UNIVERSITY of RWANDA

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Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

Design and Development of Mobile app for Maintenance of Medical Equipment

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A Dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfilment of the requirements for the Master's Degree in Biomedical Engineering.

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DECLARATION

I, HATEGEKIMANA James, declare that this dissertation entitled **“Design and Development of Mobile app for Maintenance of Medical Equipment”** is my original work based on research, design and development and has not been submitted for any other degree or professional qualification.

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CERTIFICATE

This is to certify that the project entitled "**Design and development of mobile app for maintenance of medical equipment**" is a record of original work done by HATEGEKIMANA James (Reference number: **221028517**), a MSc. Degree student in Biomedical Engineering.

This work has been submitted under the guidance of **Assoc. Prof. Damien HANYURWIMFURA** and **Dr. Louis SIBOMANA**.

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ABSTRACT

All over the world, biomedical technology is advancing as fast as possible, African countries are playing a great role in the advancement of the biomedical engineering field hence improving the healthcare sector. Rwanda is a developing East African country that aims to reach Upper Middle-Income Country (UMIC) by 2035 and High-Income Country (HIMC) by 2050. The government implemented a variety of techniques to achieve the SDG (Sustainable Developing Goals) goals of improving population health. Public health facilities in Rwanda are more than 500 Health centers, 45 District hospitals, 6 Referral Hospitals, and 4 Provincial Hospitals located throughout the province. Technology has played a significant role in the evolution of medicine to increase healthcare quality. Medical equipment plays a key role in health service delivery. To ensure the lifetime of medical equipment, regular maintenance should be put in place. Biomedical technicians in the hospital do need a tool that could facilitate them in troubleshooting and repair of medical equipment in order to boost the quality of maintenance. The adoption of a mobile application would help alleviate the problem of unrepaired medical equipment held in hospitals across the country. This project aims to design and develop a mobile application "**Mobile-MERS**" (Medical Equipment Repair System) that will help to optimize the maintenance of medical equipment specifically for equipment, which does not have a service maintenance contract. Six Biomedical technicians from three selected hospitals participated in this study, especially as a testing team. Cloud-based mobile app technology was used to design this project. The use of the Mobile-MERS app will reduce the number of broken-down equipment in the hospital. This work provides a variety of solutions to the underlying threat of unstable medical equipment; therefore health facilities and private companies are advised to use this tool to lift up the quality of healthcare.

Keywords: Mobile application; Biomedical technician (BMET); maintenance contract, medical equipment, healthcare.

LIST OF ACRONYMS

API	Application Programming Interface
BMET	Biomedical Technician
CBM	Condition-Based Maintenance
CE	Clinical Engineering
CEBE	Center Of Excellence in Biomedical Engineering and E-Health
CHUK	University Teaching Hospital of Kigali
CM	Curative Maintenance
CMMS	Computerized Maintenance Management System
ECRI	Emergency Care Research Institute
EMR	Electronic Medical Record
EWH	Engineering World Health
GSM	Global System for Mobile Communication
HIC	High-Income Country
HTM	Healthcare Technology Management
IPM	Inspection Preventive Maintenance
IPRC	Integrated Polytechnic Rwanda College
IT	Information Technology
LMICs	Low and Middle-Income Countries
LMIS	Logistic Management Information System
LUMIS	Land Used Management Information System
MDGs	Millennium Development Goals
MEMMS	Medical Equipment Management and Maintenance System
MERS	Medical Equipment Repair System
MIS	Management Information System
MOH	Ministry of Health
MTD	Medical Technology Division
OTP	One-Time Password
PM	Preventive Maintenance
RBC	Rwanda Biomedical Center
RBM	Risk-Based Maintenance
RCM	Reliable-Centered Maintenance
ROI	Return of Investment
SM	Scheduled Maintenance
SMS	Short Messaging Service
SPI	Safety and Performance Inspection
UMIC	Upper-Middle Income Country
UR	University of Rwanda
WHO	World Health Organization

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CHAPTER 1. GENERAL INTRODUCTION

1.1 Introduction

Medical equipment maintenance is an important part of healthcare technology management to ensure equipment stability, user and patient safety. Medical equipment, unlike other forms of healthcare innovations (such as medications, implants, and disposable products), requires scheduled (Inspection preventive maintenance) and unscheduled (corrective maintenance) maintenance throughout its useful life [1]. Maintenance that is well planned and coordinated helps the government save money on medical equipment while also ensuring the health system's ROI (Return on Investment).

According to the World Health Organization (WHO), 50–70% of all biomedical equipment in low- and middle-income countries (LMICs) is partially or entirely nonfunctional [1]. The majority of hospital-affiliated technicians in LMICs lack formal training in biomedical equipment repair. The research from Engineering World Health (EWH), a nonprofit organization that mobilizes the biomedical engineering community to improve health care in the developing world, has shown that 66 percent of all equipment failures can be fixed with simple generalizable technician skills without the use of spare parts [2]. The root of the problem is that many of these technicians have never been taught solving problems in a methodical way [3].

Maintenance of medical equipment is getting increasingly expensive for hospitals, and it is routinely outsourced. Its effectiveness is crucial to the overall delivery of healthcare. In 1996, service contracts brought in more than US$ 10 billion; by 2015, they had grown to US$ 42.6 billion, suggesting continued growth [4] and 70-90 percent of donated equipment is never used [5]. According to one estimate of functioning equipment in Sub-Saharan Africa, at least 40% of medical equipment is out of service, while other research claim 50-80% [6].

In Rwanda's health system, 54% of hospital equipment do not have outsourced service maintenance contract [26]. The implementation of computerized maintenance management systems like MEMMS (Medical Equipment Management and Maintenance System) signaled the beginning of better healthcare technology management. However, MEMMS's implementation in Rwanda's public health institutions to manage and maintain medical equipment is limited only to inventory management, IPM (Inspection Preventive Maintenance) management, spare part management, and reporting systems. The system does not provide technical assistance to biomedical technicians/engineers working in various hospitals throughout the maintenance procedure of medical equipment. The introduction of a mobile application will help to optimize management and maintenance of medical and non-medical equipment in Health facilities. The app will provide a series of repair guides (on specific equipment) that will guide hospital biomedical technician to troubleshoot and repair the equipment and therefore the number of broken down equipment will reduce.

1.2 Problem statement

The Rwandan Ministry of Health (MOH) has emphasized the critical need for a functioning environment in which public sector medical staff can do their tasks in order to provide improved health services to Rwandans. In this sense, a functioning environment refers to the physical structure of the hospital buildings as well as the available (bio) medical and electromechanical equipment. According to the World Health Organization (WHO), at least 40% of medical equipment in underdeveloped nations is no longer functional and there not in use [7]

A recent study carried out by AMPC/INTERNATIONAL HEALTH CONSULTANTS in Rwanda Public hospitals, showed that 33% of medical equipment in the hospital were not functional [26]. The main cause of equipment failure is power supply failure, and other reasons were not known according to this assessment due to the low skills of Biomedical technicians to identify, diagnose and confirm the root causes of the equipment failure [8][26].

The Ministry of Health purchases a large amount of medical equipment for public hospitals, with an average value of 0.6 billion Rwandan Francs per health facility in 2016 [26] [8]. However, one Biomedical Technician with an advanced diploma in Biomedical Engineering is assigned to manage all brands of medical equipment in the facility. This explains the large number of faulty machines in all health facilities around the country. Despite various initiatives such as the introduction of MEMMS (Medical Equipment Management and Maintenance System) and the opening of a Biomedical Engineering option at IPRC Kigali, still there are rising complaints related to non-functional equipment, unskilled biomedical technicians, and insufficient number of biomedical technician per hospital. In addition, the trained biomedical technician is not enough to support all brands of medical equipment with various technologies. To address this gap, the introduction of a mobile application to guide and assist biomedical technicians in troubleshooting, repairing, and maintaining biomedical equipment will help biomedical technicians through repairing process and improve the quality of health care delivery by minimizing equipment downtime [9].

1.3 Research Questions (Hypotheses)

The following five questions are the baselines, which guided this study:

1. How will we design a mobile application that will improve the maintenance of medical equipment?
2. How will the app help to equip BMET with knowledge and hands-on skills to maintain medical equipment in hospital settings?
3. How to validate the developed mobile app for effective and efficient management of equipment?
4. How will technician know if equipment has hardware issues or hardware?

1.4 Objectives

1.4.1 General Objective

This project aims to design and development of mobile app for the improved maintenance of medical equipment without a maintenance contract.

1.4.2 Specific Objectives

To achieve the general objective of this project, the following specific objectives are used as guiding points.

1. To design a mobile application that will improve maintenance of medical equipment.
2. To develop a mobile app that will help to equip BMET with knowledge and hands-on skills to maintain medical equipment in hospital settings.
3. To test mobile medical equipment repair application in its fully functionalities.
4. To validate the developed mobile app for effective and efficient management of equipment.

1.5 Study Scope

This work intended to design and develop a mobile application to optimize the maintenance of medical equipment in hospital settings. The developed app "**Mobile-MERS**" (Medical Equipment Repair System) is designed to overcome drawbacks imposed by existing applications either mobile or web-based. Mobile-MERS is focusing on cumulative maintenance of medical equipment with no maintenance contract.

In this research, for sake of accurate measures, precise results and successfulness of research, the researcher narrowed the scope to context of limiting the app to some users, in this case, the app will be used by android users and will only be maintaining infant incubator.

1.6 Study limitations

Generalization of the finding in the major key limitation that may the project research process. In this work, the researcher assumed that all biomedical technicians hired in the hospitals had some skills on specific hospital equipment not in all equipment, and forgot that some biomedical technicians could be experts on some hospital equipment. The project assumption is that may hind the app use in future if not put into consideration during project design and implementation.

The researcher also assumed that all baby incubators have the same problems regardless of the different models and manufacturers due to a high number of baby incubator models released by different manufacturers in the hospital settings.

The budget constraints is very big hindrance to the young entrepreneurs and researchers nowadays. The implantation of Mobile-MERS project require a huge budget that a student cannot afford. Knowing this limitation lead to improvising by using local available materials and labor to minimize the project relative cost. If the challenge is not addressed the project would not be realistic.

Apps sometimes might jam due to its partial dependence on storage memory of the smartphone. Finally yet importantly, this app will pull data (inventory of medical equipment and spare part) from MEMMS (Medical Equipment Maintenance and Management System), which is currently still under rectification. The updated inventory of medical equipment and spare part cannot be fetched from MEMMS if it is not fully utilized.

The acknowledgement of the project limitations helped the researcher to develop the app considering existing challenges that might mislead the research and might result in wrong result once not noted.

1.7 Significance of the Study

1.7.1 Personal interests

This work helps me to apply knowledge gained during the academic field to solve society problems. It raised inside me as Biomedical Engineer the scientific pleasure of solving society problems by developing at tool that will help technician to maintain equipment that save lives of people. This project helps me to shift researcher's academic skills into the real world experience, by associating the gained skills into the real life by engaging in the problem solving, hence increasing researcher's experience which is will changing society by using mobile applications to maintain technology and this will boost my personal income.

The implementation of IT related project improved my knowledge in the field of Mobile Application development skills along site my knowledge in field of engineering will make me an innovative engineer who will be able to cope with this world of technology. It is an open window ahead the development health related software that may solve health sector problems to improve healthcare services.

1.7.2 University of Rwanda interests

The researcher's findings will provide the solutions to the society's problems, which helps University of Rwanda to meet its goal of becoming hub of solutions or problem-based academic programs aligned with Rwanda's development needs. The University of Rwanda will be achieving its goal of preparing students for their communities and country through applied service leaning programs nationally and internationally hence becomes the real hub of knowledge in East Africa.

1.7.3 Hospitals interests

The use of developed Mobile MERS will help the hospital to reduce the number of broken-down equipment in the hospitals 'store. This leads to improve health care services delivery and increase equipment stability. The equipment stability will results in less equipment downtime, which in turn reduce equipment maintenance cost. This project will help the hospital to ensure equipment ROI (Return of Investment) and save the money that government invest in hospital equipment for healthcare delivery.

The use mobile application will help hospitals to ensure safety of users, and patient due to equipment stability. It will reduce number of death especially in newborns as the part of this app is dedicated to infant incubators.

1.8 Organization of the thesis

Chapter one is General introduction, in this chapter vied the overall introduction of the study, from the main idea of app development, problem statement, aims and objecting of thesis and impact of the study to the community.

Chapter two is Literature review, it strengthens the research by ensuring that researcher has revised the current research by providing strong evidences of the found research gap that the researcher is about to fill.

Chapter three talks about Research methodology, the researcher described the method used in conducting research and describes the needed tools for conducting the research.

Chapter four is Design and implementation, in this section the researcher developed an app by ensuring the configuration features to meet the health system's requirements as its name Mobile-MERS (Medical Equipment Repair System).

Chapter five is the Results and findings of the study, it's about the fruit of our production, it's the generated outcome from the designed Mobile-MERS (Medical Equipment Repair System). It summarizes the app testing outcomes and system workflow.

Chapter six is Recommendations and Conclusions, where the researcher give advised to the professionals and industry in health sector especially in medical equipment management system and finally conclude on the thesis.

1.9 Summary

This section presented the introductions and objectives of the Design and development of mobile-based optimization app for maintenance of medical equipment, its benefits towards the hospitals, and biomedical technician efficiency as well.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter presents the theoretical concepts and fundamental definitions used for the study.

Medical equipment upkeep is just as vital as its design and development. The cost of sustaining a piece of equipment over its lifetime is usually substantially more than the cost of purchasing it [11]. The main objective was to provide useful information and explain the different technologies and techniques necessary to develop the medical equipment maintenance and management systems and make comparative study of the work done by other researchers in the related area of research.

2.2 Impact of Healthcare technology management on medical equipment maintenance

On many levels and in professional journals, a substantial debate about preventive maintenance (PM) intervals is taking place among clinical engineering (CE) practitioners. The issue is centered on regulatory authorities' and accreditation organizations' standard requirements in many countries that PM intervals must follow the equipment manufacturer's recommendations [27]. Manufacturer-recommended intervals for certain items that appear to be very identical in function and design differ by a factor of two or more. The legitimacy of these recommended intervals has been questioned, as well as whether they are based on significant test data. Debating PM intervals with equipment makers does not appear to be a viable option, as manufacturers may be hesitant to share data with end-users if there is any. It is impossible to judge maintenance outcomes based on PM or safety and performance inspection (SPI), and the same is true for periodic part replacement or calibrations [28].

Despite evidence from other industries that traditional PM is sometimes unnecessary, if not counterproductive [29], clinical and biomedical engineering experts continue to focus on process measures rather than analyzing the outcome of maintenance. The Emergency Care Research Institute (ECRI) [30] released a recommendation in 1984 to utilize risk as the key criterion for determining which pieces of equipment should be subjected to SM as well as the frequency of the SM, with risk being classified as high, medium, or low. For most medical equipment, ECRI has established scheduled (planned) maintenance (SM), also known as health device inspection and preventative maintenance (IPM). PM and SPI guidelines are included in the IPM. Fennigkoh and Smith [31] proposed a new classification system based on three criteria: function, physical risk, and maintenance requirements. This method, later known as risk-based inclusion criteria, allowed CE professionals to concentrate their PM efforts on a small number of medical devices (life support).

2.3 Development of maintenance philosophies

In recent years, maintenance management techniques have undergone a significant transformation. The rise in complexity in manufacturing processes and variety of goods, as well as a greater awareness of the influence of maintenance on the environment, people safety, business profitability, and product quality, has sped up maintenance progress. Maintenance solutions such as condition-based maintenance (CBM) and reliability-centered maintenance are undergoing a paradigm shift (RCM). Then there was a focus on risk-based maintenance (RBM). Figure 1 depicts the evolution of maintenance philosophy. This diagram in Figure 2.1[16] shows how maintenance policies have changed over time and can be divided into four generations: first, second, third, and most current [16]

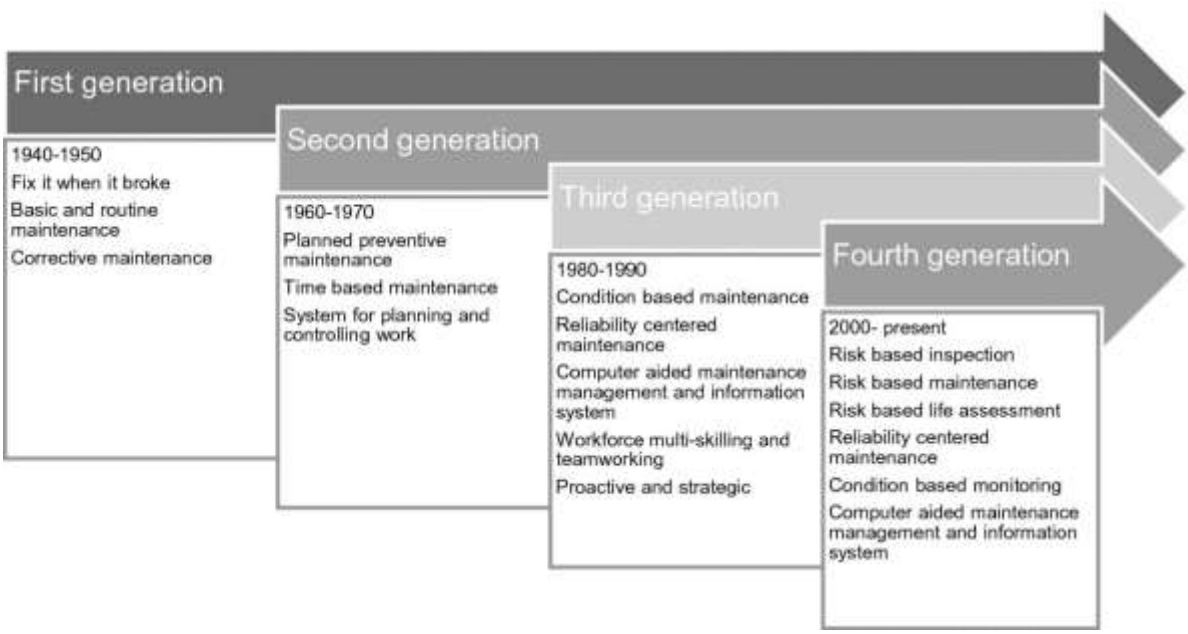

Figure 2. 1: Development of maintenance philosophies

2.4 Empirical approaches versus mathematical models

According to a survey of the literature, relatively little research has been done to use mathematical modeling to quantify the availability of medical equipment in connection to maintenance. The empirical technique is widely utilized in other industries, and numerous mathematical models have been created to quantify equipment and system availability and dependability. The literature reveals that maintenance policies based on mathematical models are significantly more flexible than heuristic rules, and the mathematical approach has the advantage of being able to optimize outcomes and achieve maximum dependability or least cost [17].

Experience and manufacturer suggestions inform the empirical approach. RCM (reliability-centered maintenance) is one method that was introduced around 30 years ago and is deemed empirical. Condition monitoring, study of failure reasons, and investigation of operational needs and priorities are all part of RCM. RCM, according to Endrenyi [17], identifies important equipment components that lead to equipment failure or financial loss and implements severe maintenance regimens for these components. RCM, according to Endrenyi, aids in deciding where to spend the next dollar budget for maintenance and is useful for comparing policies, but not for true optimization. Six basic failure patterns have been discovered in RCM based on industrial experience (very little data is available for medical equipment). Figure 2.2 [18], shows the results of a 1982 research that used six patterns to analyze maintenance data from the US Navy industry.

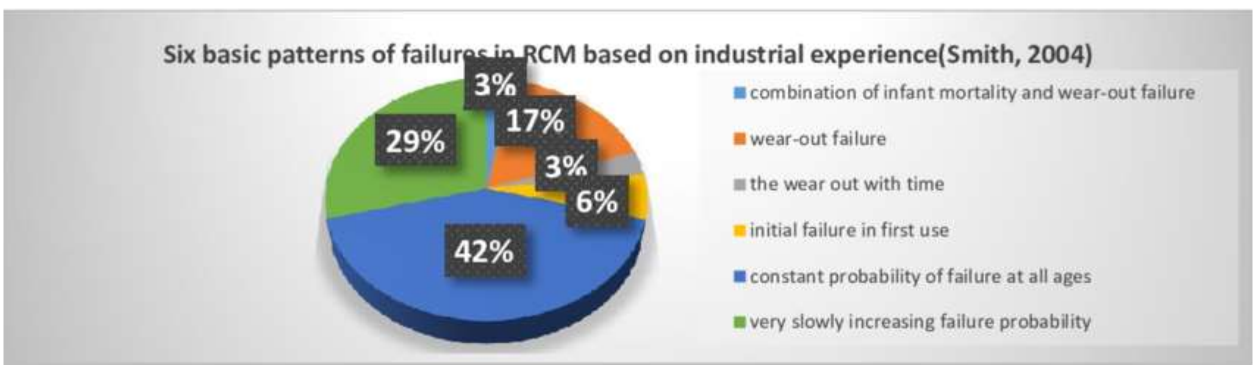

Figure 2. 2: Six basic patterns of failure in RCM

According to Hall [19] there are two keys to RCM method, the first key to the RCM approach is having a strong maintenance history of medical equipment, and the second important is the age. RCM, according to Hall, may be a preferable method for younger equipment. Condition based maintenance (CBM) was established to balance both sides of maintenance (preventive and corrective), and it observes and forecasts real-time machine health, whereas RCM investigates failure reasons over time and launches maintenance programs to increase the up time of these machines. CBM research has recently yielded promising technology for enhanced fault detection and forecasting. CBM also improves the productivity, availability, and safety of machine systems [20]. Machines are continuously monitored by numerous sensors in CBM to detect faults in real-time, making CBM valuable in predicting the timing of a potential breakdown and remaining useful life.

2.5 Maintenance outsourcing

Maintenance of medical technology should be outsourced when a health care facility lacks the technical knowledge or specialized assets required. Despite the rise in popularity of outsourcing, scholarly research on medical device maintenance outsourcing is still lacking. Research into the outsourcing of medical device maintenance services and the hazards associated with it in hospitals is still in its early stages, and further empirical research anchored in management theory would help advance the topic. This subject is worth studying in the healthcare setting because healthcare institutions that lack the competence to deal with these challenges may incur much greater expenditures [21]. Figure 2.3 [22], summarizes the main reasons behind the equipment failure as per Ridgway's study.

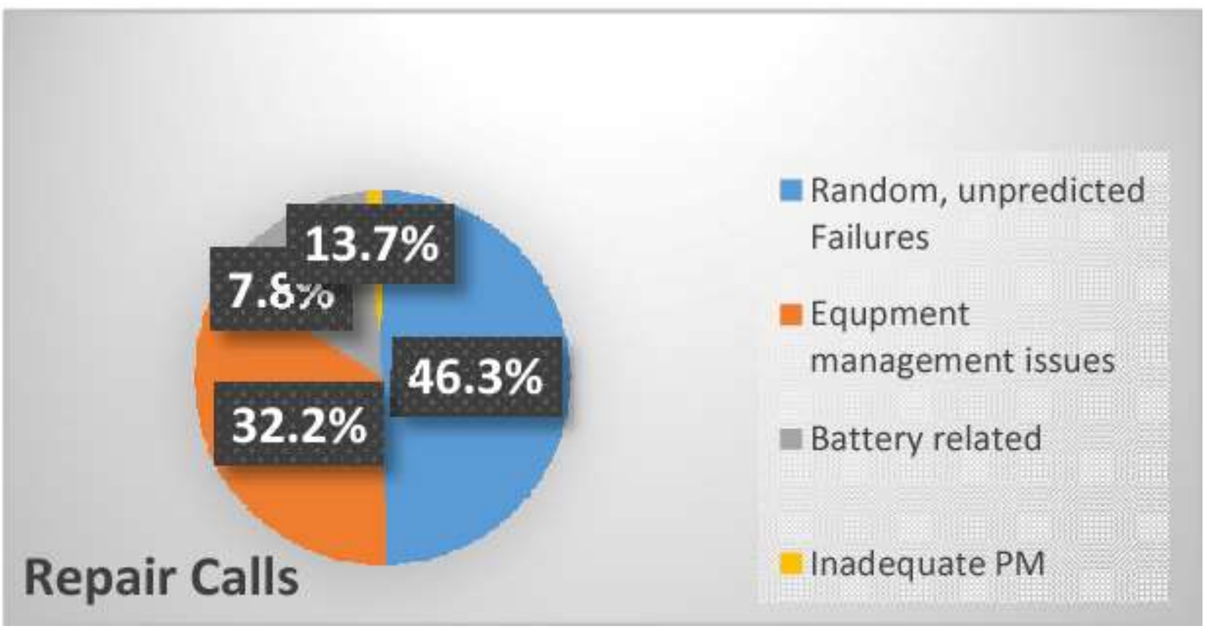

Figure 2. 3: Result of Ridgway's 2009 study

2.6 Reasons behind equipment failure

It is a paramount that substantial medical and hospital equipment is not functional due to various reasons. The down time of medical equipment, undermines the quality of healthcare services delivery. For any non-functional medical equipment, the barrier is to place the equipment back into service. Most likely out-of-services equipment are donations[2].

The study done on medical equipment, found that 38,3% of hospital equipment in developing countries are out of service. The study identified lack of training to BMETs and users, health technology management and infrastructure as the main cause of the equipment failure[3]

2.7 Automation of management and maintenance of medical equipment

The MIS (Management Information System) all over the world have been playing vital role in development in all fields; it is used in banking, health, social network, e-governance in order to digitalize normal workflow and improve the quality of services. The following are some examples of the MISs used:

- **LMIS** (Logistic Management Information System) used in Rwanda Medical Supply Ltd in charge of all health commodities in Rwanda
- **EMR** (Electronic Medical system) used in hospital for the digital management of patient files
- **Openclinic** used in hospital for the digital management of patient files
- **LUMIS** (Land Used Management Information System) for digital land management
- etc

The introduction of technology including use of MIS in health sector improves the qualities of healthcare output. The automation of maintenance practice is reported by Centers of Medicare and Medicaids Services to be having the significant impact of maintenance of medical equipment in US hospital [32]. Technology brings more advantages like easy visibility of medical equipment, data based decision-making, portability of the system and remote access of system information.

2.8 Development of app for medical equipment management

It is a paramount that substantial medical and hospital equipment is not functional due to various reasons. The down time of medical equipment, undermines the quality of healthcare services delivery. For any non-functional medical equipment, the barrier is to place the equipment back into service. Most likely out-of-services equipment are donations [21]. Some of proposed solutions are health-applied applications.

2.8.1 Application life cycle

Every application passes through the following steps. The Figure 2.4 [23], gives a view on different involved in app development.

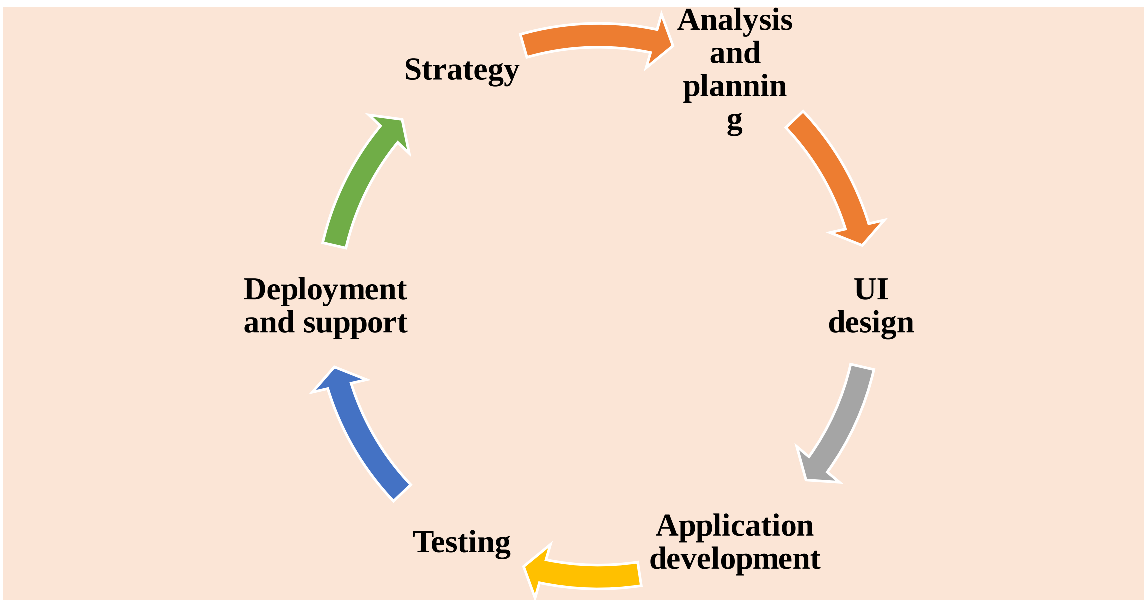

Figure 2. 4: App development life cycle

1. **Strategy**: evolving the idea into successful application. In this stage, someone needs to identify the app users, research completion, establish the app goal and objectives, and select the mobile platform for the app.

2. **Analysis and planning**: consists of defining functional requirement, product roadmap and minimum variable product to make app idea start taking shape and turning into actual project

3. **UI Design**: creating excellent user experiences making the app interactive, intuitive and user-friendly.

4. **Application development**: this step consists of defining technical architecture, picking technological stack and defining development milestones in its integral parts: back-end/server technology, API(s) and the mobile app front end.

5. **Testing**: is a quality assurance process to make application stable, usable and secure. Various testing methods can be made to deliver a quality mobility solution. The methods include user experience testing, functional testing, performance testing, security testing, device and platform testing.

6. **Deployment and support**: consists of a mechanism of releasing application to the user. In this step the own perform a continuous monitoring of the application for application evolution.

2.9 MIS in Health Sector

Hospital management systems are the systems that are meant to manage and control hospital environment from hospital performance, hospital efficiency and management of food supply, scheduling operating rooms, identifying safety concerns, streamlining communications within departments, regulatory compliance managing utilities, waste, and laundry.

Medical equipment plays an important role in healthcare delivery. It ranges from small and simple devices such as sphygmomanometer to complex and big devices such as Magnetic Resonance Imaging (MRI) machines. It is, therefore, of vital importance that healthcare organizations manage their assets to keep their expenditures under control as well as ensure the quality of healthcare delivery.

Health related apps help in monitoring the hospital's performance, basing on the satisfaction level of the patients who get healthcare service from that hospital. The increasing the level of hospital equipment reliability due to technology-based solutions, will define high-level healthcare facility's performance. Return of investment (ROI) of hospital equipment, through quick and successful maintenance of equipment, which usually was replaced instead of being repaired. Error detecting which is on high level, which increases the chance of hospital in saving lives of patients.

The cons defined above pushed different institution to develop various health related apps in order to improve the quality of healthcare at reliable cost.

2.9.1 BG Maint-KM Benin

"BGMaint-KM Benin", designed, developed, tested, validated and deployed in the Department of Biomedical Engineering, Ecole Polytechnique d'Abomey-Calavi, University of Abomey-Calavi, Benin. The methods followed to design the CMMS, was inspired by closed-loop control theory. It is based on the idea that an effective CMMS could have been designed using as reference international standards and best practices, while controlling and optimizing CMMS inputs and outputs basing upon information and data measured in Beninese medical locations, following a closed-loop feedback control strategy. The tool is currently fully functional in three Beninese hospitals [12].

Overall, with BGMaint-KM Benin and its 78 outputs, the data reach a well-defined channel in the biomedical engineering service, commonly called biomedical maintenance service in hospitals in developing countries. The tool considers the components of healthcare activity and is flexible so that it can satisfy potential needs that vary from one hospital to the other. For example control, measurement and test equipment can be entered in the tool BGMaint-KM Benin, so that this equipment can be maintained and documented with precision [12].

Fifteen categories of information and 69 direct outputs were finally identified. In order to manage such a variety of information, in each network, and therefore for each hospital, the BGMaint-KM Benin^ tool was offered a set of filters allowing to display the 69 direct outputs [12].

Apart from those 69 direct outputs, nine indirect outputs (from out70 to out78) were also obtained, indeed, with the GSM option integrated, the BGMaint-KM Bénin tool offers the possibility by SMS of [12]:

1. Out70 - **Request for intervention**: To receive an SMS alert immediately, coming from the BGMaint-KM Bénin tool as soon as a user requires intervention.
2. Out71 - **Preventive maintenance**: To receive a reminder SMS, coming from the BGMaint-KM Bénin tool, on the eve of each scheduled preventive maintenance.
3. Out72 - **Contract**: To receive an SMS reminder, from the BGMaint-KM Bénin tool, every seven days when there are maintenance contracts, whose deadlines are in less than fourteen days?
4. Out73 - **Recipient**: To receive an SMS reminder, coming from the BGMaint-KM Bénin tool, every five days when there are external service appointments, whose deadlines arrive in less than thirty days?
5. Out74 - **Evaluation report**: To receive each Saturday, an SMS reminder, coming from the BGMaint-KM Bénin tool, on the update of the evaluation report of the activities of the week.
6. Out75 - **Request suffering Intervention**: To receive each fifth of the month, an SMS of alert coming from the BGMaint-KM Bénin tool, which indicates the interventions, whose deadlines have been exceeded by more than thirty days.
7. Out76 -**Technical characteristics of a device** (Optional): Possibility of sending an SMS to ask the BGMaint-KM Bénin tool the technical characteristics of a device and to receive in return an SMS, which contains the required characteristics.
8. Out77 - **Devices attached to equipment** (Optional): Possibility of sending an SMS to request the BGMaint-KM Bénin tool the devices attached to given equipment and receive in return an SMS that contains the list of these devices.

9. Out78 – **Functional state of a device** (Optional): Possibility of sending an SMS to ask to the BGMaint-KM Bénin tool the operating status of a device and receive an SMS that provides information on the operating status of the equipment.

2.9.2 EQUIMEDCOMP

The EQUIMEDCOMP is software-based system designed to achieve valuable improvements in the maintenance management of medical technology [13]. EQUIMEDCOMP utilized to carry out multiple medical equipment management-related tasks. The designed system is in a modular format to allow independent development of the individual modules (subsystems). These subsystems include medical equipment inventory, work order system, PM scheduling system, and equipment quality control system developing a technology evaluation system that can perform reliability assessment of medical technology to ensure safe and cost-efficient functionality is of vital importance has been requested and prioritized [14].

The outcomes of this technology assessment can help in planning and deploying future technology requirements, determining whether a particular medical system needs to be replaced, and helping in brand selection of the purchased technology. Usually, the quality evaluation (control) process takes the form of statistical surveys that are performed during the life span of a particular device [13].

These surveys may include various parameters, such as the device's probability of failure, mean downtime, usability, and performance measures. These statistical surveys give insight into the actual performance of medical equipment. The equipment quality control sub-system employed by EQUIMEDCOMP provides an objective and quantitative reliability assessment for the registered devices. It aids in the identification of equipment that should be replaced, as well as decisions on the subsequent brand selection for new devices being purchased [13]. Figure 2.5 and figure 2.6 show the navigation process of user in EQUIPMEDCOMP during the registration of medical equipment.

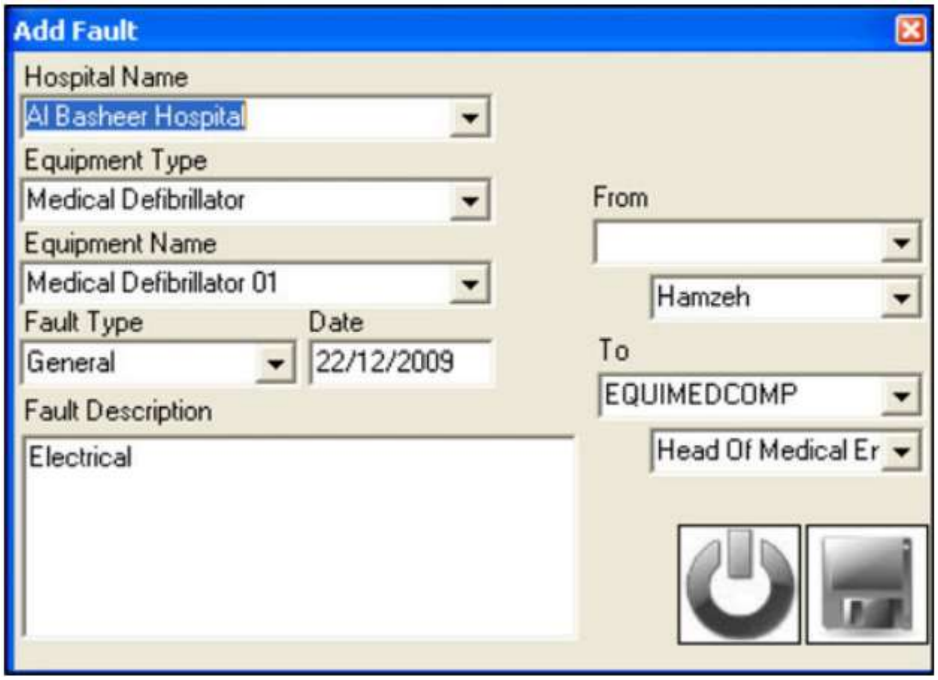

Figure 2. 5: The "Add fault" windows for requesting service for a device registered within the system

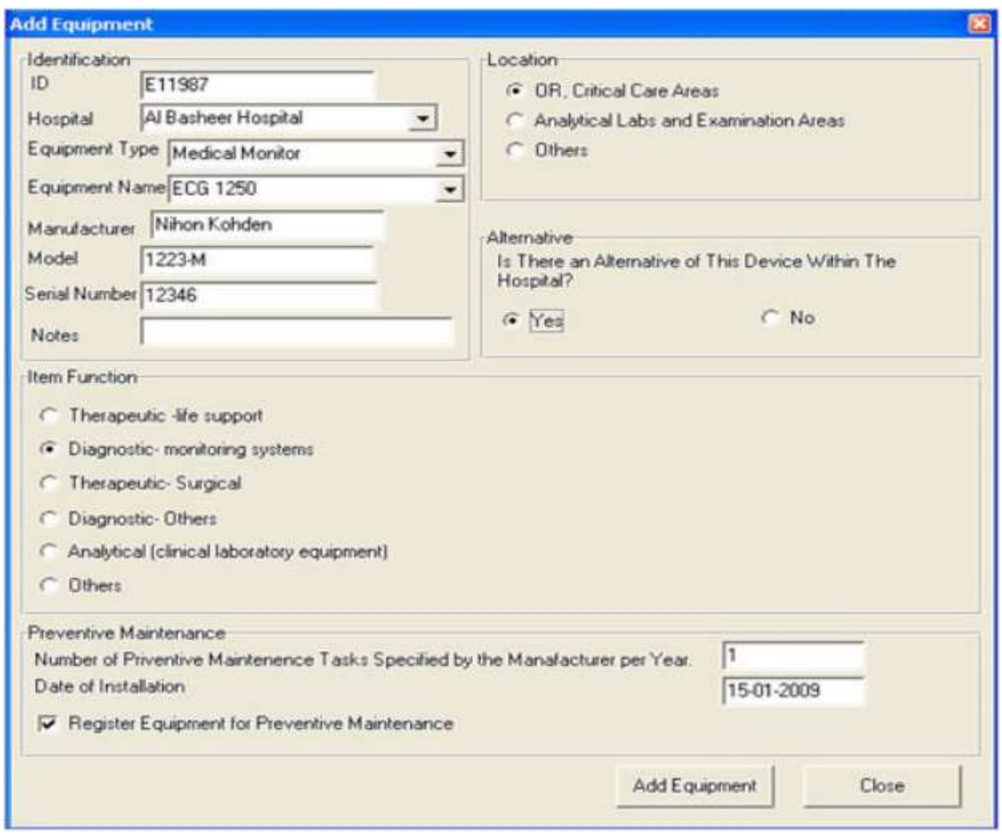

Figure 2. 6: EQUIMEDCOMP equipment registration window

The sub-system includes an integrated history record (time-line) that keeps track of all maintenance and repair activities performed on a particular device throughout its service life.

2.9.3 MEMMS (Medical Equipment Management and Maintenance System)

MEMMS (Medical Equipment Management and Maintenance System) is a web-based portal designed to help maintenance staff at public health facilities perform their functions more efficiently and to help the MoH to gain visibility over the management and maintenance of medical equipment ahead the improvement of Healthcare Technology Management (HTM) [15]. MEMMS is intended to capture medical equipment data for all public health centers and district, provincial and referral hospitals and to accommodate updated information for medical equipment, such as type, model, supplier, manufacturer, current physical and operating status, location, and lifespan.

The system includes four modules:

- **Inventory**: to manage and maintain the inventory of medical equipment at health facilities.
- **Maintenance**: to improve the process of corrective maintenance by establishing an agile line of communication between different stakeholders – equipment users, DH technicians, and MTD technicians and to enforce better preventative maintenance practices at the HF level by establishing regular preventative maintenance schedules.
- **Spare Parts Management**: to manage and maintain the inventory of spare parts at all warehouses across the country – MTD-RBC warehouse and facility warehouses.
- **Reporting**: to help the managers at various levels get a snapshot of the effectiveness of implementation of maintenance activities, a summary of inventory levels, etc.

Figure 2.7, shows MEMMS interface and all MEMMS modules. It was extracted from MEMMS during the registration of new user.

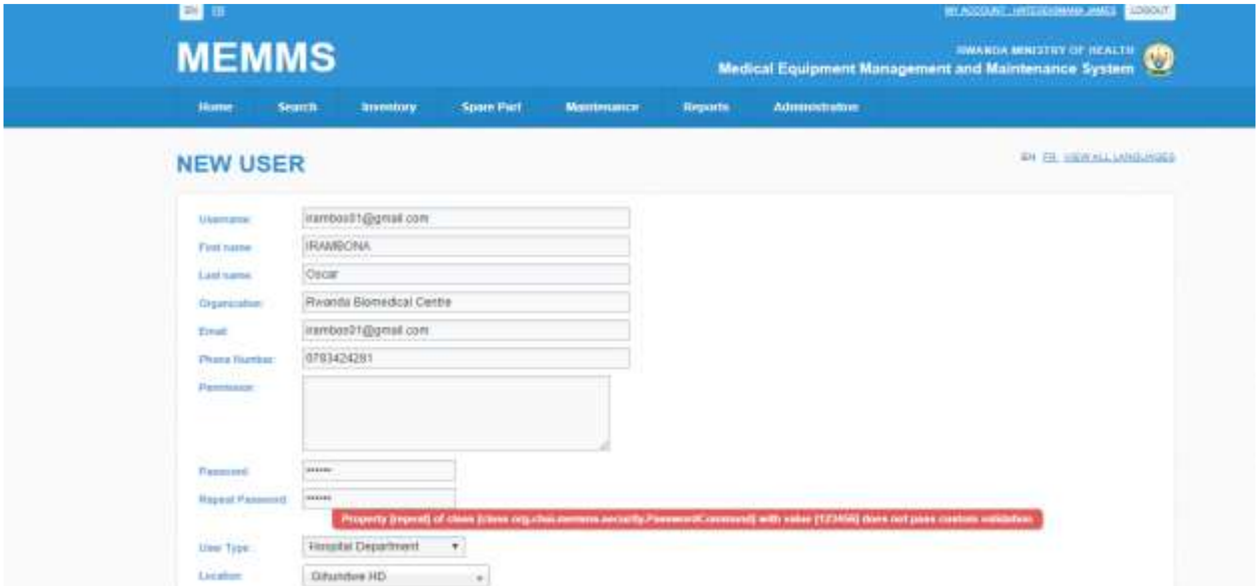

Figure 2. 7: MEMMS interface

2.9.4 Cworks as Computerized management and Maintenance System

Cworks is a web-based system that enable technicians and engineers to easy track the who, what, When, Where and why for your maintenance work and equipment. As per MEMMS this system makes preventive maintenance a priority that result in lowering the maintenance cost. Cworks is used in many hospital all over the work and in Rwanda this application is used in CHUK hospital (The University Teaching of Kigali) as MEMMS back up. The application gives the following features:

- **Tracking Assets** – A CMMS from CWorks allows you to take control of your assets. Track location changes, track work that has been done to them (preventative or breakdown), track life-cycle information (depreciation, etc), and much more.
- **Work Order Creation (Automatic and Manual)** – Manage both planned and unplanned work, from the initial request, all the way through completion, complete with technician information, and a detailed work log. Preventative Maintenance is a pleasure with a CMMS from CWorks.
- **Inventory management** – Take control of your parts inventory, with a CWorks CMMS. Document details, cost, and usage of your stockroom, no matter how large.
- **Purchasing** – CWorks Purchasing makes inventory replenishment and other parts requisitions simple.

- **Report**: Cwork offer the ability to view various report for hospital decision making on management of health facilities asset suh us purchasing a new type of equipment, making equipment obsolete, decommission and disposal of medical equipment, etc. Figure 2.8, shows CWORKS application modules at user login.

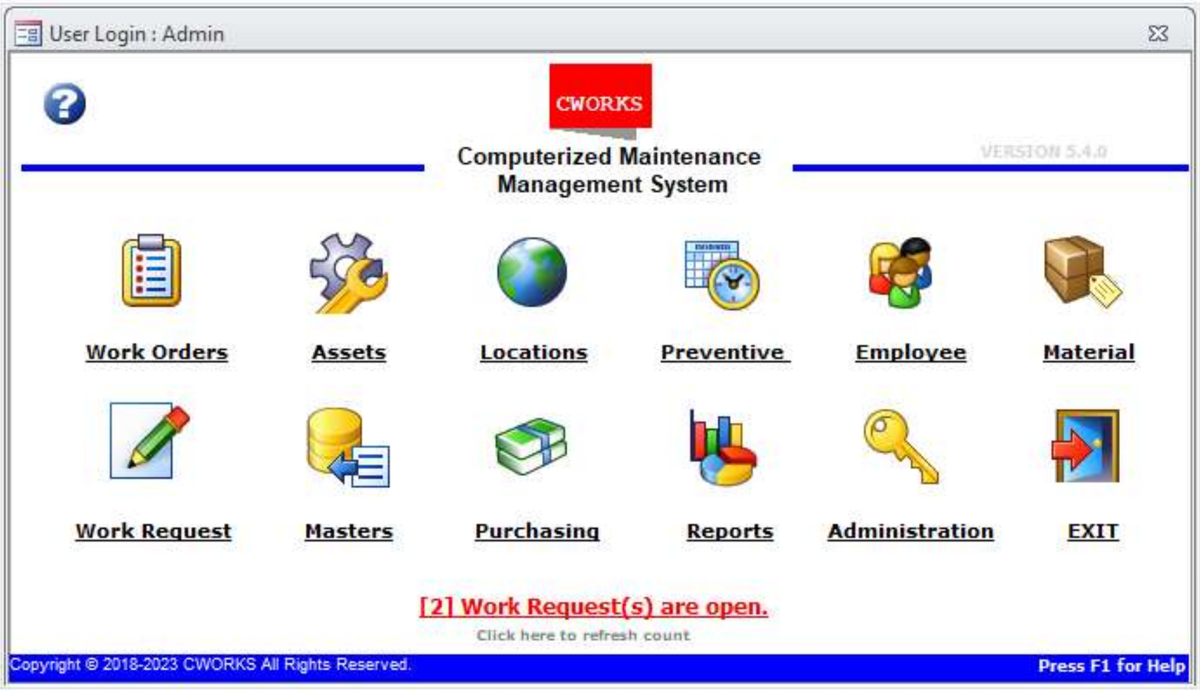

Figure 2. 8: Login window for CWORKS

Figure 2.9, shows the interface of CWORKS when user is creating a new work order

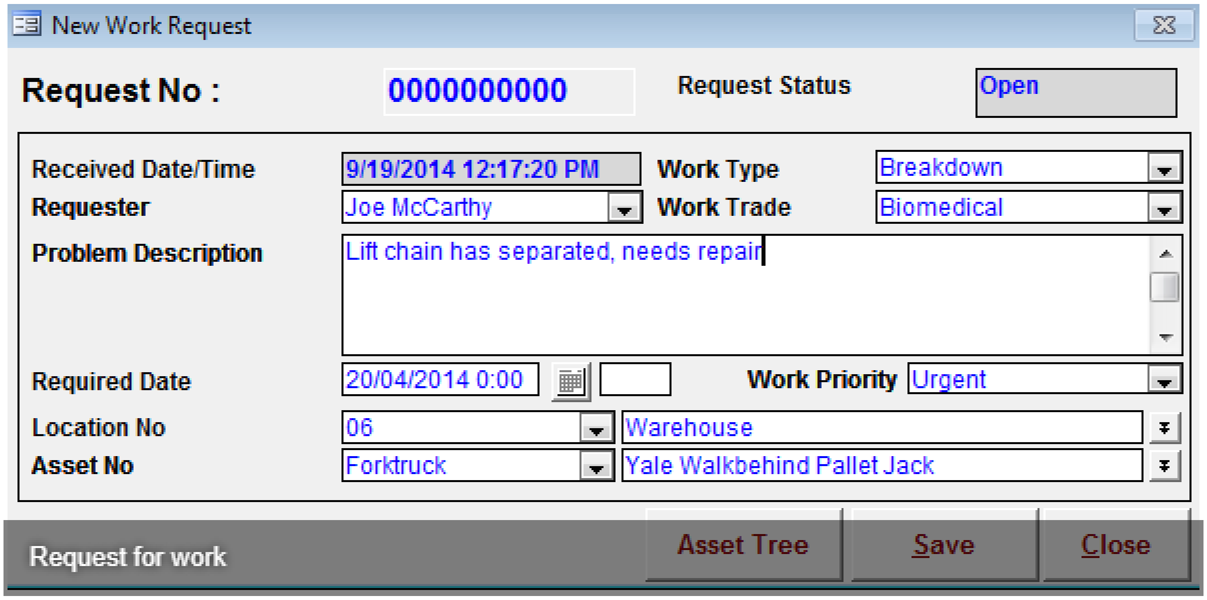

Figure 2. 9: Work order window

The figure 2.10 indicates the system interface when administrator is recording new user

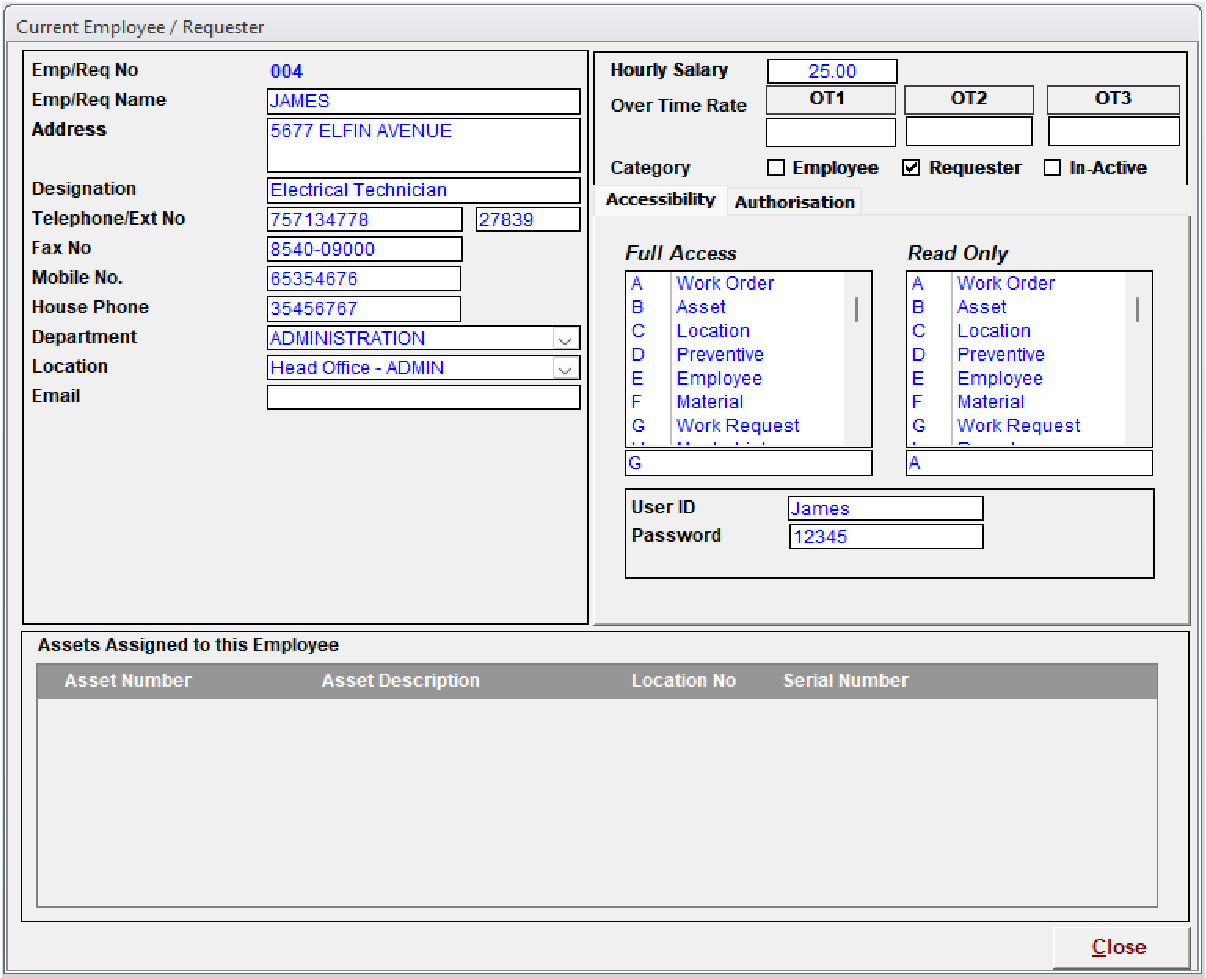

Figure 2. 10: User definition in CWORKS

There exists a long list of apps, which are dedicated to the management of medical equipment in hospital setting, however, none of them is providing equipment repair feature. The table 2.1 summarizes the health related app discussed in this paper.

Table 2. 1: Summary of discussed CMMS

Name of the app	**Technology**	**Functionalities**
BK Maint-KM Benin	GMS-based Artificial intelligent	1.GSM-based preventive maintenance 2.Provide option of monitoring of maintenance contract 3.Report module for decision making

EQUIPMEDCOMP	Software-based	1.Provide alert on preventive 2.Report module: mean downtime, equipment usability and performance
MEMMS	Web-based	1.Provide alert on scheduled preventive 2. Allow user to create ticket (maintenance order) 3.Management of spare parts 4. Ensure visibility of medical equipment and spare part countrywide 5.Report module for decision making
Cwork computerized maintenance and management system	Web-based	1.Provide alert on scheduled preventive 2.Provide the information of location of the equipment in the hospital 3.Provide the information on hospital buildings 4.Report module for data-based decision making

2.10 Developed Mobile-MERS

The development of Mobile-MERS come out as the alternative solution to remove challenges impose by previous health related application. All discussed apps discussed in this paper are web-based and cannot be access unless the user is connected to the internet; in additional to that they only provide reminder on preventive maintenance and allow the user to send the maintenance ticket to the technician via SMS, email notifications.

The developed Mobile-MERS is a mobile application as indicates the name; it will be used with additional features compared to the existing applications. This app offer the advantage of being portable even in rural area where there is no internet; biomedical technician login in Mobile-MERS using the smart phone with internet, once login the user is no longer need the internet to perform maintenance. Inventory and spare parts of the medical equipment records in the app for maintenance, is pulled immediately from MEMMS and hence technician can perform repair without internet. After the repair process, the repair information is temporally save on internal memory of smart form until the phone is back the internet waiting for synchronization to the central server.

Mobile-MERS has the second uniqueness of the developed app of having a feature that previous app does not have. It provides a series of algorithm that guide the technician a specific type of equipment. That app has a chat engine that help user to chat with other technician to share experience and challenges during the repair process. This reduces the technician headache, panic and will cut the repair time as well repair cost.

2.11 Summary

This section summarizes various related literatures related to this project. It discusses how technology affects various field of live and how it improves the quality of life in general. This section highlights various health related apps introduced in health sector to boost quality of life and held high the innovations brought by Mobile-MERS compared to previous applications and archaic medical equipment maintenance methods.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

In this research, cloud-based mobile app technology was used. The purposive sampling technique was used, as all biomedical technicians in selected hospital participate the iterative testing sessions. The design science process includes six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication, this process were choosing to reduce cost in implementing the app development [33]. The prototype of proposed mobile application will be developed alongside with solution demonstration.

The figure 3.1, explains the implementation steps of this project [33]

- **Identification of user's (BMETs) needs**: This step helped to identify challenges that undermine the maintenance process and helped to develop the app that will address challenges in management of hospital equipment. The identification of hospital BMET need was done during field placement in hospital country and my experience in health sector. Existing medical equipment software like MEMMS were analyzed in terms of weakness and strength in maintenance of medical equipment. Findings proved that the medical equipment software in place works only on preventive maintenance, this lead the researcher to the development of the app that would respond to gap of not having the mobile application that may deal with curative maintenance.
- **System architecture**: at this step I defined data model and programming language that was used throughout the development process of this app : "Python language was used to develop the mobile app"
- **Application design and iterative testing:** Consists of all process of coding and debugging the app and there will be the iterative testing after every phase of development to check the app functionalities. At this stage, I will develop tables, codes and perform various tests to ensure the app output.
- **Testing and Application documentation:** this step consists of the whole app testing and Development of application technical manual for users. Implementation of Mobile-MERS project implied three iterative test with hospital BMETs
- **Future use of the system:** after the testing exercise of the app the system may be expanded to next level of being deployed in various hospitals as per testing results . The evolution of this

work will be to integrate the developed app with existing web-based medical equipment management system like MEMMS and it will be the open gate to other researchers to extend this work to next level of usage.

Figure 3. 1: Project roadmap

3.2 System Requirements

The development of mobile app requires different steps, the utmost important is definition of system requirement specification that describes the features and behaviors of the app. System requirement include a variety of element that attempts to define the intended functionality required for users' satisfaction. The developed mobile app for maintenance of medical equipment in this project runs on android platforms. The success of design and development of this app required knowledge, settings and devices that would lead me to obtain an android version app. The table 3.1 summarizes minimum requirement that guided me to the success of this work.

Table 3. 1: System requirements

<table>
<tr><td colspan="3">App description: This mobile-based app provides a series of nested algorithms that guide the user/ Hospital Biomedical Technician to troubleshoot and repair a piece of hospital equipment based on its working principle.</td></tr>
<tr><td>Feature/item</td><td>Description</td><td>Minimum requirements</td></tr>
<tr><td>Operation System (OS)</td><td>Android12</td><td>At least 6GB RAM
Processing power: i5 or i7
Available disk space: 4 GB recommended (500 MB for IDE + 1.5 GB for Android SDK and emulator system image)</td></tr>
<tr><td>Language</td><td>Python</td><td>Modern Operating System:</td></tr>
</table>

		Windows 7 or 10 Mac OS X 10.11 or higher, 64-bit Linux: RHEL 6/7, 64-bit (almost all libraries also work in Ubuntu) x86 64-bit CPU (Intel / AMD architecture) 4 GB RAM 5 GB free disk space
Platform	Play store	
App storage	The maximum app size on play store	Less than 50MB
System interoperability	The application will be able to share data existing CMMS like MEMMS for example	APIs for interoperability with MEMMS and other health sector CMMS is in place
Minimum System Requirements for Android Studio		
Item	Description	
Laptop	Microsoft Windows 7/8/10 (32 or 64 bit). Mac OS X 10.8.5. GNOME or KDE or Unity desktop on Ubuntu or Fedora or GNU/Linux Debian. 2GB RAM. 4GB RAM recommended. 500 MB disk space 1 GB for Android SDK. Java Development Kit (JDK) 7 or latest version 1280x800 screen resolution. A faster processor (i5/i7).	

3.3 System Components

The developed app has different features and modules that allow user to navigate the app with ease.

a. **Login**: The app should be having the authentication scheme (username and password) to ensure the security of data in the app.

b. **Database of medical equipment**: The application will be having the information of one equipment to be working on during this work and this inventory module will fetched from MEMMS after integration as API is in place.

c. **Dataset of maintenance guidance**: The app has the tables of logical statement of every type of equipment. This helps the user to logically follow step by steps during the troubleshoot and repair process.

d. **Repair history directory**: The app is able to hold repair history until the app is synchronized to the central server that host the existing CMMS via internet.

e. **Spare part directory**: The app will be able to predict the type and name of spare-part to be used in case the repairing process needs it, in other to return the equipment into functional status

f. **User directory**: The system provides to user the ability to know all app user either online or not.

g. **Gate to other technicians/engineers**: The user has window to chat and talk to other similar technicians/engineers in order to share expertise and experience on a particular failure on a given piece of equipment.

3.4 System model

System model design is a process for identifying the sub-systems making up a system and framework for sub-system control and communication. The output of this design process is a description of the system architecture as shown in Figure 3.2.

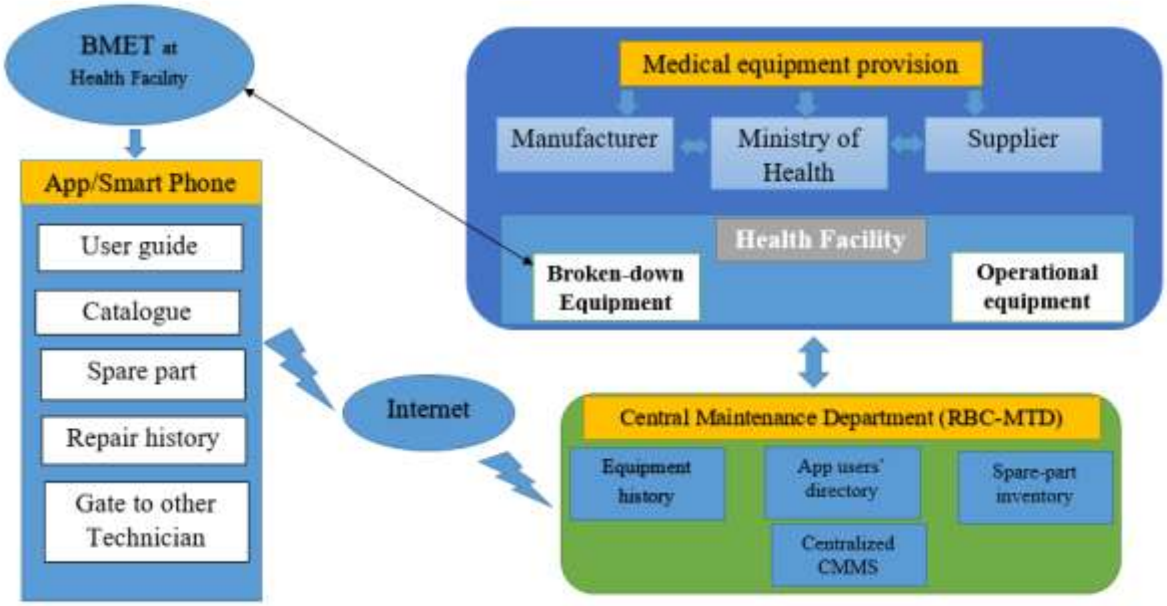

Figure 3. 2: App business block diagram

3.5 Research Design Method

A flowchart is a graphical representation of an algorithm. It is often used as a program-planning tool to solve a problem. It makes use of connected symbols among them to indicate the flow of information and processing.

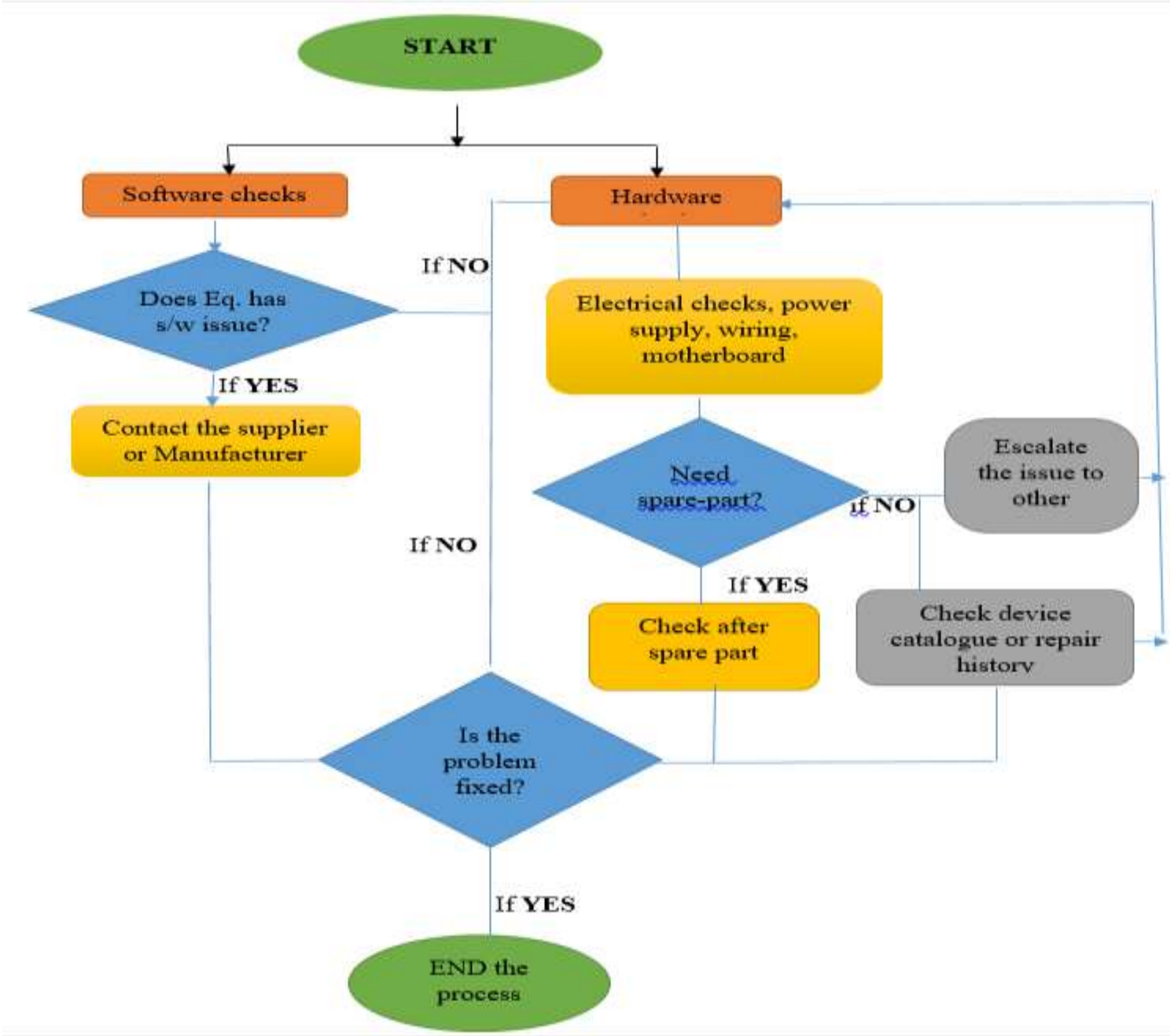

Figure 3. 3: App business block diagram

As Figure 3.3, Mobile-MERS (Medical Equipment Repair System) flowchart diagram we start by reading the status of the equipment in its performance by checking if the problem is either on software or hardware parts of the equipment and the biomedical technician follows the prompt until he solves the problem completely.

3.6 The Research Plan

The design and development of a mobile application requires the preliminary studies on the existing similar applications in order to avoid system duplication [33]. This requires having tangible data to guide the developer to meet the system expectations. This work became realistic because I had already known challenges of Rwanda Health sector in terms of management of medical equipment and MIS used in management of medical equipment.

3.7 Project design

This project consists of design and development of mobile app that will help to optimize the maintenance of hospital equipment without maintenance contract. During project implementation, there is a need to conduct a longitudinal cohort tests to evaluate the reliability of developed app. The Technician provided data on app functionalities as per the test tool. The goal is to assess how the app met the expectation as per technical specification ahead improvement actions. This would lead to the output of having a tool that will affect BMETs' perspectives on quality of work life, perceived usefulness, perceived ease of use, user control, and rate of equipment repair, by providing logical guidance steps during troubleshoot and maintenance process of the device .

3.7.1 Sampling and study site

The Government of Rwanda counts 53 public Hospitals [26]; each hospital has at least two hospital biomedical technicians, therefore average 106 Hospital Biomedical Technicians are the target of this study. The following criteria was used to design sample size that will be involved in this project of designing and development of mobile app to maintain medical equipment as iterative test members:

Location of the hospital: Rural, semi-rural and urban as the location can define the number of patients, hospital bed and the number of equipment as the prevalence of equipment failure is proportional to the number of equipment.

Chosen Hospital: BMETs from district Hospitals participated the study as District hospital do not have enough budget dedicated for maintenance of medical equipment, therefore there is a great probability of big number of equipment failure compared to referral equipment. In addition to that Biomedical technician from district hospital do not receive training on management of medical equipment as those from referral hospital.

Sample size: Six biomedical technicians from three hospitals (2BMETs from each hospital) Biomedical Technicians from three public hospitals: such as Gahini, Nyamata, Muhima (One from rural area, one from semi-rural, one from urban respectively) participated iterative testing exercise of the developed app. All six technicians currently employed at selected public hospitals were contacted and invited to participate in the study.

3.7.2 Sampling technique

The purposive sampling technique was used to determine the sample of testing team, as all hospital staff do not have technical skills on maintenance of medical equipment, therefore hospital BMET were the targeted group at the hospital. Three hospitals were chosen to participate the testing session. One hospital from rural area (Gahini District Hospital), One hospital from semi-urban area (Nyamata District Hospital) and one hospital located in urban area(Muhima District Hospital).

3.7.3 Study population

The study population is biomedical equipment technicians at selected hospitals. Six hospital Biomedical Technicians participated the iterative testing session throughout the development process of Mobile-MERS.

3.7.4 Main exposures and/or confounders and/or outcomes to be measured

Outcomes*:* Equipment repair rate using the existing application and the rate of equipment failure alongside with failure reasons. From there we derivate a new app that will give repair algorithm that will boost equipment repair rate and therefore improved health outcomes.

Confounders*:* the iterative testing questionnaire helped the developer to the user characteristics (training, years of experience, English proficiency, average number of repairs in a month, type of education, frequency of smart phone use), facility characteristics (type of hospital, weekly equipment repair, type of equipment) in improving the app throughout the development process

3.7.5 Selection of study population

a. Inclusion criteria

Participants were employees of hospital maintenance departments who repair medical equipment, are over the age of 18, are able to understand spoken and written English, possess an Android smartphone with internet access, and were able to correspond with the study team via email or a messaging application such as WhatsApp.

b. Exclusion criteria

Participants who did not repair medical equipment or were not currently employed by the hospital, were not able to understand spoken and written English, who do not possess an Android smartphone, and who were unable to correspond with researchers through indicated channels were excluded from the study.

3.7.6 Analysis of the results

Findings from data collected from iterative test session were analyzed using quantitative method and some statistical tool were used for result visualization.

3.8 Summary

This sub-section discussed the scientific research method used to make this project successful as a scientific research work. It emphasizes a lot on sampling techniques used to design the study population and analysis of the testing result using statistical tools.

CHAPTER 4. PROJECT DESIGN AND RESULTS ANALYSIS

This work comes out with a mobile app “Mobile-MERS” that will help hospital biomedical technician to optimize maintenance outcomes. The developed app has different functionalities as per system requirements and expectations to fill the existing gaps in terms of management and maintenance of hospital equipment.

The development of Mobile-MERS requires the design of data flow diagram made of a series of algorithm, workflow or process that will guide the developer throughout the app development process. In this work, the diagrammatic presentation shown in figure 4.1 illustrates the solution model to fix the issue of failed infant incubator.

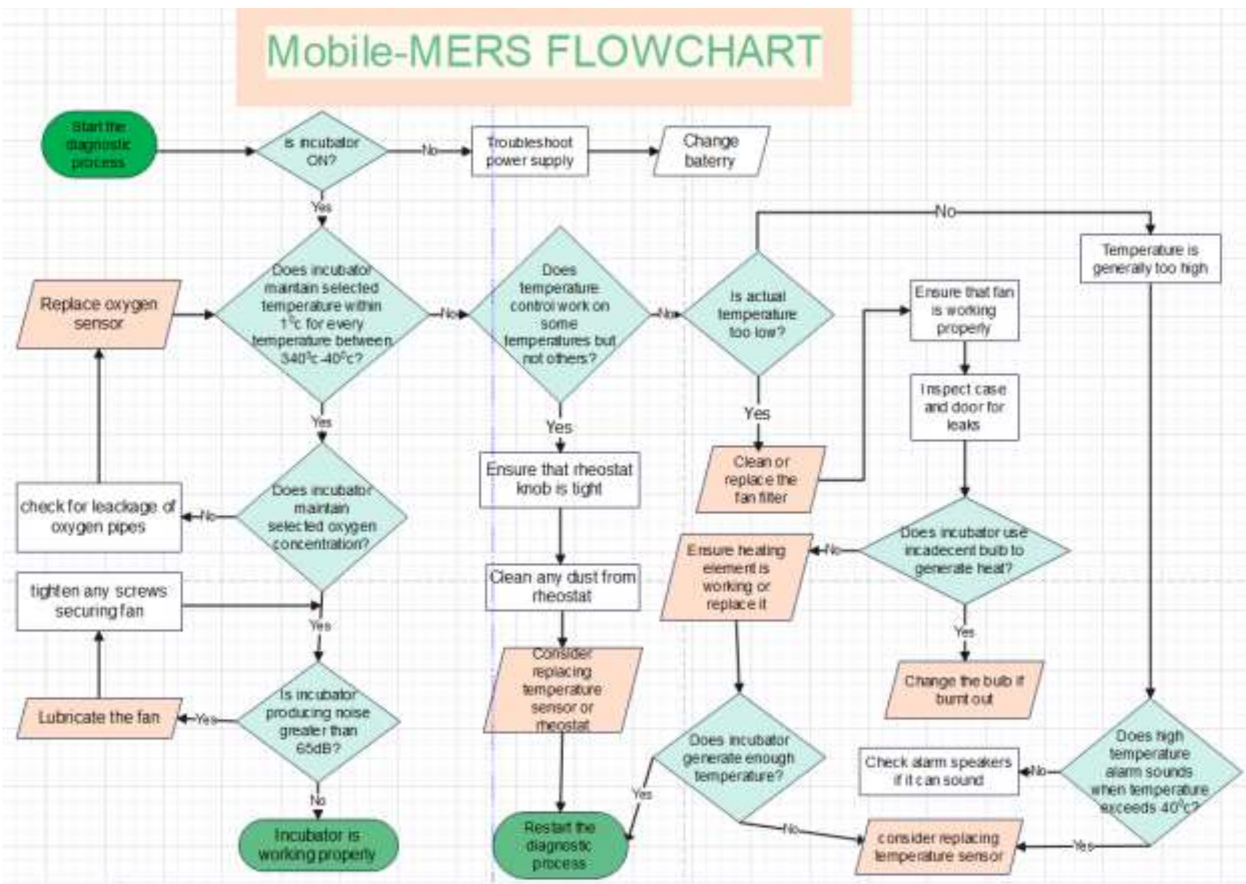

Figure 4. 1: Mobile-MERS follow diagram

4.1 System LOGIN and Authentication

Developed System “Mobile-MERS” has the login interface where the user should write down his/her **username** which is generally his/her email address and there also a reserved space for

password. This is done for security purpose so that nobody can access data from Mobile-MERS and other integrated systems without prior permission.

The security of Mobile-MERS data is controlled at the registration the new user. When the user prompt to register him/herself in Mobile-MERS, the system auto generates an OTP code that the system admin should share to the new user for authentication of the requester. The OTP code will help the new user to set his own password. Figure 4.2 shows Mobile-MERS login interface.

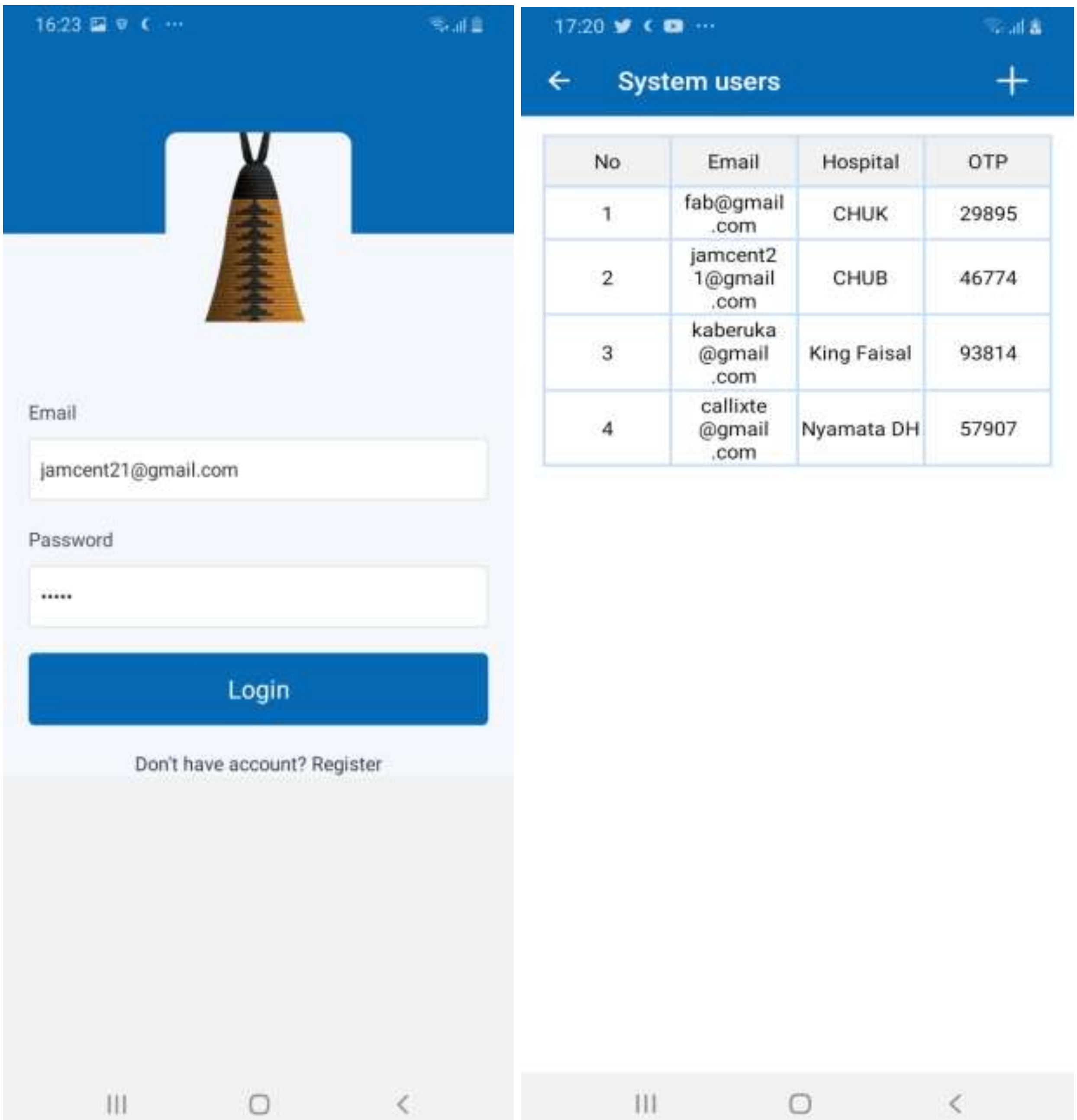

Figure 4. 2: Login interface and system users

After login, Mobile-MERS may work without internet, and the repair history save to the phone storage will be synchronize to the central server and every maintenance action will be saved to the dedicated equipment referencing to its serial number as equipment unique identifier.

4.2 User interface and app workflow

Mobile-MERS has a user-friendly interface. When the user chooses the type of medical equipment to be repaired, the system provides a menu bar of possible problems that the equipment could have. This is done to avoid the technician passing even through the unnecessary troubleshooting steps, which may increase maintenance time for no reason. The app will also display the latest device issues that might be updated in the system. Mobile-MERS has a search engine that will allow users to search and access quickly the likely possible issue to be fixed. The figure 4.3 summarizes app algorithm during repair process

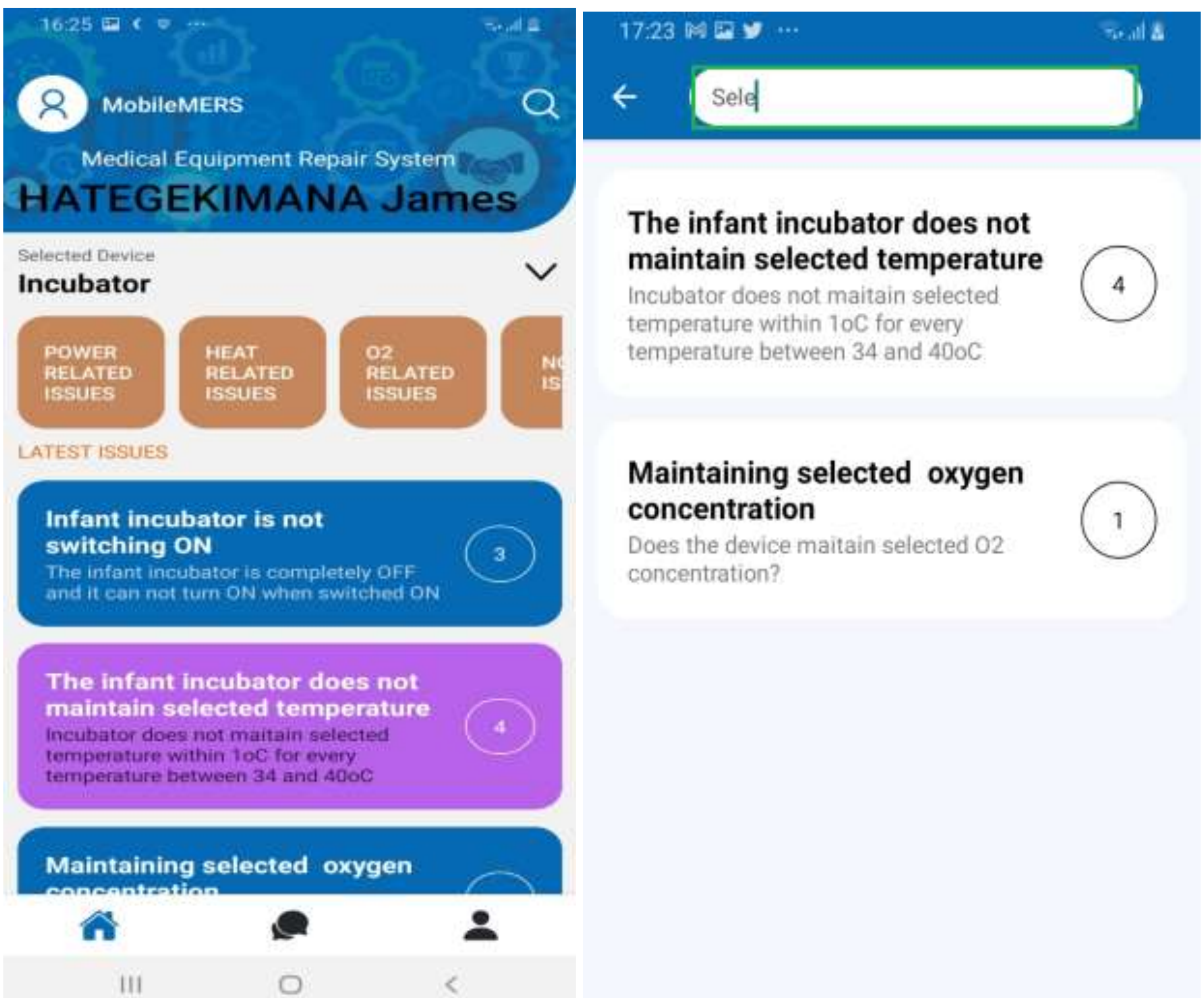

Figure 4. 3: Mobile-MERS interface and issue search engine

4.3 Maintenance flow and link to other Engineers

The developed app provides a sequence of troubleshooting steps ahead the repair of medical equipment. A series of repair statement guidance will be provided until the problem is solved. If the issue is not fixed, the app provides an online chat so that hospital BMET can chat with other technicians who might have met the same challenge for experience sharing. Once the issue does persist, it will be escalated to the next maintenance level (provincial maintenance center or to national maintenance center; RBC/MTD for Rwanda) by leaving maintenance ticket to alert maintenance challenge. Figure 4.4 indicates MERS navigation process.

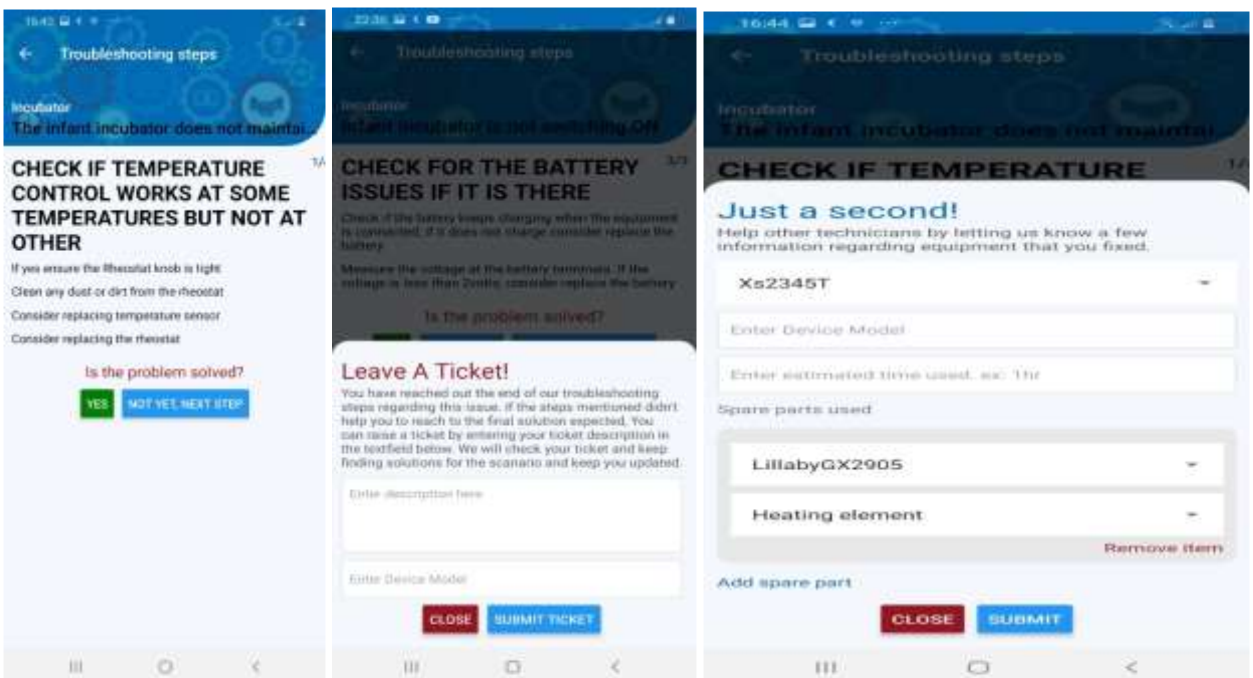

Figure 4. 4: Navigation of maintenance steps

The app provides the link to the manufacturer and other maintenance firm for more detail of the issue.

4.4 Hospital equipment and spare part inventory

The system admin will record the type/name of hospital equipment to be maintained using MERS. The system API will help to set the interoperability with MEMMS so that all recorded equipment in Mobile-MERS will retrieve equipment information like model, manufacturer, serial number and related spare parts. This is done during login stage only for equipment recorded in Mobile-MERS in order to avoid phone stop working due to the storage outrun. Figure 4.5 shows the database of medical equipment and spare parts

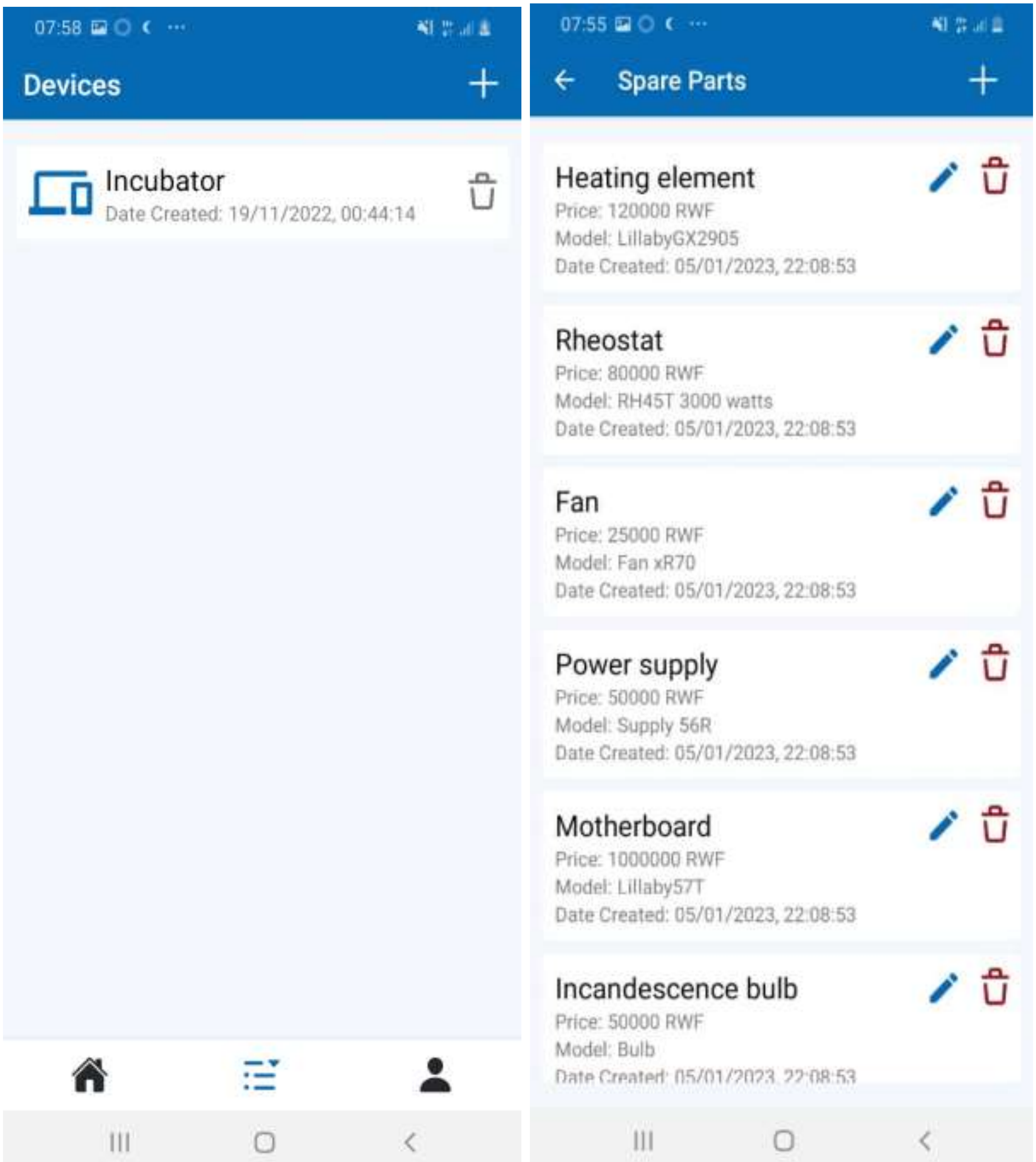

Figure 4. 5: Devises and spare parts in Mobile-MERS

4.5 Report and dashboard

For data-based decision making, Mobile-MERS provides a series of reports and dashboards. The app gives the report on equipment that fails most, the equipment whose maintenance cost is too high, etc. The maintenance cost will help if the equipment should or not remove from the service. Figure 4.6 shows dashboard and report of Mobile-MERS.

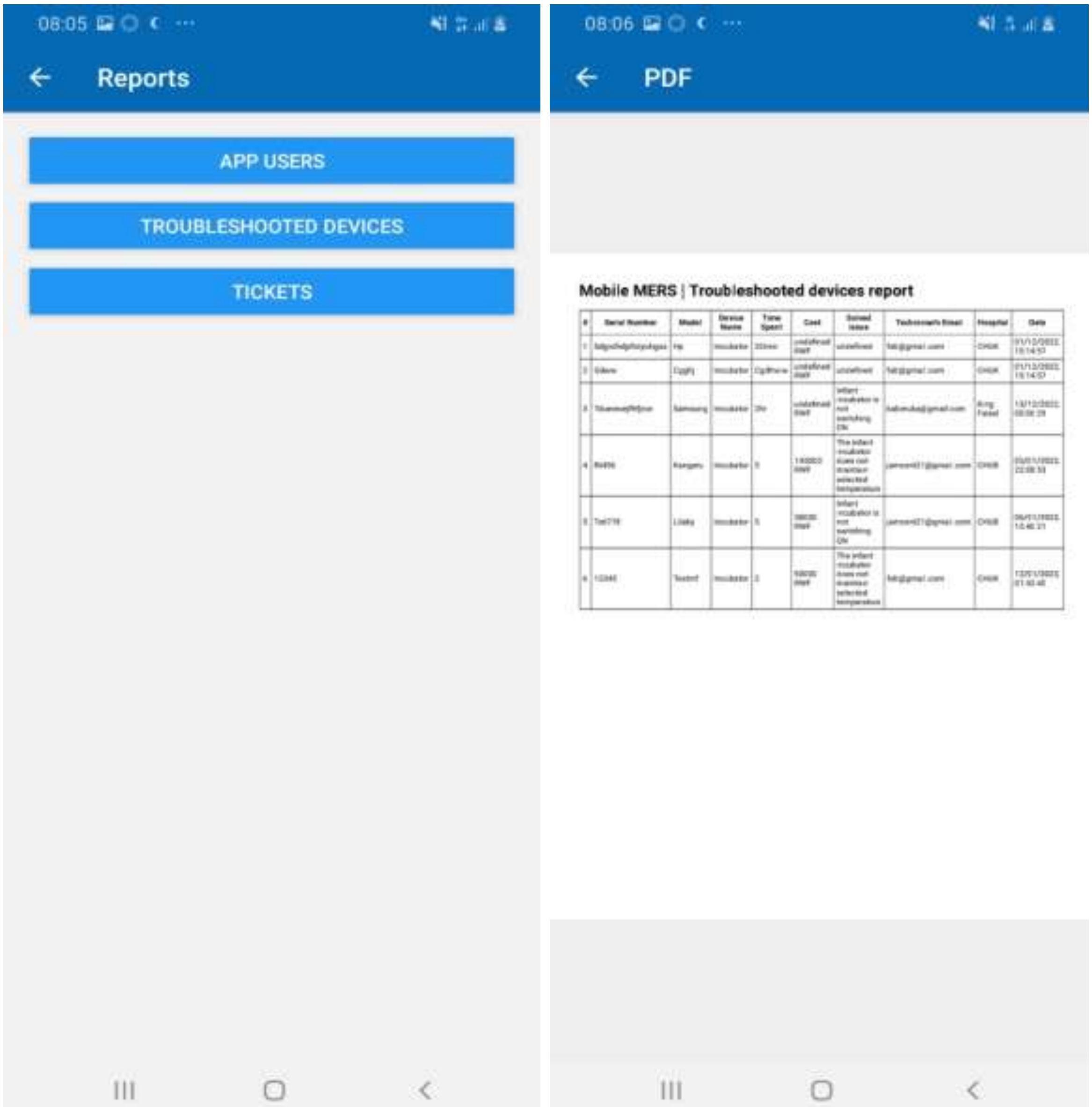

Figure 4. 6: Report module of Mobile-MERS

4.6 Mobile-MERS iterative preliminary test

According to the feedback from the application testing team that are summarized in the following table, approximate 89% agreed that the app is useful in healthcare technology management and different system improvement requests were raised by testing team to enhance system functionalities based on their experience in the field of biomedical engineering in hospital settings. The table 4.1 highlights the rating frequency of Mobile-MERS.

Table 4. 1: Rating Mobile-MERS during app testing sessions

Test 1		**Test 2**		**Test 3**		**Total**	**% of the frequency**
Rate	**Response**	**Rate**	**Response**	**Rate**	**Response**		
Poor	0	Poor	0	Poor	0	0	0
Below average	0	Below average	0	Below average	0	0	0
Average	1	Average	1	Average	0	2	11.1
Good	1	Good	2	Good	1	4	22.2
Very impressive	4	Very impressive	3	Very impressive	5	12	66.7
Total	6		6		6	18	100%

Every biweekly testing session, participant filled test feedback form and mention how useful is the app idea. Feedback from iterative testing team helped to improve the app. After improvement, the retest session is re-organized. The number of testing session lead to clear understanding of the app hence the increment in rating marks. Figure 4.7 summarizes how useful is the app.

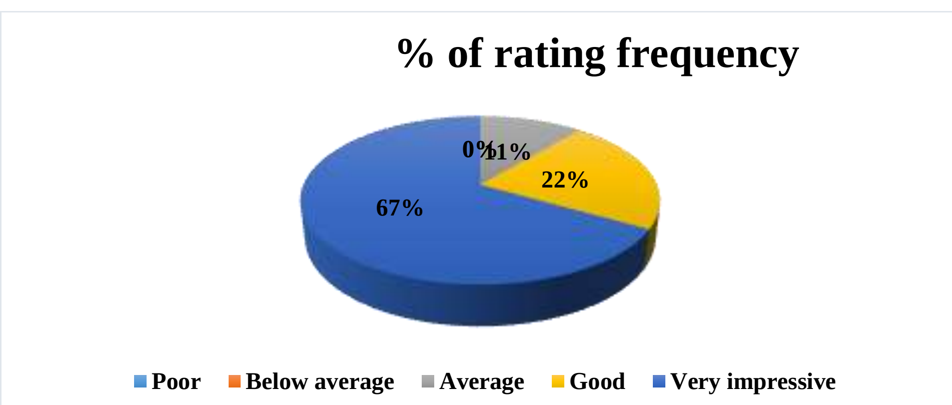

Figure 4. 7: Pie chat of app rating during iterative tests

After three iterative tests, the rating frequency is as follow:

- 66.7% strong agree that the usefulness of the app and rating the app to be very impressive
- 22.2% agree the app will be useful and rate it to be good
- 11.1% rate the app to be average
- None of the testing team had rated the app to be poor or below average

During app iterative test, participant propose various improvements as they try to understand Mobile-MERS business. The table below summarized the top three proposed improvements The table 4.2 indicates system improvement requested by users during iterative tests of the app.

Table 4. 2: Proposed improvements for Mobile -MERS

Iterative Test 1		**Iterative Test 2**		**Iterative Test 3**		**Total**	**% of the frequency**
Improvement	**Response**	**Improvement**	**Response**	**Improvement**	**Response**		
Interoperability	5	Interoperability	6	Interoperability	6	17	94.4
Interface	4	Interface	6	Interface	6	16	88.9
user-friendliness	3	user-friendliness	2	user-friendliness	2	7	38.9
Total	12		14		14	40	

The analysis of the feedback from iterative testing of the developed app reveal the need of some improvement proposed. 94 responses proposed to link Mobile-MERS with MEMMS to fetch important data like inventory of medical equipment and spare part (**interoperability**), 88% of response suggested to improve interface and user visibility and 38.9% advised to work on system user-friendliness. Figure 4.8, provides a chart of proposed improvement .

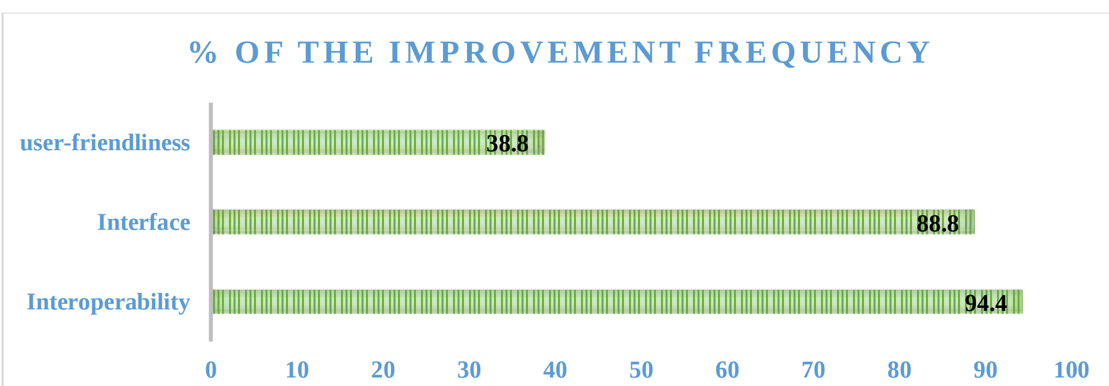

Figure 4. 8: Chat for proposed MERS app improvement frequency

4.7 Summary

This section discusses various functionalities of the developed mobile app during troubleshoot and repair process. Tables and charts highlight the feedback from testing team stating at which extend they found app useful and proposed improvements.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

During this technetronic era, technology is tremendously changing the lives of people. Technology is being used in every corner of life. Various innovations were made due to the use of technology to make life easy, MIS (Management Information System) is one for innovation and has pushed developers in developing various applications used in social networking, shopping, banking, entertainment, health, etc.

The introduction of medical device technology in the health system dramatically boosts the quality of health services by saving the lives of people. To reach medical equipment maintenance output, maintenance personnel should have important knowledge of healthcare technology; however, various reports highlight the lack of knowledge as the main cause of damped nonfunctional equipment in hospital stores.

The developed mobile application MobileMERS (Medical Equipment Repair System) helps the hospital biomedical technicians to maintain medical equipment with no outsourced maintenance contract and this will help the hospital to ensure the return of investment of medical equipment ahead sustainable healthcare provision.

This study presents the design and development of MobileMERS to improve the quality of health service delivery by stabilizing medical device. The work is limited to the app development, design, and preliminary testing; therefore, researchers could initiate various researches for app evolution and improvement for deployment at large scale.

As MobileMERS will be integrated with existing MIS used in health sector, researchers are welcome to conduct research on the system interoperability of developed app and other system in place.

5.2 Recommendations

In the closure of my conclusion, I recommend various institutions and bodies with my best acknowledge that the following recommendation will boost the field of engineering in the country.

My recommendations are addressed to:

- **UR** (University of Rwanda)/**CEBE** (Center of Excellence in Biomedical Engineering and E-health)

The University of Rwanda and Center of Excellence in Biomedical Engineering and E-Health are recommended to:

- Put in place an innovation center for implementation of best ideas presented in final research projects of undergraduate and post graduate students, this will lead the UR/CEBE to be the center of solution innovation hub to solve society problems
- Mobilize and collect project implementation fund, the UR/CEBE should set strong partnership with partners in to mobilize fund that could help students to implement their respective presented projects.
- Increase the research fees and ensure that the fee is paid to students on time for the best implementation of the project for future students.
- Introduce a loan scheme fund that could help graduates to implement their final year projects; this will reduce the rate of unemployment in youth.
- Open a certified training center in the field of Biomedical engineering; this will solve the issue of lack of qualified biomedical technicians/engineer at the labor market.
- Liaise with other international institutions or bodies with is strong expertise in biomedical engineering,

❖ **Ministry of Health**

The Ministry of Health is recommended to:

- To overtake the study of Mobile-MERS as this app is developed to address weaknesses presented by existing health systems and deploy the app in all hospital to solve medical equipment issues.

❖ **Private sector and researchers**

As this field of biomedical engineering needs high investment, it means this field needs the implication of the private sector and researchers. are recommended

- Invest in health by developing technological solutions and innovations that will solve health sector problem. Conducting further research on the developed app “Mobile-MERS” will be one way of such an investment, which may produce a huge benefit relatively to the high investment of the government in medical equipment.

❖ **Academicians and Students**

Academicians and students are recommended to:

- Expand several researches on Mobile applications applied on health sector as Mobile-MERS in order to elevate the quality of health with technology

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APPENDICES

Appendex1: Technical Experts Informed Consent Form

<u>Technician Experts Informed Consent Form</u>

Informed Consent Form

Title:	**Mobile-MERS**: Mobile based Optimization app for Maintenance of Medical Equipment
Principal Investigator:	Mr**.** HATEGEKIMANA James, University of Rwanda-CEBE
Date:	……/…./2022

PURPOSE OF RESEARCH STUDY:

You are asked to participate in a research study as testing team member. I, HATEGEKIMANA James, a Masters student in Biomedical Engineering in the University of Rwanda, Center of Excellence in Biomedical Engineering and E-Health(CEBE), with approval from the University of Rwanda, am doing a study with Biomedical Technicians at several health facilities across Rwanda for testing the developed app. The design of **Mobile-MERS** is done as my final year research project entitled "**Design and Development of Mobile based Optimization app for Maintenance of Medical Equipment**" as partial fulfilment of the requirements for the Master's Degree in Biomedical Engineering. The purpose of this research study is to gather feedback from biomedical technicians on Mobile-MERS, a mobile application designed to aid biomedical technicians in equipment repair. This feedback will be used to assess the initial version of the application's areas of strength and weakness so that the development team may improve the application and make it better suited to the needs of the intended users: Rwandan biomedical technicians.

PROCEDURES:

If you agree to this study, you will be asked to:

- Provide contact information and you will be give an OTP to access Mobile-MERS. You may then choose whether or not to answer the question. If you choose to answer, your response will sent to the inquiring biomedical technician via email.
- Answer open-ended questions about your experience responding to Mobile-MERS inquiries. This process will be conducted over the phone or via video interview, and is expected to take no longer than one hour.

RISKS/DISCOMFORTS:

The risks associated with participation in this study are no greater than those encountered in daily life.

BENEFITS:

- You may receive no direct benefit from participating in this research study.

- You may be satisfied to know that the results of this study may aid in the further development of the Mobile-MERS app, and in the future may improve biomedical equipment repair and safe surgery in Rwanda and other low- and middle-income countries, but this is not guaranteed.

VOLUNTARY PARTICIPATION AND RIGHT TO WITHDRAW:

Your participation in this study is entirely voluntary: You choose whether to participate. If you decide not to participate, there are no penalties, and you will not lose any benefits to which you would otherwise be entitled. If you choose to participate in the study, you can stop your participation at any time, without any penalty or loss of benefits. If you want to withdraw from the study, please contact us by emailing **jamcent21@gmail.com**.

1. CONFIDENTIALITY:

Any study records that identify you will be kept confidential to the extent possible by law. The records from your participation may be reviewed by people responsible for making sure that research is done properly, including members of the University of Rwanda and Center of Excellence in Biomedical Engineering and E-Health. (All of these people are required to keep your identity confidential.) Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

When you are recruited to the study, your name will be collected and you will be assigned a random number. In all later correspondences, this number will be used in place of your name. Your name is collected so that the study investigators have the option to reach out to you for additional information if necessary during the study. The information connecting your number to your name will be secured in a password protected database that is exclusively separate from where the survey data is stored. The reason behind using two separate storage entities is to minimize the chance of breach of confidentiality. Both databases can only be accessed by the study investigators. No other identifying data will be collected.

2. COSTS

There will be no costs to the participant.

COMPENSATION:

You will not receive any payment or other compensation for participating in this study.

IF YOU HAVE QUESTIONS OR CONCERNS:

You can ask questions about this research study now or at any time during the study, by talking to the researcher(s) working with you or by calling Prof. Damien HANYURWIMFURA at +25078394447 and Dr. Louis SIBOMANA at +250782588422 Center of Excellence in Biomedical Engineering and E-Health, University of Rwanda.

If you have questions about your rights as a research participant or feel that you have not been treated fairly, please call Dr. TWIZERE Celestin at +250788634578 and Dr.RUSHINGABIGWI Gerald at +250785469187, the Center of Excellence in Biomedical Engineering and E-Health at University of Rwanda.

CONSENT

Do you consent to be a part of this study? By signing below, you indicate that you understand the information in this consent form and that you agree to participate in the study.

By giving consent, you are not waiving any legal rights you otherwise would have as a participant in a research study.

Participant's Signature **Date**

Signature of Person Obtaining Consent **Date**
(Investigator or approved Designee)

Appendex2: Adapted Health Information Technology Usability Evaluation Scale

Adapted Health Information Technology Usability Evaluation Scale
(To be filled by BMET after every iterative Mobile-MERS testing)

Project Title: Design and Development of Mobile based Optimization app for Maintenance of Medical Equipment "**Mobile-MERS**"
Principal Investigator: Mr. HATEGEKIMANA James

BMET study ID	______________ (ex. ___GH01___)	Date				
			Year	Month		Day

RESPONDENT INFO	
Age:	**Sex:**
Facility:	
Years of Work Experience:	

Mobile-MERS Usability Scale *(Please tick in the correspondent box)*

Item	**Concept**	Poor	Below average	Average	Good	Very impressive
Quality of Work Life						
I think **Mobile-MERS** has been a positive addition to my job.	System impact-personal level					
I think **Mobile-MERS** has been a positive addition to our hospital.	System impact-organizational level					
I think **Mobile-MERS** has been a positive addition to medical equipment maintenance.	System impact-career mission					
Perceived Usefulness						
Mobile-MERS makes it easier to repair equipment.	Productiveness					
Mobile-MERS helps me troubleshoot more quickly.	Performance speed					
Using **Mobile-MERS** helps me find the root problem with a device.	Productiveness					

I am satisfied with **Mobile-MERS** for troubleshooting.	General satisfaction					
I am able to repair equipment in a timely manner because of **Mobile-MERS**.	Performance speed					
Using **Mobile-MERS** increases the number of repairs I can complete.	Productiveness					
Perceived Ease of Use						
I am comfortable with my ability to use **Mobile-MERS**.	Competency					
Learning to use **Mobile-MERS** is easy for me.	Learnability					
I find **Mobile-MERS** easy to use.	Ease of use					
I can always remember how to use **Mobile-MERS**.	Memorability					
User Control						
Whenever I make a mistake using **Mobile-MERS** , I recover easily and quickly.	Error Prevention					
Mobile-MERS works well on my phone.	Compatibility					
The information provided with **Mobile-MERS** is clear.	Content					
The repair guides in **Mobile-MERS** are clear.	Content					
The guide resources (images and text documents) in **Mobile-MERS** clear.	Content					
It is easy for me to give feedback on **Mobile-MERS** .	Feedback					

Participant's Signature **Date**

Signature of Person Obtaining Consent **Date**
(Investigator or approved Designee)

Appendex3: Biomedical technician in-depth feedback interview guide

BIOMEDICAL TECHNICIAN IN-DEPTH TEST FEEDBACK INTERVIEW GUIDE
(to be administered to BMET by the researcher)

Project Title: Design and Development of Mobile based Optimization app for Maintenance of Medical Equipment "**Mobile-MERS**"
Principal Investigator: Mr. HATEGEKIMANA James

BMET study ID	________________ (ex. _GH01_____)			Date					
					Year	Month		Day	
Start time		End Time							

Interviewer's Name:	**Transcriber's Name:**
RESPONDENT INFO	
Age:	**Sex:**
Facility:	
Years of Work Experience:	

Thank you again for participating in this study. The purpose of today's interview is to better understand your overall experience using **Mobile-MERS** to repair equipment. We can learn a lot from your experience using **Mobile-MERS**.

Let me tell you a little about the process. I will be asking you a range of questions and request that you answer questions in your own words. Take your time and ask me to clarify if you have any questions about what is wanted. Your opinions are very important. May I have your permission to record this interview? [IF NO, TAKE NOTES. IF YES, START RECORDING AND STATE NAME, STUDY ID NUMBER, DATE, AND START TIME.]

1. To begin, please walk me through how you would normally repair equipment? PROBE: What resources would you use? How long does it normally take? What steps would you take if you had difficulty repairing a piece of equipment? What other challenges have you faced on the job in the past, regarding biomedical equipment repair?

2. Please tell me on about what percentage at you find Mobile-MERS useful in repair of medical equipment repai. How useful Mobile MERS ? (select one) <25% / 25-50%_/ 50-75% / above 75% of shifts

3. What was your experience using **Mobile-MERS**? PROBES: Are there any features of **Mobile-MERS** that make your job easier or more difficult? Is there anything you specifically like or dislike about **Mobile-MERS**? How did it change or enhance your workflow for repairing equipment?

4. Please walk me through a time when you used **Mobile-MERS** to repair a piece of equipment. PROBE: How did you decide to use the app? What features did you use? Did you continue using the app once you were able to troubleshoot the issue? What features, if any, did you wish the app had that would have helped in the repair?

5. Now I'd like to ask you about specific features of the app

    a. How easy or difficult was it to use the app?

    b. What features, if any, did you find most useful?

    c. What features, if any, did you not find useful? Find difficult to use?

    d. Are there any features you would change? Why? How?

    e. Did you use the 'contact an expert' feature?

        i. If no, what were your reasons for not using the feature?
        ii. If yes, what was your experience using the 'contact an expert' feature? How long did it take to receive a response? How did this feature change your workflow? What value, if any, did this feature add to the app? Would you suggest any changes to this feature?

6. If we do introduce Mobile-MERS into another facility, what improvements would you suggest for training of BMETs? Is there anything you would suggest stay the same?

Appendex4: Project Logbook

East Africa's Center of Excellence in Biomedical Engineering and E-Health (CEBE)

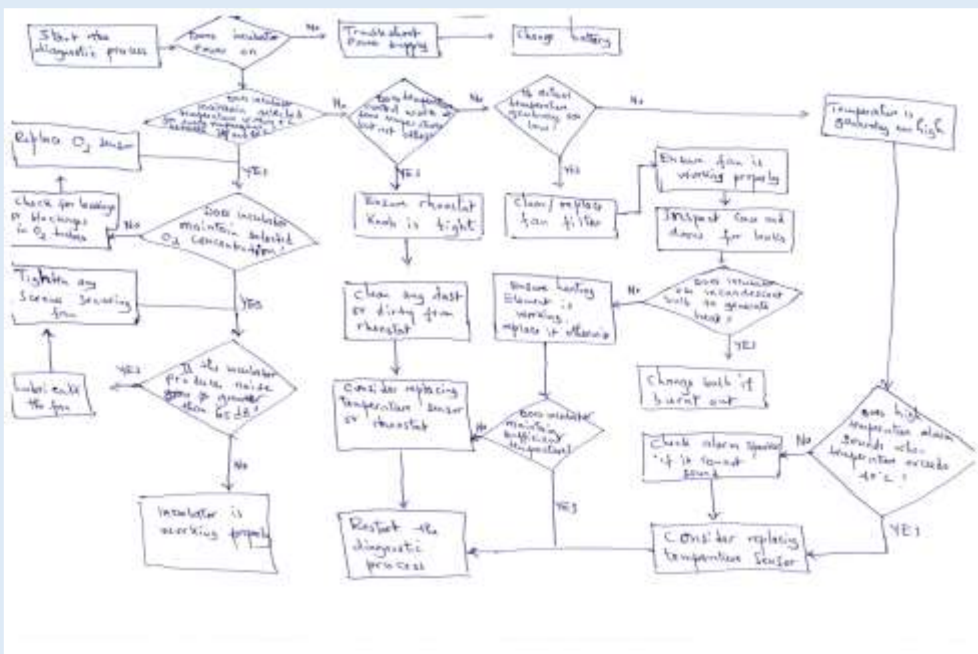
Master's Degree Program in Biomedical Engineering

PROJECT LOG BOOK

Project Title: Design and Development of Mobile based Optimization app for Maintenance of Medical Equipment: Mobile-MERS

Researcher: **HATEGEKIMANA James**
Supervisors:
1. **Prof. Damien HANYURWIMFURA**
2. **Dr. Louis SIBOMANA**

Date	Notes of Problems, Events and Activities
1-12 February 2022	**Writing Project abstract** After problem identification, I tried to write the abstract highlighting the general idea of my final year project. The project related to the reduction of nonfunctional equipment in hospitals
15February 2022	**Discussion on Project abstract**: Presenting the project idea Discussed with Dr. Gerald RUSHINGABIGWI, CEBE coordinator. I present my area of interest for my final year project. My area of interest is Mobile application applied on healthcare technology management for the final year project. We come up with the project title **“Design and Development of Mobile based Optimization app for Maintenance of Medical Equipment”.**
16-28February2022	**Writing the project proposal:** **Project idea research**: Researched online for Mobile-based project ideas. The idea about creating a centralized system for an effective management of medical equipment. The use-case diagram was drawn to identify and analyze the features and functionalities the system must provide comfort to every user type. This mobile-based system has the aim of guiding hospital biomedical technicians during T-shoot and repair of nonfunctional hospital equipment.
20 March 2022	**Discussion with Supervisors on research proposal** Presentation of the research proposal to supervisors ahead the research presentation to panelists.
21-22 March2022	**Review of research proposal**: Insert the inputs from supervisors in the research proposal.
23 March 2022	**Prepare the PowerPoint** presentation of the research proposal
24March2022	**Presentation of the research proposal**: The research proposal was presented to panelists and various comments were received. The research proposed to be working on the top five medical equipment that fails the most, panelist proposed to develop an app that works on one type of equipment to narrow the research. The finding of one piece of equipment will be generalized to five pieces of equipment.
25-31March2022	**Rectify the research proposal document**: Accept recommendation and insert the provided inputs from the panelist
11 April2022	**Submit the research proposal**: After considering all comments from the panelist, the final version of the Research proposal is submitted

15-30 April2022	**Definition of system requirement** • Mobile-MERS will work on android platform • The development language is Python
1April to 31 May2022	**Review of relative literature** • Review of recent papers written on management information system • Review of novels on mobile applications and maintenance of medical equipment • Listen to webinar on YouTube channels relative to the project • Attending the public speech on impact of IoT(Internet of Thing) for green city at Kigali-City • Read recent publication on medical equipment
1June 2022	**Consult App developer: Webinar with developer** on the design and development of android mobile applications for the inputs
2-3 June 2022	**Project research idea**: Develop Mobile-MERS flow diagram that will guide the developer throughout the app development process.  The use-case diagram was drawn to identify and analyze the features and functionalities the system must provide to the users.
6June-December 2023	**Mobile-MERS development** • Start designing various database tables • Writing code • Debug

15-17June2022	**Development of Testing forms** • Develop user consent form • Develop MERS usability feedback form • Design the after-test feedback interview
24-26 August 2022	**MERS Iterative Test1** Day1 Conduct app iterative test1 with the testing team at Gahini DH Day2Conduct app iterative test1 with the testing team at Nyamata DH Day3 Conduct app iterative test1 with the testing team at Muhima DH • Record comments and improvements proposed by participants
5-16September2022	Mobile-MERS development: Implement the proposed improvement from test1
20 September 2022	**Discussion of the development process** Meet other developers and present the project and perform system demo for inputs on the Mobile-MERS project
22-24 September 2022	**Iterative test2** Day1 Conduct app iterative test1 with the testing team at Gahini DH Day2Conduct app iterative test1 with the testing team at Nyamata DH Day3 Conduct app iterative test1 with the testing team at Muhima DH • Record comments and improvements proposed by participants
25-10 October2022	Mobile-MERS development: Implement the proposed improvement from test2
11-13October2022	**Iterative test3** Day1 Conduct app iterative test1 with the testing team at Gahini DH Day2Conduct app iterative test1 with the testing team at Nyamata DH Day3 Conduct app iterative test1 with the testing team at Muhima DH • Record comments and improvements proposed by participants
November2022	Mobile-MERS development: Implement the proposed improvement from test3
6 January 2023	**App demo**:
6-10January 2023	**Mobile-MERS development:** Implement the proposed improvement from the app demo with supervisors
11-12January2023	**Finalize thesis** • Work on the final thesis document considering the various input from the supervisors • Finalize chapter 4 of the thesis concerning project result
12January 2023	**Submission of final thesis draft to supervisors**
15January 2023	**Consider input from supervisors**
16January 2023	**Submission of Thesis to CEBE**

Appendix 5: The Utilized Codes

Login code file*: src/screens/login/index.js*

```
import React, {useRef, useState, useEffect} from 'react';
import {
  View,
  StatusBar,
  Image,
  Text,
  TextInput,
  Pressable,
  ActivityIndicator,
  Dimensions,
  TouchableOpacity,
} from 'react-native';
import {KeyboardAwareScrollView} from 'react-native-keyboard-aware-scroll-view';
import colors from '../../constants/colors';
import Axios from 'axios';
import {backendUrl} from '../../constants/app';
import {useDispatch} from 'react-redux';
import Toast from 'react-native-toast-message';
import {errorHandler, toastMessage} from '../../helpers';
import {
  resetUser,
  setUserCompanyName,
  setUserEmail,
  setUserId,
  setUserNames,
  setUserRole,
  setUserToken,
} from '../../actions/user';

const {width} = Dimensions.get('window');
function Login({navigation}) {
  const dispatch = useDispatch();
  const [email, setEmail] = useState('');
  const emailRef = useRef(null);
  const [password, setPassword] = useState('');
  const [isSubmitting, setIsSubmitting] = useState(false);
  const handleSubmit = () => {
    setIsSubmitting(true);
    if (email.trim() === '' || password.trim() === '') {
      emailRef.current.focus();
      setIsSubmitting(false);
    } else {
      Axios.post(backendUrl + '/users/login/', {email, password})
        .then(res => {
          const {email, fullName, companyName, role, id, token} = res.data;
          dispatch(setUserEmail(email));
```

```
        dispatch(setUserNames(fullName));
        dispatch(setUserCompanyName(companyName));
        dispatch(setUserId(id));
        dispatch(setUserRole(role));
        dispatch(setUserToken(token));
        toastMessage('success', 'Logged in successfull');
      })
      .catch(error => {
        setIsSubmitting(false);
        setPassword('');
        errorHandler(error);
      });
  }
};
useEffect(() => {
  dispatch(resetUser());
}, []);
return (
  <KeyboardAwareScrollView>
    <StatusBar backgroundColor={colors.BLUE} barStyle="light-content" />
    <View
      style={{
        flex: 1,
        alignItems: 'center',
        justifyContent: 'center',
        backgroundColor: colors.BACKGROUND_COLOR,
      }}>
      <View
        style={{
          backgroundColor: colors.BLUE,
          padding: 10,
          height: 150,
          width: '100%',
          // borderBottomEndRadius: 80,
          // borderBottomStartRadius: 80,
          position: 'relative',
        }}>
        <View style={{position: 'absolute', bottom: -70, width}}>
          <View style={{alignItems: 'center', justifyContent: 'center'}}>
            <View
              style={{
                backgroundColor: colors.BACKGROUND_COLOR,
                borderRadius: 10,
                // padding: 10,
              }}>
              <Image
                source={require('../../../assets/logo.png')}
                style={{width: 150, height: 150, borderRadius: 10}}
              />
            </View>
```

```
    </View>
  </View>
</View>
<View style={{marginTop: 80}}>
  {/* <Text
    style={{
      fontSize: 20,
      fontWeight: 'bold',
      color: colors.BROWN,
      textAlign: 'center',
    }}>
    Login
  </Text> */}
</View>
<View style={{width: '90%', marginTop: 40}}>
  <View style={{marginVertical: 10}}>
    <Text style={{color: colors.FOOTER_BODY_TEXT_COLOR}}>Email</Text>
    <TextInput
      style={{
        backgroundColor: colors.WHITE,
        marginTop: 10,
        borderRadius: 5,
        padding: 10,
        borderWidth: 1,
        borderColor: colors.BORDER_COLOR,
      }}
      placeholder="Email address"
      onChangeText={text => setEmail(text)}
      ref={emailRef}
      value={email}
    />
  </View>
  <View style={{marginVertical: 10}}>
    <Text style={{color: colors.FOOTER_BODY_TEXT_COLOR}}>Password</Text>
    <TextInput
      style={{
        backgroundColor: colors.WHITE,
        marginTop: 10,
        borderRadius: 5,
        padding: 10,
        borderWidth: 1,
        borderColor: colors.BORDER_COLOR,
      }}
      secureTextEntry
      placeholder="Enter your password"
      onChangeText={text => setPassword(text)}
      value={password}
    />
  </View>
  {isSubmitting ? (
```

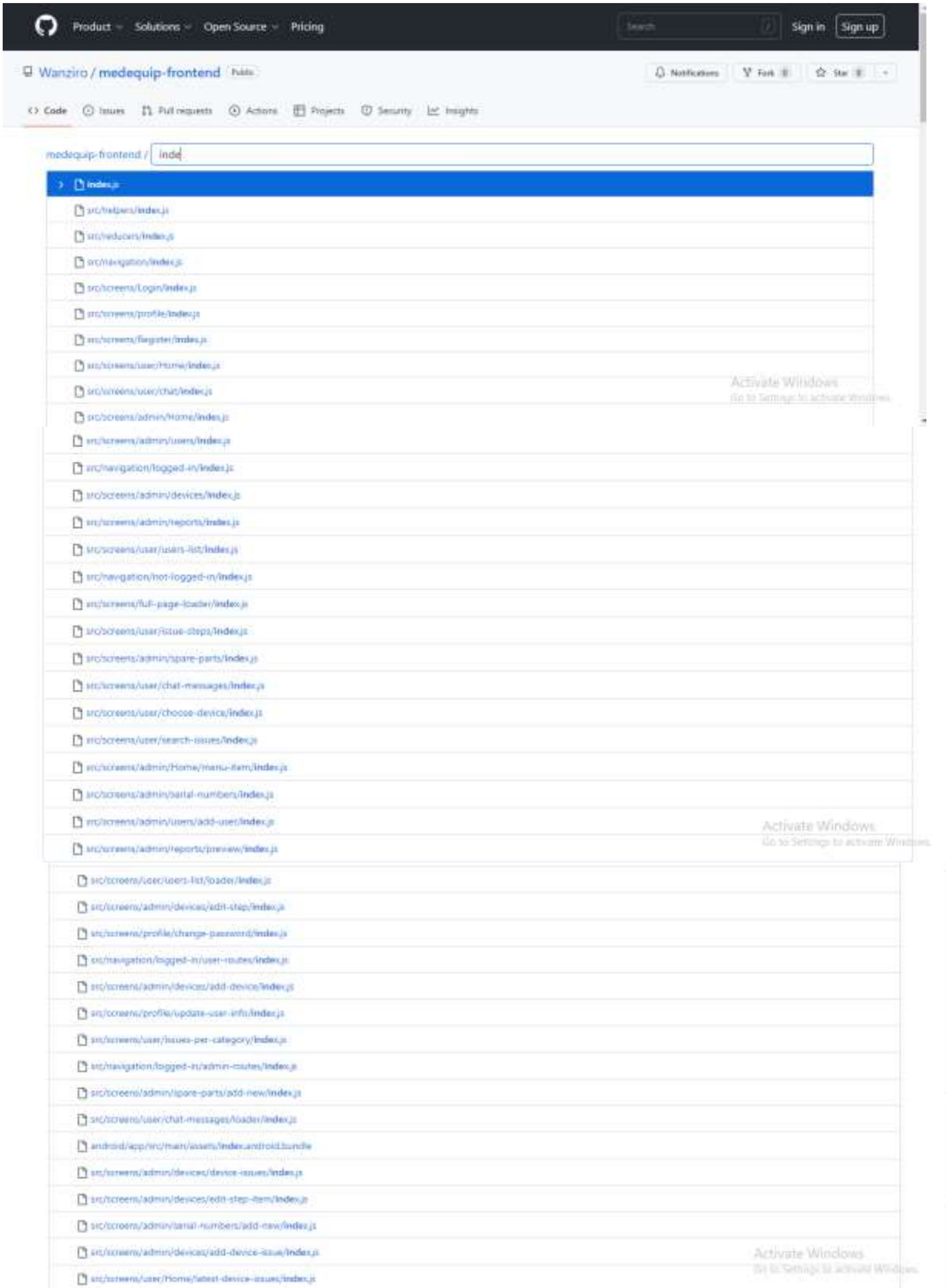
```
    <View
      style={{
        backgroundColor: colors.BLUE,
        padding: 15,
        marginTop: 10,
        borderRadius: 5,
        justifyContent: 'center',
        alignItems: 'center',
        flexDirection: 'row',
      }}>
      <ActivityIndicator color={colors.WHITE} />
      <Text
        style={{
          color: colors.WHITE,
          textAlign: 'center',
          fontSize: 18,
          marginLeft: 10,
        }}>
        Login
      </Text>
    </View>
  ) : (
    <Pressable onPress={() => handleSubmit()}>
      <View
        style={{
          backgroundColor: colors.BLUE,
          padding: 15,
          marginTop: 10,
          borderRadius: 5,
        }}>
        <Text
          style={{
            color: colors.WHITE,
            textAlign: 'center',
            fontSize: 18,
          }}>
          Login
        </Text>
      </View>
    </Pressable>
  )}
  <TouchableOpacity onPress={() => navigation.navigate('Register')}>
    <View style={{marginTop: 20}}>
      <Text style={{textAlign: 'center', color: colors.OXFORD_BLUE}}>
        Don't have account? Register
      </Text>
    </View>
  </TouchableOpacity>
 </View>
</View>
```

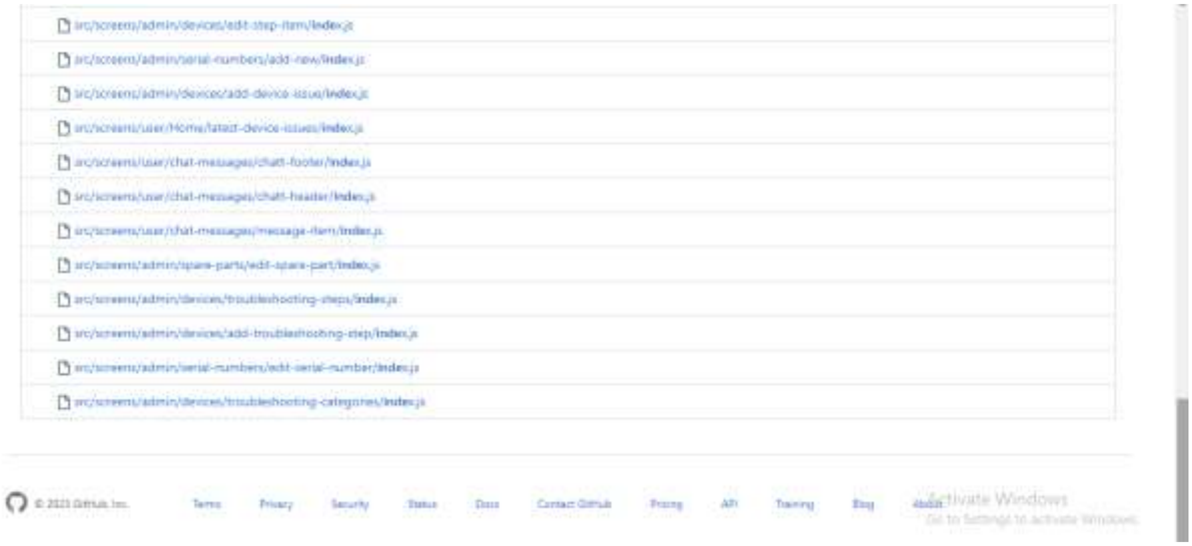
```
    </KeyboardAwareScrollView>
  );
}

export default Login;
```

Troubleshoot code File: ***src/screens/admin/devices/troubleshooting-categories/index.js***

```
import React, {useEffect, useState} from 'react';
import {View, FlatList, Text} from 'react-native';
import {useDispatch, useSelector} from 'react-redux';
import {fetchDeviceIssues} from '../../../../actions/deviceIssues';
import {fetchTroubleshootingcategories} from '../../../../actions/troubleShootingCategories';
import colors from '../../../../constants/colors';
import FullPageLoader from '../../../full-page-loader';
import CategoryItem from './categoryItem';
import LoaderItem from './loaderItem';

const placeholderList = [
  {id: 1},
  {id: 2},
  {id: 3},
  {id: 4},
  {id: 5},
  {id: 6},
  {id: 7},
  {id: 8},
  {id: 9},
  {id: 10},
  {id: 11},
  {id: 12},
];

function TroubleShootingCategories({navigation, route}) {
  const {deviceName, deviceId} = route.params;
  const [isLoadingData, setIsLoadingData] = useState(false);
  const dispatch = useDispatch();
  const {isLoading, categories} = useSelector(
    state => state.troubleShootingCategories,
  );
  const {issues} = useSelector(state => state.deviceIssues);

  useEffect(() => {
    dispatch(fetchTroubleshootingcategories());
    dispatch(fetchDeviceIssues());
  }, []);

  return (
```

```
    <>
      <View
        style={{
          flex: 1,
          backgroundColor: colors.BACKGROUND_COLOR,
          paddingHorizontal: 10,
          paddingVertical: 20,
        }}>
        <Text style={{color: colors.BLACK, marginBottom: 5}}>
          Devices / {deviceName} / Troubleshooting categories
        </Text>
        {isLoading && categories.length === 0 ? (
          <FlatList
            data={placeholderList}
            showsVerticalScrollIndicator={false}
            renderItem={(item, index) => <LoaderItem item={item} />}
            numColumns={2}
            style={{padding: 10}}
          />
        ) : (
          <FlatList
            data={categories.filter(item => item.deviceId == deviceId)}
            showsVerticalScrollIndicator={false}
            renderItem={(item, index) => (
              <CategoryItem
                item={item}
                navigation={navigation}
                setIsLoading={setIsLoadingData}
                deviceName={deviceName}
                issues={issues}
              />
            )}
            numColumns={2}
            style={{padding: 10}}
          />
        )}
        <FullPageLoader isLoading={isLoadingData} />
      </View>
    </>
  );
}

export default TroubleShootingCategories;
```


Product
Solutions
Open Source
Pricing
Sign in
Sign up
Wanziro / medequip-frontend
Code
Issues
Pull requests
Actions
Projects
Security
Insights
medequip-frontend / inde
index.js
src/helpers/index.js
src/reducers/index.js
src/navigation/index.js
src/screens/Login/index.js
src/screens/profile/index.js
src/screens/Register/index.js
src/screens/user/Home/index.js
src/screens/user/chat/index.js
src/screens/admin/Home/index.js
src/screens/admin/users/index.js
src/navigation/logged-in/index.js
src/screens/admin/devices/index.js
src/screens/admin/reports/index.js
src/screens/user/users-list/index.js
src/navigation/not-logged-in/index.js
src/screens/full-page-loader/index.js
src/screens/user/issue-steps/index.js
src/screens/admin/spare-parts/index.js
src/screens/user/chat-messages/index.js
src/screens/user/choose-device/index.js
src/screens/user/search-issues/index.js
src/screens/admin/Home/menu-item/index.js
src/screens/admin/serial-numbers/index.js
src/screens/admin/users/add-user/index.js
src/screens/admin/reports/preview/index.js
src/screens/user/users-list/loader/index.js
src/screens/admin/devices/edit-step/index.js
src/screens/profile/change-password/index.js
src/navigation/logged-in/user-routes/index.js
src/screens/admin/devices/add-device/index.js
src/screens/profile/update-user-info/index.js
src/screens/user/issues-per-category/index.js
src/navigation/logged-in/admin-routes/index.js
src/screens/admin/spare-parts/add-new/index.js
src/screens/user/chat-messages/loader/index.js
android/app/src/main/assets/index.android.bundle
src/screens/admin/devices/device-issues/index.js
src/screens/admin/devices/edit-step-item/index.js
src/screens/admin/serial-numbers/add-new/index.js
src/screens/admin/devices/add-device-issue/index.js
src/screens/user/Home/latest-device-issues/index.js
Activate Windows



Picture of MERS code files on github

Note: Please access all code files on: https://github.com/Wanziro/medequip-frontend/find/master