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Master

Mobile nutrition assessment and decision support system for village health teams in Uganda.

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Abstract

Introduction: The government of Uganda through the Ministry of Health and other stakeholders are in efforts of strengthening information systems for nutrition, through data collection, management and dissemination. In these efforts health centers at the regional level were used to carry-out nutrition assessments and training to VHTs to extend the service to the families. The Ministry of health and other implementing partners are encouraging community based service delivery and this is being done by involving the VHTs in all services provided to the community. The VHTs work as the vocal people for the families in the communities hence are able to idenify the needs of the communities.

Objective: The main objective of this study is to design and develop a mobile nutrition assessment and decision support systems for VHTs in Uganda to support them in nutrition assessment and giving families feeding recommendations.The study will use the available nutrition assessment data to design and develop a decision support system that supports proper feeding, manage follow-ups and referrals to avoid relapses among children who are enrolled in the nutrition clinic.

Method: In this thesis a Design Science Research Methodology (DSRM) was used to help us direction in coming up with an artefact.In addition, the User centered design approach was followed, to allow involvement of users throughout the design of the prototype.The project worked closely with the staff at the health center. Interviews and focus group discussions were applied to get qualitative feedback.Furthermore, a prototype was demonstrated and the questionnaires distributed to get feedback on the designed prototype.

Results:A low and high fidelity prototype for nutrition assessment and decision support has been developed to be used by VHTs and health facilities to manage nutrition and make real time decisions.

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Abbreviations

WHO- World Health Organisation
UN- United Nations
HMIS-Health Information Management System
DSS - Decision Support System
VHTs- Village Health Teams
UNICEF -United Nations International Children's Emergency Fund
IMAM- Integrated Management of Acute Malnutrition
RUTF - Ready-to-use therapeutic food
UNAP-UGANDA NUTRITION ACTION PLAN
NDP- National Development Plan
RDF - Resource Description Framework
OWL - Web Ontology Language
CHW - Community Health Worker
CDSS- Clinical Decision Support System
OPD-Outpatient Department
MUAC-Mid-Upper Arm Circumference
SAM-Severe Acute Malnutrition

Chapter 1

Introduction

Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients(WHO, 2021). Malnutrition is increasingly becoming a major health problem in Africa with over 282 million people being undernourished as per the UN report 2020. Poor nutrition is a major limitation to growth and development throughout the African continent. Many African countries faces poor access to clinics and hospitals and the rise of both under- and over nutrition throughout Africa has created a double burden of disease,increasing the risk of both infectious and chronic diseases(J1 & Gewa CA2, 2011). The impact of COVID-19 plus many other factors affecting the East and South African region (including the impact of desert locusts, drought and floods) have led to disruption to essential nutrition service(UNICEF, 2020). In East Africa, malnutrition affected from around 26 % to 36 % of children below five year(Julia Faria, 2022). Malnutrition prevails in two forms; over nutrition and under nutrition. Under nutrition leads to low immunity therefore exposing most of the children to the higher risk of infections hence increasing the frequency and severity of such infections which may lead to a delay in recovery (Agho et al., 2019). Although the problem of under nutrition still exist, there is an increasing burden of overweight and obesity plus diet-related chronic disease(Atinmo et al., 2009). In Uganda the Ministry of health developed a standardized nutrition data management training package based on the Health Management Information System(HMIS) that strengthens reporting and improves the data quality from the regional health facilities to the national level. The HMIS acts as an integrated system used by the Ministry of Health, partners, and other stakeholders to collect relevant and functional information

that helps in the monitoring of the health sector, this is mostly used for planning,monitoring and evaluating the health care system(MOH, 2017). Decision Support Systems (DSS) are defined as a computer-based information system that support business or organizational decision-making activities , they help with management, operations, and planning levels of an organization and help to make decisions(Rahamathunnisa & Chellappa, 2018). In this study a DSS is an interactive mobile-based system which is intended to help health village health teams(VHTs) carryout mobile nutrition assessment through gathering useful information from the available nutrition data, documents, and individual assessment for identifying and solving nutrition related problems plus make decisions inform of recommendations to the families. In Uganda, nutrition care can easily be improved by developing nutritional systems that have maximum impact on the families with malnourished children, health facilities and special nutrition clinics(Mistades et al., 2019). In the current health care service provision system of Uganda, nutrition is among the services that the government is integrating especially at the village level where families are encouraged to assess their children and also monitor their nutrient intake.

1.1 Research Motivation

To reduce the number of children below 5 years who loss their lives due to under nutrition, the ministry of health and other partners are working towards integrating malnutrition data capture into the Hospital Management Information System(HMIS) and District Health Information System(DHIS2) at a regional level. This induces the need for more information systems that will support data gathering and interpretation of this data at village level. There are no clear systems that provide recommendations at a village level, most of the data is being used to inform implementation of government support services.
More so, Uganda is reported to be among the countries with high levels of malnutrition with over 2.4 million young children stunted(Kasule, 2020). The Ministry of Health in Uganda and partners like UNICEF are providing nutritional support services and influencing strengthening information systems. The focus is mainly on nutrition assessment, counselling and support at a village

to family level using different health facilities(The Uganda Ministry of Health, 2016). According to (Trtovac & Lee, 2018) addressing, identifying, and monitoring malnutrition properly may improve the outlook for older hospitalized patients. Therefore, interventions focusing on identification and treatment of malnutrition have positive impact on reducing the risk and rates of malnutrition in hospitals.

More still,to enhance health services' innovation,there are increasingly a need for:software design and health services research including a lot of innovations geared towards eHealth(Gregório et al., 2021).Technology is very important to help in identifying malnutrition due to its scalability, timeliness, and effectiveness. Based on the above background it is therefore imperative to come up with a technological solution that will help support the nutrition assessment, follow-up and referrals using a bottom-up approach. The study intends to come up with a mobile nutrition assessment and decision support system that will guide in the nutrition support services and also provide feeding recommendations at the village level.

1.2 Problem Statement

Every year, more than six million children will die before their fifth birthday and most of these deaths are caused by disease and malnutrition(Worldvision, 2019).Undernutrition is among the factors causing deaths in children under 5 years, this also puts such children at risks of getting common infections(UNICEF, 2021). Rural areas in Uganda today face a higher burden of malnutrition than do urban areas where 30% of children under 5 years are stunted(UBOS, 2014). A lot of discussions about advancing the nutrition agenda took place between World Health Organisation,UNICEF and other stake holders, under the theme strengthening Information System for nutrition(WHO Africa, 2021). The government and nutrition partners recognize a need in collection, management and dissemination of nutrition data starting from the communities to the health facilities so as to reduce the malnutrition problem. However,the current nutrition process is still manual especially how data is received from the villages to the health facilities. There are alot of data loss and mismatch

due to human errors.The long process of capturing data within the HMIS reduces the efficiency,decision making is also done manually by the nutritionist which may lead to bias in the results given to the child.It is noted that loss to follow-up(Nahalomo et al., 2022) is also a major limitation for support in the communities. This poses a need to design a system that can support data collection,decision making and follow-up of patients from the communities or villages to the nearby health facility.This system will act as the link between the service providers and the patients hence easy follow-up of such patients.

1.3 Objectives

1.3.1 Main Objective

The main objective of the research project is to design and develop a mobile nutrition assessment and decision support system that supports nutrition assessment at village level. The system will provide feeding recommendations on feeding based on the patient's assessment. The project aims at helping village health teams carryout referrals and also guide the regional health facilities in doing follow-up of the patients enrolled in the nutrition clinic.To help the health facilities track malnourished children, do follow-up and referrals to other support centers. The VHTs will be able to assess the children in their villages and capture more information in the systems which will then be used to give recommendations and schedule appointments for the children.This is to improve the health care that is provided to these children in order to avoid deterioration and hence or reduce the death rates of children under 5years who are malnourished.

1.3.2 Specific Objectives

1. To carryout data collection on the current nutrition assessment process and follow-up procedures of malnourished children at village level.

2. To design and develop a prototype of a mobile decision support system for village health teams.

3. To evaluate the proposed solution of a mobile nutrition assessment and decision support system.

1.4 Research Questions

RQ1. What is the current nutrition assessment process and follow-up process of malnourished children at village level?

RQ2. How can the nutrition assessment process be improved by designing and developing a decision support system at a village level?

RQ3. How can the decision support system help in referral and follow-up of malnourished children through recommendations?

1.4.1 Scope of the study

The scope of the thesis is to look at the process of gathering requirements, designing, prototyping and user-testing of a mobile based decision support system. It looks at the follow-up and referral process and how to fill the gap between the medical facilities and the families through providing real-time recommendations. It also looks how to improve nutrition assessment through a decision support system at a village level.The project focused on working with one health facility in Kawempe division as a case study.In terms of time scope we focused on using the available time for a master thesis to carryout all the project activities

Chapter 2

State of the Art

2.1 Background

2.1.1 Nutrition Management in Uganda

High and increasing population will reduce food adequacy which leads to inadequate food intake or intake of foods of poor nutritional quality and quantity in developing countries of Africa. Many governments in Africa have not actually measured the burden of malnutrition, and consequently fail to consider the fight against malnutrition as a priority(Bain et al., 2013). Child malnutrition in Uganda remains largely a hidden problem and micronutrient deficiencies are similarly difficult to detect. Malnutrition remains one of Uganda's most fundamental challenge. In Uganda management of malnutrition is primarily facility based where children who are malnourished are identified in health facilities and those that are severely malnourished are referred to hospitals or rehabilitation centers for management(Bachou & Labadarios, 2002). There are also a lot of efforts to transform nutrition management into community-based programs.

2.1.2 Health care system in Uganda.

In Uganda the national health care system is decentralized and incorporates the public and private sectors(WHO, 2018), and the administrative head of the health system in Uganda is the Ministry of Health which governs both the public and private sectors. The private sector is composed of the private not for-profit health care providers, private health practitioners, and traditional and complementary medical practitioners(WHO, 2018). According to (Qi et

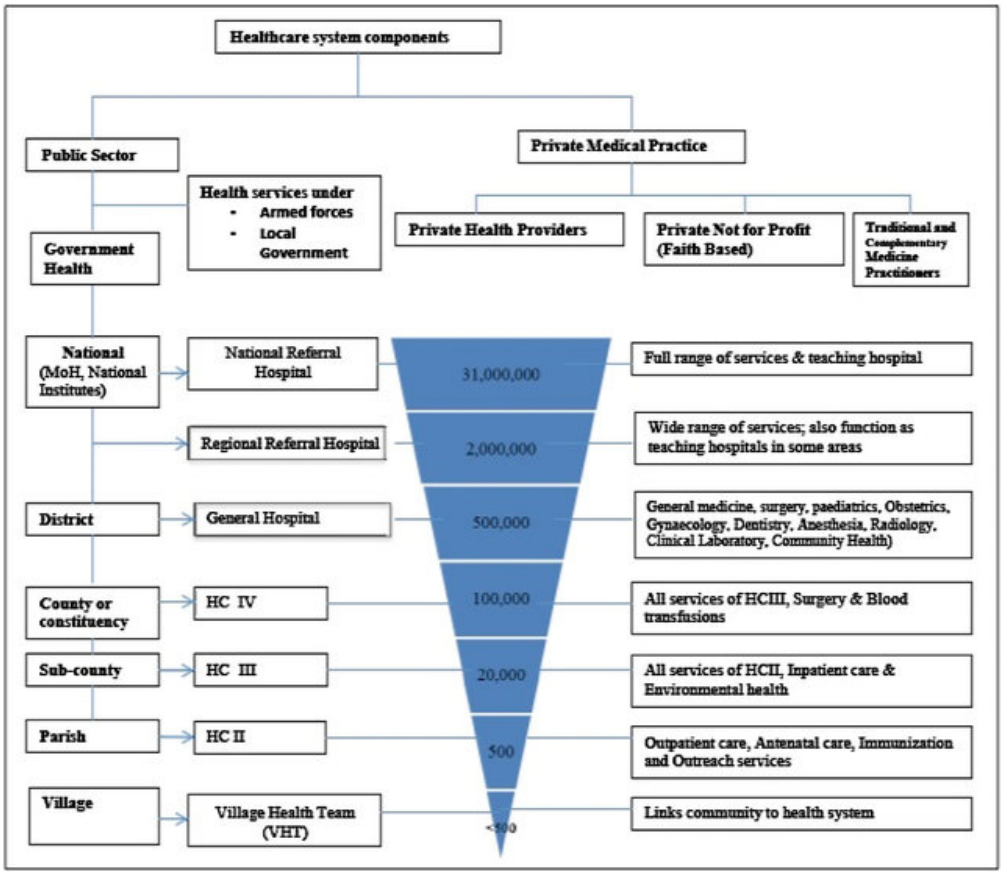


Figure 2.1: Healthcare structure of Uganda from VHT to the Ministry of Health(Acup et al., 2017)

al., 2018), in Uganda, nearly a third of the population live more than five kilometers (3.1 miles) away from the nearest health facility, public transportation is also limited and that available is not affordable to most people that need it. This is among the reasons why the health care services need to be brought closer to the communities to reduce on the long distances for services like nutrition,immunization among others.Figure 2.1 shows the hierarchical structure of the health care system from the ministry of health to the village level.

2.1.3 Nutrition assessment

Nutrition assessment involves taking anthropometric measurements and collecting information about a client's medical history, clinical and biochemical characteristics, dietary practices, current treatment, and food security situation(NACS, 2016). In Nutrition screening full nutrition assessment can be done mainly by a simple identification of people who may be malnourished or at risk of malnutrition and need more detailed nutrition assessment(NACS,

2016). As there is no objective tests that measures nutritional status, numerous screening methods have been developed to determine the nutritional status of individuals through the use of : (a) assessing clinical signs and symptoms, (b) biochemical indicators (c) dietary survey and (d) anthropometric measurements(Bhattacharya et al., 2019). There is need for proper knowledge for evaluating the clinical signs and symptoms in assessment. Anthropometrics are known as a set of non-invasive, quantitative body measurements used to assess growth, development, and health parameters among individuals, they normally include measurements of length or height, weight, and head circumference(Wilder, 1921). With these measurements it helps health care providers to determine whether a child is growing properly and is not affected by malnutrition.

2.1.4 Existing process flow of nutrition assessment

Management of acute malnutrition historically, has been hospital-based with treatment integrated within the paediatric ward or within a separate nutrition rehabilitation unit affiliated to the paediatric ward with minimal community mobilisation and/or involvement(The Uganda Ministry of Health, 2018). The process starts when the family care taker brings the child for assessment to the village health teams, this normally happens as a door to door activity or in form of community outreaches organised by the health facility.The child is assessed by the VHT and later referred to the health facility for reassessment.All the data captured by the VHT is recorded in the Ministry of Health(MOH) Integrated Management of Acute Malnutrition(IMAM) counter book and later sent to the facility for reporting and decision making.At the facility the child is provided with RUTF for feeding and recommendations, if the child is not manageable at the facility he/she is sent to the nutrition support center for further management. The Figure 2.2 illustrates the current process, focus is on the linkage between the VHTs, community-level personnels and families to the Health facility for malnutrition management. In Uganda there has been progress in reducing HIV, malaria, and tuberculosis plus production of sufficient food nationally to meet the needs of the population. The poverty levels have also reduced in the country, however the levels of malnutrition among women

and young children have improved at a minimal rate and some indicators like micronutrient deficiency, have even worsened over the past two decades(UNAP, 2011). The development of the UNAP has created an unprecedented opportunity to achieve NDP objectives in nutrition(Agaba et al., 2016).

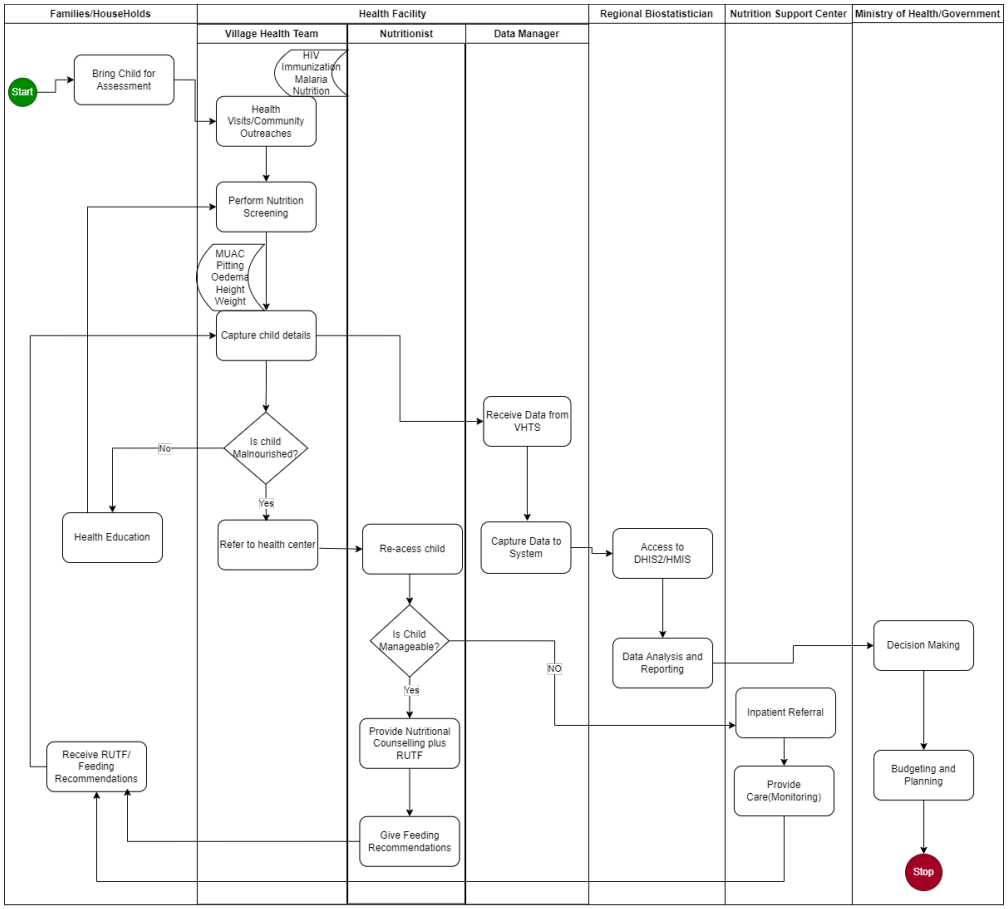


Figure 2.2: Current nutrition assessment process from the families to care and feeding recommendations(The Uganda Ministry of Health, 2018);(MOH, 2017).

2.1.5 Data management Challenges in Nutrition assessment

Despite the importance of nutritional data there is a challenge in the centralized structure to house existing survey data(Coates et al., 2017).There are challenges like lack of motivation for personnel to collect data, inadequate training for data collectors, and the use of outdated tools for data collection. In Uganda the data collected are used to inform planning and budgeting. Local leaders are required to analyse and interpret the data and make use of the findings before submitting the data to the central registry where they are aggregated, however, the analysis and use are not optimal, due to a number of reasons – for example, some districts do not have sufficient capacity to analyse and interpret their

findings(World Health Organization & Alliance for Health Policy and Systems Research, 2017). A lot of data production is not linked to the decision-making process directly, and there are challenges between the type of information available and the information needed(Turcan & Bene, 2017). The challenge mostly is that the data and information are scattered in different hospital information systems and are not very accessible and there is no plan, guidance or tools for integrating evidence into specific stages of the policy development process, both at national and local level(Turcan & Bene, 2017). Given the situation, a comprehensive, robust means to collect existing sectoral and intersectoral data on nutrition for analysis could provide nutrition information to decision-makers at all levels of government for policy development and programme planning. A deeper analysis of the information needs of decision-makers would be a useful starting point(Turcan & Bene, 2017). A report by (UNCDF, 2022) discusses a digital tool that was used in digization of a village health team in Uganda and highlights th different challenges that the tool addresses although, the tool focused on all health services provided by the VHTs in Uganda. In that report some of the challenges that the digital tool was developed for helped the thesis in understanding what needs to be designed and developed for the VHTs inorder to achieve the objective of bringing the service of nutrition assessment closer to the people. Some of the concerns in the report include;

- Supporting the routine reporting and decision-making using digital technologies hence reducing data inaccuracies.
- Improving monitoring and supporting supervision with real-time data and insights into VHT performance.
- Improving reporting of community health data through integration into the National District Health Information System (DHIS2)

Proposed Process Flow

The Ministry of Uganda is working with other stake holders to implement nutrition assessment at the village level. This is being done by integrating the nutrition services into other health care services like malaria screening, immunization, HIV testing among other activities.The project looks at coming up with a decision support system that reduces the traditional way of data capture, referral and follow-ups. This will be done by eliminating the data manager who is employed by the health center to capture family data to the HMIS. We propose a system that allows the community health workers to capture the data and forward the data to the nutritionist who then does the final assessment and gives feed backs and feeding recommendations. The nutritionist is also responsible for synchronising the captured data to the national HMIS for better decision making and budgeting by the Ministry of Health.

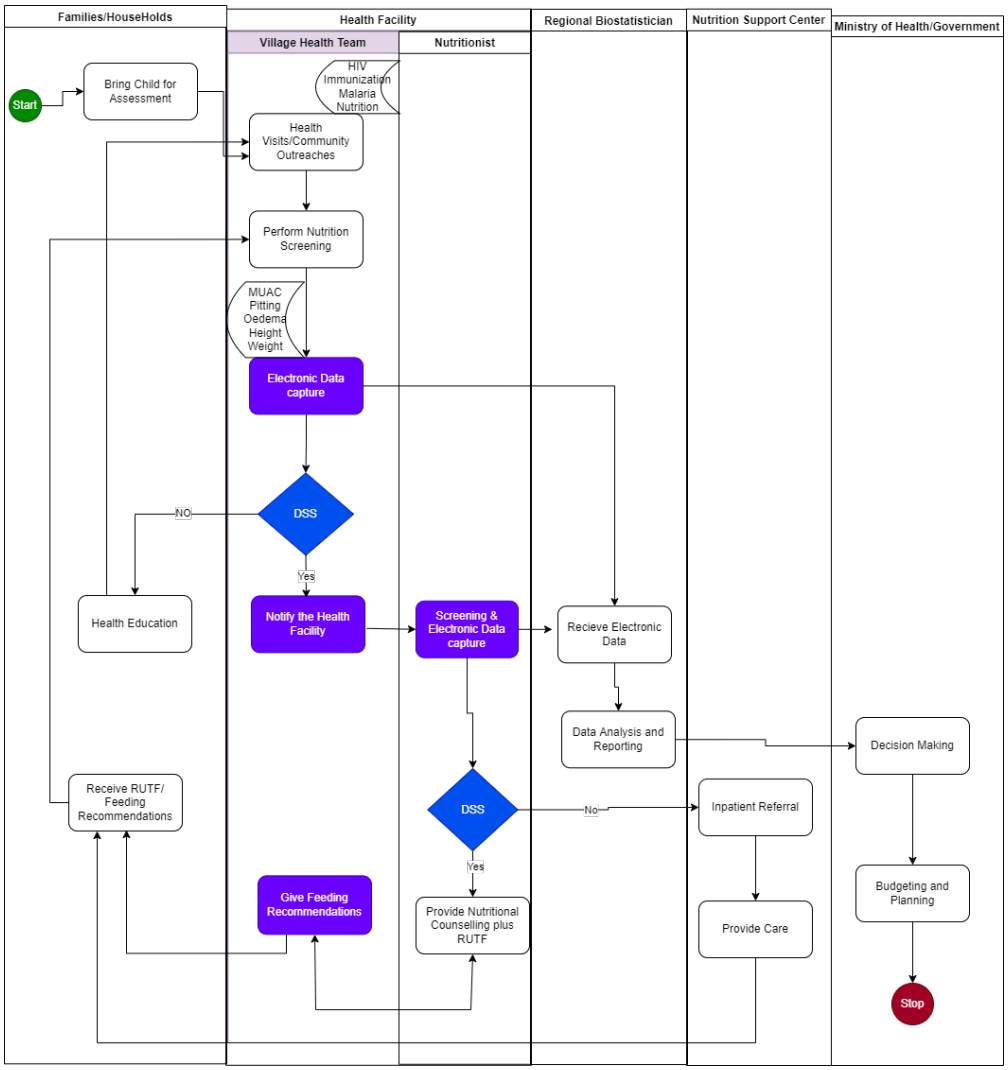


Figure 2.3: Proposed flow of nutrition assessment which focuses on the village health team

The figure 2.3 describes the proposed activities where the focus is on the VHTs and the nutritionist at the facility. This is denoted by the coloring.

2.2 Decision Support systems in Nutrition

Decision Supports Systems (DSS) are computer-based information systems that help managers to select one of the many alternative solutions to a problem(Tripathi, 2011). They normally use data to automate decision making because they allow analysis of large amount of information. DSS handle large amounts of data like database searches,obtain and process data from different sources including internal and external data stored on mainframe systems and networks and provide report and presentation flexibility to suit the decision maker's needs(Tripathi, 2011). They also allow a representation of the data inform of graphs like charts,table and more.

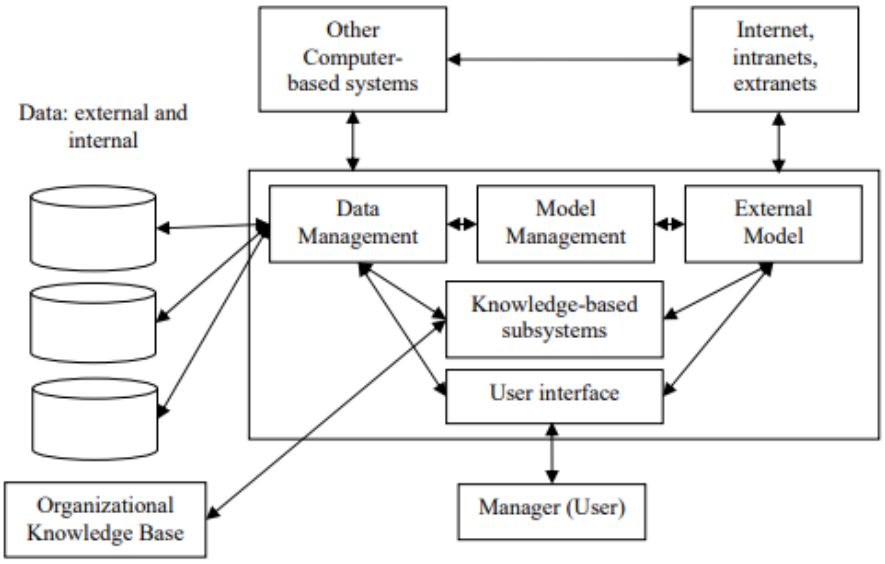


Figure 2.4: The structure of a typical decision support system(Tripathi, 2011)

Data management

The data management component is responsible for retrieving,storing and organizing relevant data for a particular decision context, it also contains some components like security functions,data integrity and data administration duties(Alexander, 2002)

Model Management

In the model management this is where the application models to solve the

domain problem are implemented for example the mathematical models.

Knowledge base

In the knowledge base the knowledge storage, representation and management is developed. This knowledge mostly recommend actions to be taken by the decision makers. The decision making is done basing on the knowledge that is generated by the decision support system.

User Interface

In the user interface component focuses on the way a user interacts with the system.The user to system interaction component is very important in a decision support system because it improves the functionality of the system. Normally this involves the exchange of information between the user and system and providing the result of the DSS computation as the output(Jain, 2021). In a DSS, direct interaction between the user and the system allows a more responsive and user centered view of the current problem to be solved. It is therefore important for the DSS to provide the right information to the right people at the right time.

2.2.1 Clinical Decision Support System

Clinical Decision Support Systems (CDSS) link health observations with health knowledge to influence health choices by clinicians for improved health care. These systems are aligned with medicine objectives to a more personalize diagnosis and treatment, predict the patient status and follow-up based on multi-level observations, generate preventive polices in risk patients and empower patients to actively participate in their health(Martínez-Pérez et al., 2014). In order to make the diagnosis as accurate as possible, it is not enough to simply estimate the questionnaires, but a clinical decision support system (CDSS) is needed to assess the inter-dependencies between symptoms and syndromes, as well as some uncertainties arising from subjective survey data(Petrauskas et al., 2021). In this section we describe some of the clinical decision support systems that informed the study.

2.2.2 Rule based Systems

Rule-based systems are also called production systems or expert systems) and are commonly applied in areas of artificial intelligence(Çelik Ertuğrul et al., 2021).Rule-based systems also depend almost entirely on expert systems that mimic the reasoning of human expert in solving a knowledge intensive problem. The rule based systems represent knowledge in terms of set of rules that result into conclusions instead of declarative and static results. Rule based systems use set of assertions and the rules are expressed as a set of if-then statement using IF-THEN rules or production rules(Abraham, 2011). For example IF weight is less than 3kg for a child THEN he/she is malnourished, these rules help the system come up with recommendations that are displayed for the user to understand. (Çelik Ertuğrul et al., 2021) proposed a rule-based decision support system for aiding iron deficiency management. The system is based on IF - THEN rules to carryout different diagnosis for patients that have iron difficiency and then help the physician make decisions based on the results provided. This system contains five units that is a fact base,an ontology knowledge base,a semantic medical rule base, an inference engine, and graphical user interfaces for physicians. The system does not clearly show how the recommendations are given to the intended users who are not physicians but the patients themselves.

2.2.3 Ontology based systems

Ontology is one of technologies for semantic web technology development. It represents Resource Description Framework (RDF) and OWL in the WWW Consortium (W3C) standard(Lertkrai et al., 2018). Ontology is easy to understand, use, and work-on. Ontologies are becoming an important means for interchanging knowledge and integrating this knowledge into systems. Ontology allows classification of things, which are existing and these are organized in a systematic manner and analysed in a structured way. Morestill, Ontology is mostly used by knowledge based systems(Jain, 2016). Lertkrai et al., 2018 uses ontology model to describe the domains and class required for recommending food and nutrition, the data properties helped in coming up with results that can be interpreted by the physician. In this proposed system, there is a missing

functionality of the user interface and mobile technology is not applied. It is not clear how the patients receive their food and nutrition recommendations from the system. According to Tejaswini, 2020 the main purpose of ontology-based patient data representation is that it is easy to collaborate with the people working in similar domain.The data properties are specified and new instances are classified. In the clinical test result of nutrients, algorithms are also used to classify the types of nutritional deficiency for a particular person. The ontology shows the appropriate first-level decision that can be given by the system to provide a base level analysis of each of the fields used in the clinic test and reduce the burden on medical experts. In this literature semantic representations for storage of test results and automatic classification of nutritional deficiency are applied. Ontologies also describe the meaning for example the semantics of content in a way that can be interpreted by machines(Jain, 2021). Semantic web technologies and decision support systems have also been used in the last decade for providing accurate solutions for a number of applications especially in the health care systems.

Table 2.1: The table below represents studies that have applied Ontologies to support decision making in systems.

Reference	**Tittle**
(Tejaswini,2020)	An ontology-based decision support system for nutrition deficiency
(Nisheva-Pavlova et al.,2021)	Implementation of an Ontology-Based Decision Support System for Dietary Recommendations for Diabetes Mellitus
(Spoladore et al.,2021)	An Ontology-Based Framework for a Telehealthcare System to Foster Healthy Nutrition and Active Lifestyle in Older Adults
(Hsu et al.,2011)	A Web-Based Decision Support System for Dietary Analysis and Recommendations

2.2.4 Fuzzy logic decision Support systems

In a fuzzy logic based system models that have fuzziness or vagueness are dealt with, unlike other methods that use classical theory.(Kumar et al., 2013) explains how fuzzy logic decision support systems work based on a set of objects that are input into a system and the system is able to use an inference model to generate output. In a fuzzy system, certain inputs are given to rules, depending upon the system under consideration and the outputs given by the system are

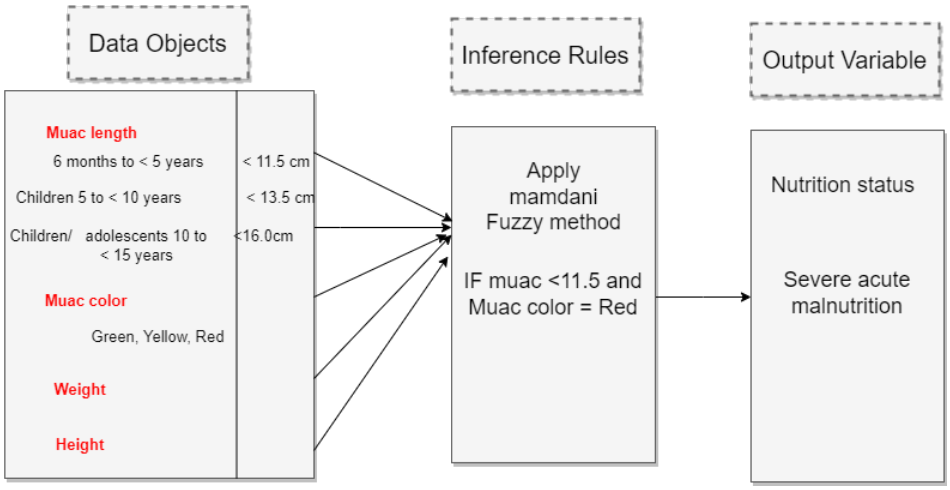


Figure 2.5: The structure illustrating how the fuzzy bsed system works to support decision making, adopted from (Hadianfard et al., 2015)

then utilized to reach the final decision(Kumar et al., 2013). There are two main types of fuzzy inference systems that can be implemented that is Mamdai-type and sugeno-type(Kalogirou, 2014). In this project we look at the mamdani-type inference method that allows aggregation and outputs a fuzzy set that is then defuzzified. The method is more efficient. Permatasari et al., 2017 describes a system that uses fuzzy inference systems to classify toddler nutrition status, the system uses inputs like the weight and length to come up with an output of nutrition status. The study describes a fuzzy set being characterized by its membership functions where elements are classified in the set. For example if X is a set of objects, then the fuzzy set A in X is a set of sequential pairs. In this project we have a set of objects X = {weight, height, muac color, muac length among others};these are inputs into the mamdani inference method that can output the nutrition status of a child. This is illustrated in the Figure 2.5.

2.3 Mobile technology Application in nutrition

In both low and middle-income countries mobile technology has spread its roots rapidly(Davey & Davey, 2014).The increase in use of mobile devices in the recent years, has led to new solutions including mobile technologies to fulfill requirements or suggest better solutions in the vast area of medical informatics to add to the existing ones(Kalem & Turhan, 2015). Mobile technology

is seen changing the health-care delivery in the developing countries(Davey & Davey, 2014). Today it is possible receive and process a vast amount of real-time data and situational information on mobile devices in a manner that has not been witnessed previously(Haghighi, 2013). A lot of developments in mobile technologies have centered data collection to the final end users of the health services. This methodology reduces the burden for data collection from the interviewer to the patient and have the potential to improve the dietary assessment process(Shriver et al., 2010). Inaddition nutrition assessment methods using technology may reduce the cost of collecting data and the burden of recording foods eaten, thus increasing completeness of measurements(Hongu et al., 2011 cited in Shriver et al., 2010).Nutrition assessment methods with advanced technologies offer various advantages in the collection and processing of data from both the participant's/client's perspective and the nutritionist perspective(Hongu et al., 2011). The ubiquity of mobile and smart devices even provide opportunities for more personalized real-time data collection, data synthesis, analysis, and feedback at the consumer to enterprise levels(Limketkai et al., 2021). Implementation into clinical practice may range from the using of mobile apps to track diet intake and the use of wearable technologies to collect supportive data to the development of decision support tools for parenteral nutrition and the use of telehealth for remote assessment of nutrition(Limketkai et al., 2021). In a measurement system(Almaghrabi et al., 2012), an instrument that measures daily food intake using mobile devices with a built-in camera to capture a photo of the food intake before and after eating, in order to estimate the amount of consumed calories. The proposed system depends on a new technology for example the usage of the thumb as a calibration reference to estimate the amount of food from the captured photoc(Almaghrabi et al., 2012).The system uses the thumb as a measurement reference to then calculate the amount of calories using a nutrition table.

In Tanzania, Arusha city in a study of Enhancing management of nutrition information using mobile application for Prenatal and postnatal requirements, a mobile-based information management platform was developed to improve accessibility of nutritional information which was integrated with the existing health information system(Mduma & Kalegele, 2017). The application is in-

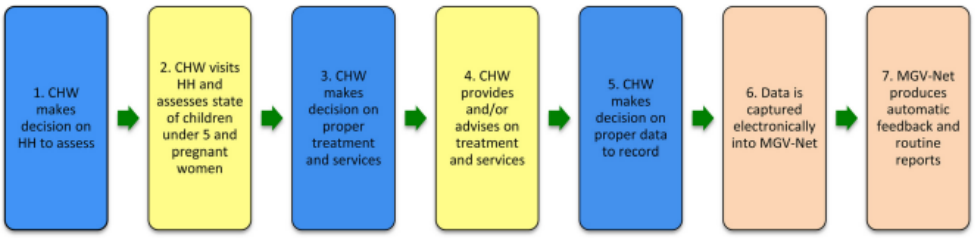


Figure 2.6: MVG-Net System Framework: Data-Driven Feedback in Real Time to CHWs for Improved Decision Making(Sarma et al., 2018)

tegrated with the exisiting heath systems and allows nutrition practitioners to send information and recommendations to the end users.The application uses technologies like PHP, MySQL for backend database and Java as a language.

A project by Millenium Villages Global Network; The open-source components of this system used for community health worker (CHW) support were comprised of Child Count, a mobile platform used to collect data, and OpenMRS, an electronic medical record in which patient health information was stored. Included in these interventions was the equipping of CHWs with mobile technology (SMS, or short message service) for data collection, reporting, communications, and point-of-care support(Sarma et al., 2018). This is illustrated in Figure 2.6

Paulsen et al., 2020 discusses about the Myfood decision support system that was developed and evaluated for improving nutritional treatment and care. The system comprises of a mobile application and a website for use by nurses and health care professionals. It starts by registering the patients by capturing information like the weight, height, chewing problems,fever among other information.The system also allows recording of pictures and nutritional content of all dishes,foods and medical nutrition products, evaluation of the recorded intake is compared to individual requirements in the body. The report is then printed for the health care professional and recommendations are given. The system does not look at involving the community health workers and also taking the services to the communities for better health care services. In this thesis we focus on malnutrition in children and also involving the communities in reducing the problem at village level and closing the gap between the health care professionals/nurses and the community by involving village health teams.

Chapter 3

Research Methodology

In this chapter, a description on the different methodology that was used to achieve the objectives of the project. It also describes a theoratical background of these methodologies used in this thesis.

3.1 Design Science Research Methodology

Design Sciences Research is of importance in a project that is oriented to the creating a successful artifact. This methodology involves six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. (Peffers et al., 2007). Apart from other models of user-centered design, DSRM also involves a series of cycles in which problems are identified and users' needs are assessed in a scientific sound way(Gregório et al., 2021).The design science process in this thesis was customised but still followed the six phases in coming up with an artefact; that is, problem identification,objective definition,design and development,demonstration,evaluation and communication.

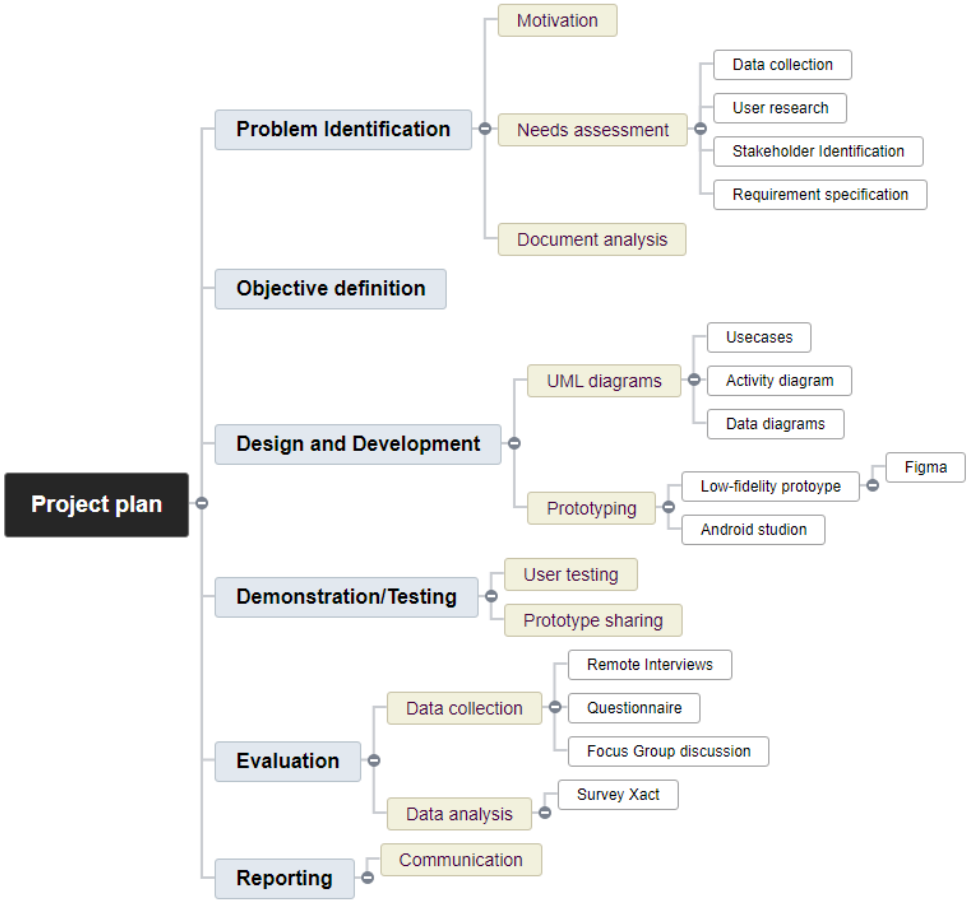


Figure 3.1: Design science research framework (Adapted from Peffers et al.,(2007))

3.2 User centered design

This thesis was also guided by an iterative methodology for design and development, user centered design allowed the project involve users in all the steps of design and development. This helped us come with the user needs and systems requirements by putting the users at the center of the project activities.

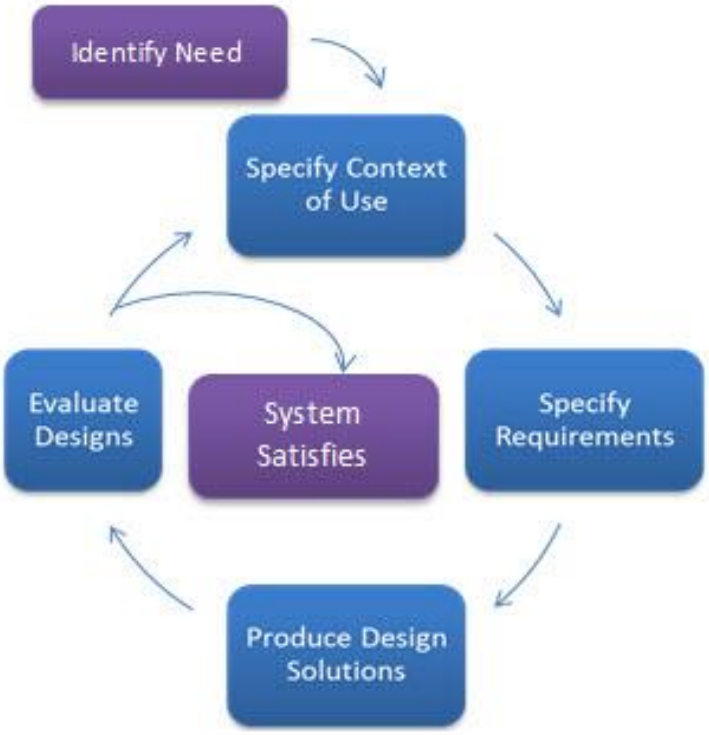


Figure 3.2: User centered Design Process(Usability.gov, 2020)

3.2.1 Problem Identification

In this project, the problem was identified basing on previous experience with a malnutrition project that was spear head by FHI360 and Child and Family Foundation Uganda(CFU), this aimed at integrating the nutrition assessment within the Ministry of health services especially at the village level.Interviews with the biostatistician and the program officer at the CFU medical center allowed an understanding of the real problem and how the village health teams can be helped in terms of nutrition assessment and care for the children. Literature review was also used to find out the different theories that relate to the problem that is being discussed.During the interview we focused on our research questions.

3.2.2 Context of Use and Requirements Identification

This section describes the intended users, their goals,associated equipment (including hardware, software, and materials), the physical and social environment in which the product will be used, and examples of scenarios of use.In this thesis scenarios where a VHT performs nutrition assessment on the child was consid-

ered to find out the end results in the recommendations. In this thesis the researcher who works with the health facility was used to talk to the VHTs that are attached to the facility. In the case study scenarios these are the users that participated in the evaluation of the proposed system process.

Users and stake holders

In order to prototype they system we identified the different users and stakeholders that will benefit in the system. There are several stakeholders/users of the proposed system including; Nutritionist will provide the expert knowledge that will be used within the system and also provide recommendations within the system. Nurses;the nurses will use the system to capture the information about the patients, these will work in different facilities that cannot employ nutritionist. Village Health Teams(VHTs), these are the users who will use the system to capture all the information from the families and households. They are to interview the families about their nutrition status to allow the system derive recommendations. Government/Ministry of Health; The government will support the system to carryout data collection and also allow access to the national Health Management Information System.This will help us in working with other stakeholders like UNICEF,WHO for smooth implementation of the project.

Scenarios

After understanding the context of use the project used assumptions and scenarios to develop the prototype of the application that can be used by the village health teams(VHTs) to capture the relevant data and come-up with recommendations.These scenarios helped us better understand better which data will be used in the decision Support System to come-up with feeding recommendations. According to (Klaus et al., 1998) using scenarios help in reducing the complexity and enforce interdisciplinary development of a proposed system. Also scenarios are tell stories about the systems to ensure that people(stakeholders) share a sufficiently wide view of the tasks and also understand their requirements(John Wiley & Sons Ltd, 2004). In this thesis we used scenarios to explain what the users want to capture and check whether the proposed system is able to meet

the user requirements. We list some of the scenarios that based on (MOH, 2017) to guide the use of the system.

Scenario 1

On 10th June 2020, Agaba Joshua, a 4-year-old boy from Kalerwe village, Ikumbya sub-county in Luuka District was referred to the nutrition corner from OPD. His guardian's telephone number is 0755678971. On reassessment, he was severely malnourished but had no bilateral pitting oedema and no medical complications. His HIV status was negative. He was enrolled on OTC and assigned INR No. 064 and received 42 sachets of RUTF on enrolment.

Scenario 2

On 12th July 2015, Mr. Kalule Ismail Mukasa, 37 years from Bulongo village in Kiyunga sub-county was referred from ART clinic with SAM and weighing 49 kg. His ART number was 0065/15. His nutritional status was confirmed (MUAC 18.6 cm) and he was enrolled in OTC. His contact number was 0772612814. He was advised to report for review on 28th July but returned on 30th July with weight 50 kg and MUAC 18.2 cm. He was counselled and asked to return on 11th August but reported on 17th August with MUAC 18.2 cm and weighing 47 kg. He died on 29th August.

Needs Assessment

In this activity we looked at the current process which is the present state of nutrition assessment at village level and determined what needs to be done to improve the existing nutrition assessment process.A set of questions were asked to understand where the decision support system can support, inorder to get the answers on what they system should support the following questions were asked during the interviews. Open ended questions were asked to allow the health facility staff who represented the users to elaborate more of what is required by the village health teams while they carryout the nutrition assessment.

Qn1; Tell us about the nutrition assessment process at the health facility

Qn2; What is the follow-up process on patients enrolled in the nutrition clinic?

Qn3; How are the nutrition results presented to the clients

Qn4; What is the referral procedure at the health facility?

Qn5; How are the feeding recommendations presented to the families?

System Requirements

The project used the Volere requirement specification template to specify the requirements of the system.We considered both the functional requirements and non-functional requirements of the system basing on what the user needs are.

Functional requirements

They provide the fundamental and essential subject matter of the product, describing what exactly the product has to do or what particular tasks it must take in(Robertson & Robertson, 2000).

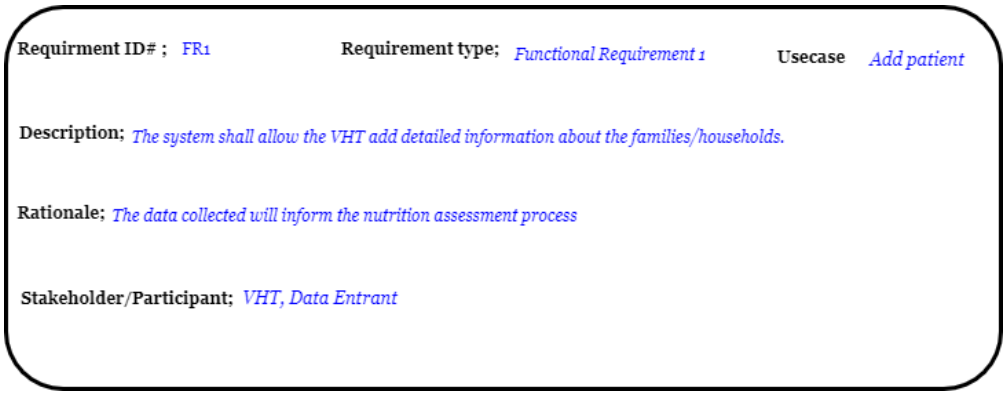


Figure 3.3: Requirement for VHT to add child details

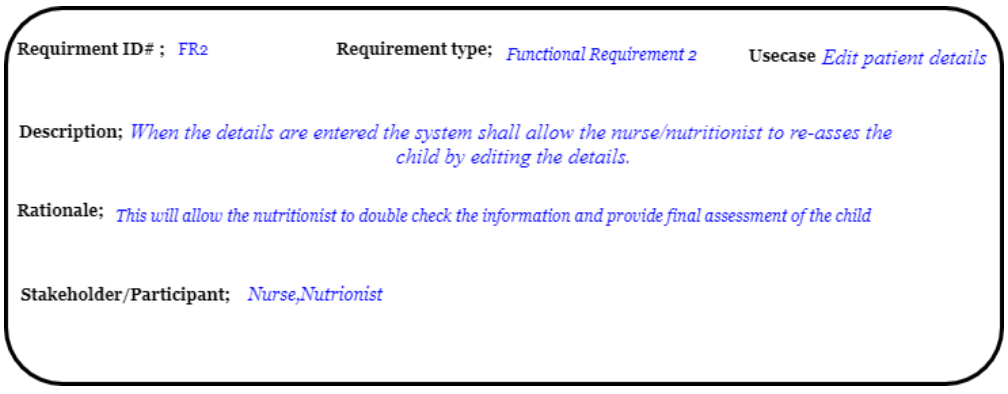


Figure 3.4: Requirement for the nutritionist to do a re-assessment by editing the details

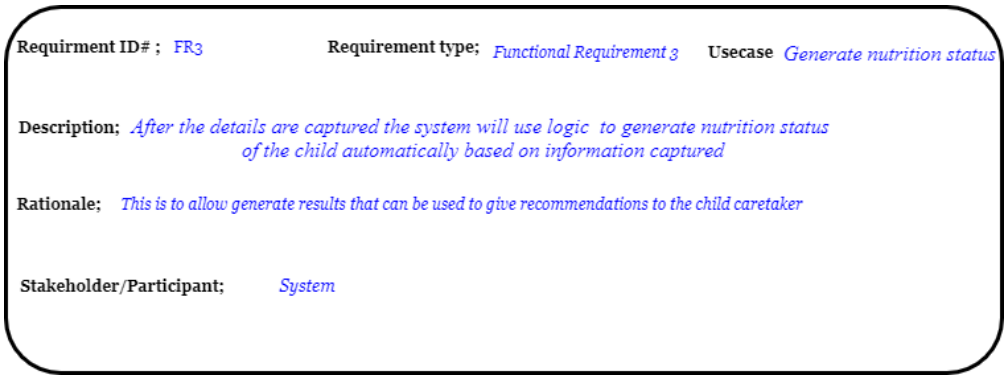


Figure 3.5: Requirement for the system to produce nutrition status

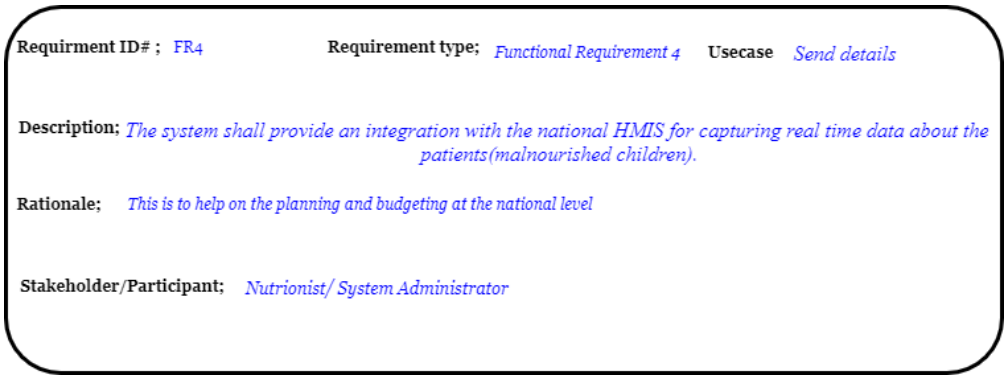


Figure 3.6: Requirement to allow the nutritionist to send information to the HMIS

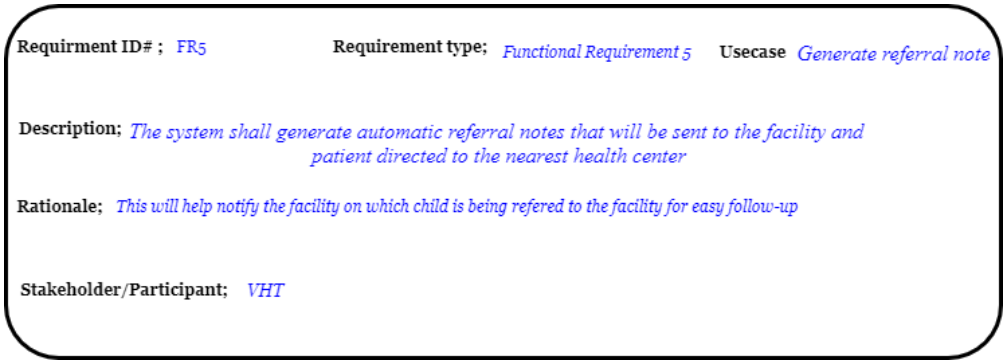


Figure 3.7: Requirement for allowing referral of children

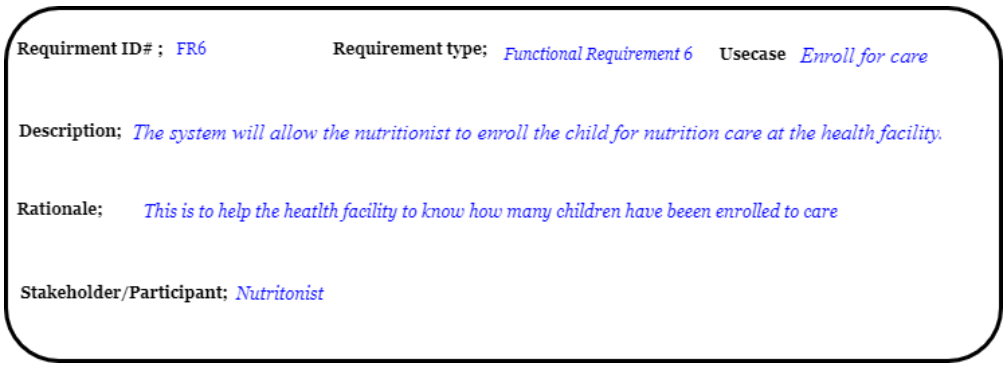


Figure 3.8: Requirement for enrolling the child.

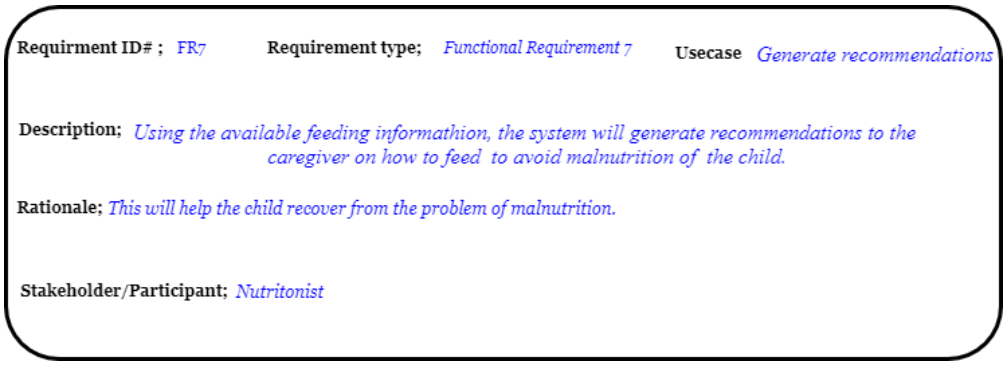


Figure 3.9: Requirement for generating feeding recommendations

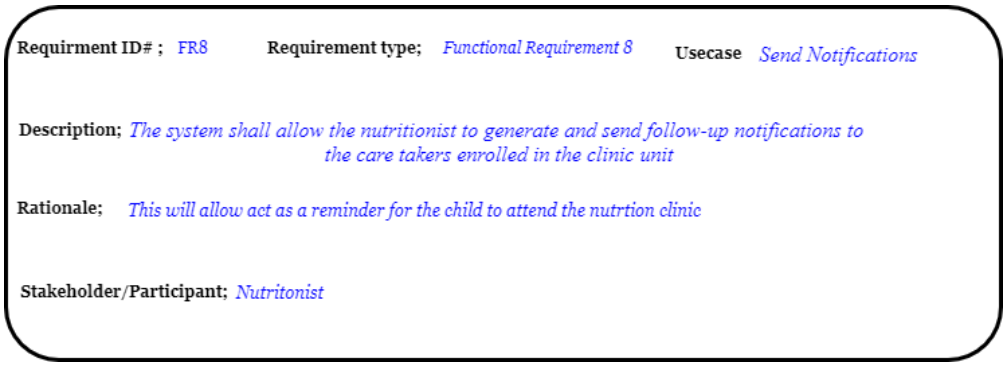


Figure 3.10: Requirement for notifications

Non-functional requirements.

The project considered the non-functional requirements below. To specifically define how the system behaves,its features and other characteristics that affect the user experience.

Table 3.1: Summary of non-functional requirements

REQUIREMENTS	DESCRIPTION
Usability	The system will user interface and how users interact with the system.Focusing on ease of use
Security	User authentication and authorization will be included in the system
Efficiency	The system will be able to produce recommendations and reports with efficiency, meeting use needs.
Effectiveness	The system will allow the users to carryout assessment independently

3.3 Materials and Tools for development

3.3.1 System Design

The section explains the diagrammatic designs of the mobile decision support system. In the system design we used activity diagrams and use cases to illustrate the different functionalities of the system.The necessary information that will be required to measure nutrition is illustrated in the diagrams. The project used the Unified modelling language to come-up with the different diagrams as illustrated in the sub-sections below.Unified Modeling Language (UML) is a graphical language that allows visualization, specification, construction, and documentation of the artifacts of the proposed mobile decision support system(Padmanabhan, 2012). The UML diagrams offered a clear way to conceptualise and come up with a blueprint of a system including the system functions.An online platform called draw.io was used to create the diagrams. It was used because it allows collaboration on the designs and contains alot of features for any UML diagram.The diagrams are also stored on different platforms like in the cloud or on the drive of the users. The project also applied user centered design approach where qualitative user research was used to help design the system basing on user perspectives. User centered design was chosen because of its ability to allow involvement of the user perspective throughout the design process. The user centered design allowed us come up with a design of the system that focuses on users core needs, problems and requirements to allow system usability. In the design we looked at what is necessary for the user to carryout the nutrition assessment, which data needs to be captured and the ease of use of the system. We also looked at which color patterns can be applied on the prototype to help attract the user and create an emotional feeling towards nutrition assessment.

Use Case for proposed system

Use case diagram was used to show a sequence of events and interactions of a particular user with the system as shown in Figure 3.11. This helped us communicate the proposed system's tasks to the users for feedback and easy implementation of the prototype.The use case diagram contains four compo-

nents;

Figure 3.11: Use case diagram for the proposed system

1.Actor

The actors represent the end-users of the system.Shows the actual people that

interact direct with the system.

2.System boundary

This represents the scope of the system.It houses all the usecases that are in the system.

3.Use case

These are the specific tasks that the users do while they interact with the system.

4.Relationship

The relationship represent how the different users of the system interact with the system. This interaction is between the end-user and the system.

Activity Diagrams

The activity diagram is presented to describe the workflow of the system showing the points in which the decision making is being supported. The activity diagram depicts the flow of the system from beginning to the end of execution.

Table 3.2: Description of the activity diagram

Usecase	Description
VHT	The VHT must register and create a username and password. The system will then store the details in the database for the user to be able to login. On login the system will then check the username and password against that in stored in the database. After the authentication will take place and then the VHT will access the system.After login then the VHT will be able to capture the details of the child for the system to perform the nutrition assessment and provide decisions on the nutrition status.
Nutritionist	The nutritionist will work at the health center and will also login to the system to view the available children captured. The nutritionist will be able to edit the existing details and re-assess the child to show the nutrition status. If the child is not manageable at the health facility then the nutritionist will use the system to notify the nutrition support center. The system will also provide a follow-up functionality of the child sent to the nutrition center. The nutritionist will be able to give feeding recommendations to the child with the use of the system especially for those that are manageable at the health center.
System	The system will then perform automatic assessment basing on the captured details by the VHT, the system will then display the nutrition status whether the child is malnourished or not. The system also provides feeding recommendations that are pre-programmed in the system. The system will also support the nutritionist in sending referral notifications and follow-ups.

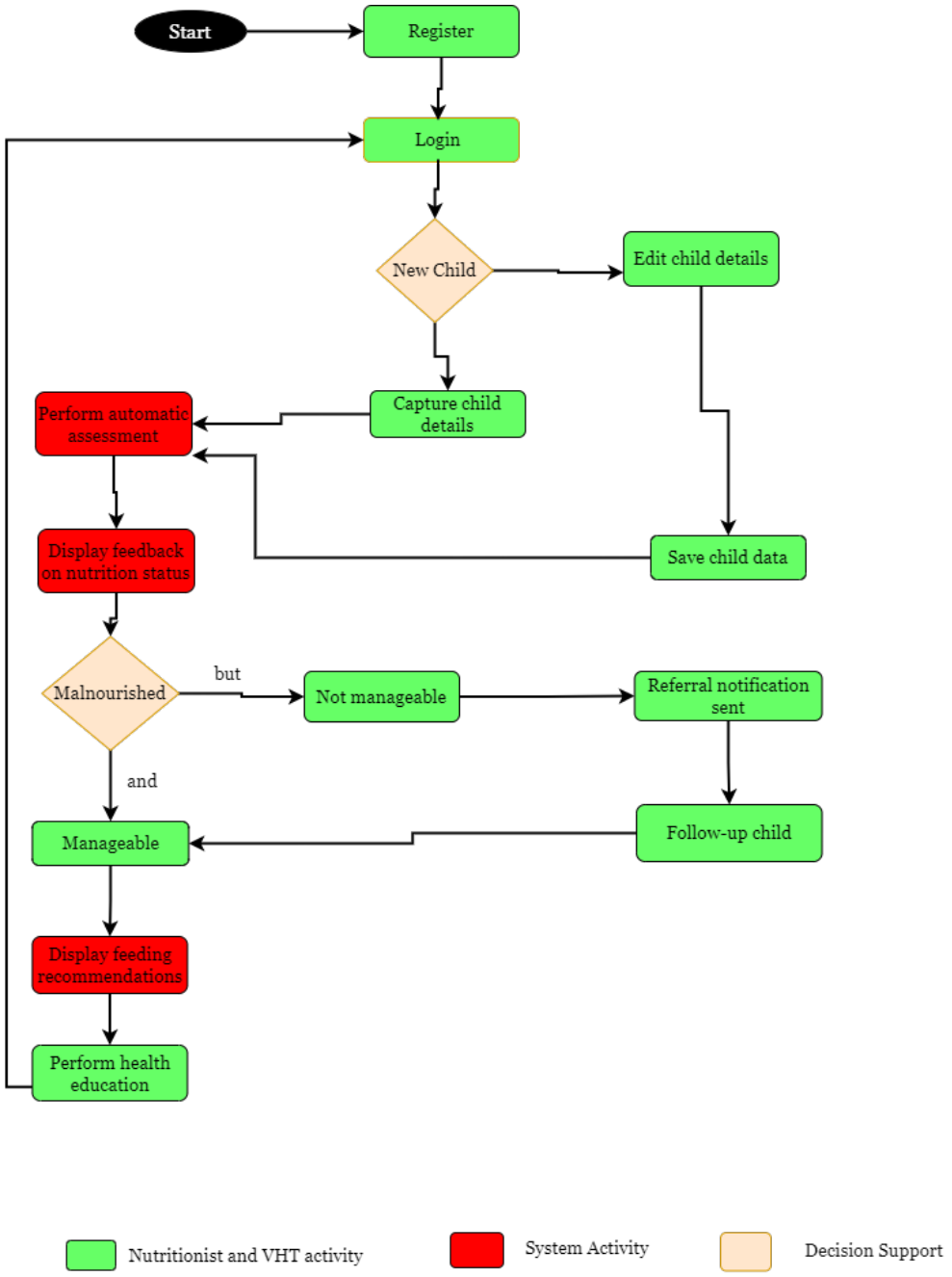


Figure 3.12: Activity diagram showing the work flow process of the system

Nutrition data representation

Data required during the nutrition assessment and the functioning of the system was retrieved from the Ministry of health nutrition manual in relation to the patients records at the health center. The data was captured for different entities like the nutritionist,village health team, child and the assessment details. This information was used to come up with a data representation that was used to design the prototype for nutrition assessment. The assessment of the child is based mostly on the weight, height,age, muac and the calculated_bmi

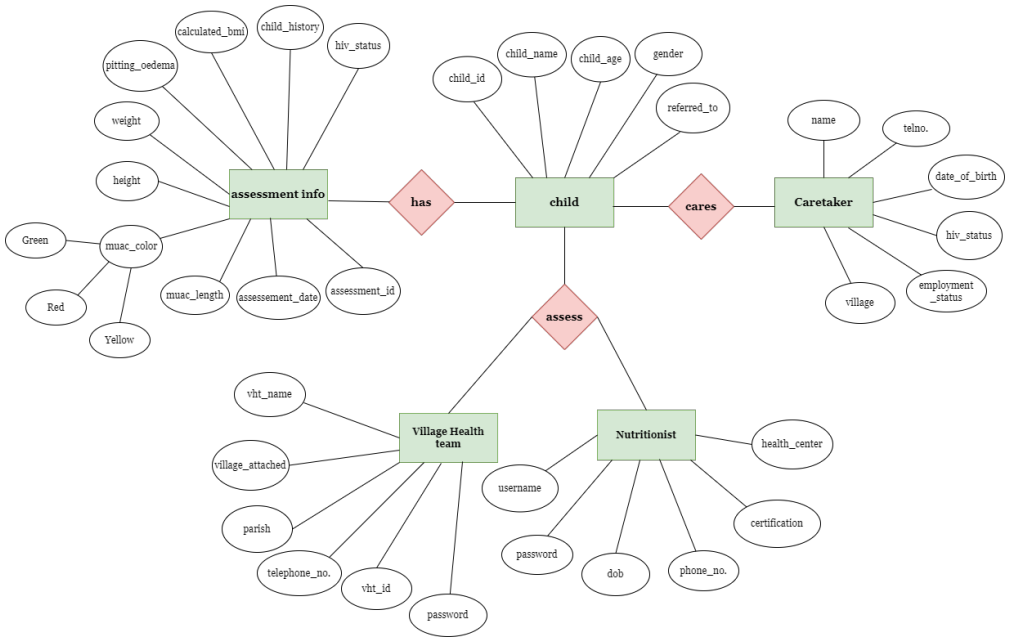


Figure 3.13: Data model representing the entities,relationships and attributes

to provide the final nutrition status.
The body mass index(bmi) is calculated as $\frac{weight(kg)}{height(m^2)}$

3.3.2 Data collection Methods

During data gathering,we have reviewed existing documents about nutrition assessment especially the HMIS manual (MOH, 2017) that was drafted by the Ministry of Health in Uganda to identify the different objects that are required for the system. In addition we had an interview with the expert at the health center who works in the data department to allow us access to the secondary data that was captured during the previous project. In this thesis we engaged the nutritionist through remote interviews on phone to get the information on how the families receive their feedback on the nutrition status of the child after assessment. Also identifying the different information that is required by these families.

3.3.3 Software and Hardware

The system will run on android as an operating system on the mobile phones using android version 4.5 and above for easy running of the tasks and also improve system performance. Mobile phones that can connect to the internet will be used for the application. The back-end of the application will be

implemented using Android platform in the Android studio development environment, using java programming language.Android programming is the most popular used for developing mobile applications and android phones are readily available around the world that is one of the reason the first draft of the application was proposed for this technique.

3.3.4 Participants

The project looked at staff of Child and Family medical center and VHTs, the VHTs are also attached to the health facility located in Kawempe division. These participants were invited through emails and watsapp messages also announcements on community health days at the facility for example when VHTs come for community training and community outreaches but we were not able to get the VHT due to limitation of time.The participants who showed interest were provided with the prototype of the decision support system and helped us get feedback on the usability of the system and how to improve nutrition health care.Questionnaires were distributed to the participants at the beginning and end of the session for feedback. Before getting feedback each participant had to sign a consent form which authorizes the collection of such information. The project worked with CFU medical center to provide secondary data that was already collected from the families and this was also used to come up with the high fidelity prototype system. The health workers at the facility like nurses,nutritionists and doctors also participated in the evaluation of the system design to provide feedback on how it can be improved to help on nutrition health care at the health center.

3.3.5 Prototyping and Mockups

Prototyping is the activity of creating a representation of a final product but with the most of the features that meet the user requirements.A prototype helped us in evaluating the importance and value of the mobile decision support system by taking it to the people and getting feedback from them on how the final product can be implemented. In this thesis a high-fidelity prototype was designed with realistic user interactions. This helped us come-up with a true representation of the user interfaces of the system. The prototype was used

to carryout user experience evaluation in order to measure the efficiency and effectiveness of the system.The prototype allowed us to think through the real solution of the problem we want to address. Figma is the designing software that was used to come up with the high fidelity prototype.

Low Fidelity Prototype

The prototype was designed using draw.io to illustrate the different interfaces that make up the application. The interfaces start with the nutritionist and VHT registering into the system as illustrated in the diagram A.

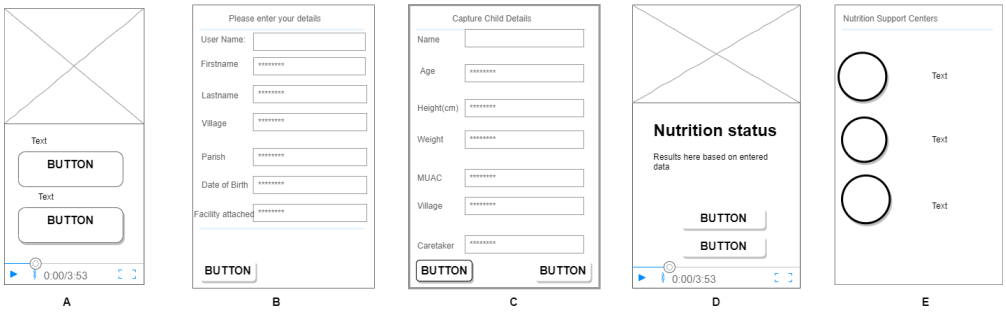


Figure 3.14: Illustrating a low fidelity prototype of the mobile decision support system

In A there are two buttons for Login and Registration, the task of the user is to click the button and then is redirected to B where they enter their details. In C then the details of the child are captured to allow the system assess and display the results as shown in D. In D the nutritionist also has two buttons and the text about the child nutrition status. In E we display the available nutrition support centers where the child can be referred if he/she is not manageable at the health center.

High Fidelity Prototype

A computer based prototype was developed using Figma to show the different interactions between the users and the system. The high fidelity prototype also helped in the evaluation of the usability of the application with the users. Figma was used because of its ability to allow iteration in the design and collaboration interms of team supervision.

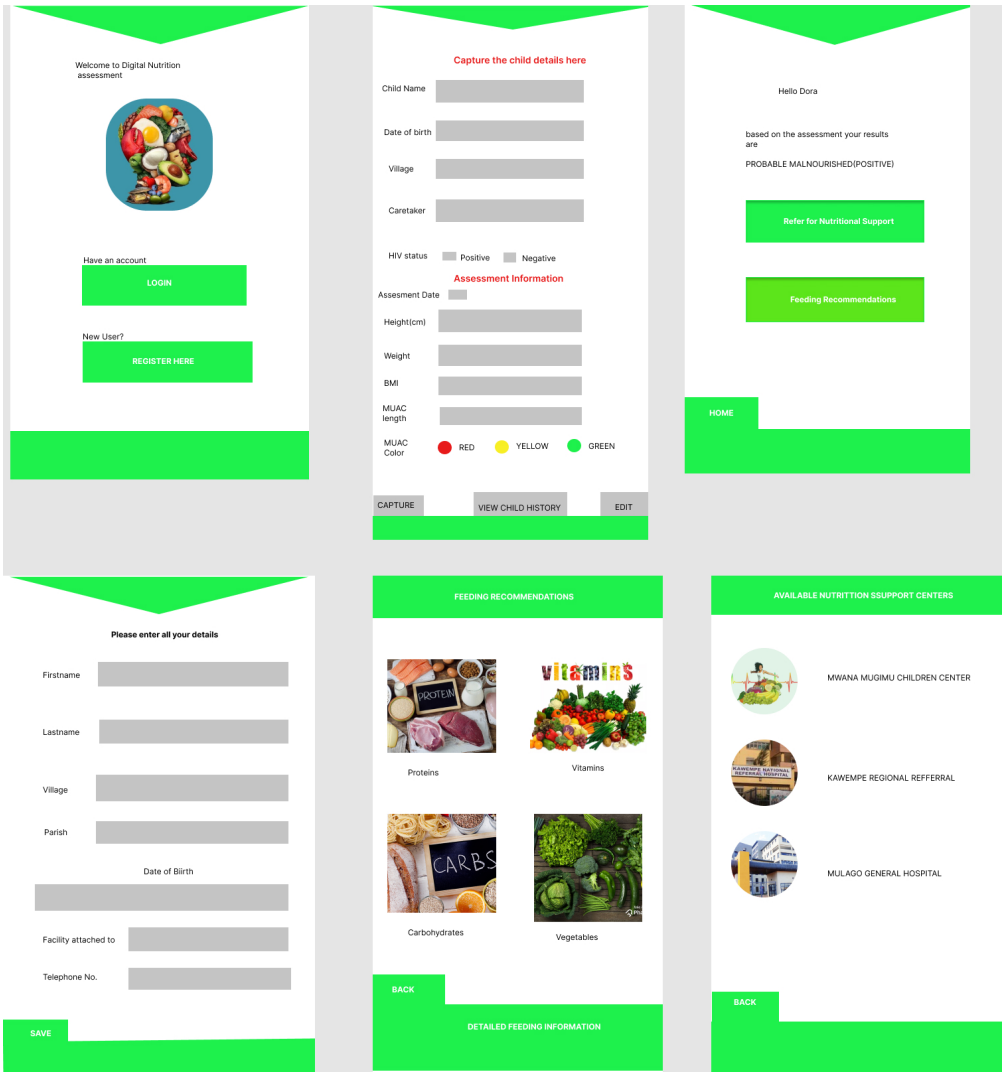


Figure 3.15: Illustrating a high fidelity prototype designed using Figma

Story map

The figure 3.15 shows how the navigation takes place on the different interfaces of the system. The process starts with the user registering into the application. This information is stored and he/she can login to the application on second visit. After registration, the details of the child are captured and also saved within the system. This information is then used in the back-end to come-up with the nutrition status of the child. The nutritionist/VHT will also have two buttons for referral to a health facility or for feeding recommendations. Then the child will either be given feeding recommendations on the system or referred to a nearby nutrition support center.

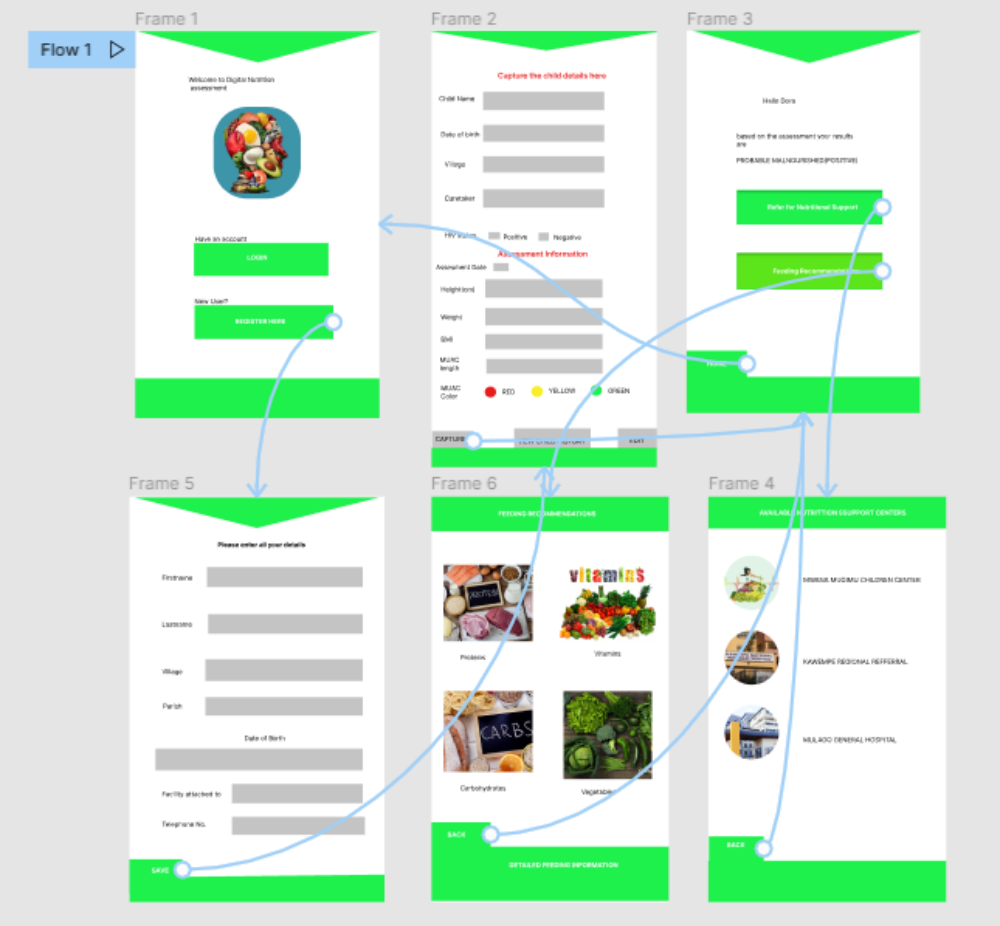


Figure 3.16: Illustrating the navigation of the system

How Decision making is Supported

This section describes the different parameters that are considered for the system to perform decisions on behalf of the user. (Permatasari et al., 2017) describes a how to use fuzzy systems and rules to come-up with decisions in a nutrition assessment decision support system.This literature was used to understand how fuzzy logic can be applied in future implementation of the decision support system. In this thesis we looked at the information provided by the Ministry of Health IMAM guidelines(The Uganda Ministry of Health, 2018) and the (MOH, 2017) to guide us in understanding how malnutrition is measured especially among children hence allow application of the fuzzy logic in the future implementations. Currently the health facilities are using this information to provide nutrition status and feeding recommendations without a clear system to support the decisions. The decision making is based on body measurements like the Mid-Upper Arm Circumference(MUAC) , body weight,height or length, oedema in consideration of bilateral pitting which leaves a depression

on pressure applied for at least 3-5 seconds. The Ministry of health describes an algorithm that is followed in measuring acute malnutrition, this helped this research understand the different ranges that are considered while coming up with final decisions.

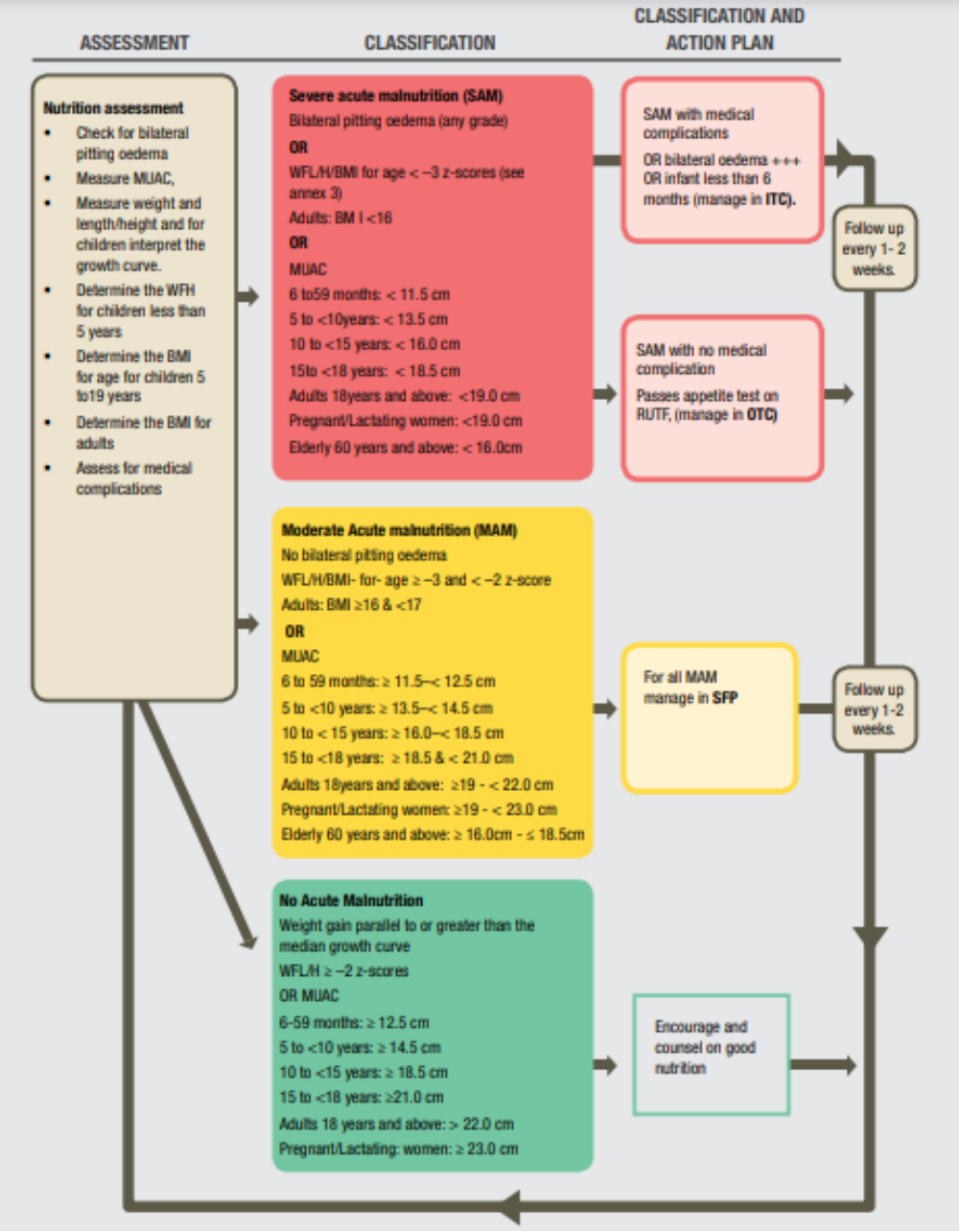


Figure 3.17: Summary of the Nutrition Assessment and Classification of Acute Malnutrition Algorithm by The Uganda Ministry of Health, 2018

3.3.6 User test plan

In the scope of testing the mobile application, the focus was on user interface and the different data that is collected by the application. The project also fo-

cused on how users navigate through the system while carrying out their tasks. This in turn was used to measure the efficiency of the application in terms of meeting the user requirements. We also tested whether the users can easily find information they require on the mobile application. For example the main focus was on the Village health teams being able to capture all the required information from the families and this information was also easy to edit and hence give recommendations. These concerns were mainly focused on the scenarios that were identified for the system. The test was planned to be online since most of the users of the application are located in Uganda. The mode of communication to request for testing was the use of emails and social media platforms like watsapp. The participant requirement was planned to be done by the biostatistician who was the focal person at the health center during the project testing. The nurses,doctors, lab technicians and the administrators at the health center were used as the test participants. In the recruitment process emails were sent out to them about the project testing. At first an interview with the focal person at the health facility was done to explain whether the system meets the objectives of the users. This helped in gathering qualitative data that helped in coming up with the results. Among the equipment used was a laptop and a mobile device that connects to the internet. The scenarios presented above were used to check whether the system really has all the features that are required for the assessment to be successful.

3.3.7 User testing

User testing of the prototype was done remotely where the focal person at the health center worked as the mobiliser for the nurses,doctors and nutritionist to try out the design and give feedbacks. Scenarios were used to show the users what the prototype wants to achieve. The prototype was explained in terms of what the Village health team needs to capture all the data and also how the system can support in the decision making. The users were tasked to register, capture child details, give feeding recommendations and also refer a child to the nearest nutrition support center. We used a purposive sampling technique where the staff at the health facility were chosen to take part in the testing process because of the limitted time that was available for data collection.

3.4 Evaluation

The Likert scale and the system usability scale(SUS) were used to come up with qualitative feedback from the users about the prototype that was shared. The goal of the evaluation was to findout whether the designed prototype meets the objectives of the stakeholders and it is easy to use, learn and carryout the decision support.The questions were shared by email and the designed prototype in Figma was shared on watsapp. During the usability evaluation the user test plan was used to evaluate 5-10 users to participate in the evaluation of the system prototype. The evaluation allowed us understand the effectiveness and Efficiency of the system designed prototype. Design science research allows for an iterative approach therefore after evaluation and getting feedback a re-design is proposed before the actual implementation. The project was also presented in a workshop organised by the university of Rwanda to get feedback on how we can best design the decision support system. To evaluate the efficacy and feasibility of the project feedback from experts in the field of research who participated in the workshop were able to give feedback. The feedback will be used for further implementation of the designed prototype.

3.4.1 Summary of methods

This section briefly explains how the different research questions were answered and the different output from the study. This is shown in a summarised table shown below. In this thesis a set of three research questions were focused on to help the study solve the problem.

Research Question 1. What is the current nutrition assessment process and follow-up process? of malnourished children at village level? In the initial stages of the study to understand the current nutrition assessment process a meeting was conducted on zoom with the biostatistician and the program officer at the health center. This is because they were part of the project that was initiated by UNICEF in Uganda in parternship with FHI360 to integrate nutrition screening and assessment at the community level. This meeting help us understand the current process that is used to identify the children and also carryout assessment up to the time of referral to the health facility. Questions

around data capturing and storage were also asked. In this meeting it was noted that the health facility uses REDCAP as a tool for data collection and the VHTs have to report monthly to the health facility about the families they have visited. To make it easy for the VHTs to capture data in real time and also make decisions that why this thesis looked at coming up with a mobile nutrition assessment prototype to support decision making.

Research Question 2. How can the nutrition assessment process be improved by designing and developing a decision support system at a village level?

To get an insight on the validity of this question, a prototype was designed and feedback was got from the end-users. A small sample of 7 participants were used to test the usability of the system. However this being done remotely we could not get a clear picture of how the users feel about the system. The collected data showed that the system will be useful in terms of real time data capture at the the village level. The questionnaire distributed was not able to capture the decision making support required by the users of the prototype. Re-designing the prototype and sharing it with a more large sample of participants especially the VHTs and families would give more valid results in terms of usability.

Research Question 3. How can the decision support system help in referral and follow-up of malnourished children through recommendations?

Discussion with the VHTs and mothers to understand how to support the referral and follow-up helped us get feedback. The VHTs encouraged a system having notification messages to show whether the mother has reached the facility and also an electronic referral note that can be seen by the nutritionist at the health facility.

Table 3.3: A table showing a summary of methods used to answer the research questions of the study

Research Question	**Methods Used**	**Output**	**Participants**
RQ1	Document review analysis, Interviews	Requirements Specification	Nutritionist, Biostatistician,Program Officer
RQ2	Prototyping	Low and high fidelity Prototype	Nurses, Doctors, Nutritionist,Lab technicians, Biostatistician
RQ3	Focus group discussions Semi-structured interviews	Proposed process model	VHTs, Caretakers, Nutritionist

Chapter 4

Demonstration and Discussions

In this section we discuss how the proposed nutrition process model and the designed prototype were demonstrated to the users and other stakeholders. It describes the different methods used in evaluating the process and a summary of the findings from the evaluation.

4.0.1 The proposed nutrition assessment process

In chapter 2 we discussed a proposed nutrition assessment process that incorporates the electronic data capture and decision making at the village level. Here we describe the methods and a summary of findings from the focus group interviews.To evaluate the user acceptance of the proposed process,in this thesis we worked with the data person at the health facility to act as a research assistant to help in mobilizing the village health team(VHTs), the nutritionists, the nurses and the families. The research assistant suggested focus group discussions because normally it saves time compared to having a one on one interview.

The Focus Group Discussions

In the interview process we looked at some of the different methods available for performing the interviews.The mobilization started with him calling the VHT co-ordinator(Nyirabuntu Robinah) who works closely with the health facility and introduced the study to her.A purposeful method of sampling in qualitative research the snow ball(Allen, 2017) was then applied where the VHT coordinator helped to recruit other study participants.After recruitment a meeting was organised at one of the VHTs residence where the mothers and other VHTs gathered on 17th May 2022. The Research assistant then introduced himself

the purpose of the study to the participants and asked for consent to record and take pictures, then the participants were able to sign the consent form which is attached in the appendix section. The research assistant introduced the proposed process plus the designed prototype but the focus was more on process. In the initial interview plan a meeting with the data person at the health facility was conducted to come-up with a focus group interview guide and also plan how the VHTs and some mothers can be mobilised in one place to carryout the interview. The thesis applied a guide by Carson et al., 2011 to come up with a plan for the focus groups, in the health facility mobilization was done by the moderator or research assistant who organized the VHTs in groups. The VHTs normally attend the community training at the health center, this opportunity was used to help us communicate the model and get feedback from the VHTs.

Summary of Feedback from Focus Group Interviews

During the VHTs appreciated the proposal of moving from a papaerbased approach for nutrition assessment to a digital solution which is also mobile and assessment can be done anywhere at anytime. The VHTs recommended that the system should also consider collecting all data related to children in different zones plus also including an interconnection between different health facilities in Uganda to allow mothers get services smoothly at any health facility nearby. They also emphasized bridging the gap between the health facility and the community, recommended that the proposed system should consider adding notifications that alert the VHTs incase a child has been recieved and treated at the health facility. The VHTs appreciated the proposed process for quick data capture and synchronisation to the health facility which saves alot of time for both the mothers and the VHTs. They agreed that the system should be able to communicate direct to the Ministry of health for proper planning for example one VHTS talked about a surveillance application that they use in the community for immunisation alerts to the ministry which helped a child who was later identified with measles and had to be immunised. This in-turn improved on the communication between the government and the community level workers. The VHTs also talked about the system improving on efficiency

in a way that the accounts will be created for each user who logs in and it will be easy to monitor their performance as they work in the communities. This will help improve service delivery. The VHTs and mothers recommend the system also having the child previous history for example immunisation,measles,HIV status among others so that it is very easy to understand the underlying conditions before assessing for malnutrition.

4.0.2 The Designed Prototype

This section describes the process of demonstrating the designed prototype and the different methods that were used to get feedback from the participants. The study focused more on the qualitative methods of data collection and this section describes the results from this evaluation.

In the demonstration stage we started by recruiting the participants who are the health workers at the facility. Through the person responsible for the data at the facility, snow balling was applied and we were able to get emails of the participants. Most of the discussions were done online using watsapp calls and messaging.Emails with the link to the application design were shared and users were able to interact with it to share feedback in return. The focal person at the facility helped as the user research assistant to persuade and recruit the participants and also explaining the intentions of the study. After sharing the design of the application an explanation was required for some participants on how the application will work. All discussions were done using whatsapp platform using audio and message recordings.The participants were able to send out their feedback and later also participated in filling out the questionnaire that was shared with them through emails. For the evaluation of the designed prototype the plan was for 5-10 users and we managed to get feedback from 7 participants. After distributing questionnaires through email and also giving guidance through watsapp calls and messaging feedback on the design was received from 7 participants.

Results for the designed prototype

In the feedback we used the Likert scale options where we had strongly agree, agree, strongly disagree, disagree and the responses are as below.
Question 1; The interface of the application is userfriendly

One of the goals of user evaluation was to findout whether the designed prototype was user friendly to the users.The below figure... shows the results from the participants.

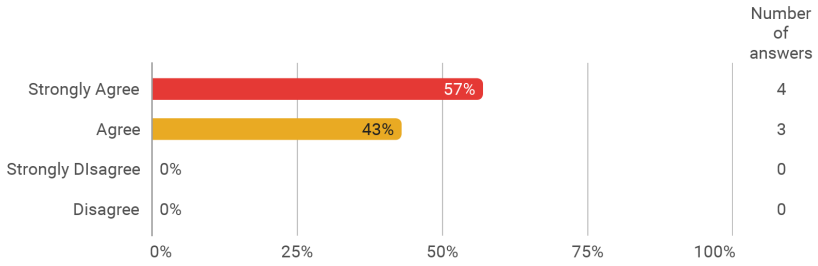


Figure 4.1: Feedback from qestion 1

Question 2; The application design is easy to navigate
In this thesis we also wanted to findout the navigation on the designed prototype. The figure 4.2 shows the feedbacks

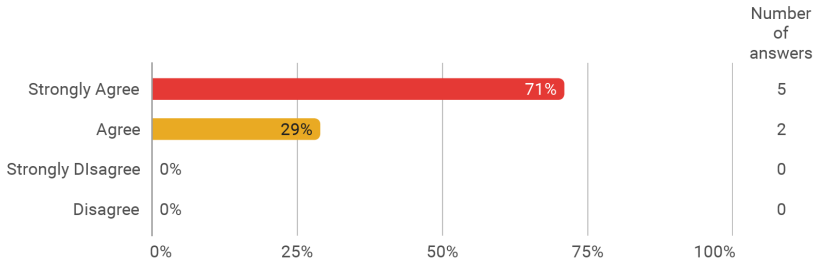


Figure 4.2: Feedback from question 2

Question 3; The application has pleasing color scheme. To understand the emotional impact of the interface color scheme to the participants feedback was also requested since different colors have different meanings on the design.

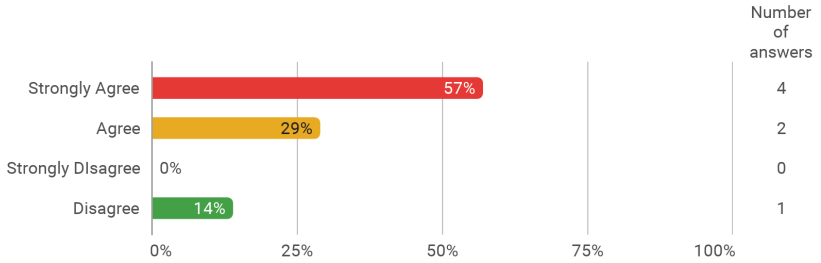


Figure 4.3: Feedback from question 3

Question 4; There is too much inconsistency in this system.

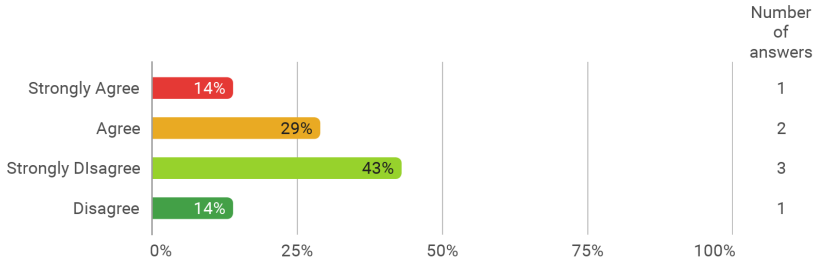


Figure 4.4: Feedback from question 4

Question 5; I need the support of a technical person to be able to use this system design.

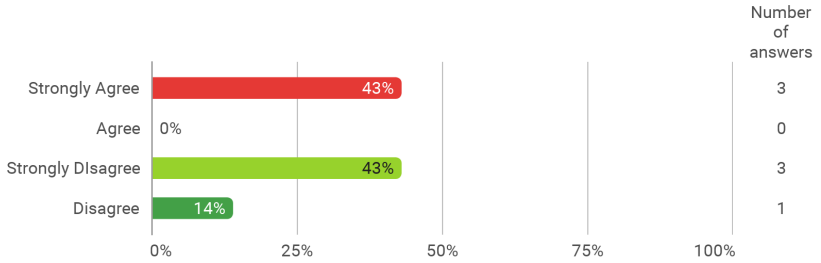


Figure 4.5: Feedback from question 5

Question 6;The designed prototype is easy to use

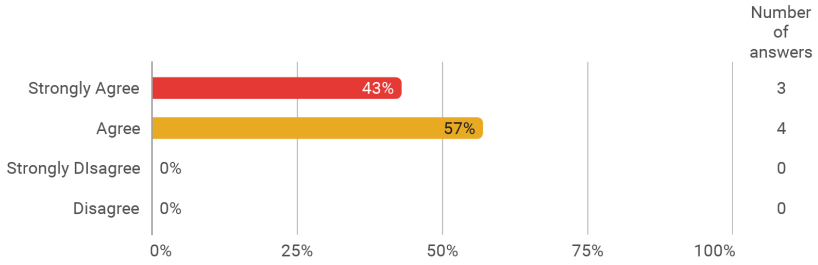


Figure 4.6: Feedback from question 6

Question 7;The application reduces the time taken during nutrition assessment

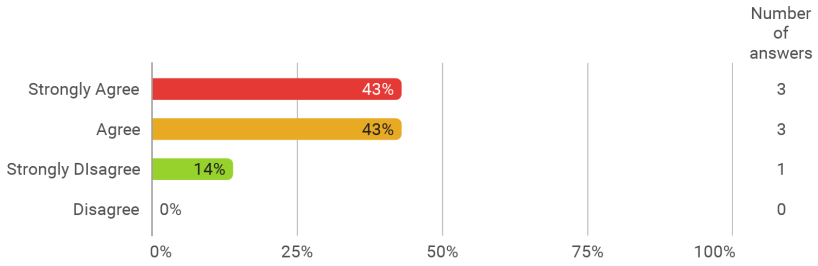


Figure 4.7: Feedback from question 7

Question 8;It is very easy to find information on the designed prototype. In this question we wanted to understand the usability in terms of how to improve the interface such that users are able to find all the information in terms of nutrition assessment.

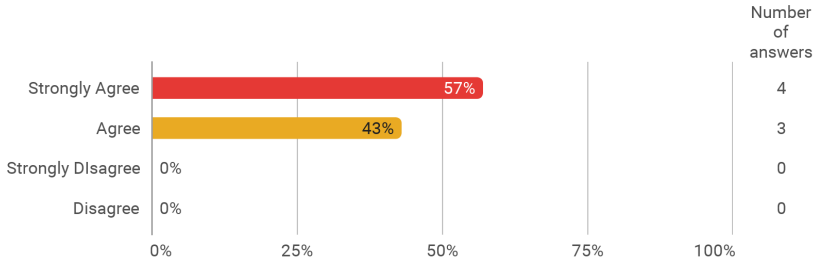


Figure 4.8: Feedback from question 8

For more and direct feedback from the users open-ended questions were also asked.The participants were able to put in their views about the design whether it meets their needs.

Open ended Question 1; What do you think should be improved in the designed prototype? The participants commented on the colors that were used on the interface for more favourable colors that favor their vision. The participants also commented on adding more other parameters like, Height, Weight/height or length and Z-Score,BMI and these were added in the second iteration of the design. A participant was concerned about the data quality checks within the system and also including numerous information representation formats.

Open ended Question 2; Is there anything you would like to comment on the current nutrition assessment process? The participants gave feedback on the application being able to help in real time data capture and helps in guiding program decisions. They also gave feedback on assessing for under nutrition and neglecting over nutrition which is assessed using BMI,instead of concentrating on weight and MUAC The participants also gave feedback on the age to be disaggregated into those less than 2yrs (reported in months) and above 2yrs reported in years and this was noted for implementation in the next iteration of the prototype.

Chapter 5

Limitations and future work

5.0.1 Limitations

The major limitation that affected the completion of the project is the time available to do the writing,data collection and also prototyping.This also affected the implementation of the project hence coming up with a prototype that shows a simple interaction between the user and the system. In this research the focus was more on the qualitative feedback and yet quantitative is also vital for evaluating the system. In this thesis we could not get alot of participants to give feedback on the design. There was also a limitation of internet connection among the participants in Uganda who were supposed to help in giving the feedback, this slowed the process of data collection. These limitations also led to us narrowing the scope of the project and focusing mainly on the VHTs assessing for nutrition.

5.0.2 Future work

In this thesis, in the first phase of design and development a high fidelity prototype was developed showing the interfaces of the system.In the future work a more working system can be implemented and tested with the different village health workers to solve the community problem. In the recommendations application of food and nutrition ontologies can be applied to come up with a clear decision support system. The application should also show how the nurses and nutritionist will give referrals and also the follow-up process. An investigative study is required to find out how many village health workers can afford smart phones that can be connected to the internet. There is also need

to understand how the data is going to be stored and retrieved within the system, taking into consideration the server specifications and configurations for a smooth implementation of the decision support system.
In the future work the data collection should focus on the VHT who are the end users of the application because in this thesis evaluation was done using the staff at the health center including the nurses,doctors,lab technicians. This is because there was no person to mobilise the VHTs to come for orientation and most of them do not have emails for receiving this information. In more work, the VHTs need to be oriented on how to use a smart phone to install the application and capture all the neccessary data.

Implementation

In this thesis due to limited to time, a high fidelity prototype was designed but it does not clearly show how the implementation. In future work an implementation using ontologies can be considered to help come-up with a set of data objects and classes that can be used to make decisions. The use of nutrition ontologies should be considered in the future work. Applying Apache Jena as an open source Semantic Web framework to help come-up with a web-based system that provides feeding recommendations based on the different objects and classes.This also helps in extracting the data to come up with Resource Description Framework(RDF) graphical representations. The implementation should consider the algorithm that can best be used to help the users in performing decision making especially at the village level. During the focus group discussion, the VHTs were concerned about the system working offline because most villages do not have access to the internet. Therefore in the future implementation an application that can be used in remote areas with no internet will be developed to allow access to all VHTs in villages.

Future Analysis

In this thesis the analysis was done using survey xact to understand the user perspective on the designed system prototype. For future analysis we recommend using thematic analysis especially to understand the feedback from the focus group discussions that were done by the VHTs. More data needs to

collected from the VHTs and the mothers especially through semi-structured interviews to understand effectiveness and efficiency of the proposed nutrition assessment process. In this thesis focus group discussion was carried out and the feedback is discussed in chapter 4 above. In this thesis the focus was mainly on qualitative data therefore thematic analysis therefore it is imperative to understand and learn this qualitative analysis approach(Braun & Clarke, 2006) because it provides core skills that are useful for conducting many other forms of qualitative analyses.

Ethnographic analysis

In future work we recommend applying ethnographic analysis to further understand the design problems for both the prototype and the proposed nutrition process.In this thesis qualitative feedback from the participants was collected in form of interviews from focus groups. Applying this analysis method would help better understand how VHTs work within the communities and also the behaviours of the mothers towards the nutrition assessment process being proposed. In addition since this project involves VHTs using mobile phones, this method would help in understanding the usability of the prototype through observing the different behaviours while doing a mobile nutrition assessment in the communities.

Chapter 6

Conclusions

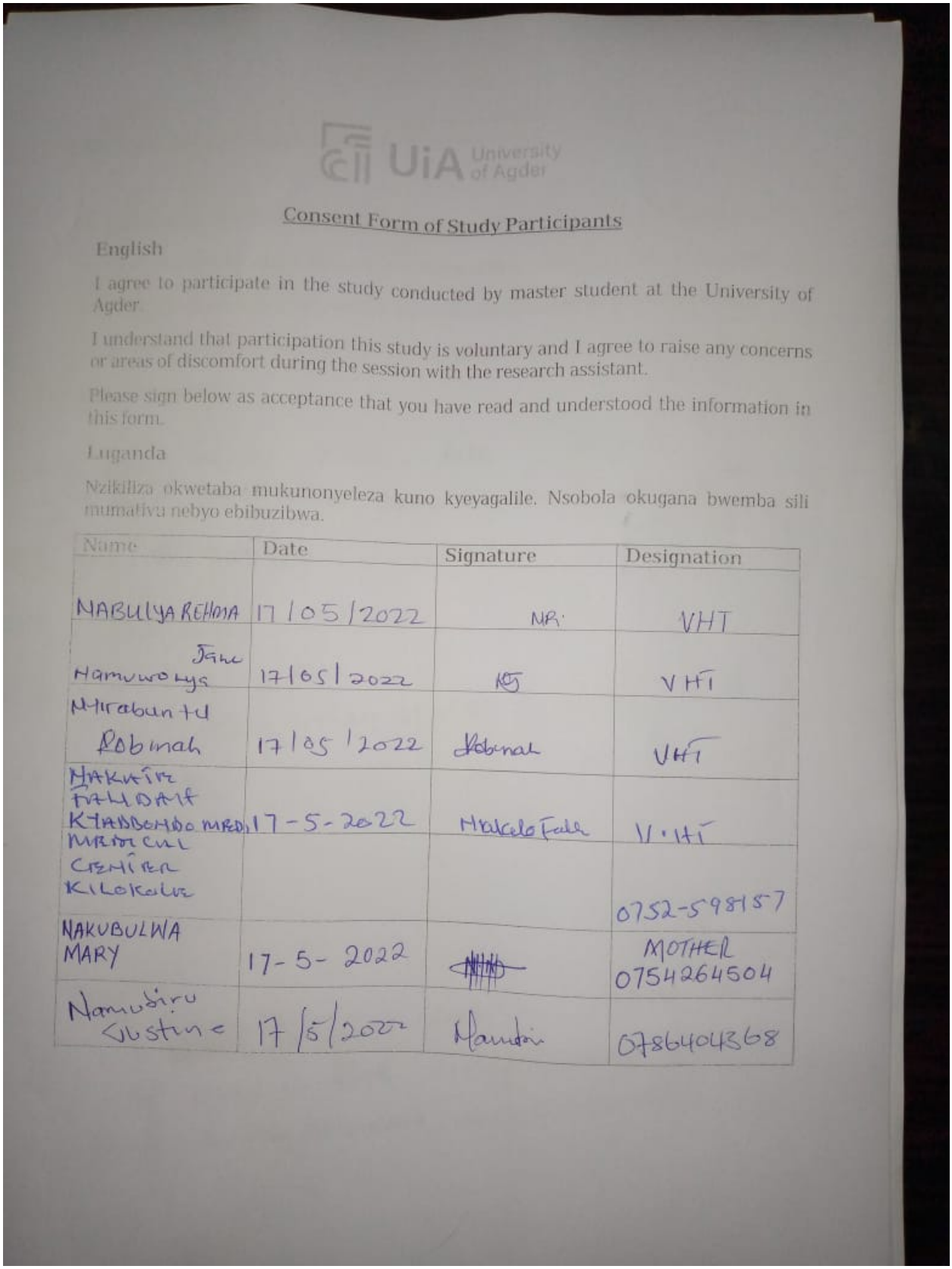
In conclusion, decision support systems are seen to reduce the burden of medical practitioners remembering all the diagnosis that is presented on a certain condition. In previous studies, a lot of decision support systems are mainly for the experts like nurses, doctors among others, in this study we found-out that it is very important to involve the other stakeholders especially at the community level.From the study perspective it can be concluded that the problem of malnutrition can be addressed from the community level where the root cause of the problem is identified.This is why we proposed a decision support system that links the health facilities, government,VHTs and other stakeholders starting at the village level in a bottom-up approach to support decision making. This is because there is a centralised way of managing data and decisions are made basing on all the necessary parameters. In this study, the VHTs perspective about the solution was very important and during the discussion with them we found-out that they are willing to learn the use of technology to solve the health challenges in their communities. In this study we found-out that mobile decision support systems have been widely used in dietary assessment and giving feeding recommendations.

Appendix A

Datasheet A

Link to survey questionnaire;
https://www.survey-xact.no/LinkCollector?key=8365MNNFJ19N
Prototype designs in Figma;
https://www.figma.com/proto/DZ1tLyFeuKiHzIjQvYUPTc/Untitled?node-id=40%3A 47&scaling=scale-down&page-id=0%3A1&starting-point-node-id=40%3A47

A.0.1 Consent form



UiA University of Agder

Consent Form of Study Participants

English

I agree to participate in the study conducted by master student at the University of Agder.

I understand that participation this study is voluntary and I agree to raise any concerns or areas of discomfort during the session with the research assistant.

Please sign below as acceptance that you have read and understood the information in this form.

Luganda

Nzikiliza okwetaba mukunonyeleza kuno kyeyagalile. Nsobola okugana bwemba sili mumativa nebyo ebibuzibwa.

Name	Date	Signature	Designation
NABULYA REHMA	17/05/2022	NR	VHT
Namwanya Jane	17/05/2022	KJ	VHT
Nkirabuntu Robinah	17/05/2022	Robinah	VHT
NAKATIM HALIMA KYABBOMBO MARIAM	17-5-2022	Nakatim Halima	VHT
CHEMIER KILOKOLO			0752-598157
NAKUBULWA MARY	17-5-2022	[illegible]	MOTHER 0754264504
Namubiru Justine	17/5/2022	Namubiru	0786404368

Figure A.1: Consent form

Focus group interview Guide

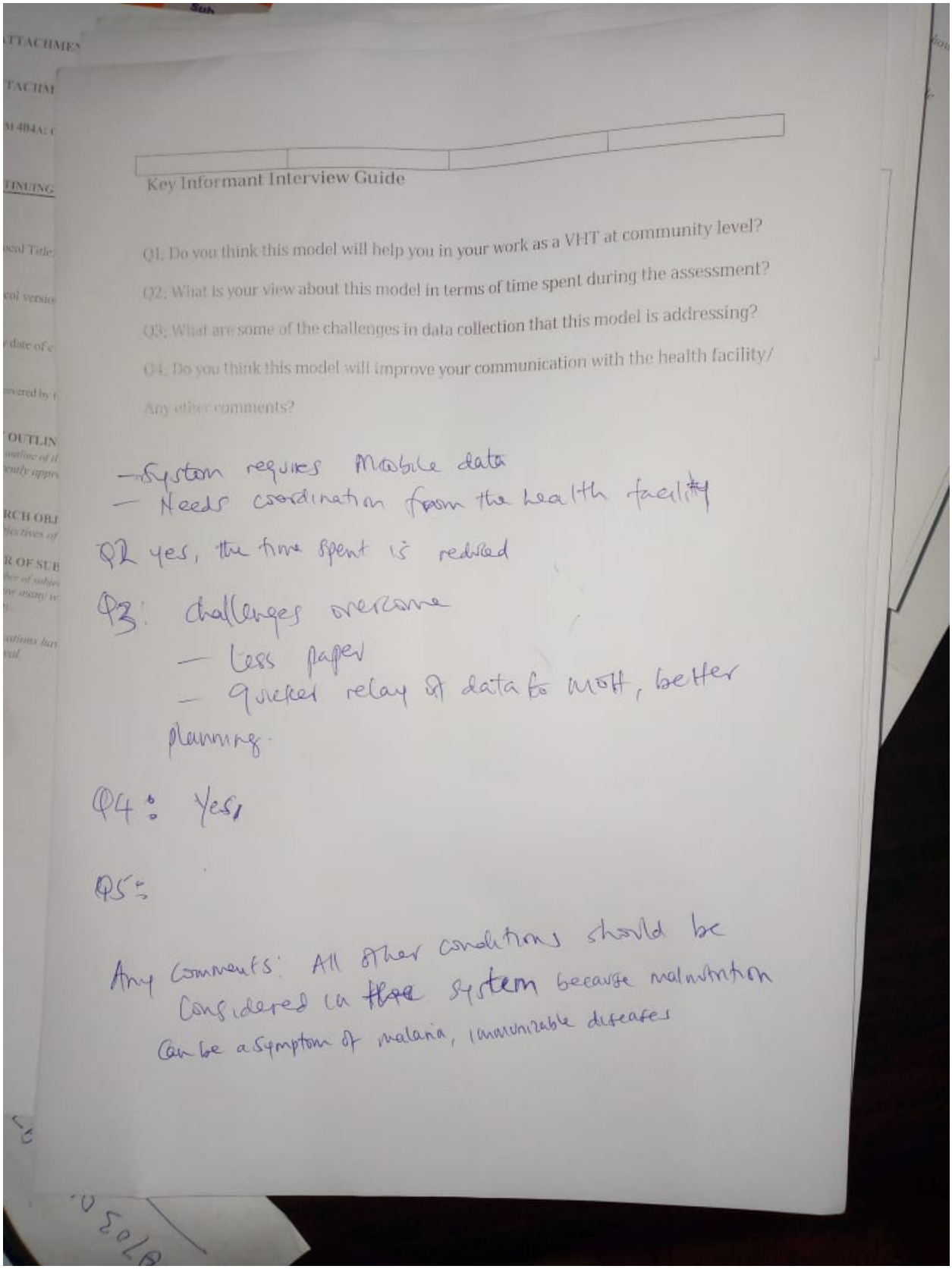


Figure A.2: Focus group interview guide

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