assessment for pregnant and lactating women (PLWs).

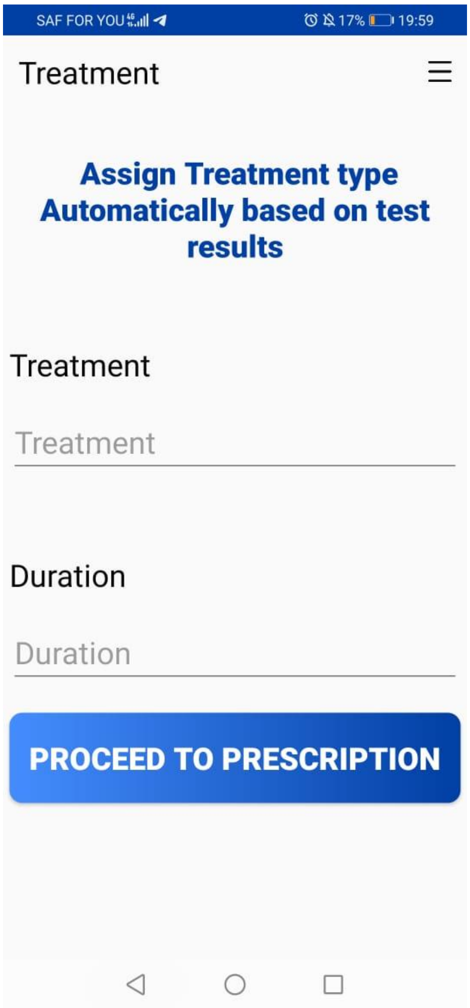

Begin Assessment
Personal Details
Child's Name
Full Name
Care Giver's Name
Care Giver's Name
Phone Number
Guardin Phone
Guardian National ID
Guardian National ID
NEXT

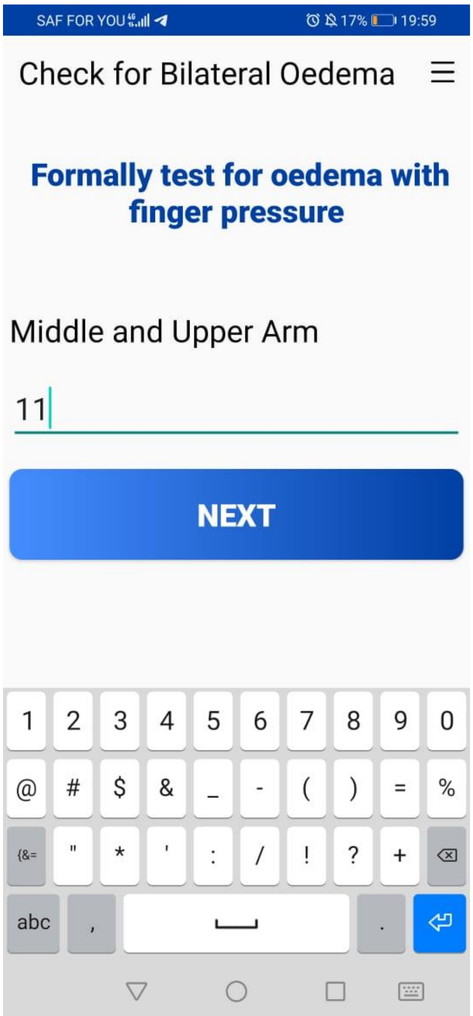

Enter Bio Data
Bio Data
Date of Birth
Date of Birth
Height (Centimetres)
Height (Centimetres)
Weight (KGs)
Weight (KGs)
Gender
Select Gender
NEXT


Check for Bilateral Oedema
Formally test for oedema with finger pressure
Severity
Select severity
NEXT


Test Results
Test Results
MUAC score
11
Weight to Height score
30
Malnutrition Rate
SAM
START TREATMENT
-MS3m8j45hbv8DbSkDhO


Prescription
Vitamin A
Vitamin A
Albendazole
Albendazole
Measles Vaccine
Measles Vaccine
Plumpy Suppliment Packets
Plumpy Suppliment Packets
PRESCRIBE


SAF FOR YOU
17% 19:59
Treatment
Assign Treatment type Automatically based on test results
Treatment
Treatment
Duration
Duration
PROCEED TO PRESCRIPTION


SAF FOR YOU
17% 19:59
Check for Bilateral Oedema
Formally test for oedema with finger pressure
Middle and Upper Arm
11
NEXT
abc

Chapter 5: System Implementation and Testing

5.1 Introduction

This chapter contains the system specifications required when using the system. In addition, it contains test cases performed during development and test results. Testing was conducted to provide stakeholders with information regarding the quality of the system being tested.

5.2 System Implementation

This refers to the method in which the system was built regarding the system analysis and design methodology as mentioned in chapter 3 and has been explained in chapter 5. The system was developed on the Android studio development platform in the JAVA programming language. Using the proposed system development methodology, it was developed using an object-oriented approach that helped in providing a systematic and efficient development process.

Once development of the different modules was completed via prototyping, they were integrated to form the complete system with a seamless user experience. The CRUD functionalities and user access rights were divided according to the different actors in the system and their specific functions.

5.2.1 *Installation procedure*

The system is t be installed via google play store because it is an android application is made available via the application store. First, download the application onto your device and after completion the installation process starts automatically.

5.3 System Testing

This section aims to focus on the system testing and whether the system has succeeded through functional testing, usability testing and unit. This section also aims to detect system failures and defects that can be discovered before the system is fully implemented into its intended environment.

5.3.1 *Test environment*

The mobile application system that has been developed is designed to run on a mobile device which is also used to test the system's functional to verify and validate the system. The following requirements were met to test the system.

Operating system	**Android**
Processor	Kirin

Random Access Memory	4GB
Database Management	Firebase Real Time Database
Programming environment	Android Studio

5.3.2 *Test cases*

Test ID	Related requirement	Inspection check	Pre-condition	Test Data	Priority level
T1	FRQ1	Authentication.	The user of the system must be assigned a role by the admin	Email: admin@gmail.com Password: 12345678	High
T2	FRQ2	Admins should be able to create users and assign roles.	Counties, Sub Counties, Community health units should already exist in the system.	County id: 46	High
T3	FRQ3	Health workers should be able to assess children and PLWs.	Users must have CHV rights to access data and all test must be carried out sequentially.	Role: CHV	High

T4	FRQ4	Monitoring and tracking patient malnutrition rate and treatment progress.	Users must have admin rights to access data.	Role: CHMT, SCHMT or Link Facility Admin.	Medium
T5	FRQ5	The Admins should be able to monitor health worker performance.	Users must have admin rights to access data.	Role: CHMT, SCHMT or Link Facility Admin.	Medium
T6	FRQ6	The Health workers should be able to manage patient records and data.	Patient record should already exist in the system.	Role: CHMT, SCHMT or Link Facility Admin.	High
T7	FRQ7	Admins should be able to view reports and visualizations based on data input into the system.	Users must have admin rights to access data.	Role: CHMT, SCHMT or Link Facility Admin.	Medium

Chapter 6: Conclusion, Recommendations and Future Works

6.1 Introduction

The aim of this chapter is to summarize the discussion on the objectives mentioned in chapter 1, and to provide conclusions related to each of the objectives specified as well as the achievements of the system. Moreover, this chapter will also highlight the challenges and future works with regards to the system.

6.2 Discussion

As described in chapter 2 above, the malnutrition management method is rooted in the CMAM methodology to enables health workers to manage malnutrition within low-income urban communities. The developed system can be used by county, sub-county, link facility, and community health management teams to view progress of the CMAM campaign as well as performance within the system.

The primary user of the system is the community health volunteer whose primary role is to move around various communities and assess children and various PLWs for malnutrition as well as administer relief foods and medication. They also help in educating the public on good nutritional practices. After logging in they can assess children and PLWs for malnutrition and refer those with SAM for treatment in various linked health facilities within the same sub county.

The admins at various levels can request for and allocate resources accordingly to the sub counties, link facilities, or community health units withing their jurisdiction in the system as well as view relevant reports.

As per the completion of the system it is reasonable to observe that the main purpose of the system, that is to help manage malnutrition in low-income urban settlements has been accomplished and the different actors can perform their tasks independently on their specific sides. Data collected showed that the system was able to aid in the data management aspect of managing malnutrition as a medical extension service. This also showed that the digitization of the data collection was feasible. There was the identification of the different types of malnutrition that the target group was suffering from and the various treatments such as outpatient care and targeted supplementary feeding.

6.3 Future Works

The mobile malnutrition management system is currently functional however the current scope is limited to the remote treatment of acute malnutrition through the TSFP program and does not extend to in patient care.

Future works will focus on follow up of discharged patients and monitoring progress because the main challenge facing malnutrition management is that there is a high relapse and mortality rate post discharge. This will help provide data relevant in finding solutions to curb this trend.

6.4 Conclusion

While performing malnutrition assessments, it was found out that ensuring food security and education of good nutrition practices was important. It was found that most children and PLWs suffering from malnutrition had limited education on good nutrition practices.

6.5 Recommendations

It would be important to integrate the current system with the DHS in Kenya to provide data that would help in the improvement of health services in Kenya.

References

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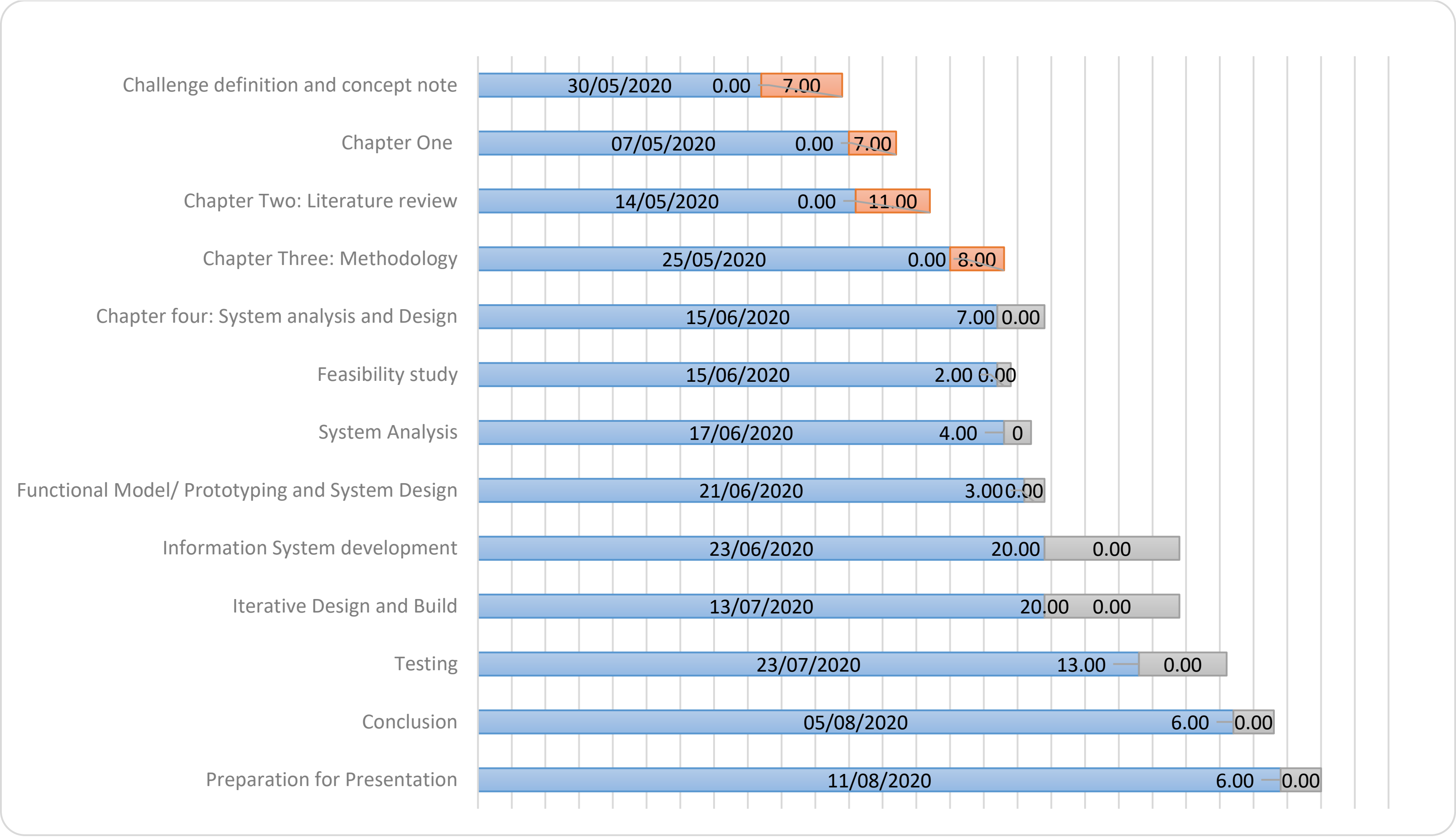

Appendix A: Timeline of Activities